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European-Mediterranean Seismological Centre
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EMSC Newsletter

N° 23/ April 2009

This issue of EMSC Newsletter is the first one of a new kind. You may have noticed its slightly different look. Previous Newsletters had been produced by an independant Communication Agency. We were satisfied with the results but felt a lack of control over the production process.

At the end of 2008, EMSC decided to produce its Newsletter itself. That is this brand new version of our Newsletter you are holding in your hands. Being produced roughly once a year, its look will be versatile - it has to, so as to accomodate all articles sent by our contributors.
This brand new look comes with a new EMSC logo. EMSC members have been invited to vote for their favorite the past few weeks, and here's the winner!
We stick to our previous color code: black and red. We used a seismogram to have a link with our activity and a world map centered on the euro-med zone. Following your overwhelming comments, it's been decided to keep the double mention CSEM/EMSC. We hope you like our new logo! A whole new visual identity will be implemented shortly.

We hope you will enjoy this new look. Do not hesitate to make any comment or criticism (Marie-Line Nottin, nottin@emsc-csem.org)

Example of picture received from a witness through our website. Dust cloud over the mountain due to rolling stones caused by the Mw 7.7 of 14/11/2007 in Northern Chile. The pictures was taken during the shaking from the city of Tocopilla, 24 km west of the epicenter.

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NEWSLETTTER EDITORIAL APRIL 2009

Following our General Assembly in Crete, where 5 new institutions were endorsed as members of EMSC, the University of Patras has also applied for membership. This brings our community to 84 institutes and observatories from 55 countries; there are only a few other possibilities in our geographic range unless countries like Scotland become independent. Through our members, we now have comprehensive data collection, with all permanent networks delivering all of their data in a timely fashion, and I would like to thank everyone for their efforts and open attitudes towards freely sharing their information; we have come a long way in the past two decades, to our collective benefit.

Within this issue, you will find articles on seismic networks of the Arabian Peninsula that follow on from the Gulf Seismological Forum held in 2008, which provided some stimulus to existing and new collaborations. A number of presentations, here, are from new members of EMSC, and we thank them for these.

There have been continuing discussions on ways to improve the EMSC bulletin (together with alert services), including the proposal of guidelines on defining authoritative earthquake locations. EMSC initiated this move and has been leading an IASPEI working group on the subject, which met in January during the IASPEI meeting in Cape Town (South Africa). Of course, the aim is to avoid multiple locations appearing for the same earthquake, issued by different agencies. An outstanding issue to be resolved for the Bulletin is how we can better discriminate non-earthquake events (explosions etc) for which we will need even greater collaboration from and between our members. A seismicity map from the Bulletin, covering the years 1998-2008, will be published in 2009 for the Euro-Med region. The Bulletin itself is openly available through the web-site using autodrm. It will require a declaration that it is not being accessed for commercial purposes. If that is the intent, the enquirer will be required to contact the Secretary General in order to discuss the issue. We anticipate that this will not be a frequent occurrence and that it may lead us to new corporate members.

Spin-out from EMSC alert services includes some 10 of our member institutes exploring the implementation of the felt map algorithms on their own systems. We recognise that using surges in our web traffic to provide alerts and to encourage the public to act as “research assistants” (by completing questionnaires), is a valuable tool that can go beyond our research interests. The approach will also be of interest to appropriate authorities engaged in emergency response and disaster mitigation; potentially beyond our own field of earthquakes. EMSC has just entered into a partnership agreement with the company Digital Envoy, the leading provider of IP Intelligence and geotargeting technology, to improve the localisation of IP addresses, and, thereby, the accuracy of our near real-time felt maps.

As a part of the “French Science in Europe” Exhibition at the Grand Palais for 3 days in mid November (2008), Remy Bossu presented, and starred in, a movie about the EMSC. This gave us considerable exposure in France and among external delegates, and continues to do so. Remy’s fluent and faultless exposition of EMSC, its work and international value, can be viewed on the YouTube and DailyMotion web-sites with English subtitles (keywords: EMSC + earthquakes). Also, I would like to commend those who, in this issue, have provided overviews on the status and progress of the large community projects in which EMSC is involved, with a particular commendation to those working on the NERIES project which came through a critical review, last year, with flying colours.

I am looking forward to catching up with friends and colleagues at our next General Assembly, in Utrecht on June 29th and also at the ESC General Assembly in Montpellier (September 5-9, 2010), which is being organised by EMSC. Further details and a call for proposals will be found within this Newsletter.

Chris Browitt
President

EMSC to organise the ESC2010 meeting in Montpellier

The EMSC is honoured to have been selected to organise the XXXII General Assembly of the European Seismological Commission.
It will take place on September 5 to 9, 2010 at the Corum (conference centre) in Montpellier. Our aim is to offer an attractive scientific program and an enjoyable stay while strengthening the Mediterranean dimension of this event. The Local organising Committee includes Michel Cara (Strasbourg), Serge Lallemand and Marie-Odile Piétrusak (Montpellier); Marie Line Nottin and Rémy Bossu (EMSC). The first announcement, as well as the web site (www.esc2010.eu) will be available soon and we would welcome your suggestions for special sessions.

Second accelerometric workshop on accelerometric data exchange, November 10-12 2009, Ankara Turkey

The 2nd Accelerometric workshop on accelerometric data exchange and archiving will be held at the Middle East Technical University in Ankara Nov. 10-12 2009. The meeting will be the follow-up of the first workshop that was organized by LGIT and Joseph Fourier University in March 2008 through the grants provided by the NERIES project. As of the first meeting, the current activity aims to improve the interaction between strong-motion networks through the participation of strong-motion data providers all around the world. This year, representatives of K-Net, Kik-Net and COSMOS will also participate in the workshop to extend the discussions about the major impacts of strong-motion databases on global and local ground-motion predictive models. The workshop will also host researchers from the FP-7 granted SHARE project that aims to harmonize hazard around Europe. List of participants and further information about the workshop can be found on the following link: http://www.adea.metu.edu.tr

The EMSC real time activities

Gilles Mazet-Roux: mazet@emsc-csem.org

- 2008 report for the EMSC real time activities

The annual report on our real time activities is available in the News section of our web site (www.emsc-csem.org). 66 networks have contributed with data to the system in 2008. The rapidity of the Earthquake Notification Service for the Euro-Med earthquakes has further increased. Thanks to more rapid data contributions and to the professionalism of the seismologists on duty both at LDG and IGN, SMS and emails were distributed within 22 minutes of the earthquake's occurrence.

The online macroseismic questionnaires, currently available in 20 languages, the collection of pictures depicting earthquake damage as well as the felt maps mapping the areas where an earthquake was felt according to the variations of the geographical origins of the visitors of EMSC's web site have started to produce regular results and these trends should be confirmed in 2009.

- Implementation of Joint Hypocenter Determination for fault plane identification

The modified Joint Hypocenter Determination developed by Dr. Hurukawa *(Hurukawa and Imoto, 1992; Hurukawa, 1995)*, director of the **International Institute of Seismology and Earthquake Engineering (IISEE)** is being implemented at EMSC.

First of all, we want to express our sincere thanks to Dr. Hurukawa who modified his algorithm for a semi-automatic application at EMSC. He will visit us late April to finalise the implementation.

Tests have been performed at EMSC on the aftershock sequence of the Oct. 11th 2008 earthquake in Caucasus region (Russia) and results are available on EMSC web site in the "Earthquake News and highlights" section.

Other applications are available on the IISEE web site http://iisee.kenken.go.jp. They show that, at least in certain cases, this may help to identify the fault plane of a large earthquake.

A new web site in development

A new web site for the EMSC is being developed by our webmaster, Frédéric Roussel.

Our aim is to take advantage of our new hardware infrastructure, ease the access to our more recent services and tools (macroseismic maps and questionnaires, felt maps, pictures collected from witnesses…) and improve data distribution.

A prototype will be made available for EMSC members to comment in the upcoming months.

Meanwhile, we strongly encourage you to send your ideas and comments to Frédéric (webmaster@emsc-csem.org)

SHERPA: A new application to bring pictures to the users

SHERPA stands for **SHaring Earthquake Rupture Pictures and Archiving.** It is an Internet application developed by Yann Théo (theo@emsc-csem.org) during his internship at EMSC.

SHERPA aims at collecting, archiving and making available pictures of earthquake rupture and related phenomena collected on the field after a large earthquake. Investigators can upload their pictures related to a same earthquake, geo-reference them interactively using a GoogleMap interface (or using the location of the EXIF file if their camera is equipped with a GPS) and tag them through a predefined list of words to describe the observed phenomena. They also have the possibility to add comments.
The database users will be able to visualise all the pictures related to the same earthquake, the same owner, the same region or the same phenomena but observed at different earthquakes. SHERPA only intends to put together and organise pictures from different sources, but there is no transfer of copyright. By default, all the collected pictures will be barred with the text "NOT FOR PUBLICATION". This will still allow users to browse through the database and explore what does exist but they will have to contact the owner of the pictures (directly through the SHERPA interface) to get the picture in a form suitable for publication.
By doing so, we aim at ensuring proper credit to the photographers while easing the access to the existing pictures.

The prototype application is available at http://www.emsc-csem.org/sherpa.php and comments would be much appreciated.

We thank Laurent Bollinger (LDG), Stéphane Dominguez (University of Montpellier), Yann Klinger (IPG Paris), and Antoine Schlupp (IPG Strasbourg) for their helpful suggestions.

Evolutions of the Euro-Med bulletin

Stéphanie Godey: godey@emsc-csem.org

The data collection of the Euro-Med bulletin is now comprehensive. The Euro-Med bulletin is computed until the end of 2007 and we will maintain our delay of production between 12 and 18 months (the year 2008 will be available by this summer). Finally, the Euro-Med bulletin is now included in the **ISC (International Seismological Center)**. All of these are significant achievements but there are still several improvements to be finalised on the inclusion of small magnitude events, the proper identification of the type of events and a location using a more up-to-date velocity model. New procedures are being tested to tackle these 3 issues and the whole bulletin since January 1998 will be reprocessed by the summer.

- How to include small magnitude events?
The Euro-Med bulletin initially focused on earthquakes greater than magnitude 3. However, there has been a growing demand coming from the users of the NERIES portal (currently in development jointly between EMSC and ORFEUS) to lift this limitation. This inclusion required to significantly modify and test our procedures. This work is currently being finalised within the framework of the NERIES project and will be the subject of a detailed NERIES report. This new procedures will be applied on the whole bulletin (i.e. since January 1998).

- How to get rid of quarry blasts and explosions?
The aim is to get rid of the non earthquake events such as quarry blasts or explosions in the Euro-Med bulletin. The difficulty we encounter is that there is no uniform procedure to deal with this issue and each observatory and institute has developed its own approach. Some of the contributors report all seismic events, among them some indicate the type of events, some others do not, other networks only report earthquakes... This heterogeneity can cause EMSC to report non-earthquake events in its bulletin. For example, a network which only reports earthquakes in its bulletin will rightfully omit a large quarry blast in a border region, but the same event will be included in the Euro-Med Bulletin if reported by 2 neighbouring networks (which are unlikely to know it is a quarry blast). This is only an example and we know this happens. In order to clean-up the bulletin, we have been asking the different networks to explain their own policy concerning the different types of events and we are working on the definition of appropriate procedures to reduce this problem as much as possible. Your cooperation is critical on this issue.

- Relocation using the ak135 velocity models
After many tests, the Jeffrey Bullen velocity model currently used to perform the locations will be phased out both for the Euro-Med bulletin and the real-time locations (the ones available on our web site) and replaced by the ak135 model. All the locations of the bulletin since 1998 will be recomputed as well as the real time ones since January 2009.

THE ROLE OF THE ICG/NEAMTWS FOR THE IMPLEMENTATION OF THE TSUNAMI WARNING SYSTEM (TWS) IN THE EUROPEAN REGION

by Stefano Tinti[1]

There are four ocean regions in the world where the efforts to implement a new system or to improve the existing system of tsunami warning are coordinated by **Intergovernmental Coordination Groups (ICG)** in the frame of the **UNESCO Intergovernmental Oceanographic Commission (IOC)**. These are the Pacific Ocean, the Indian Ocean, the Caribbean sea and the EuroMediterranean region. This last region includes the north-east Atlantic, the Mediterranean and the connected seas, such as the Marmara sea and the Black sea in the south, and the North sea and the Norwegian sea in the north. It is not a surprise that three of the ICGs were established in June 2005 as a response to the catastrophe in the Indian Ocean caused by the 26 December 2004 tsunami. The emotion was enormous worldwide. In the aftermath of that event, the first response was humanitarian and materialised in rescue operations, assistance for food and health, and first help for initial reconstruction and repair works. But since the beginning, the big general question in everybody's mind was: how could the tsunami hit coasts as far as two or more hours from the source without any warning to the population? It was clear that if a tsunami warning system had been in place in the region, a large number of human lives could have been saved and the tragedy could have been reduced to a more acceptable size. The tsunami came unexpected to most, but not to all: indeed scientists had made some warnings that there was a potential for large tsuna-

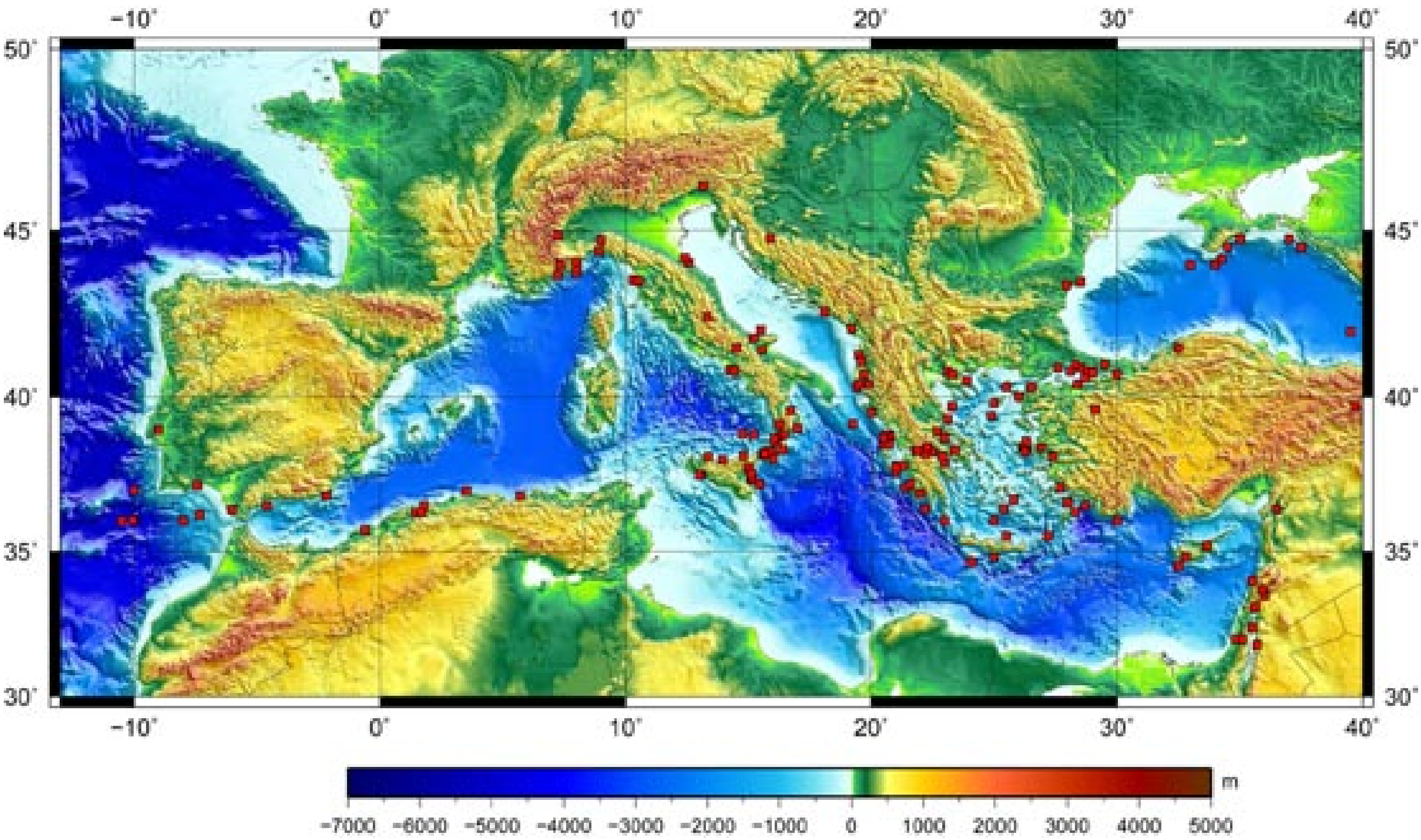

Figure 1. Distribution of tsunamis in the southern European region, according to the recent catalogue of the European and Mediterranean tsunamis, covering the period from 1600 BP to 2006. The catalogue is strongly incomplete until 1000 AD, and probably complete only in the last century. The most important tsunamigenic regions are in the Gulf of Cadiz, north of Algeria, southern Italy, along the Hellenic Arc, with its eastern continuation involving Cyprus and the Marmara sea.

mis crossing the whole Bay of Bengal well before 2004. They had repeatedly stressed the need for building a tsunami warning system in the area, but unfortunately, this alert remained unheard. The world found out with astonishment that only the coasts of the Pacific were, to a certain extent, protected from tsunami attacks through a system of warning. Therefore the creation of the ICGs in those basins of the world that, according to scientific knowledge (i.e. known tectonic setting and historical records), might be potentially affected by tsunamis large enough to create serious risk to coastal population and coastal activities, was seen as a necessary first step to fill a gap.

As regards the EuroMediterranean region, the ICG denominated ICG/NEAMTWS grouped most of the countries of the three continents (i.e. Europe, Asia and Africa) watered by the north Atlantic Ocean and by the Mediterranean and related seas. After its birth in June 2005, its starting session was held in Rome in November 2005, where the basic operative structure of the ICG was established. It consists of a chair and two vice-chairs, a secretariat (provided by the IOC), and four working groups addressing essential thematic issues for the TWS in the region, namely hazard and risk assessment including numerical modelling (WG1), seismic monitoring network (WG2), sea level monitoring network with coastal and offshore stations (WG3), and advisory, mitigation and public awareness (WG4). The general ICG assembly has met five times since 2005 (about once per year) in different European countries (Italy, France, Germany, Portugal and Greece), while the WGs have organised additional intersessional meetings to monitor the progress of their works and activities. In 2007, a new group called Task Team was created with the specific purpose of discussing the basic architecture of the TWS and the relationships between the national and the regional tsunami centres. The conventional denominations of such centres are **national tsunami warning centres (NTWC)** and **regional tsunami watch centres (RTWC)**.

The main starting points or motivations to create the ICG/NEAMTWS were:

1) the EuroMediterranean region has been the theatre of large tsunamis in the past with disastrous effects, mostly with local, i.e near-shore effects, but some also with damaging effects far from the source, since tsunamis travelled all across the basin;

2) practically no coasts in the region can be considered exempt from tsunami attacks, though the most exposed countries from west to east are found in the southern belt of the EuroMediterranean region running from Portugal and Morocco to the west to Turkey in the east (see the tsunami catalogue displayed in Figure 1);

3) most of the tsunami sources are very close to the coast, therefore the leading time of the tsunami to the nearest coast is very short (less than 5-10 minutes);

4) the Mediterranean basin and its sub-basins (e.g. the Marmara sea) are small compared to the large oceans, and therefore even remote coasts that are under the menace of disastrous waves may be reached in less than one hour (Figure 2);

5) the EuroMediterranean region is among the most developed in the world with a growing importance of the coastal belt for all the countries, both offshore and onshore, and with an increasing usage and occupation of the coastal territories in terms of economic and industrial activities, including tourism, and of the residential settlements;

6) hence the vulnerability and risk of the coasts has been enormously increased in the region. The repetition of some of the largest historical tsunami occurrences could result, under unfavourable circumstances (i.e. if it happened in coincidence with peak touristic season and in daily hours), in a disaster even larger than the Indian Ocean 2004 one;

7) tsunami can affect some mega-towns in the region (such as Lisbon and Instanbul), or big towns (see Catania, in Italy, Alexandria in Egypt, …);

8) no national or regional TWS had been in place in the region before the creation of the ICG.

The main objective of the ICG was to establish a TWS covering the region as soon as possible and to foster the creation of the national TWS. Everything was to be made according to an implementation plan that was adopted rather soon by the ICG and that dictated the steps and the related milestones to achieve the goal in the next years. The chief idea was to create the TWS using the existing national experiences and resources and to start a two-phase process:

- implementation of an **initial or interim TWS (ITWS)** in a two year-time (i.e. within 2007);
- establishment of the full operational system in the following four years (i.e. within 2011).

These were the intents of the countries forming the ICG. Unfortunately the process was slower than desired and the implementation of the ITWS is still to come, though a very large number of intermediate auxiliary steps have been taken. The process, that never stopped, is little by little approaching its target: the creation of the ITWS.

It is important to understand the reasons behind such a lack of success. They can be categorised in economical and organisational reasons. The ICG is a coordination body, or technically speaking, a subsidiary body of the IOC. It has no specific budget apart from some support given to logistical and secretariat activities. No donations were ensured by the member states, though they were solicited several times. This means that the ICG can only provide directions, guidelines, or recommendations for the governments and the authorities of the countries in the region. It cannot finance directly plans or projects, not even for the countries of the region with the weakest economies. In this optics, the ICG is bound to solicit the member states and the European Commission to finance plans (usually through their ordinary financing procedures), plans that can be seen as advancement and partial realisation of the ICG implementation plan. In this framework, a number of scientific projects have been run in recent years and were very useful for the ICG purposes. Their results have been included with significant impact in the list of the ICG achievement (examples can be given of projects on tsunamis funded by the European Commission, such as TRANSFER, DEWS, SCHEMA, SEAHELLARC, NEAREST, NERIES and SAFER). The main contributions were made especially in the fields of numerical modelling and creation of tsunami scenarios, identification of the sources, methodologies to assess vulnerability and risk, in improving the seismic monitoring network and exchange of data, in improving the performance in terms of quality and time of earthquake determination procedure, in devising platforms to support decision in the operational tsunami centres.

So, all the tasks of the ICG implementation plan fulfilled were fulfilled thanks to the results of projects born outside the ICG. These projects had to respect their own deadlines and objectives, but found in the ICG a strong international frame providing harmonisation of the individual project goals and activities towards a common aim.

One of the consequences of this situation is that most achievements regard scientific advancements, because most tsunami projects were funded in the framework of basic or applied research financing schemes. But progress in developing an adequate infrastructure for the TWS suffered from the lack of specific plans from the member states or international authorities. One interesting example comes from the monitoring network. The seismic monitoring network in the region was already very advanced before 2004 and was close to the requirement for a TWS, which mainly means real-time connection of an adequate number of stations, and quick detection capability of large earthquakes with determination of location and magnitude in a few minutes for all the offshore and coastal source areas in the EuroMediterranean region. Progress made since the creation of ICG in terms of increasing coverage and performance by means of national and international programmes have ensured that the seismic monitoring system is today adequate to support the ITWS in the region. The picture is different if we consider the sea level monitoring network. Due to a number of reasons, its state in 2004 was quite far from the requirements for a quick tsunami detection system, particularly in terms of characteristics of the single stations, of the number of distinct networks and micronetworks not mutually exchanging data, of the geographic distribution of the stations not ensuring general coverage, etc. These drawbacks are slowly being eliminated to establish a core network of real-time tsunami stations for the ITWS, as defined in the ICG implementation plan. But the process is ultimately in the hands of the agencies, usually national agencies, that

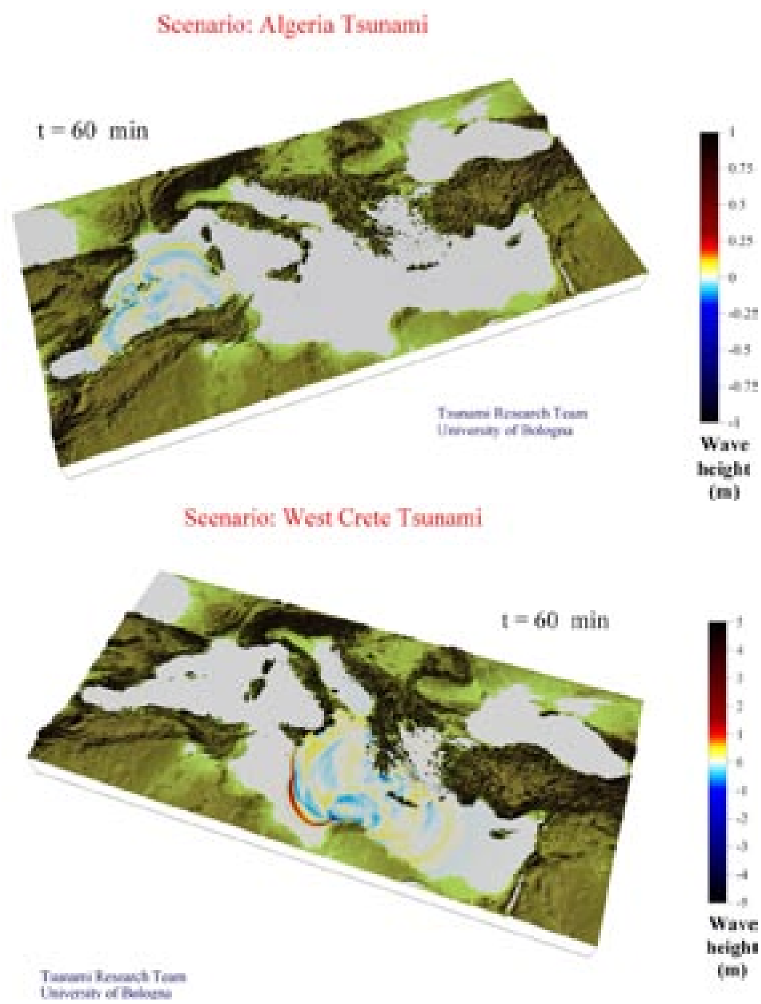

Figure 2. propagation field of a tsunami generated off Algeria (upper panel) and in the west Hellenic Arc (lower panel) after one hour since the parent earthquake. These cases can be seen as examples of tsunamis occurred in 2003 and in 365 AD respectively. Observe that one hour is enough for the front to travel across the basin and reach the coasts opposite to the source.

have operational responsibility on the tide-gauge networks and have to harmonise this goal with their internal priority schemes. At the moment, one of the main obstacles to create the ITWS for the EuroMediterranean region is just the lack of a sea level network capable of detecting tsunamis in real time.

A second weak aspect was labelled organisational in a previous section. What is pointed out here is the uncertainty or lack of decision that still accompanies the construction of the architecture of the TWS. In order to understand this aspect better, it is convenient to recall how a TWS is expected to work. In principle, a basic TWS is formed by the seismic network that (lato sensu) detects the tsunamigenic earthquake, the sea level network that (lato sensu) detects the generated tsunami, a regional centre that collects and processes the real-time data, formulates the proper alert messages and transmits them to the national tsunami centres and to the national authorities that are in turn responsible for the dissemination of the messages (including cancellation) to the population. In this basic procedural scheme, the role of the regional centre differs from the role of the national authorities since only these have the legal commitment to send the alert to the citizens of their territories. Therefore the regional centre can only transmit watches to the authorities, while the national states follow their own procedures to transform such watches into warnings, including evacuation orders and other emergency measures. The ICG has correctly addressed the problem of the architecture of the TWS and has also stated that it has to be a system of systems, meaning that at the top hierarchical level one places the regional tsunami watch centre (RTWC) and at the second level one finds the national tsunami warning centres (NTWC). Moreover, functions and requirements of all these centres have been discussed and defined within the abovementioned Task Team of the ICG where the interrelations among all these interacting centres have also been properly figured out and are in course of further definition.

But the weak point of the construction is that there are still a number of crucial unresolved organisational questions. The basic one is: how many regional centres are needed for the NEAMTWS, one or several ? and where, that is in which countries will it or they be established ? This point attains to the organisation of the TWS, though the decision to be taken is essentially a political one, and the main actors here are the member states. The discussion made so far has made clear the existence of a number of candidates and the perspective of dividing the region into a number of subregions with possible marginal overlapping. In each of these subregions, one centre would take the role of RTWC: for example, an RTWC could be established in Lisbon with responsibility for the North-East Atlantic, another RTWC could be placed in Paris with responsibility for the western Mediterranean, a third RTWC could be opened in Rome covering the Central Mediterranean, a fourth in Athens embracing the eastern Mediterranean, and a fifth in Istanbul with responsibility on the Marmara sea, the Black sea, and part of the eastern Mediterranean. The multiplicity of the RTWC poses the problem of their mutual relations.

But, most importantly, it poses the problem of how to find the necessary resources to create the centres in the start-up phase and to sustain their role and function in the long term. Such centres couldn't survive over years if the system is established only for tsunami defence. Tsunamis are very rare, and therefore those centres are expected to be most of the time in an idle state, which is not sustainable. All centres, as in the other TWS in the world, should be dedicated to a plurality of hazards, one of which is tsunami related. The choice is left to the nations where these systems will be established. There are examples where they are attached to meteorological services, and other where they are attached to geohazard monitoring agencies covering earthquakes and volcanic eruptions cases.

It is clear that as long as no decision is taken on the number and location of the RTWCs to build in the EuroMediterranean region, the process of establishing the Interim Tsunami Warning System lies in a sort of suspension, which does not mean that all the ICG activities are in a waiting state, but certainly that all the operational aspects of the enterprise are suffering. The role of the ICG is to continue to stimulate the member states to make this decision as soon as possible and, in the same time, to induce them also to build the NTWC that are equally essential for the TWS in the region. Comparison with the other oceanic regions covered by ICGs is unfortunately unfavourable to the ICG/NEAMTWS. In a sense, the EuroMediterranean region is today the only one in the world with no TWS in function and hence with no protection given to the population. It should sound as a great incentive to make new efforts and give momentum to this undertaking in order to reduce and fill the gap with the other regions.

1) Chairman of the ICG/NEAMTWS. Dipartimento di Fisica, Settore di Geofisica, Università di Bologna, Italy (email:stefano.tinti@unibo.it)

PROGRESS IN THE ESTABLISHMENT OF THE PORTUGUESE TSUNAMI WARNING SYSTEM

by Alessandro Annunziato[3], Fernando Carrilho[2], Luis Matias[1,2], Maria Ana Baptista[1,4], Rachid Omira[1] (alphabetical order)

This short note presents the state of the on-going efforts towards the implementation of the **Portuguese national Tsunami Warning System (PtTWS)**, as part of the NEAMTWS, IOC-UNESCO global tsunami warning system. This system is the natural response to the historical and recent instrumental events generated in the Gulf of Cadiz.
After the Sumatra event in December 2004, the UNESCO, through the IOC, recognized the need for an end-to-end global tsunami warning system. The NEAMTWS Intergovernmental Coordination Group was then established to cover the Atlantic, Mediterranean and Connected Seas area.
The Gulf of Cadiz is located at the eastern end of the Nubia-Eurasia plate boundary in the Atlantic and belongs to the NEAM region. This area has been the place of several tsunamis, like the well-known event of 1st November 1755. During the 20th century other smaller tsunamis were generated and recorded in the area: the 25th November 1941, 28th February 1969 and 26th May 1975 ones. The extensive occupation of coastal areas in the surrounding countries – Portugal, Spain and Morocco - , the enormous influxes of tourists during high season and the large economic value of ports, harbours and other coastal facilities increases the risk of tsunami impact. The catalogue of tsunamis that affect Portugal mainland and Madeira have been recently revised by *Baptista and Miranda (2009)* and a summary is shown in Figure 1.

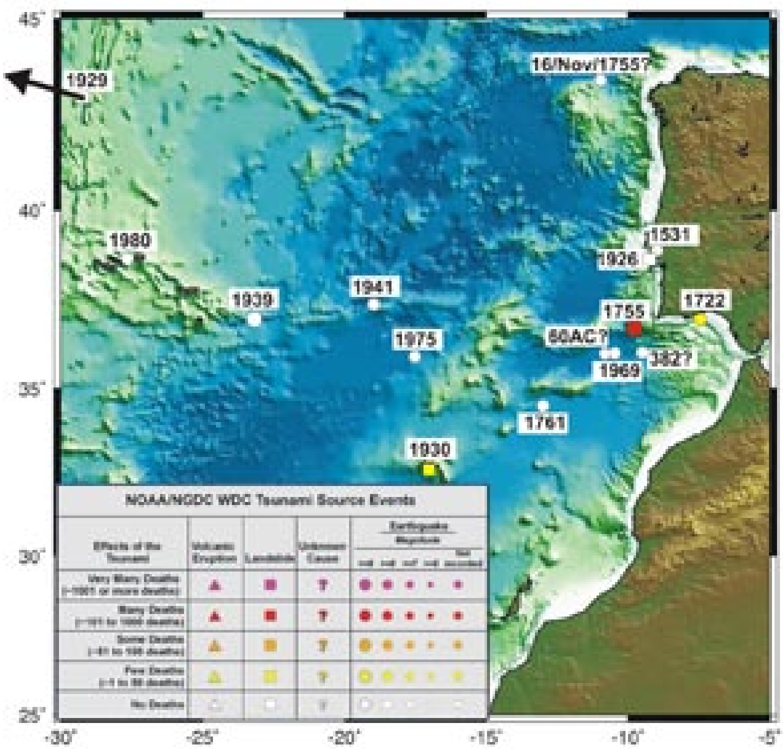

Figure 1 - Summary of the Portuguese catalogue of the tsunamis that affected the mainland and Madeira Islands, according to Baptista and Miranda (2009). The legend is taken from the NOAA/NGDC Global Tsunami Sources poster (http://ioc3.unesco.org/itic/). The 1929 event refers to the Great Banks landslide that is out of the figure.

The development of the Portuguese Tsunami Warning System comprises a sequential data collection and analysis, from the origin of the tsunamigenic earthquake to the issuing of messages to the Portuguese Civil Protection authorities, as indicated schematically in Figure 2. The PtTWS includes three main components: the seismic detection, the tsunami detection/analysis and the issue of warnings/alerts. In Portugal, the **Instituto de Meteorologia (IM)** is the only national institution operating on a 24x7 basis that is also responsible for the Portuguese seismic network, which makes IM the natural candidate to host the Portuguese system. IM is the Portuguese National Tsunami Focal Point as regards the NEAMTWS.
The seismic technology is the first one to be used in the detection of a possible tsunamigenic earthquake. In recent times there has been a significant enhancement in the seismic network coverage around the Azores-Gibraltar plate boundary, and in particular for the Cadiz Gulf region (figure 2). Real time data (latency <10sec) from 35 broadband stations and near real-time data (latency~2min) from 22 additional enhanced short-period stations are transmitted by VSAT and Internet to the IM Operational Centre, located in Lisbon. The records are processed in near real-time using a solution mixing Seiscomp *(Hanka*

et al., 2000) and Seisan *(Havskov & Ottemoller, 2005)* platforms, making it possible to compute earthquake locations, validated by a human operator, in less than 5 minutes since origin time. One of the major problems is to rapidly evaluate the magnitude of large earthquakes (MW>7) using data from regional stations, mostly because the commonly used procedures to evaluate magnitudes from short distance records usually underestimate the size of the great earthquakes. However, a recent development *(Bormann & Saul, 2008)* makes it possible to compute reliable MW from mB magnitudes using broadband records from stations at distances starting from 500km, which means that it is possible to have hypocentre location and Mw magnitude estimates within the mentioned 5 min.

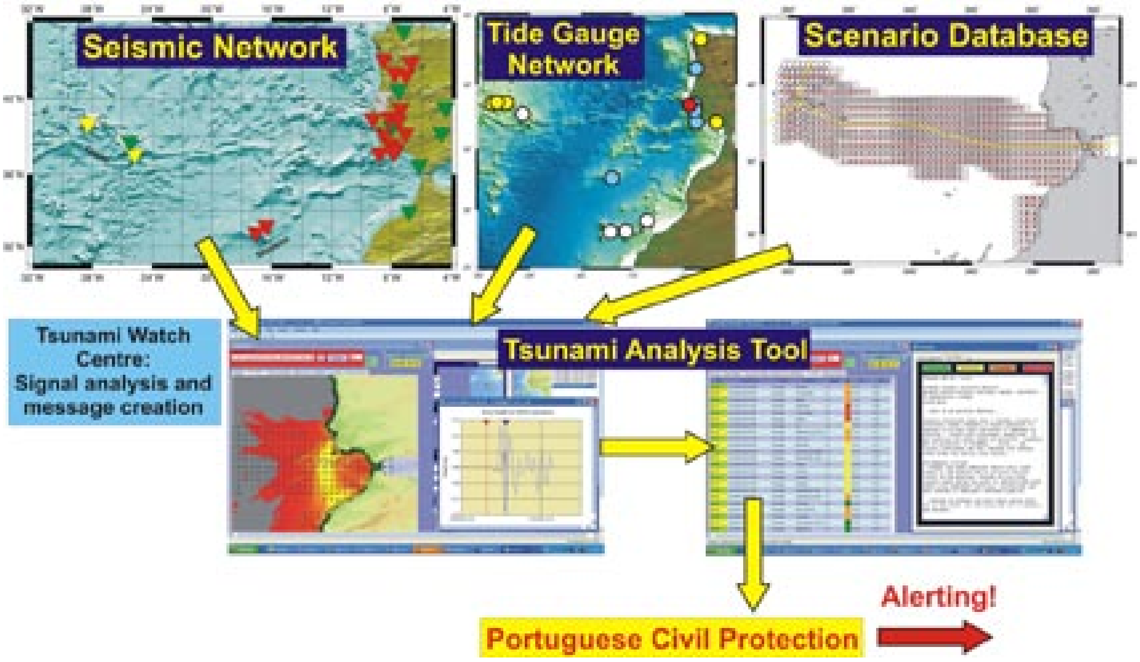

Figure 2 - Main operational components of the PtTWS. Top center: Status of the tide-gauge monitoring network operating at IM. In red, real-time station; in blue, real-time stations to be connected in 2009; in white, tide-gauge data acquired at the GLOSS web site (http://www.vliz.be/gauges/) with a latency between 6 and 15 minutes; in yellow, tide-gauge data collected at dedicated web sites, with a latency less than 5 minutes (http://www.puertos.es/es/oceanografia_y_meteorologia/redes_de_medida/index.html http://oceano.horta.uac.pt/azodc/tidegauge.php).

The next level of decision in the PtTWS is taken with the help of the **Tsunami Analysis Tool (TAT)**. TAT is being developed at the **Joint Research Centre of the European Commission (JRC)** to assist the TWC operator, in case of a large enough seismic event, in deciding if a tsunami has been generated or not.

When the first information, based exclusively on seismic data, is received by TAT then, according to the decision matrix defined for the North-East Atlantic by the ICG/NEAMTWS Working Group 1, TAT triggers the broadcast of the first message to the **Portuguese Civil Protection Authorities (ANPC)**. This message includes the **estimated tsunami travel time (ETTT)** and maximum tsunami amplitude on selected sites of the Portuguese coast (the forecast points). These parameters are taken according to the best scenario selected from a large database of pre-computed tsunami scenarios (Figure 3a). These were computed for a wide area surrounding the Azores-Gibraltar plate boundary, one point every half a degree, all magnitudes from 6.5 to 9.5 (0.25 interval) in a total of over 1700 scenarios (see *Annunziato, 2007*, for details on the tsunami simulations). However, it is well known that only a few of the large earthquakes do generate tsunamis. It is then essential to confirm the generation of a tsunami by the observation of sea level at tide-gauges or DART buoys. Currently the number of coastal tide-gauges that provide timely information to the IM data collector is insufficient but this pattern will change rapidly during 2009 (see Figure 2). Through TAT, it is possible to compare in real-time the sea level observations and the tsunami waveforms for the selected scenario, allowing for a fast evaluation of the generation of the tsunami (Figure 3b). The messages to Civil Protection Authorities are updated accordingly.

Currently, the PtTWS is not working in a operational regime for two main reasons:
i) the simultaneous monitoring of earthquake and tsunami requires operational shifts with two persons, while now only one is part of the operational section;
ii) the sea-level monitoring system is still very incipient, a situation expected to change in the near future. In January 2009 only one tide-gauge was available in real-time at the IM Data collector (Cascais) but with one sample every 6 minutes.

Meanwhile, we are working on improvements to the system, namely the computation of a completely new set of tsunami scenarios based on the knowledge of the faults that can originate

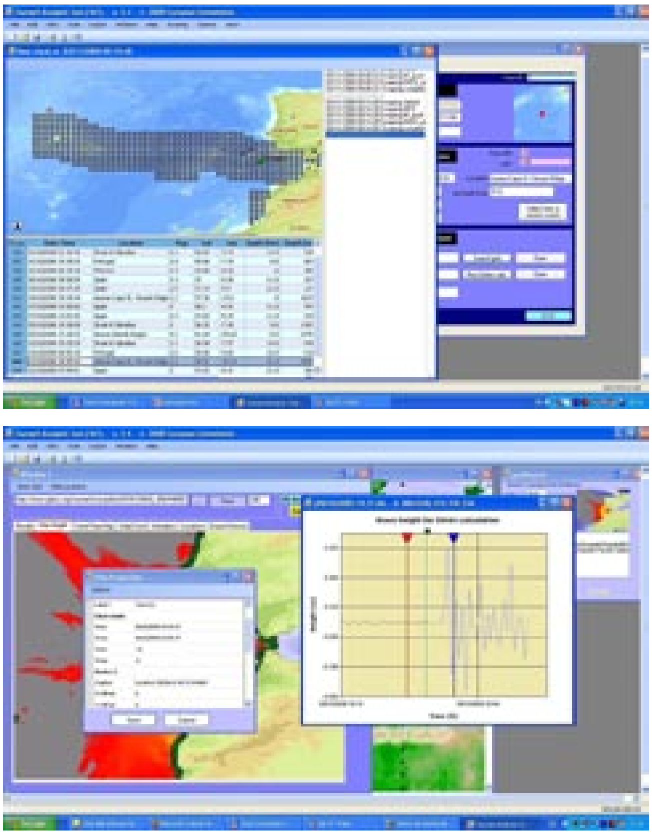

Figure 3 - a) Example of TAT multi-screen display showing the selection of one scenario upon a trigger by the seismic network; b) TAT running a synthetic case illustrating the capacity to compare real-time observations with pre-computed tsunami waveforms.

large earthquakes in the Gulf of Cadiz. This work is expected to be completed by the end of 2009.

The main limitation of the current design of the PtTWS is the fact that, in the absence of sea-level observations offshore, the generation of a tsunami and its amplitude can only be confirmed when the waves attain the closest tide-gauge connected to the Warning System. This means that the near coastal areas cannot be alerted in time in case a regional tsunami is generated. Considering that Sines and Lagos tide-gauges are operating and that it takes 5 minutes for data transmission and analysis, a tsunami generated in the Horsehoe-Fault will give none or less than 10 minutes of warning time for most of the southwest and southern coast of Portugal. We consider that the future PtTWS will have to include also sea-level observations in the open-ocean, as provided by DART buoys or cabled systems.

In summary, the backbone of the future Portuguese Tsunami is already in place and the basic functionalities are installed at the Instituto de Meteorologia. Very little is required for the PtTWS to go in operation and plans are already devised for its development and improvement, benefiting from the ongoing international cooperation developed at the ICG/NEAMTWS: a) refining of the tsunami scenario database; b) definition of the PtTWS Communication Plan; c) real-time connection of additional coastal tide-gauges; d) installation of deep-ocean sea-level sensors. Some of these actions are in our hands and we can reasonably improve the system by the end of 2009. For other (e.g. installation of buoys) larger national commitment and international cooperation are needed.

Acknowledgements

This work is a joint effort between the Instituto de Meteorologia (Portugal), the Joint Research Centre and with the coordination of the Portuguese Group for the implementation of NEAMTWS in the area. This work has been financed by different European projects such as NEAREST and TRANSFER, and also by the JRC, the IM and CGUL/IDL institutions.

We would like to acknowledge the collaboration of Mesquita Onofre and Joana Reis from **Instituto Hidrográfico (IH)** and Gonçalo Crisóstomo and Manuela Vasconcelos from **Instituto Geográfico Português (IGP)**. The authors wish to thank E. Bernard, V. Titov and all the team from PMEL (NOAA). GFZ (Potsdam) made a major contribution to the development of the real-time seismic network funded by the **Portuguese Science and Technology Foundation (FCT)** through the MODSISNAC project. Additional sea-level information in the Azores is provided by the Departamento de Oceanografia e Pescas – Universidade dos Açores (**DOP-UAç**, Ana Martins).

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THE INGV CONTRIBUTION IN THE FRAMEWORK OF NEAMTWS

by Giulio Selvaggi[1]

In the framework of the **North-East Atlantic and Mediterranean Tsunami Watch System (NEAMTWS)**, supported by the IOC-UNESCO, Italy has offered to establish a prototypal regional watch centre for large earthquakes in Central Mediterranean. The **"National Earthquake Centre" (Centro Nazionale Terremoti, CNT)** of the **"Istituto Nazionale di Geofisica e Vulcanologia" (INGV)** plays a major role in the system and will exploit the already existing 24H/7 surveillance service operated in its headquarters in Rome for the national Civil Protection Department for real time monitoring of earthquakes (Figure 1). We have recently upgraded our monitoring room by installing a wide screen monitor (Figure 2) that allows us to better visualise earthquake occurrence on geographic tools. Moreover, we have introduced on our web site (www.cnt.ingv.it) rapid information on italian earthquakes that include thematic maps, shake maps, moment tensors and "did you feel it" tools for every seismic events.

INGV has established the National Earthquake Centre (Centro Nazionale Terremoti, CNT) in 2001 to help the **National Civil Protection Dept. (DPC)** in assessing the effects of earthquakes in Italy and Central Mediterranean as fastly and accurately as possible. After a few years of strong technological development, today the CNT manages hundreds of high-quality seismic stations in Italy and in the Mediterranean. Data are received and processed in real-time at the CNT in Rome, but some functions are doubled in the monitoring facilities of Catania, Naples, and Grottaminarda, to guarantee redundancy and disaster recovery. CNT also manages MedNet, one of the oldest broad-band networks worldwide, today focused on the implementation of a Tsunami warning system for the Mediterranean. This is one of the main goals of CNT for the next years. Most CNT stations (MedNet included) are equipped with broad-band seismometer, accelerometer, and continuous GPS receiver, in order to recover the whole range of frequencies and amplitudes of solid Earth phenomena: microearthquakes, large events worldwide, strong shocks nearby, slow tectonic deformation.

Figure 1 - The INGV monitoring room in Rome. Old fashion drum recorders are still in use together with SisMap software (on the PC monitor) developed at INGV for geographic restitution of earthquake information

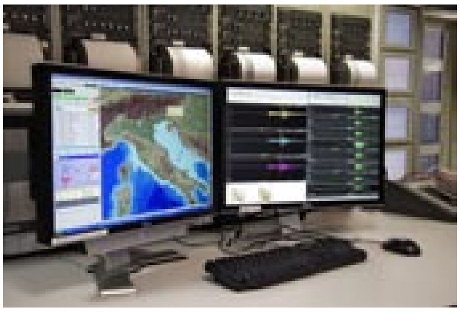

Figure 2
The new wide screen videowall recently installed in the monitoring room.

The surveillance for NEAMTWS will be based on the backbone seismic network, as delineated by Working Group 2 in the framework of NEAMTWS activities, on the dense Italian and MedNet broad band seismic networks , and by other networks sharing data through ORFEUS or other bi- or multi-lateral agreements. We will also take advantage from data sharing with GFZ who has recently offered to act like a seismic background data centre for the interim NEAMTWS. Among hundreds of available broad band stations, we are presently involved in the evaluation of the best practise fit for a seismological virtual network dedicated to earthquake-generated Tsunami detection and location.

Software tools for rapid earthquake location and magnitude determination are presently under test and current developments, including quality check of real time seismic data, rapid determination of seismological parameters as moment tensors. All are under development in the framework of the EU project NERIES.

Future developments are related to GPS data usage for rapid displacement determination, as INGV maintains a real time high frequency GPS network of tens of receivers located in its territory.

1) INGV

GEOFON INVOLVEMENT IN EUROMED TSUNAMI WARNING

by Winfried Hanka[1] and Jörn Lauterjung[1]

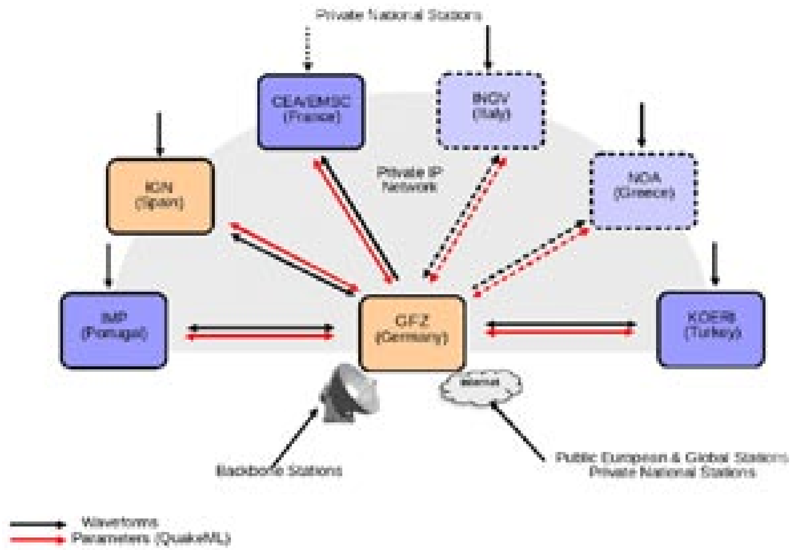

Figure 1: Virtual SeisComP3 cluster as being established for the interim NEAMTWS. GFZ serves as central background data centre for real-time data feeds from VEBSN, additional private stations and the VSAT backbone network. The 24/7 RTWCs obtain selected RT data feeds and automatic processing results for verification and dissemination.

It may not be so obvious, why Germany should take an active part in tsunami warning in the EuroMed area.
But after the tsunami tragedy following the great Sumatra quake of December 26th, 2004, also causing 585 German fatalities, the German government decided to fund the **German-Indian Ocean Tsunami Warning System (GITEWS)** project for the support of setting up tsunami warning systems in Indonesia and other Indian Ocean rim countries. The **GEOFON** program of GFZ Potsdam was appointed to design and implement the land-based seismic component of GITEWS *[Hanka et al., 2006]*, mainly due to its expertise in Internet-based near real-time data acquisition *[Hanka et al., 2003]*, rapid near real-time earthquake alerts (http://www.gfz-potsdam.de/geofon/new/eq_inf.html) and virtual seismic network management *[van Eck et al., 2004]*.
The time available to warn the Indonesian population in coastal areas after a tsunami has been generated by a large earthquake in the Sunda trench is extremely short since the expected tsunami travel times are only in the order of 20-40 minutes. Therefore tsunami watch or warning bulletins have to be issued preferably within 5 minutes in order to be able to initiate timely civil protection measures. Thus, these bulletins must primarily be based on rapidly determined earthquake parameters - such as estimates of location of rupture start, depth and magnitude - and selected pre-calculated tsunami scenarios which fit the initial seismic parameters. Other sensor data such as measurements from the various seal level systems and from CGPS will usually not be available within such a short time frame but will be needed later-on to either validate a warning status or to be able to cancel it.
The earthquake monitoring part of GITEWS built around the SeisComP3 (SC3) software package is already operational since September 2007 and e.g. enabled the Indonesian tsunami warning center to issue a tsunami warning after 4 ½ minutes for the small local tsunami following the Bengkulu quake on September 12th, 2007 *[Hanka et al., 2008]*.
Meanwhile, Seiscomp3 was also successfully installed in other Indian Ocean tsunami warning centers, such as Maldives, India, Pakistan, Malaysia and Thailand, and several more to follow.
Meanwhile also in the EuroMed area, preparations for the establishment of the **NEAMTWS** (**NE Atlantic and Mediterranean Tsunami Warning System**, coordinated by UNESCO/IOC) have been initiated. Due to partly extremely short expected tsunami travel times, the situation at least for the Mediterranean, the Marmara and Black Sea is maybe even more challenging than the one for Indonesia. And since in the case of a major tsunami in the Mediterranean or the NE Atlantic a lot of German casualties would have to be claimed, it was obvious for the German government to offer GITEWS-gained expertise to the NEAMTWS process.
Although local tsunami warning is a national task rather than the responsibility of a regional system such as NEAMTWS, it is proposed to assist the planned VSAT based NEAMTWS seismic backbone network (~90 stations) with a dense Internet based extended **VEBSN** network (**Virtual European Broadband Seismic Network** *[van Eck et al., 2004]*

plus selected non-public stations) to speed-up the earthquake monitoring.

As a first initial step towards an interim system, an experimental multi-node earthquake monitoring system is under testing on basis of SC3 with several 24/7 centres acting as preliminary **regional tsunami watch centres** (**RTWCs**) responsible for specific coastal regions. All of these should be connected with GFZ as background data center serving both selected real-time data feeds from the VEBSN+ and the backbone network and automatic processing results to the RTWCs for visual verification, manual interaction and dissemination. For this, GFZ Potsdam has started from January 1st, 2008, to operate its global earthquake monitoring system as an experimental seismic background data centre. The **SeisComP3** (**SC3**) software was extended to test the export and import of individual processing results within a cluster of SC3 systems (Fig. 1). On-site or remote SC3 installations and on-site training were provided to the potential regional tsunami watch centres at IM (Portugal), CEA/EMSC (France) and KOERI (Turkey), as well as for IGN (Spain, no RTWC candidate though). Similar installations at INGV and NOA have also been completed, while their connection to the SC3 cluster is still pending. The virtual real-time seismic network (Fig. 2) available at GFZ for re-distribution to the RTWCs was substantially extended by many stations from Western European countries optimizing the station distribution for NEAMTWS purposes. To amend the public seismic network, some of the attached centres provided additional stations for NEAMTWS usage. In parallel to the data collection by Internet, the GFZ VSAT hub for the secured data collection of the EuroMED GEOFON and NEAMTWS backbone network stations became operational and the first data links were established.

Although the test is not completed, the experimental system has already prove its performance since a number of relevant earthquakes has happened in the NEAMTWS region in 2008. The results are very promising in terms of speed as the automatic alerts (reliable solutions based on a minimum of 25 stations and disseminated by emails and SMS) were issued between 2 1/2 and 4 minutes for Greece and 5 minutes for Iceland (Fig. 2). They are also promising in terms of accuracy since epicenter coordinates, depth and magnitude estimates were sufficiently accurate at a very early stage of processing, and usually didn't differ substantially from the final solutions and provide at least a good starting point for the operations of the interim NEAMTWS. However, although an automatic seismic system is a good first step, 24/7 manned RTWCs are of course needed for regular manual verification of the automatic seismic results and the estimation of the tsunami potential for a given event.

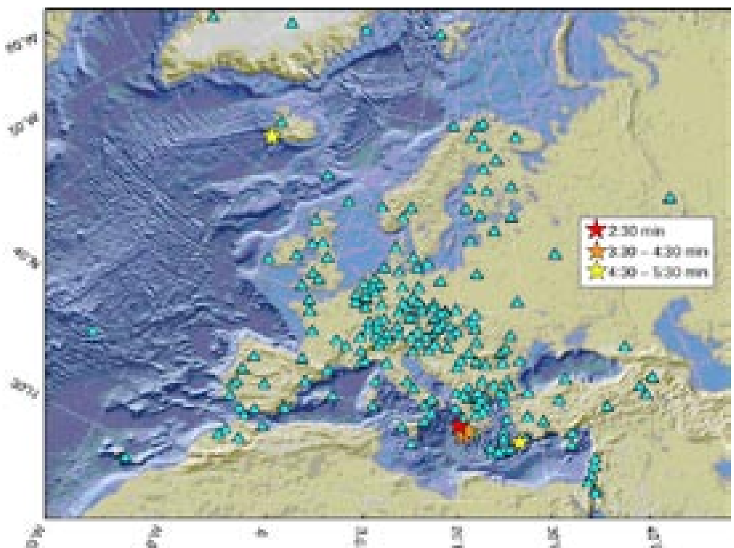

Figure 2: Virtual NEAMTWS real-time seismic network as presently collected by GFZ as an extension of the public VEBSN for re-distribution to the interim NEAMTWS 24/7 RTWCs. Primary data acquisition is by Internet, but the VSAT backbone network has also started to be established. The stars show the M>6 EuroMed earthquakes in 2008 and the colours indicate the time of automatic event parameter distribution from GFZ background centre to the RTWCs.

Acknowlegements

This is publication no. 55 of the GITEWS project. The project is carried out by GFZ Potsdam and other institutions in Germany and Indonesia and in close cooperation with other international partners. Funding is provided by the German Federal Ministry for Education and Research (BMBF), Grant 03TSU01.

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1) GFZ German Research Centre for Geosciences, Potsdam, Germany.

EARTHQUAKE MONITORING FOR TSUNAMI DETECTION IN THE UK

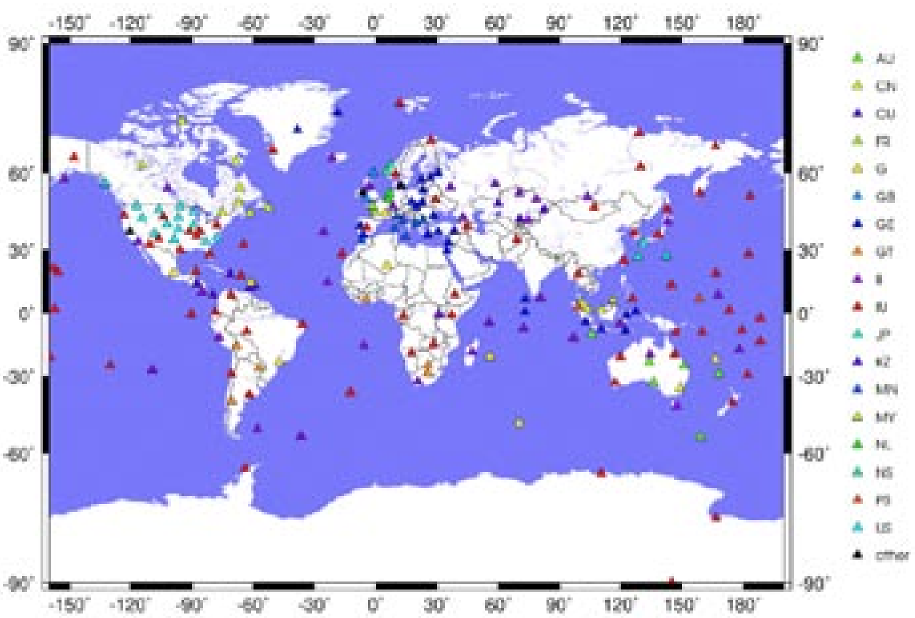
by Lars Ottemöller[1,2], Richard Luckett[2] and Brian Baptie[2]

Following the Indian Ocean tsunami in 2004, **DEFRA (UK Department for Food, Environment and Rural Affairs)** commissioned two studies to investigate the tsunami hazard to the UK. The first study, 'The threat posed by tsunami to the UK,' was carried out by the British Geological Survey (**BGS**), Proudman Oceanographic Laboratory (**POL**), the Met Office and HR Wallingford. The second study, 'Tsunamis – Assessing the Hazard for the UK and Irish Coast', was carried out by HR Wallingford, BGS and POL. Reports from both studies were published by DEFRA (2005; 2006).

Following consideration of the results of these studies which showed that there is a small but non-negligible risk to the UK coast from tsunami originating in the north-eastern Atlantic region, DEFRA commissioned BGS to work on a further project, 'Development of seismic methods to automatically identify tsunamigenic events and generate alerts'. The aim is to strengthen the national capability to detect earthquakes that could generate tsunami affecting the UK. Such a system has been in place at the BGS for over two years now and is detecting earthquakes around the globe successfully. These efforts go in parallel with developments in Europe to establish a regional tsunami warning centre for the North East Atlantic and the Mediterranean.

We have selected and implemented the EarlyBird software developed by Paul Whitmore (see web link) at the US West Coast and Alaska Tsunami Warning Center that has all the functionality required to detect earthquakes for tsunami warning. The software is well established and has been in operation at tsunami warning centres for a considerable time. We have selected more than 200 seismic stations worldwide (see Figure) to provide good coverage in particular for our monitoring area, which extends from the UK and surrounding waters to most of the North Atlantic, including offshore Portugal, the Mid-Atlantic ridge, the Caribbean, and the northeast coast of America. Earthquakes in this area with magnitude greater than 5 are detected within minutes, magnitudes are determined and automatic alerts issued (also to the EMSC).
One example of accurate automatic location and magnitude determination was the San Vincent Cape on 12 February 2007 off the Portuguese coast. This is where the 1755 Lisbon earthquake most likely took place, generating a tsunami that reached the UK and Irish coasts. The impact of the 1755 event on the UK and Irish coast was investigated in an earlier study *(DEFRA 2006; Horsburgh et al. 2008)*. Modelling results predict wave heights that locally can be as large as 4 metres, which matches historic observations from 1755. A repeat of this event is possibly the most likely source to generate tsunami that could reach the UK. The functionality of the system was also tested in the UK during the Dover Straits earthquake on 28 April 2007 and the Market Rasen earthquake on 27 February 2008. Accurate magnitudes and locations of the events were determined within 5 minutes of the earthquakes.

Figure: Map of seismic stations used within the UK EarlyBird setup. Different colours are used for the network codes.



As part of the latest study, we also tested methods to automatically determine the style of faulting of

TOWARDS THE ESTABLISHMENT OF A NATIONAL TSUNAMI WARNING CENTER IN MOROCCO

by Aomar Iben Brahim[1], Azelarab El Mouraouah[1], Abdelouahad Birouk[1] and Mohammed Kasmi[1]

Introduction

The Moroccan marine coast is open at the same time on the Gulf of Cadiz; the North-eastern part of Atlantic Ocean and the Mediterranean. This vast marine space, shared by several bordering countries, in particular Portugal and Spain, remained until now among the areas of the globe that are still not equipped with a tsunami regional warning center.

In fact, Moroccan coasts are more than 3000 km long, on which the majority of its population and its infrastructures are established. Historically, Morocco knew important tsunamis, the most important of which being the 1755 one provoked by the so-called Lisbon earthquake, which was particularly disastrous. The zone of Gorringe-Ampere in the Atlantic is a source area able to generate important earthquakes in the area. Morocco is thus not safe from important tsunamis which could possibly have a disastrous impact on the socio-economic development of the country. Thus, it is important that Morocco urgently takes practical measures of prevention against tsunamis.

Since the large Sumatra earthquake of December 26th, 2004 and the Indian Ocean tsunami that followed, the UNESCO has worked so that all the countries exposed to tsunami risk could establish their own tsunami warning center. Starting 2005, the UNESCO has set up an **Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS)**. Morocco, represented by the **National Institute of Geophysics (ING)**, takes part regularly in the meetings of this group. In this context, Morocco is undertaking efforts to set up its own **national tsunami warning Centre (NTWCM)**.

Knowing that a seismological network is a major tool for real time tsunami detection, the NTWCM will thus be established within the National Institute of Geophysics in order to benefit from the already invested equipments, and benefit from the expertise of its scientists in the field of seismology. Moreover, the Moroccan Ministry for Foreign Affairs and Cooperation has appointed the National Institute of Geophysics as the national focal point within the Intergovernmental Group of Coordination for the installation of Tsunamis warning system ICG/NEAMTWS.

The NTWCM will be working together with the Department of Harbors and the Maritime Public Do-

Earthquake Monitoring for Tsunami Detection in the UK (continued)

the earthquake. The tsunami wave height directly relates to the amount of vertical seafloor displacement. The worst case would be a near vertical fault with movement mostly in the vertical direction. The vertical displacement also depends on the depth of the earthquake below the surface. Earthquakes that are particularly efficient in generating tsunamis are the so-called tsunami earthquakes. These are shallow subduction earthquakes that release less energy than other earthquakes with the same fault dimensions. We have implemented a procedure to detect this type of earthquake automatically. While quick automatic determination is essential in the tsunami warning context, we find that the automatic solutions still have to be manually reviewed. At present, the results are not fed into a 24/7 tsunami warning centre, but this possibility is being discussed.

Link to DEFRA reports: http://www.defra.gov.uk/environ/fcd/emergencyplanning/tsunami.htm
Link to EarlyBird software: http://wcatwc.arh.noaa.gov/DataProcessing/ew-eb.htm

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Horsburgh K. J., C. Wilson, B. J. Baptie, A. Cooper, D. Cresswell, R. M. W. Musson, L. Ottemöller, S. Richardson, S. L. Sargeant (2008), Impact of a Lisbon-type tsunami on the U.K. coastline and the implications for tsunami propagation over broad continental shelves, J. Geophys. Res., 113, C04007, doi:10.1029/2007JC004425.

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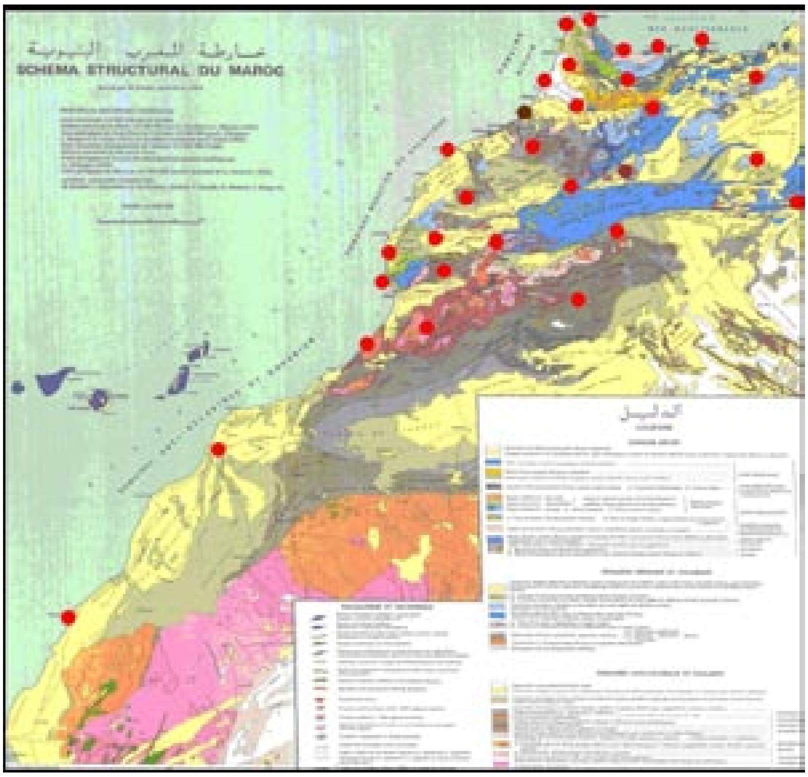

Figure 1 - Morocco New National Seismic Monitoring and Warning Network Configuration

main, in order to have access to tide-gauges data on a real-time basis and will establish a network of Moroccan scientists working in the field of tsunamis. This Center will also collaborate with national and local authorities in charge of post-crisis management in order to prepare scenarios of intervention in case of a tsunami on the Moroccan coasts.

In this article, we give a brief summary of our current conception of the future Morocco national tsunami warning Center; its objectives and its organization.

Objectives

A tsunami is a series of surface sea-waves produced by an offshore earthquake, a marine volcanic eruption, a massive landslide, or a meteorite impact. Sea earthquakes are, by far, the most frequent cause. Currently, there is no global (planetary) tsunami early warning system, although an ocean-broad system has been operational in the Pacific basin for more than 40 years. Since the 2004 Sumatra tsunami, several regional tsunami watching centers and several national tsunami warning centers have been established.

The objectives for the Morocco tsunami warning center are:

- To give timely tsunami warning messages to the national authorities and to the concerned populations in case of a tsunami;
- To undertake scientific studies and research in order to determine the zones that could be readily flooded in case of a tsunami;
- To undertake scientific research studies in order to help advise prevention measures against tsunamis;
- To work along with the relevant authorities so that the tsunami hazard is taken into account in the different planning schemes,
- and to help increase public awareness in populations likely to be affected in the event of an important tsunami.

Methodology and Implementation

A tsunami warning system can only be successful if it covers the whole of the techniques related to an "end to end" approach. An end to end tsunami warning system starts with the fast detection of a tsunami wave and ends up with a well-prepared community able to suitably answer a warning. A first approach in the monitoring of tsunami waves is a combination of seismometers and tide-gauge measurements. Initially, the seismometers quickly detect the occurrence of an important earthquake at sea. Afterwards and in order to provide a much earlier detection of an approaching tsunami, a tsunami evaluation and warning system is deployed at ocean-bottom (**DART**), using buoys acoustically linked to seafloor pressure gauges. The buoys would relay the sensor data to a central land site by satellite radio links.

The DART incorporates bidirectional communications which allow data transmission of tsunami on request, independently of the automatic algorithm. Thus, when the amplitude exceeds the preset threshold, the measurement process enters a fast mode of report to provide detailed information about the tsunami.

The NTWS of Morocco will initially use real-time data from the National Seismic Warning and Monitoring Network operated by the ING for an automatic fast detection of large earthquakes at sea. The arrival of the tsunami waves will be confirmed (or not) by the tide-gauges installed at the different harbors of Morocco and run by the Department of Harbors and the Maritime Public Domain, in order to access tide-gauges data on a real-time basis. Further information coming from within the sea will be relayed by the buoys deployed by the Regional Center of observation of tsunamis which will be installed in a neighboring country of the ICG/NEAMTWS. This scheme will hopefully enable the NTWSM to alert the concerned authorities according to a pre-established scenario. It is worth mentioning that the data acquisition center recently installed in Rabat is powerful enough to allow the acquisition and integration of various types of data. Thanks to the international co-operation carried out by UNESCO in this field, the NTWSM of Morocco will be able to get some assistance in the interpretation of the collected tide-gauge data and thus give warning messages against tsunamis.

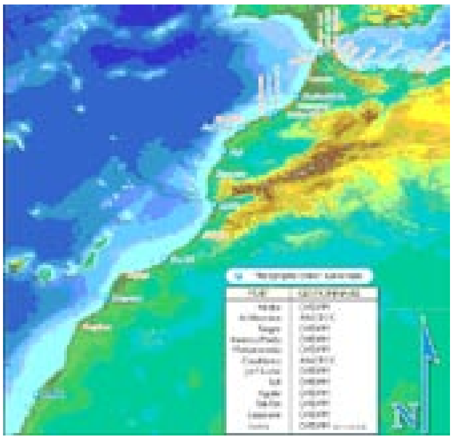

Figure 2 - Map showing the distribution of tide-gauges in Morocco.

Organization

Setting up the NTWSM should take three years. Two years will be necessary for the installation of a prototype tsunami warning center, which will be tested for one year before definitively becoming the National tsunami warning center. Setting up the NTWSM of Morocco requires a full-time employment of a number of scientists and technicians. Furthermore, interested research scientists from different universities will take part in the activities of the NTWSM. It is also worth mentioning that the NTWS of Morocco as currently designed will require a modest mobilization of financial resources.

The NTWSM will be run by two boards: a management board and a national coordination board. Also, the NTWSM will be organized around two scientific teams:

1. a tsunami warning team, using seismology and tide-gauges data. This team will be formed mostly by scientists from the ING.
2. a team for scientific studies on tsunami risks such as tsunamis flooding and vulnerabilities. This team will be formed by scientists from different institutions including the ING, the **Royal Center for Remote Sensing** (**CRTS**) and concerned university teams which will be identified according to their fields of expertise and their potential to give an important contribution in this field.

Existing Infrastructures

The National institute of Geophysics (ING) has deployed the national seismic monitoring and warning network over the Moroccan territory. This telemetry network consists of over 40 seismic stations and allows a nationwide follow-up of the seismic activity in real-time. ING has also installed about 50 accelerometers for the monitoring of strong motion in sites with large public works in the country. Currently, the ING has acquired and is in the process of deploying a new generation, state-of-the-art **National Seismic Network (NSN)** and Seismic Information System. It consists of twenty (20) very-broadband and eleven (11) shorts-period seismic stations transmitting in real-time modes to the ING Data Center located in Rabat. Communication from the 31 remote stations to the ING will be achieved by using **Very Small Aperture Final (VSAT)** satellite technology. The ING is further planning to couple GPS stations with the Broadband seismic stations that will be installed in areas of interest.

Data from the new Moroccan NSN will be transmitted to two host computers which will provide Command and Control of the remote seismic stations and subsystems, as well as real-time and off-line processing capabilities and data archiving.

Network of Tide-Gauges

12 tide-gauges are currently deployed in Morocco. Two of these tide-gauges are operated by the **ANCFCC (the National Agency for Land Conservation, Land registration and cartography)** and 10 tide-gauges belong to the Department of Harbors and the Maritime Public Domain (Figure 2). Data from these tide-gauges are not currently transmitted in real time but are rather recorded on a readable medium and transferred later on.

Furthermore, the ING is currently in the course of installing a digital tide-gauge based on radar technology at the harbor of Casablanca. The data of this tide-gauge will be transmitted in real time to the main seismic acquisition centre of the ING in Rabat and to the Department of Harbors and the Maritime Public Domain.

The ING will soon sign a convention of co-operation for the transmission of the data of several tide-gauges in real time to the power station of acquisition of Reduction.

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THE DEVELOPMENT OF THE NATIONAL TSUNAMI WARNING SYSTEM OF GREECE

by Gerassimos A. Papadopoulos[1]

Introduction

The area of Greece is a highly active region from the geodynamics point of view.

Large earthquakes are common there and because of this, tsunamis are generated from time to time.
Volcanic eruptions are unfrequent but they also produce tsunamis. In addition, tsunamis from seismic or aseismic landslides are quite common in the Greek region. Several examples of large destructive tsunamis have been documented since the antiquity up to recently (see recent review in *Papadopoulos, 2009a, b*). The most tsunamigenic zones are the western and eastern segments of the Hellenic arc, South Greece, as well as the closed sea of the Gulf of Corinth, Central Greece (Fig. 1).

Short Travel Times

From a physical point of view, the most important feature of Greek tsunamis, which is of interest for the early warning, is that the travel times of tsunami waves are very short, as they are in the entire Mediterranean Sea.

The first tsunami arrivals produced by the most important tsunami sources occur a few minutes after the wave generation. Relatively more distant coastal zones may be affected up to 30-40 minutes after the tsunami generation.

Therefore, the development and reliable operation of a tsunami early warning system in Greece, and generally in the Mediterranean Sea, is quite challenging from a technological point of view, and a hard goal from an operational point of view.

Present Status

On June 2005 the national delegations at the **Intergovernmental Oceanogrpahic Commission (IOC)** of UNESCO decided to organize the **North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS)**. Greece supported the proposal and since that time became one of the most active nation member. Greece made clear its interest to develop a **National Tsunami Warning Center (NTWC)** with the prospect to become a **Regional Tsunami Warning Center (RTWC)** of NEAMTWS. The general architecture predicts that there will be two components for the NTWC. The first will be a **National Tsunami Network of Greece (NATNEG)** for the monitoring of the seismic and sea level phenomena. The Institute of Geodynamics, National Observatory of Athens, has been asked to develop and run the NATNEG. The second component will be the operational one which is predicted to be under the responsibility of the General Secretary for Civil Protection.

As for the NATNEG, the telemetric national seismograph system is already existing and operating with a staff on duty on a 7/24 basis.
Seismic signals are presently transmitted to the seismograph center in Athens mainly by dedicated telephone lines. They are able to transmit at the same time signals of several other geophysical parameters, such as sea level changes and GPS signals. Recently, an effort started for the establishment of a national telemetric tide-gauge system operating on a 24-hour basis by transmitting signals to the seismograph center in Athens. Priority has been given to the Hellenic arc which is the most tsunamigenic. Two stations were installed in Crete island and five others are expected to be obtained for an installation in the Ionian Sea islands.

A tool of particular value for the early tsunami warning is the decision matrix: a set of prescribed empirical rules supporting decision on the possibility of tsunami generation depending on the focal parameters of the earthquake. The decision matrix was developed by one of the working groups of ICG/NEAMTWS on the basis of Greek

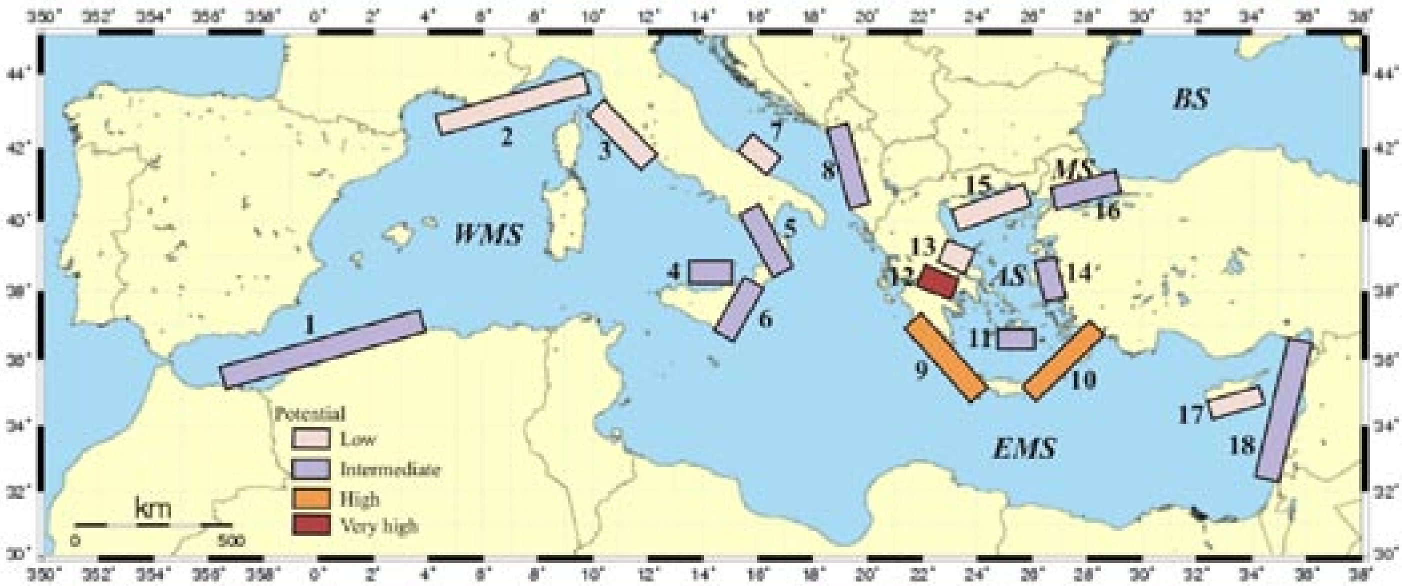

Figure 1. The tsunamigenic zones of the Mediterranean Sea (modified from Papadopoulos and Fokaefs, 2005): WMS = west Mediterranean, EMS = east Mediterranean, AS= Aegean Sea, MS = Marmara Sea, BS = Black Sea, 1= Alboran Sea, 2= Liguria and Cote d'Azur, 3= Tuscany, 4= Aeolian islands, 5= Calabria, 6= Messina straits, 7= Gargano promontory, 8= SE Adriatic Sea, 9= west Hellenic arc, 10= east Hellenic arc, 11= Cyclades, 12= Corinth Gulf, 13= Evoikos Gulf, 14= east Aegean Sea, 15= north Aegean Sea, 16= Marmara Sea, 17= Cyprus, 18 = Levantine Sea. The tsunami potential of each zone is classified in a relative scale according to the frequency of occurrence and intensity of tsunamis.

earthquake and tsunami data covering about the last 100 years. It is similar to the decision matrix developed several years ago in the Pacific Ocean as well as in Japan.
Of importance is also the knowledge on the tsunami phenomena accumulated mainly in the last 20 years or so about the tsunamigenic sources, tsunami cataloguing, wave generation and propagation, numerical modeling, hazard assessment and risk mitigation.

What is Missing?

One of the primary goals is to further develop the national tide-gauge system.

Apart from NOA, other institutes are also involved in this effort, primarily the Hydrographic Service of the Greek Navy and the Hellenic Marine Research Center.
Components still missing are the creation of a data basis of pre-calculated numerical simulations, plans for alert transmissions, plans for public warning, and an education programme for the general public.

Conclusions

Several components needed for the Greek national tsunami warning system already exist and operate: telemetric national seismograph system, staff on duty on a 7/24 basis, decision matrix, good knowledge of earthquake and tsunami phenomena.

Other components are under development, such as the telemetric tide-gauge system or are still missing: data basis of numerical simulations, plans for alert transmissions, plans for public warning, education programme for the general public.

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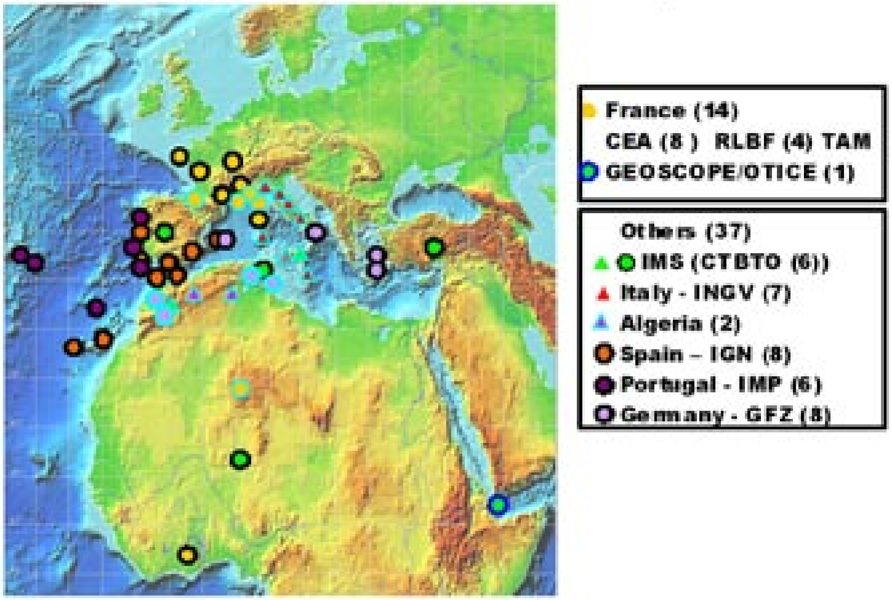
THE FRENCH WESTERN MEDITERRANEAN AND NORTH-EAST ATLANTIC TSUNAMI WARNING CENTER

by François Schindelé[1], Bruno Feignier[1]

The French Western Mediterranean and North-East Atlantic Tsunami Warning Centre will be operated by the **Commissariat à l'Energie Atomique (CEA)**.
Based in Bruyères-le-Châtel, close to Paris, it is established so that France will have a capability to detect, monitor, verify and warn the civil defence authorities of the existence of tsunami in the region and of possible threats to Western Mediterranean coast and French coastal locations.

The major objective of the French TWC is to provide French emergency managers and all the Western Mediterranean region's Member states with warnings in case of a possible tsunami impact in that region, within 15 minutes of an earthquake occurrence.

Figure 1 : NEAM Western Mediterranean and North-East Atlantic seismic monitoring for tsunami Warning



The French Western Mediterranean TWC is a key component in the establishment of the fully functional Tsunami Warning System in the Euro-Mediterranean region.
This three-year project, funded by the French Government, is due to be completed in December 2011.

This includes :
- establishment of the French Tsunami warning center with 24/7 tsunami monitoring, operation and analysis for France and the Western Mediterranean region
- upgrade of the seismic monitoring and extension and upgrade of the sea-level monitoring
- assistance to the Intergovernmental Oceanographic Commission in developing the **North-East Atlantic and Mediterranean Tsunami warning and mitigation system (NEAMTWS)**

The centre will start the international warning operation in December 2011.

CEA will use real-time data from over 10 seismic stations located in France (6 CEA, and 4 CNRS that will be upgraded with VSAT satellite transmission), and 4 implemented in other territories (2 CEA and 2 IPGP) (Figure 1).
About 40 additional seismic stations data will be received from other countries by robust high speed leased lines, most stations being implemented and maintained by IGN (Spain) IMP (Portugal), INGV (Italy) and GFZ (Germany).

The seismic data will then be analysed by specifically designed automatic systems that will form part of CEA's established 24/7 operations centre.
Experts will use the results of the automated process, historical tsunami and tsunami scenario data, to make within 15 minutes an analysis of the potential for the detected earthquakes to cause a tsunami and will disseminate the rele-

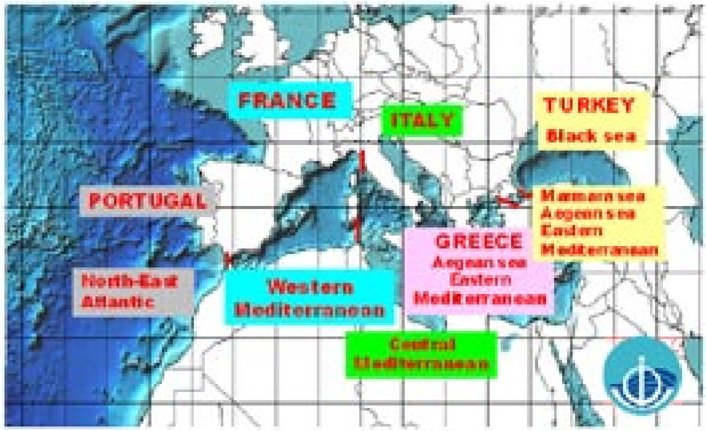
vant information on the expected hazard.
Depending on the location and magnitude of the earthquake, a message defined by the ICG/NEAMTWS will be sent to all regional watch centers, national warning centers and focal points nominated by the Member states, in accordance with the decision matrix adopted by the ICG (UNESCO/IOC 2007). In case of a large earthquake able to induce a tsunami, the tsunami arrival time will be calculated and included in the messages.

As the closest real-time sea-level station records the signal, the detection and height of the tsunami waves received and processed in CEA will provide the confirmation and level of warning. In necessary, additional messages will then be disseminated.

The enhancement of the current sea-level network is the second pillar of this warning system. The **Service Hydrographique et Océanographique de la Marine (SHOM)** will upgrade most of the French tide gages to be able to record and transmit the tsunami waves signal in real time (Figure 2). Three new sea-level stations in Corsica and 1 on the French Riviera Coast will be implemented.
In addition, sea level stations should be implemented in priority close to known seismic zones such as the North Coasts of Algeria, Morocco and Tunisia.

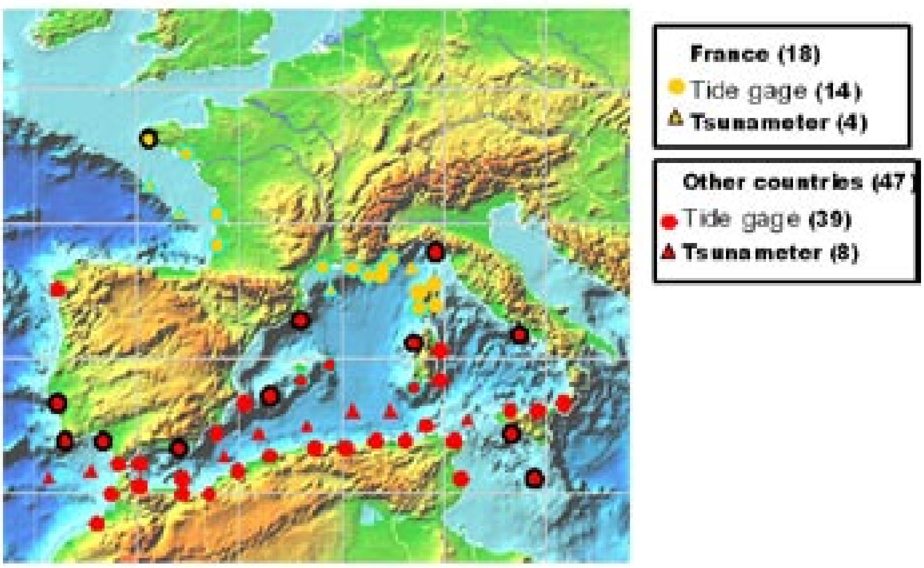
At the completion of the project, France will have: improved earthquake and tsunami detection in the Western Mediterranean and North-East Atlantic regions; a better and faster scientific modelling of tsunami; a new tsunami decision support; a responsive and fast warning system.

Figure 3 : Proposed NEAM Regional Watch centers Network



The French Western Mediterranean TWC is contributing to the network of international, regional and national tsunami watch centres of the Euro-Mediterranean region that cooperate under arrangements coordinated by the UNESCO **Intergovernmental Oceanographic Commission (IOC)**. Currently three other Member states have announced their plan to implement a regional watch center: Portugal, for the North-East Atlantic region, Greece, for the Eastern Mediterranean and Aegean sea, and Turkey for the Aegean sea, Eastern Mediterranean, Marmara sea and Black sea. Italy is in position to decide to monitor the Central Mediterranean and Adriatic sea (Figure 3).

Figure 2 : NEAM : Western Mediterranean and North-East Atlantic Sea level network



This strong international collaboration will allow the mitigation of tsunami hazard in the Euro-Mediterranean basin, as this is already performed in other oceanic basins.

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http://www.ioc-tsunami.org/

1) CEA/DAM/DIF

THE SEA OF MARMARA
SEA BOTTOM OBSERVATORY PROJECT (MSBOP)

by Doğan Kalafat[1], Cemil Gürbüz[1], Mehmet Yilmazer[1], and Kıvanç Kekovali[1]

Introduction

Marmara is one of the most important seismic active regions in Turkey. Current seismicity in the Marmara Sea Region results from the present day movement of the **North Anatolian Fault (NAF)**. The NAF is the major active right-lateral strike-slip tectonic feature of Turkey.
The North Anatolian Fault (NAF) runs along the tectonic boundary between the Eurasian Plate and the Anatolian Plate. The Sea of Marmara has affected the extensional tectonics of the Aegean Sea and strike-slip system of the NAF. The northern branch of NAF is the most active fault zone in the Sea of Marmara. Seismic activities are compatible with the strike-slip geometry of northern branch of NAF in the region (Figure 1).

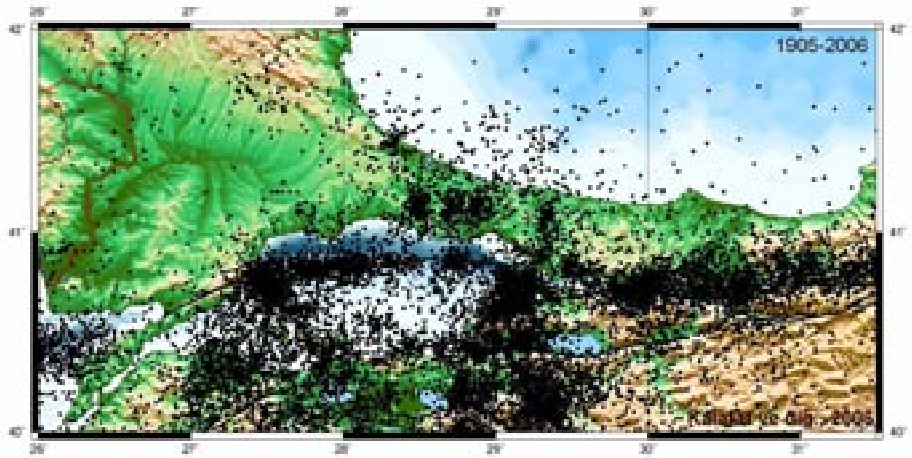

Fig.1: Seismicity of Marmara Sea Region

After the 1939 Erzincan Earthquake (Ms=7.9), nine big earthquakes (Ms> 7.0) occured along the westward of NAF. In 1999, two big earthquakes (August 17th, 1999 İzmit-Gölcük and November 12th, 1999 Düzce) occurred in the Marmara Sea Region.

Seismic studies revealed that there is a seismic gap below the Sea of Marmara. Therefore, Istanbul and Marmara Sea Region have a big earthquake risk (Figure 2).

Important targets of the Sea Bottom Observatory (SBO) Project

- To improve the station distribution in the sea of Marmara seismic network and to integrate them with land-based seismic stations,
- To install new land-based stations in the Southern Marmara Region. Several gaps in the station distribution compromise reliable monitoring,
- To record and analyse earthquakes with a magnitude of about 1.0 or less,

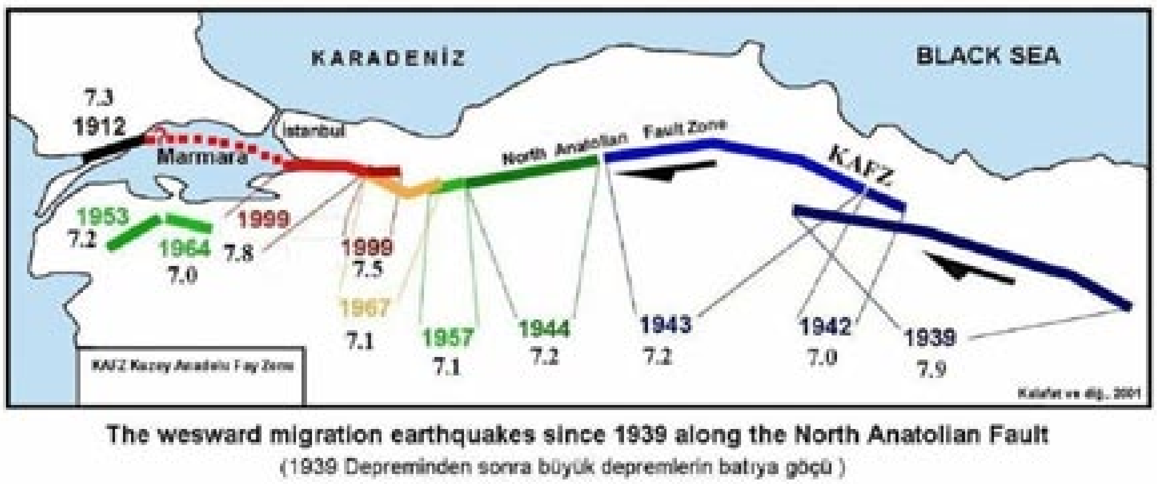

Fig.2. Westward migration of destructive earthquakes along the North Anatolian Fault Zone and Seismic Gap below the Sea of Marmara.

- To improve the resolution of hypocenter determination,
- To determine physical characteristics of fault-source mechanisms,
- To obtain high quality data for a better determination of the crustal structure in the Marmara Region,
- To better understand the tectonic structure of Marmara Region,
- To obtain multidisciplinary data such as seismic velocity, temperature, pressure and sea floor current measurements,
- To develop a Tsunami Early Warning System for Marmara earthquakes,
- To disseminate reliable and rapid earthquake information to the public and to the relevant agencies.

Fig.3: Locations of Sea Bottom Observatories (SBO) and distribution of Broadband Seismic Stations (BB) around the Marmara Sea area. (Blue symbols show SBO, red symbols show BB stations provided by Turkish Telecom, black symbols show existing BB stations)

Main Framework

- Land-based broadband seismic stations
- Sea bottom observatory stations (Figure 3)

Land Stations

- 10 Broadband stations installed in the Marmara Sea Region
- High standardized digital seismometers and recording systems
- All seismic data are recorded in real time and disseminated to the **National Earthquake Monitoring Center (NEMC)**.

Sea Bottom Observatory Stations

When selecting the station sites, the following issues have received a special attention from KOERI (we also did a vessel survey study):
- Shipping, Ship transit routes,
- Fishing, trolling and water products hunting areas,
- Fault locations and fault routes, earthquake activities, station gaps,
- Security of the point of arrival of the cables from land-based stations.

Characteristics of Sea Bottom Observatory Stations

- Use of submarine cable connection,
- Will bring some new insights to Seismological and Tsunamigenic studies that had not been studied much more in the world,
- Every SBO recording system will transmit real time data from ocean bottom stations to land-based stations using submarine fiber-optic cable,
- Data will be transmitted to the KOERI-NEMC center using a satellite system in real time.

SBO Station Components

- Broadband Sensor
3 TD 3C Guralp BB velocity seismometer, period 360 sec
- 5TD 3C Guralp Strong-Motion Sensor
- Pressure difference measurement
- Pressure Transducer
- Hydrophone measurement
- Temperature measurement
- Flow meter

Conclusion

KOERI is going to install 5 Sea Bottom Observatories in the Marmara Sea. Sea Bottom Observatories will include BB seismic sensors and pressure meters for tsunami warning purposes. This project will be completed in June, 2009. At the same time, KOERI is planning to set up a Turkish National Tsunami Warning Center in the next two years.

Acknowledgement

The **Sea Bottom Observatory Project (SBOP)** has been supported by **Turkish Telecom (TT)**. Turkish Telecom provided financial founding for SBOP. Therefore KOERI would like to say a special thank to the General Directory of Turkish Telecom (TT).

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AN UPDATE OF THE NERIES PROJECT

by Rémy Bossu[1, 2], Torild Van Eck[1, 3], Domenico Giardini[1,4]

Background

The **NERIES project (NEtwork of Research Infrastructures for European Seismology)** with 12M€ of contribution from the EC is so far the largest EC project in seismology.

This **Integrated Infrastructure Initiative (I3)** has been made possible through the existing networking activities within the EMSC and ORFEUS and the success of previous EC-projects such as MEREDIAN, an infrastructure project realising the VEBSN and EPSI promoting parametric data availability. The consortium comprises ORFEUS, EMSC and 23 partners from 13 different countries. ORFEUS is coordinating the project with Domenico Giardini as project coordinator and Torild Van Eck as project manager.

Practical information

NERIES is an I3 project, i.e. it focuses on the integration of data provider and archiving services and the development of new tools improving the data services for the scientific community. All the software developments are open-source and all reports are publicly available (www.neries.eu.org).

The project includes a strong package for technology transfer and outreach in which we organise meetings and workshops enabling the community beyond the consortium to be involved in the project developments.

Current examples are: the first Euro-Med workshop on accelerometric data organised in Grenoble in March 2008 discussing the proposed strategy for open data exchange; the observatory coordination workshop in Barcelona in May 2008 presenting new developments and providing SeisComP3 training; the web application and portal brainstorming workshop in Edinburgh in November 2008.

Upcoming examples are, among others, the Erice workshop in May 2009, with an extended observatory coordination program, a tomography and European reference model workshop in Utrecht in July 2009 and a second acceleration data meeting in November 2009 in Ankara (see announcement in the News section).

All workshops are open to non-consortium members and limited support is available. To promote broader involvement we offer grants to access five specific infrastructures: the dense broadband seismic network (ETH Zurich), the underground low-noise observatory (ZAMG, Austria), the NORSAR seismic arrays (Norway), the LDG discrimination facility (France) and SISMOS, the INGV (Italy) facility to digitize historical seismograms.

Proposals for all facilities are evaluated every 3 months. For all workshops and the transnational infrastructure access more information can be found on the NERIES project web page www.neries-eu.org.

A successful project so far

The NERIES project received an excellent review from Gorän Ekström on behalf of the European Commission in September 2008.

Some of the project results will have a transformative effect on the seismological Research Infrastructure in Europe. The **VEBSN (Virtual European Broadband Seismic Network)** currently offers data from 300 stations in and around Europea in (near) real-time and aims at reaching 500 by the end of NERIES.

The **European Distributed Waveform Data Archive (EIDA)** links four major data centers in Europe into one data archive using the ArcLink protocol. Significant progress has been achieved in creating access to European accelerometric data including a unique first network inventory for the Euro-Med region. European historical earthquake observations, up to know still scattered among many publications and a few institutes, are compiled within a newly created interactively accessible database. ORFEUS and EMSC are developing an integrated European scale data portal to facilitate access to combined datasets and services, and introducing advanced web applications into the seismological community.

NERIES also develops and continues on-going developments for new services.

The site response tools, developed within the

EC project SESAME are further developed into a pragmatic tool (www.geopsy.org) to characterise the site response from noise measurements. The **European Earthquake Forecast Testing Center (EEFTC)** has been created in coordination with the **Collaboratory for the Study of Earthquake Predictability (CSEP)** in the US. A European reference tomographic model and a damage estimation tool are being developed.
NERIES is instrumental in implementing unified shakemap services in several European countries in close collaboration with the USGS. More details on all of these developments are available on the NERIES site as well through its periodic NERIES Newsletters.

Spin-off initiatives

NERIES activities generated considerable spin-off initiatives.
Some examples are the development of the XML format named QuakeML (http://quakeml.ethz.ch) for earthquake parameter data exchange which is becoming de facto a global standard and standardized representation of tomography models currently being launched in Europe, US and Japan.

The most important spin-off development has been the successful inclusion in the 2008 ESFRI roadmap of the **EPOS (European Plate Observing System)** initiative *(for more details see article in this issue)*. NERIES has been essential as a demonstrator of the good integration of the seismological community within Europe and associated states.

On the benefits of the NERIES project for the Euro-Med community

Research infrastructure (I3) projects such as NERIES can only be run by a relatively small number of participants in order to be effective and manageable. Neither are the I3 instruments aimed at scientific research. The EC holds strict to these restrictions.

However, we have designed the project to aim at an optimal beneficial interaction with the whole Euro-Med community of data providers, data users and scientists.

The I3 project NERIES has proven to be an excellent networking and coordinating platform. And although the EC policy clearly states that investments (hardware, networks) and operational costs remain a national responsibility, concurrent developments in the individual countries and institutes (many outside the consortium) have been crucial to the success of NERIES.

We strongly encourage you to browse the NERIES web site, if you have not done this yet, to retrieve more detailed information and to let us know about relevant coordination and networking requirements in the Euro-Med region to be taken up in this research infrastructure initiative and the ones still to come.

1) NERIES Mangement Committee
2) CSEM
3) ORFEUS
4) ETHZ

General Assembly of the NERIES Consortium in Utrecht (June 2008)

EPOS: EUROPEAN PLATE OBSERVING SYSTEM

by Massimo Cocco[1], Torild Van Eck[2], Alberto Michelini[1] and the EPOS team

The understanding of the complex Earth System requires an integrated observational strategy that involves the development, the integration and the coordination of research infrastructures aimed to record the key diagnostic features of Earth dynamics. Such an integrated **research infrastructure (RI)** must include geographically distributed and multidisciplinary monitoring and observing systems. The **European Plate Observing System (EPOS)** (http://www.epos-eu.org/) is a new RI included in the 2008-updated **ESFRI** roadmap (http://cordis.europa.eu/esfri/, **European Strategy Forum on Research Infrastructures**) that aims to face this challenge. The ESFRI roadmap provides a list of research infrastructures that the EU judges to be strategic for European research. This acknowledgment is also provided in order to coordinate the efforts of national governments towards the long-term sustainability of the integrated research infrastructures.

The main goal of EPOS is to create a single sustainable, permanent and distributed infrastructure, integrating geophysical monitoring networks, local observatories (including permanent in-situ and volcano observatories) and experimental laboratories (rock physics and analogue experiments) in Europe. EPOS will give open access to geophysical and geological data and modelling tools, enabling a step change in multidisciplinary scientific research into different fields, including seismic and volcanic hazards and environmental changes.

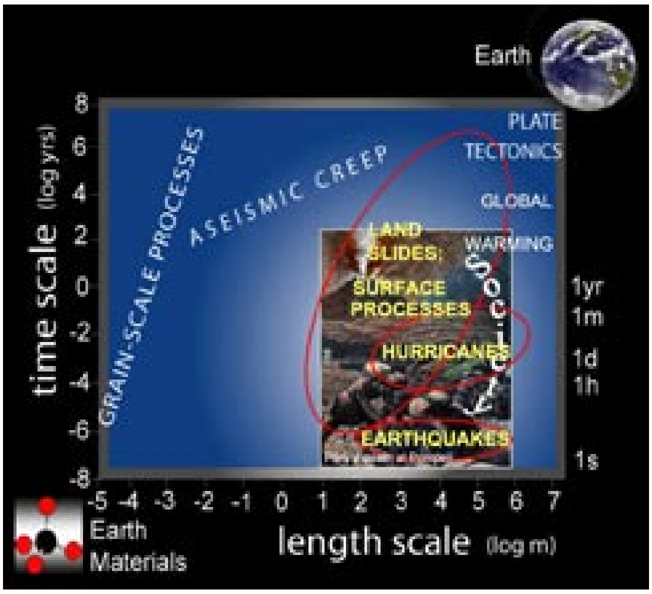

Figure 1. Time and length scales in System Earth to be covered by EPOS. Human time and length scales are also shown as well as the overlap with major processes affecting the society

We note that European research and monitoring infrastructures have already gathered, largely at a national scale, a vast amount of geological and geophysical data, which have been used by research networks to improve our models describing the active deformation processes generating earthquakes, volcanic eruptions, landslides and tsunamis. Only fairly recently have there been European scale initiatives to integrate the existing research infrastructures in solid Earth science distributed over different European countries to create efficient means to exchange data, information, modeling and monitoring tools. Thus, EPOS results timely in integrating these mature initiatives into a single infrastructure enabling Earth scientists across Europe to combine, model and interpret multidisciplinary data at different scales (Figure 1). Indeed, the EPOS challenge consists of integrating all the observations of tectonic and volcanic processes (as well as their induced effects), which cover an extraordinary range of spatial and temporal scales, in order to foster innovative approaches for a better understanding of the physical processes controlling earthquakes, volcanic eruptions and tsunamis as well as those driving tectonics and Earth surface dynamics.

EPOS plans to integrate the currently scattered, but highly advanced European facilities, and gears towards addressing these topics within one, distributed but coherent multidisciplinary Research Infrastructure. This is expected to provide a sustainable, long-term strategy for European Earth science research. This integration will take full advantage of the new e-science opportunities. We note that EPOS finds itself to be the only comprehensive RI for solid Earth science and it will complement to other large scale RI studying the planet Earth but focused on satellite and ocean observing systems (see Figure 2).

EPOS intends to integrate five existing core elements within one cyber-infrastructure:

1. A comprehensive geographically distributed observational infrastructure consisting of existing seismic and geodetic permanent and temporary monitoring networks on a European scale. This work has already been initiated within NERIES (http://www.neries-eu.org/).
2. Dedicated observatories for multidisciplinary local data acquisition (volcanoes, in-situ fault monitoring experiments, surface dynamics, geothermal and deep drilling experiments).
3. A network of experimental laboratories creating a single distributed research infrastructure for rock and mineral properties.
4. Facilities for data repositories as well as for data integration, archiving and mining (including different solid Earth data, such as geophysical, geological, topographic, geochemical data).
5. Facilities for high performance distributed computing, consisting of cyber infrastructures for collaborative computing and large-scale data analysis, through well established links with existing high performance computational infrastructures in Europe.

By creating EPOS, we also aim to minimize fragmentation and duplication of European efforts, by providing a unique and irreplaceable service for scientific research and society by exploiting the developments in ICT; and to identify relevant gaps for developing new or complementary infrastructures. In particular, in addition to the high priority e-infrastructure, EPOS aims to realize and support the development of dedicated fault zone observatories, the implementation of a European backbone network with high-quality, broad-band (BB) seismic stations as well as strong motion networks and their data archive, the gathering of all the GPS national networks within a unified European archive, a new European mobile BB and geodetic array, an infrastructure for data collection and distribution and several other initiatives.

The vision is therefore to integrate real time observations from permanent national and regional geophysical networks, with the observations from "in-situ" experiments and temporary monitoring experiments through a cyber-infrastructure for data mining and assimilation, and facilities for data integration, archiving and exchange. We believe that making observations of solid Earth dynamic processes controlling natural phenomena immediately available and promoting their comparison with experimental observations from cutting-edge laboratory experiments and their interpretation through theoretical analyses and numerical simulations will represent a multidisciplinary platform for discoveries which

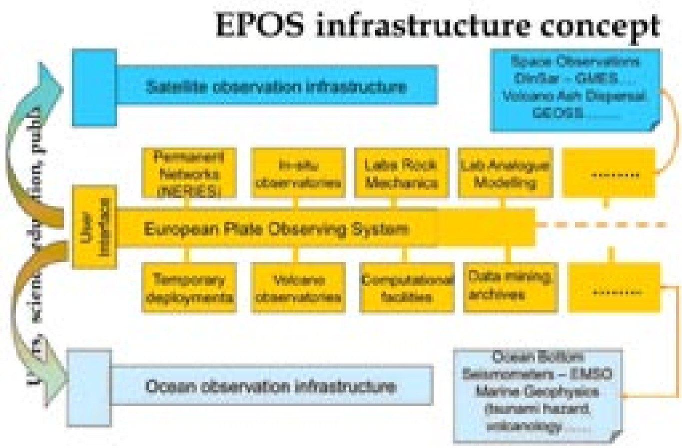

Figure 2. EPOS conceptual sketch

will foster scientific excellence in solid Earth research. In Europe the conditions now exist to integrate research across a broad range of Earth sciences by pooling efficiently the scattered national RI initiatives into one European Plate Observing System (EPOS) thus improving significantly our capacity to investigate Earth processes and their impact on natural resources and hazards.

The EPOS infrastructure will certainly contribute to dissemination, education and training. For example, it will provide universities and young scientists with unrestricted on-line access to an enormous wealth of observational data, laboratory experiments, computational software and facilities in solid Earth sciences. The EPOS infrastructure will also facilitate the development of advanced educational material, i.e. e learning, as its e-infrastructure will be based on global and open standards. The added value for Europe and the innovation resulting from EPOS's construction consists of: (i) the design of targeted multidisciplinary measurements tailored for particular investigations; (ii) the strengthening of collaborations between dispersed research groups working in the same field incorporating and integrating efforts from different methodologies toward common goals; (iii) the joint open software and web applications, which will significantly influence the operational aspects of observatories; (iii) the development of new technologies for particular infrastructures, such as experimental laboratories or in-situ observatories (deep drilling, borehole seismology, ocean bottom seismometers, geochemical data acquisition in faults and volcanoes, ….); (v) the interconnections with other proposed or currently operating networks and infrastructures in the field of Earth Sciences (such as in **Space and Ocean Geophysics and the Integrated Carbon Observation System - ICOS**). Overall, the new infrastructure builds upon existing pan-European research networks and infrastructures. Some of these have long been es-

SEISMIC HAZARD AND RISK ASSESSMENT: UPCOMING EUROPEAN AND GLOBAL PROGRAMS

by Domenico Giardini[1], Jochen Woessner[1], Greg Anderson[1]

Understanding earthquake processes and mitigating their effects on our increasingly vulnerable society are global priorities that require concerted international approaches.

EPOS: European Plate Observing System (continued)

tablished (e.g., ORFEUS, EMSC) whereas others started within FP5 and FP6 or are part of other multi-lateral programs (e.g. Topo-Europe in ESF). It is expected that these partnerships will both facilitate the planning, and provide knowledge and expertise in the establishment of the EPOS preparatory phase. A list of the major existing pan-European networks contributing directly to the EPOS conception phase is available on the EPOS website. Several relevant scientific networks and projects in the Earth Sciences including the major scientific institutions in Europe support EPOS. Each country is represented by a national team composed by several research institutions and universities and has a coordinating institution. A detailed description of the participating institutions at this stage is provided on the EPOS website. Because EPOS has been designed to be inclusive at both geographical and disciplinary levels, links to additional countries and facilities will be included progressively. The EPOS Research Infrastructure envisions a long-term development over several decades. The next step, the preparatory stage, will be to create the governance structure, setting the base for the coordination, planning and integration of the elements of the infrastructure. The concepts embodied in EPOS are vital to maintain European scientific competitiveness on the international stage.
In conclusion, EPOS is expected to provide the fundamental tools and the multi-disciplinary data required for innovative research by the next generation of Earth scientists in Europe.

1) INGV
2) ORFEUS

Rapid population growth leads to intensive urbanization, often in areas exposed to high seismic hazard and unsuitable building practices.
Our society is also increasingly complex and interconnected, and inherently more vulnerable to earthquake perils. The 1995 magnitude 7.2 Kobe earthquake, with over 6,000 casualties and 270 billion USD damage, provided a chilling example of a moderate earthquake affecting the global economy.

Probabilistic Seismic Hazard Assessment (PSHA) estimates the probability that specified levels of ground shaking will be exceeded in given locations and time periods – for example, the Peak Ground Acceleration to be exceeded with 10% probability in 50 years. Strategies to minimize the loss of life, property damage, and social and economic disruption due to earthquakes depend on reliable estimates of seismic hazard, to serve as basis for improved building design and construction, emergency response plans, and plans for sustainable development.
Seismic risk analysis couples hazard assessments with information on the distribution and vulnerability to strong ground motion of people, buildings, and critical infrastructure in order to estimate the likelihood of particular earthquake consequences, such as the number and/or spatial distribution of injured people or collapsed buildings. Such analyses can either be deterministic, based on a specific earthquake scenario, or probabilistic, based on a probabilistic seismic hazard model.
Seismic loss modelers use hazard and risk assessments to quantify the economic and social cost of earthquake consequences. Governments, the financial sector, and related organizations require reliable cost estimates as they prepare to respond to earthquakes. For example, industry now uses catastrophe bonds to help insure against the high losses that may come from a strong earthquake, and depends on seismic loss assessment to estimate how large such bonds should be. Governments need to know how much money to budget

to respond to an earthquake disaster, in both the rescue and recovery phases.
Many approaches exist for seismic hazard, risk, and loss estimation, which can result in significantly different models for a given target, particularly between neighboring countries. International organizations such as the European Union, large financial companies, and the Red Cross, need reliable, community-vetted models; the scientific and engineering communities need a unified basis on which future models can be developed. The **Global Earthquake Model (GEM)** and **Seismic HAzard haRmonization in Europe (SHARE)** projects will help fill this need over the next few years.

GEM is a public-private partnership initiated by the Organisation for **Economic Cooperation and Development (OECD)** to build an independent standard for modeling and communicating earthquake risk worldwide. GEM will provide authoritative, open information about seismic risk and decision tools to support mitigation. GEM will raise risk awareness and help post-disaster economic development, with the ultimate goal of reducing the toll of future earthquakes.
GEM will provide a unified set of modeling tools based on a common global IT infrastructure and consensus standards. The GEM Secretariat will coordinate the activities of GEM staff and partners around the world. GEM partners will develop a variety of global components, including a unified earthquake catalog, fault database, and ground motion prediction equations. To ensure broad representation and community acceptance, GEM will include local knowledge in all modeling activities, incorporate existing detailed models where possible, and independently test all resulting tools and models. When completed in five years, GEM will have a versatile, openly accessible modeling environment that can be updated as necessary, and will provide the global standard for seismic hazard, risk, and loss models to government ministers, scientists and engineers, financial institutions, and the public worldwide.

GEM is now underway with key support provided by private sponsors (Munich Reinsurance Company, Zurich Financial Services, AIR Worldwide Corporation, and Willis Group Holdings); countries including Belgium, Germany, Italy, Singapore, Switzerland, and Turkey; and groups such as the European Commission. The GEM Secretariat will be hosted at the Eucentre at the University of Pavia in Italy; the Secretariat is now formalizing the creation of the GEM Foundation. Some of GEM's global components are in the planning stages, such as the developments of a unified active fault database and earthquake catalog.
The flagship activity of GEM's first year is GEM1, a focused pilot project to develop GEM's first hazard and risk modeling products and initial IT infrastructure, starting in January 2009 and ending in March 2010. GEM1 will provide core capabilities for the present and key knowledge for future development of the full GEM computing environment and product set. We will build GEM1 largely using existing tools and datasets, connected through a unified IT infrastructure, in order to bring GEM's initial capabilities online as rapidly as possible.

We anticipate that GEM1's products will include:

- A global compilation of regional seismic source zone models in one or more common representations

- Global synthetic earthquake catalogs for use in hazard calculations

- Initial set of regional and global catalogues for validation

- Global hazard models in map and database forms

- First compilation of global vulnerabilities and fragilities

- Tools for exposure and loss assessment

- Validation of results and software for existing risk assessment tools, to be used in GEM2

- Demonstration risk scenarios for target cities
- First version of GEM IT infrastructure

All these products will be made freely available to the greatest extent possible.

We expect GEM1 to serve as the basis for the development of regional models and infrastructure in GEM regional implementation projects.
One of the largest of these is the new European program SHARE, which proposes a comprehensive, interdisciplinary, pan-European, coordinated effort for the harmonization of earthquake hazard assessment in Europe and North Africa. SHARE builds on multiple projects funded through the European Community Framework Programs FP5 and FP6, including SAFE, SAFER, RELIEF, EPSI, BEECD, PALEOSIS, SESAME, RISK-UE, LESSLOSS, and NERIES.
The EC call ENV.2008.1.3.1.1 requested for the

first time the pan-European coordination of seismic hazard assessment, with the goal of creating a unified model to serve the needs of engineering applications. The SHARE consortium consists of 18 partners from 13 countries in the Euro-Mediterranean region with the project planned to kick-off 1.4.2009.

Taking in consideration the identified areas of socio-economic relevance, the existing challenges and present limitations, SHARE experts will address the following specific objectives:

1. Build a framework for integration across disciplines, by involving participants, competences and experts spanning all fields from earthquake engineering to geology to engineering seismology, and for integration across national borders, to compile earthquake data and assess seismic hazard without the burden of political constraints and administrative boundaries. An authoritative community model will be assembled by seeking extensive expert elicitation and participation, and through community feedback.

2. Pursue best practices and high standards in all aspects of seismic hazard assessment, from data collection to the computational framework.

3. Cover the whole Euro-Mediterranean area (for the Mediterranean we will include in this phase the Maghreb countries to the West and Turkey to the East, but not the Near East and Red Sea areas).

4. Develop the appropriate computational infrastructure as well as rigorous procedures to qualify and validate all components of the hazard, as a basis for longevity and continuous improvement of a dynamic model ready to incorporate the most recent developments from science and engineering.

5. Maintain a direct connection to the Eurocode 8 applications and the definition of the Nationally Determined Parameters, through the participation of the CEN/TC250/SC8 committee in the definition of the output specification requirements and in the hazard validation.

6. Produce direct outputs for risk assessment, enabling the European participation in the Global Earthquake Model program initiated by the OECD.

7. Focus on the effective dissemination of hazard tools and results. The tools developed will be freely available and designed as an open-source project.

Both projects will gain from the synergies created through the projects and stimulate knowledge transfer triggered by the use of common methodologies and computational infrastructures on the European and global scale.

SHARE will set new standards for PSHA in Europe and, through the development of a homogeneous data assessment and evaluation, a base for following programs on the European scale.

GEM will incorporate the generated knowledge and add the components for risk assessment and loss estimation.

Together, GEM and SHARE will provide, for the first time in the public domain, a unified approach to seismic hazard, risk, and loss estimation and a living database that will meet the needs of international organizations, scientists, engineers, and the financial community.

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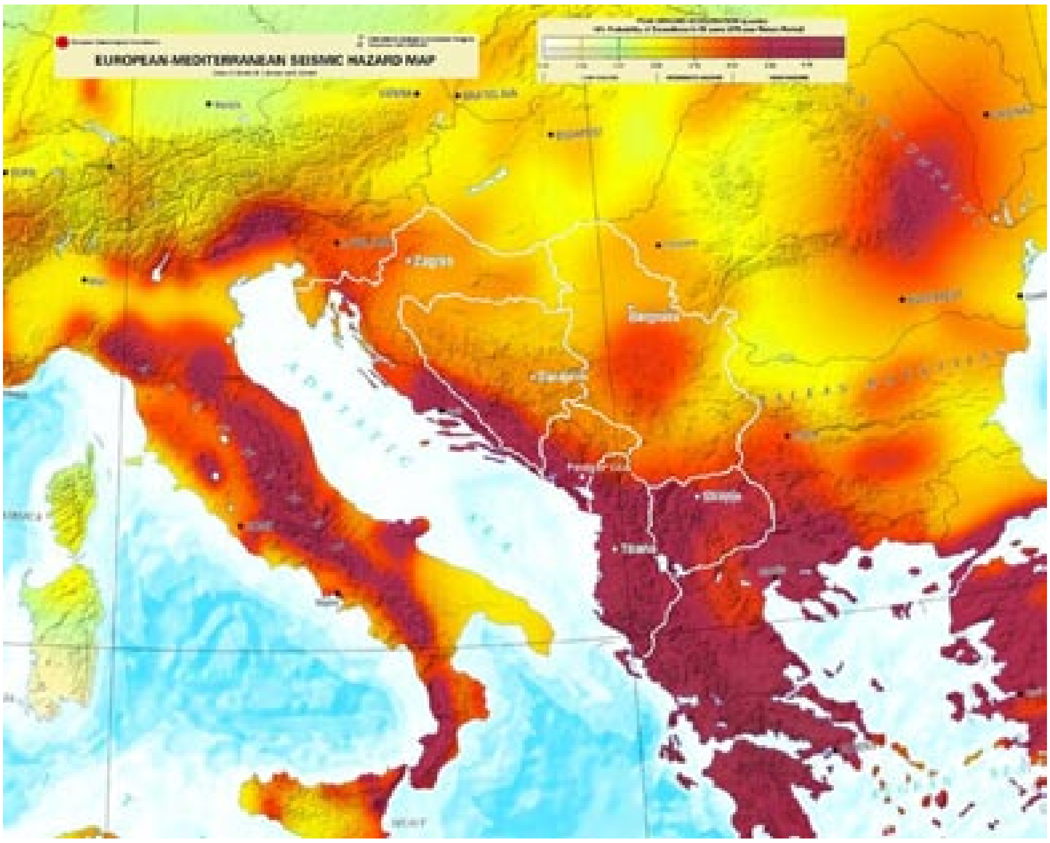
HARMONIZATION OF SEISMIC HAZARD MAPS FOR THE WESTERN BALKAN COUNTRIES

(SfP Project Number 983054)

See contributors at the end of the article

From the idea to the realization

The essential idea to get together relevant institutions from the South East Europe and to reestablish the cooperation in the field of seismic risk reduction took considerable efforts in the past decade. Some early efforts were undertaken by the ***Disaster Prevention and Preparedness Initiative (for the South East Europe) of the Stability Pact (DPPI)*** *as well as by the* ***Euro Mediterranean Seismological Centre (EMSC)****.*
Finally, by the end of 2006, the general idea of the scope of cooperation was defined and a working group was formed with the task to set up the project - lately named ***"Harmonization of Seismic Hazard Maps for the Western Balkan Countries"****. Also,* ***Montenegro Seismological Observatory (MSO)*** *was chosen as the coordinator of these activities and leading project partner of the future project.*



Participating Institutions

- Earthquake Engineering Research Center, Dept. of Civil Engineering, Middle East Technical University (METU), Ankara, Turkey,
- Montenegro Seismological Observatory (MSO) and Geological Institute of Montenegro, Podgorica, Montenegro,
- Institute of Geosciences (IGEO), Polytechnic University of Tirana, Albania,
- Department of Geophysics, Faculty of Sciences, Zagreb, Croatia,
- Ministry of Civil Affair, Center for Seismology, and Hydrometeorological Institute of Republic of Srpska / Sector for Seismology, Sarajevo, Bosnia and Herzegovina,
- Institute of Earthquake Engineering and Engineering Seismology (IZIIS) Seismological Observatory, Faculty of Natural Sciences, University «Ss. Cyril and Methodius» Skopje, Macedonia,
- Seismological Survey of Serbia, Faculty of Mining and Geology, Department for geology and Faculty for Civil engineering, University of Belgrade, Serbia.

A draft version of the project Proposal was delivered to all parties in December 2006.
The DPPI continued its activities of finding funds to finance this project and made contact with the **NATO Science for Peace and Security Programme (SfP)**. It showed an interest in the realization of such a project.
From this point on, the Proposal was adjusted to fit the standards of the SfP Programme, while authorized national representatives into SfP

clarified the importance of the project for each involved countries. Finally, the project was presented to the **Scientific Board of the SfP Environmental Panel** in June 2007, where it was accepted. The first Grant Letter from the SfP Office was issued just a couple of weeks later. The launching of the Official Project took place in Podgorica on October 2nd, 2007.

Evidence of strong seismic activity in the Balkan region

There are lots of evidence that strong earthquakes occured in the Balkan Region over the years (Fig. 1).

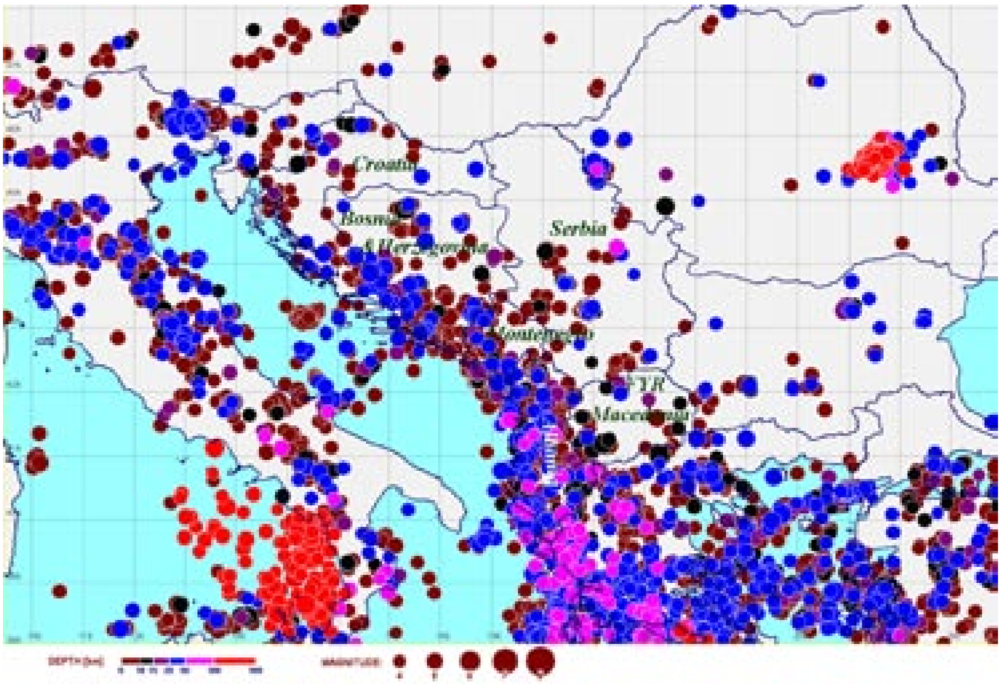


Fig.1: Seismic map of the region showing epicenters of stronger earthquakes (Magnitude 4) that have occurred during the last 33 years in the Balkan region and surroundings (NEIC earthquake catalogue).

Many events from the pre-instrumental period were well documented, even those related to medieval time. Furthermore, relatively recent events are still fresh in the collective memory.

In 1905, an earthquake of magnitude 6.6 and epicentral intensity up to X (in Mercalli scale) struck the town of Shkodra, Albania, and destroyed the whole north-western part of Albania and the southern-eastern part of Montenegro. One year later another strong earthquake of magnitude 6.1, close to Zagreb, struck northern Croatia.
Two earthquakes (both of magnitude 6.2) shook the Croatia, Bosnia and Herzegovina border region in 1923 and 1942.
The earthquake of Skopje, Macedonia, with magnitude 6.2, and a maximum epicentral intensity of X Mercalli degrees, took 1,070 lives and caused great material loss (Fig. 2, left).
Six years later, the western part of Bosnia and Herzegovina was hit by a devastating earthquake of magnitude 6.1 that caused human casualties.

On April 15th, 1979 a very strong earthquake caused vast damages along the whole southern Adriatic coast, causing 136 deaths in Montenegro and Albania and more than 4 billion US dollars (at that time) of material loss in Montenegro only (Fig. 2, right).

Just one year later, an earthquake of magnitude 6.0 hit the Kopaonik region in southwest Serbia, also causing significant destructions and material damages.

Fig.2. Left picture: destroyed building during the 1963 destructive earthquake of Skopje, Macedonia (magnitude 6.2). Right picture: collapsed hotel structure in Montenegro during the 1979 earthquake (magnitude 7.0).

Expected results of the Harmonization of Seismic Hazard Maps for the Western Balkan Countries Project

The initial idea behind this project was to make a strong statement on the severity of earthquakes effects in this region.
Assessing the seismic hazard for the region in a harmonized manner should encourage the consistent use of seismic design for buildings. Although technical norms for building earthquake safe structures exist in these countries since the 1960s (with a major revision in the early 1980s), this project is aimed at providing bases to implement **Eurocode 8** in building design practices. *"EN 1998-1 of the Eurocode 8: Design of structures for earthquake resistance, as one of the fundamental issues contains the definition of the seismic action. Hence that seismic action itself is defined in accordance to results of seismic hazard analyses performed on the national level."*
Besides and along with this, a number of important objectives should be realized. One of the most important ones is the modernization of seismic instrumentation and the improvement of local seismic networks.
Planners, engineers and civil protection agencies will ensure the implementation of the Project results into construction practices, physical and urban planning, disaster and seismic risk management practices.

The stated objectives of the Project are:

• To establish a complex, consistent GIS application database of earthquake catalogue, seismotectonics and seismic hazard data for the whole region,

• To methodologically improve and harmonize the seismic hazard maps of the participating countries so as to overcome the differences in their cross-border seismic hazard levels,

• To improve the existing seismic monitoring networks through the deployment of strong and weak-motion stations in the participating countries,

• To provide a consistent background to tailor the seismic provisions of the participating countries to EU standards (Eurocode 8),

• To establish active scientific collaboration between the participating countries and to train future-promising young scientists in earthquake-hazard related topics,

• To publish the Project major findings and hazard maps to disseminate results into the scientific and engineering community,

• Civil protection agencies, agencies for urban planning or responsible ministries as well as authorities for seismic design code legislation will use the harmonized and upgraded seismic hazard maps to improve seismic safety and seismic risk management.

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GLOBALSEIS: GLOBAL TOMOGRAPHY AND GEODYNAMICS

by Guust Nolet[1]

Since its inception in the 1970's, seismic tomography has seen very rapid progress and has significantly influenced our thinking about Earth's evolution and thermal history. The first clear evidence that oceanic lithosphere is able to sink all the way into the lower mantle induced a shift in our thinking about the chemical evolution of the Earth. Until twenty years ago, the predominant view was that the Earth convects in two separate layers, such as to preserve the distinct identity of chemical `reservoirs' inferred from isotope ratios of basalts and the argon content of the atmosphere. However, after the discovery of slabs penetrating deeply into the lower mantle *(Van der Hilst et al., 1991)* this view gave way to the now widely shared perception that upper- and lower mantle freely exchange material. The latter view had always been favoured in the geophysical community, who perceived a difficulty in the Earth's ability to cool sufficiently rapidly unless heat was advected from the deep interior directly to the surface. The resulting paradox has puzzled geophysicists, geochemists and geodynamicists for more than two decades.

The results from more recent seismic tomography are re-opening this question again. The densification of the global network of digital seismic stations, and methodological improvements in tomography led to the discovery of at least a dozen massive plumes in the lower mantle by *Montelli et al. (2004, 2006)*. Further analysis of these plumes has led to the suspicion that the plume heat flux in the lower mantle significantly exceeds the one observed at the surface *(Nolet et al., 2006)*. Together with a more nuanced view on subduction, which shows that some slabs come to rest in the transition zone *(Van der Lee and Nolet, 1997; Fukao, 2001)*, it shows that mass exchange between lower- and upper mantle is hampered, though not completely stalled, by the 670 km discontinuity. But we are not fully back to square one: a compromise between the one- and two layered convection models that satisfies both chemical and physical constraints is actively being sought through collaboration between geochemists and geophysicists (e.g. *Albarède and van der Hilst, 2002*). One major hurdle is that progress in seismic tomography is slowed because of the lack of data from oceanic regions, and also by limits in the ability of ray theory - which assumes seismic waves have infinite frequency - to handle seismic data in both low- and high frequency bands, and by the inability of the ray theory to exploit the dispersion (frequency dependence) of seismic delay times which contains information about the size of anomalies.

Mermaids

The ERC-funded project GLOBALSEIS intends to make significant progress in each of these areas. First of all on the side of observations: we plan to further develop the hydrophone-equipped floats first tested by *Simons et al. (2006)*, with the goal to improve data coverage in oceanic regions that are important to investigate heat flux: the plume-rich southern hemisphere in particular. Underwater robots, nicknamed `**MERMAID**'s when adapted for seismology **(Mobile Earthquake Recording in Marine Areas by Independent Divers)** are already widely used by the oceanographic community in the Argo project to track ocean currents at depth around 1 km, and to measure temperature and salinity along the way. These floats surface every one or two weeks to transmit data to a satellite. The plan is to equip them with a hydrophone and detect earthquake signals from earthquakes strong enough to overcome the substantial ambient noise. This

Figure 1. The first MERMAID prototype, equipped with a hydrophone (left) being launched for testing (right). Figure courtesy of Frederik Simons.

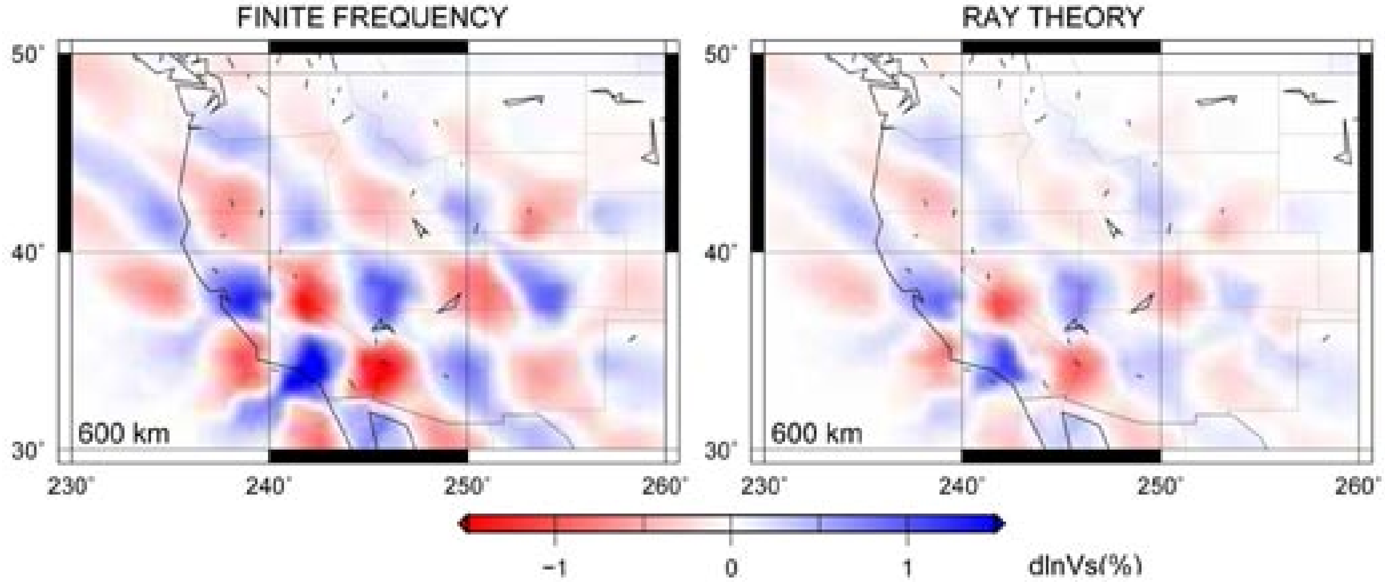

Figure 2. Checker-board resolution test for a small data set of S wave delays from 158 events recorded in North America, for multiple frequency tomography (left), or ray theoretical inversion (right).

unconventional approach can be done at a fraction of the cost of the deployment of ocean-bottom seismometers, and offers potentially revolutionary progress in seismometry of the oceanic domain. Figure 1 shows a SOLO float during its first test; we are currently working with Webbresearch in Falmouth, MA, to adapt an APEX float.

Progress in tomographic interpretation

But improving the coverage in the oceanic domain will by itself not be sufficient. For this, one needs not only to combine different seismological data sets spanning a wide range of frequencies, but also to exploit the extra resolution offered by the frequency-dependent sensitivity of body waves. This can be done by using finite-frequency tomography, in which wave energy scattered by heterogeneity is actively used to create the tomographic image - a seismological equivalent of the new techniques of 'active optics' in astronomy. Powerful methods are now available to measure the frequency-dependence of seismic arrival times and amplitudes *(Sigloch and Nolet, 2006)*. We are currently collecting a data base of some 107 P and S amplitudes and arrival times in half a dozen frequency bands (0.04-0.50 Hz), and have recently inverted a subset of these for a mantle model under North America *(Sigloch et al., 2008)*. As shown in Figure 2, a significant improvement of resolution is obtained when using multiple frequencies. We plan to combine these body wave data with surface wave dispersion measurements as well as with estimates of normal mode splitting coefficients.
A second improvement in seismic tomography comes from the parameterization of the Earth in wavelets. This technique, pioneered by *Chevrot and Zhao (2007)* and *Loris et al. (2007)*, not only allows for a significant reduction in the numerical effort of inverting very large matrices containing finite-frequency kernels; it also allows for new techniques of regularization, that emphasize large-scale structures while preserving sharp boundaries, thus significantly enhancing the degree of reality of regularized solutions.

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WHISPER: TOWARDS CONTINUOUS MONITORING OF THE CONTINUOUSLY CHANGING EARTH

by Michel Campillo[1]

Whisper is a joint project of 'Laboratoire de Géophysique Interne et Tectonophysique' of Joseph Fourier University of Grenoble and 'Département de Sismologie' of Institut de Physique du Globe de Paris.

This project focuses on the use of the seismic ambient noise to monitor slight changes of properties in the solid Earth. The implications are the detection of change of strain at depth with applications in different contexts. A major field of application is the monitoring of potentially dangerous structures like volcanoes or active fault zones. The project includes new methodological developments, massive processing of existing data and field experiments. Applications in regions where changes are induced by human activity are important both for the quantitative refinement of the method and for the economic and social implications of these problems.

The correlation of a random seismic wavefield measured at two distant points contains the Earth's response between these points (Green function). In other words, if one registers a random wavefield at two separate points, he can construct virtual seismograms that exhibit all the characteristics of the ones produced in an active experiment where a source is located at one of the points and recorded at the other. Whereas there are in theory strong requirements for this property to hold perfectly, in practice, its use is efficient in most cases because of the nature of the excitation of the seismic noise and because of the Earth's heterogeneity which results in a multiplication of scattered waves.

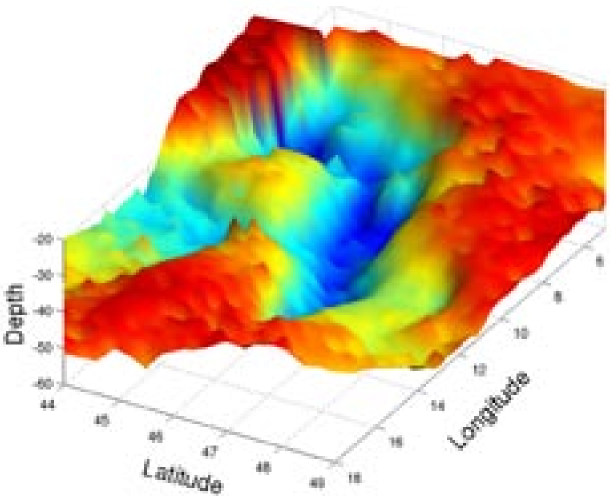

Figure 1. Example of noise-based seismic tomography: the depth of the Moho beneath the Alps (Stehly et al., 2009).

The use of field correlations has experienced a rapid growth since the first attempts (*Campillo and Paul, 2003; Shapiro and Campillo, 2004; Shapiro et al.; 2005; Sabra et al. 2005;…)*). This novel technique has been used by various groups to produce high-resolution images of the Earth's crust in various regions in the world. The main advantages of this technique are that it provides new data for imaging, which are independent of the occurrence of earthquakes and measured along possibly short paths. Figure 1 presents two examples of investigation of geological structures.

More recently, we investigated the possibility of using repeated noise-based measurements as a monitoring tool. We found that we are able to detect relative temporal changes of the velocity smaller than 10-3. This approach can be applied to the forecasting of volcanic eruptions and it showed a clearly detectable decrease in seismic velocity occurring a few days before eruptions at Piton de la Fournaise *(Brenguier et al., 2008a)*. With better seismic networks and methodological developments, we will be able to further improve the accuracy of noise-based measurements, opening a new class of phenomena located at depth to continuous monitoring with seismological methods. Our main goal is to monitor changes associated with deep processes such as magma supply, tectonic loading, or co- or post-seismic deformation. We expect implications for the forecast of volcanic eruptions, the monitoring of landslides and the search for co-seismic and possible precursory mechanical changes associated with earthquakes. Preliminary results indicate that tectonic process contributes to the velocity changes detected in the vicinity of fault zones. Velocity variations in the Parkfield area measured over seven years with continuous noise records (Figure 2) exhibit a remarkable correlation with the occurrence of earthquakes and post-seismic relaxation. This suggests that the noise-based measurements allow us to detect variations in mechanical conditions at depth.

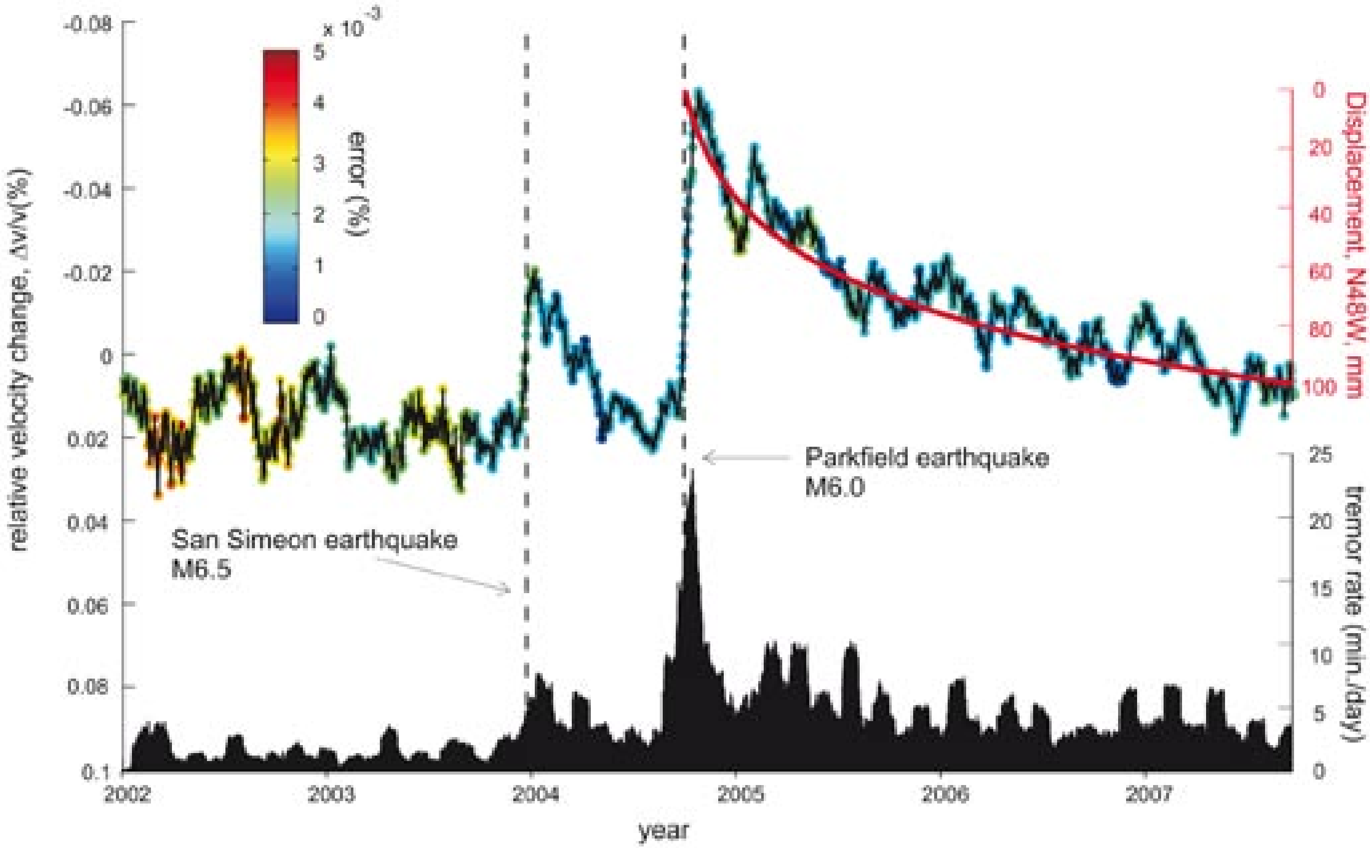

Figure 2: Results of the study in Parkfield, California. The grey curve denotes the relative change of seismic velocity deduced from the analysis of ambient noise. The green area represents the rate of activity of non-volcanic tremors. Vertical lines correspond to the occurrence of two strong earthquakes. The red line is the post seismic relaxation function deduced from GPS following the 2004 Parkfield event (from Brenguier et al., 2008b).

Improving accuracy of noise-based measurements

For the dream of using noise to monitor the solid Earth to become reality, the key issue is to improve the accuracy of the measurements. We have to solve problems of two different natures. First, while a perfect Earth response reconstruction is expected for a perfectly random and stationary noise, the actual conditions are different. The source origin must be understood and its influence on the measure of temporal changes must be corrected. This will rely on expertise in modeling oceanic waves and meteorology and in the domain of wave interaction and coupling with the solid Earth.

Indeed the processing of the seismic noise records must also be improved. We propose to use refined pre-stack data adaptive filtering to select stable contributions. As a second step we propose to use the records from a network instead of a single pair of stations.

Standard approaches for travel-time measurements and inversion used in seismic imaging are not accurate enough to detect tiny changes in seismic speeds associated with transient deformations at depth. Our first results indicate that using the 'coda' part of reconstructed Green functions allows us to increase dramatically the accuracy of repetitive differential measurements. Therefore, we plan to pursue theoretical and methodological research in order to develop this new type of measurements and their inversion for the 3D structure. We will perform numerical tests and laboratory experiments to analyze the possible resolution of this type of measurements and use our expertise in the radiative transfer theory to draw 3D maps of density of probability for the scattered energy at a given time and use them as a form of sensitivity kernels. We will systematically compare our results with seismicity, geodetic measurements of deformation, meteorological and hydrological observations, and collaborate with colleagues specialized in studies of mechanical behavior of rocks to understand the relation between the observed changes in seismic speeds and the variation of mechanical conditions at depth.

The main goal is to use the proposed noise-based methods to study the transient processes related to volcanic and tectonic activity through continuous measuring of mechanical changes in deep parts of the Earth crust. Our main research targets will be active regions and objects such as volcanoes, active faults, and subduction zones where transient deformation and associated phenomena have been detected recently. We will broadly use the continuous records provided by

modern seismological networks and carry out several dedicated seismological field experiments in different active contexts (volcanoes, landslides, fault systems).
In the absence of in situ control of the mechanical state at depth, it is necessary to validate our approach with controlled change at a scale somehow similar to that of geological objects like faults or volcanoes. There are several domains with potential applications in which the physical changes are controlled, including industrial applications such as hydrocarbon extraction or C02 storage. We will use passive records to correlate changes in seismic speeds with the known mechanical history of the rocks at depth. At a smaller scale, we will monitor the surface of a tunnel during the excavation process to detect the evolution and the distribution of damage. At the laboratory scale, we are planning our own experiments involving changes in the medium produced by changes in strain and/or temperature.

The seismic noise-based methods that we propose to develop would be combined with satellite-based geodetic observations to significantly improve our capability to study the complex time-dependent and space-variable behavior underlying solid Earth deformation in response to tectonic and volcanic forcing and to environmental changes. First of all, we expect that these new developments will have applications in reducing human and economic losses due to natural hazards. We will continue to investigate the changes of velocity associated with the onset of volcanic eruptions to identify a systematic and reliable precursory signal. The next step will be to investigate the behavior of explosive volcanoes. Although there can be long intervals between eruptions, this type of volcano represents a major threat for large populations. Improving our forecasting capability is therefore very important. It requires monitoring over periods of time that are well beyond the duration of this proposal. It is nevertheless important to show the feasibility of this monitoring and to encourage the deployment of continuous recording systems when such a volcano enters an apparently critical stage. No one can claim that efficient earthquake prediction is close at hand, and the very existence of a precursory phase with a duration sufficient for an alert to be issued is not guaranteed. Nevertheless, new discoveries have led to a revival of interest in the subject. 'Slow' transient deformation revealed by geodesists, such as silent earthquakes, and non-volcanic tremors occurring at a depth where seismic activity was considered as non-existent, are discoveries that ask new questions and raise new hopes. Our preliminary results (Figure 2) indicate that noise-based measurements are accurate enough to detect temporal changes of a living Earth. Correlations between the observed seismic speed changes and the occurrence of deep tremors suggest that the noise-based measurements are able to shed a light on mechanical processes at depth. This exciting field is open for new investigations, and could bring new elements to the discussion on the seismic cycle, and eventually to the problem of earthquake prediction.

With the environmental impact of industrial activities becoming a growing subject of concern, a new monitoring capability is an important new tool to guarantee the security of underground activities. Extraction of oil and gas relies on massive injection and pumping that result in important variations of stress at depth. Monitoring has become an important issue for the industry. It is even a growing concern with the likely development of new operations like CO2 storage or steam injection for tar extraction. Another domain in which monitoring is important is the safety of deep repositories of highly toxic wastes for which the long-term evolution of the surrounding rocks must by measured.

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GRANTS APPLICATION

The European Commission supports **grants for access to 5 European seismological centres and infrastructures** for periods of research and joint technical developments, through **NERIES**.

The infrastructures selected for access through NERIES are characterized by specific scientific and technical facilities, as well as for their capacity to provide adequate scientific, technical and logistic support to external users:

ETHZ (Switzerland) operates the most homogeneous and dense regional broad-band network in the European-Mediterranean region and specializes in the development of tools for data assimilation, data mining and hazard assessment. *Contact: Annemarie Christophersen, web: www.seismo.ethz.ch/neries*

CEA/DASE (France), experts in detection and verification seismology and provides access to an extensive database of bulletins and waveforms (seismic/infrasound). A large spectrum of software tools is available for specific studies and benchmarks (source inversion, depth estimation, AI classification, etc.) and access to our large parallel computing infrastructure can also be provided. *Contact: Jocelyn Guilbert, web: http://www-dase.cea.fr/neries/page_neries.htm*

INGV hosts the SISMOS scanning and digitalization facility, the most advanced facility for the preservation and the analysis of paper recordings of historical earthquakes through digital scanning. *Contact: Graziano Ferrari, web: http://sismos.rm.ingv.it*

NORSAR (Norway) is the premier seismological array facility in Europe and a leader in array seismology and automatic on-line data processing. *Contact: Johannes Schweitzer, web: http://www.norsar.no/c-89-NERIES.aspx*

ZAMG (Austria) runs the underground Conrad Observatory, a well equipped, ultra-quiet facility for research, testing and calibration of seismic instrumentation and acquisition electronics. *Contact: Wolfgang Lenhard, web: www.zamg.ac.at/conrad_observatory/*

Grants will cover travel and living expenses for periods of 1 week to 2 months, and a reprimarily open for researchers and network operators from the EU Member States and associated States. Nevertheless, visitors from other countries can be accepted under specific conditions. Grants will be evaluated four times per year (deadlines: 15 March, 15 June, 15 September, 15 December); the first deadline was on 15 September, 2006. Grants will be available until mid-2010.

Applications, including a short scientific proposal and the CV of the investigator(s), should be submitted to the contact point for each infrastructure.

JABAL AL-TAIR ISLAND VOLCANIC ERUPTION

by Jamal Sholan[1]

General

Jabal Al-Tair is an oval-shaped volcanic island located in the mid-axial trough of the Red Sea, nearly 173Km to the northwest of Al Hudiedah port, and about 82Km from Kamaran island. The island is approximately 3Km long, covering an area of 3.99Km^2. The basaltic stratovolcano rises from the seabed 1200 meters below the surface of the Red Sea, continuing for 244 m above the surface up to the summit of the crater. The volcanic of Holocene age lies in the volcanic and geologically active region near the divergent boundary between the African and the Arabian plates.Earlier documented eruptions of this volcano were reported in the 18th and 19th centuries, the most recent (before the current eruption in 2007) have occurred in 1883, and possibly one in 1332.

Eruption of September 30th, 2007

The volcano erupted at 7pm local time on September 30th, 2007, throwing lava and ash hundreds of meters into the air. Subsequently, youthful basaltic poheohoe lava flowing from the steep-sided central vent was seen flowing down into the sea. Pyroclastic cones were located along the NW and southern coasts, and fumarolic activity occured from two eroded scoria cones at the summit. Radial fissures extended from the summit, some of which were the source of lava flows.

Field Survey in October 21st, 2007

A scientific mission from Yemen Geological Survey and an expert from the Italian University of Florence visited Jabal Al-Tair Island on October 21st, 2007. The success of this mission could not have been achieved without the support of super found committee established by Yemeni president and chaired by the Minister of Oil and Minerals.
Super found committee made an amazing action first by air survey the following morning where the first scientific reports and pictures had been publicly announced and distributed into local/international TV and newspapers. The second mission of October 21st, 2007 was also supported by the Yemeni Navy and Hodiedah governorate who provided sea boat logistics and accounterment. More than 5 hours of night boat navigation were spent from the Hodiedah port up to a 5-mile-distance from Jabal Al-Tair Island, due to the Red Sea agitation faced by the mission boat.

Actually all sea and dizziness nausea suddenly disappeared when everyone started seeing and hearing the front view of an amazing continus volcanic harmonic eruption at one of Island summit at the first day light of October 21st, 2007.

First Yemeni mission report (day after eruption)

Five-mile-distance panoramic view of Jabal Al-Tair continuous volcanic activity observed at the first day light on October 21st, 2008.

Fissures

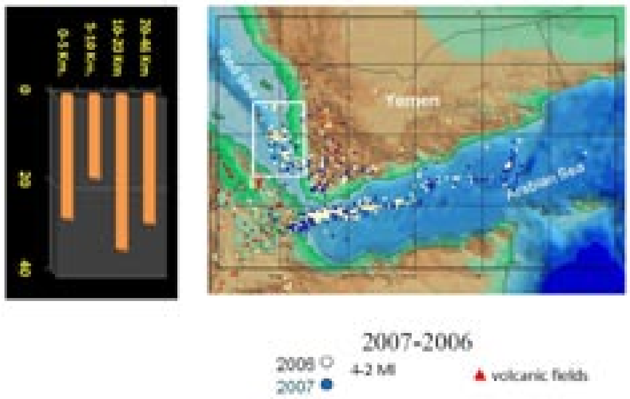
Main fissures occurred around and near the Island summits. These fissures were characterized by a 1.5 meter width particularly observed in the northeastern summit where volcanic gases were still rising through different spots along the main

Fissures occurred in the northeastern part of Island summit (left picture).
Island land propagation distinguished in the right picture as well as lava thickness which covered a half of building height.

fissures. The basaltic layer that covered some parts in the northeast and southeast areas flat ends were flowed from main fissures in the upper part. The positive benefiting phenomena of increasing areas or land due to volcanic eruption was to make nice photos during the October survey, specially at the Island coastal line with Red Sea water.

2006-2007 Earthquake Epicenter Map and Focal Depths

The 2006-2007 seismic activities in Jabal Al-Tair and surrounding areas calculated by Yemen Seismic Network indicated considerable earthquake epicenters that plotted in the underneath map. It also shows predominant shallow focal depths for these earthquakes. It is very interesting for any scientist to work in such field. It is also a good opportunity to launch cooperative studies in this part of the Red Sea, taking in consideration the local, regional and international focusing on this triple junction area located in the western flank of southern Red Sea. The volcanic eruption in Jabal Al-Tair and the historical up to recent seismic catalogues could be used as important tools for farther specific studies in this area.



2006-2007 Earthquake Epicenter Map and Focal Depths Distribution. The island is located within the white square.

Volcanic gases observed along fissures during October 21st, 2007 survey.

Yemeni Interest

Yemeni prime minister speech of the Fifth Gulf Seismic Forum opining ceremony as well as the Minister of Oil and Minerals indicated in April 2008 that Yemen Government has a contentment for supporting the scientific needs and the necessary upgrade topics that would be of help for natural disaster studies and risk assessment evaluation on a regional scale, as already recommended locally by the Geological Survey Board and Ministry of Oil and Minerals for launching volcanic observation era and volcanic studies program during near future.

I heard widespread praises from different colleagues that meet in Gulf Seismic Forum dates in Sana'a, especially if such plan should be associated with implementation support and/or an upgrade of the current scientific institutional capability represented by Yemeni Seismological Observatory Center in Dhamar province.

1) Yemen Seismological Observatory Center - Dhamar

New Member

DUBAI SEISMIC NETWORK, UNITED ARAB EMIRATES

by Yousuf Al Marzooqi[1], Eman Al Khatibi[1], Mathias Franke[2] and Ali. S. Megahed[3]

Abstract

Dubai Municipality established a broadband seismological network in Dubai Emirate, United Arab Emirates (UAE), since June 2006. The network consists of 4 remote seismic stations that observe local and regional seismic activity. Each station consists of a 6-channel high resolution, Internet Provider (IP) aware digitizer (Q330), a broad-band seismometer (STS-2) and a force balance accelerometer (ES-T). A hybrid communication link is used for data transmission which consists of spread spectrum Ethernet Radios and digital lease lines as well as an end-user provided internet access for real-time data exchange. The ANTELOPE software is used for data acquisition and analysis. The network is completely based on TCP/IP communication which allows reliable data acquisition and controls communication back to the remote sites. The system exchanges real time data with the Earthquake Monitoring Center in Oman, which increases the detectability of the network.

Introduction

The **United Arab Emirates (UAE)** is located in the eastern part of the Arabian Peninsula, extends along part of the Gulf of Oman and the southern coast of the Arabian (Persian) Gulf. Dubai Emirate is located in the northeastern area of the United Arab Emirates. UAE has witnessed rapid and flourishing economic development and long period of high rise constructions in the last few years. The majority of the population occupies the flat land near the coast covered by sedimentary deposits.

The biggest factor in terms of seismic hazard is believed to be the occurrences of moderate size earthquakes at shorter distances (northeast UAE) and large earthquakes that occurs at longer distances along Zagros belt (South west Iran) or in Makran region (North of Oman).
Information gathered from local seismic network can be used to define the location of active faults in the country, produce large scale seismic hazard maps, mitigate the effects of damaging earthquakes and achieve a workable seismic code for the country.
Dubai Municipality (DM) installed a robust and efficient seismic network that allows real-time, continuous and permanent observation of the local and regional seismic activity of the region around Dubai Emirate.
The network is functioning well and in this article, we will describe it in detail.

Design of Dubai Seismic Network

The seismic monitoring system consists of a central processing system which receives seismic data from 4 **remote seismic stations (RSS)** (table 1 & Figure 1) and 4 hybrid communication links consisting of **spread-spectrum Ethernet Radios (SSR)** and 4 **digital lease lines (DLL)** as well as an end-user provided internet access for real-time data exchange.

The real-time system includes the option to import and export data via the orb-exchange-protocol to and from neighboring networks. The Aspen system has an internet connectivity and imports data in real-time from the seismic

Table 1: Stations list of Dubai Seismic Network

No.	Station Name	Code	Latitude (N°)	Longitude (E°)	Elevation (m)	Sensor Type	Station Type
1	Hatta	HATD	24.8263	56.1313	340	STS-2 & ES-T	6-channel
2	Nazwa	NAZ	24.9863	55.6625	199	STS-2 & ES-T	6-channel
3	Al-Faqa	FAQ	24.7453	55.5926	203	STS-2 & ES-T	6-channel
4	Al Ashush	ASUD	24.6260	55.3290	132	STS-2 & ES-T	6-channel

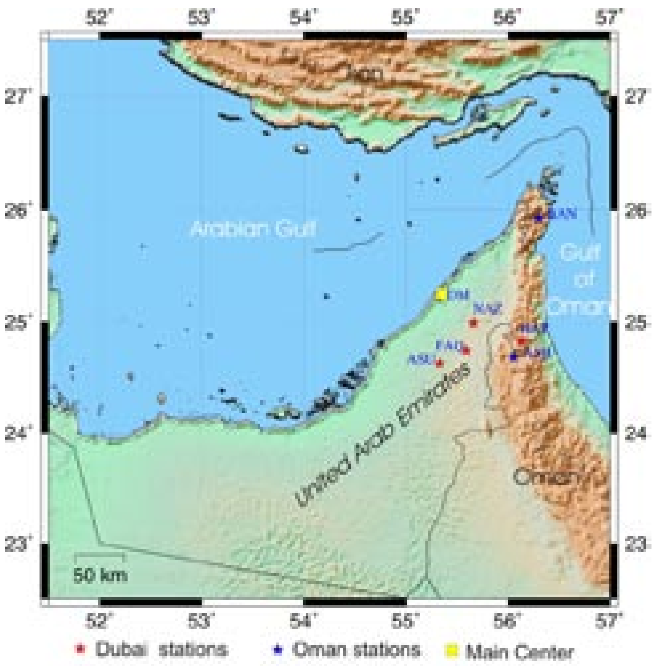


Figure 1. Dubai Seismic Network

network of Oman (BAN, ASH and SHA stations), Global Seismic Network from IRIS/IDA network, IRIS/USGS network, IRIS China seismic network and GEOFON network.
Through this connection, real-time data are provided to the seismic network of Oman.

Remote Seismic Station (RSS)

The RSS is equipped with tri-axial broadband seismic sensors (STS-2), tri-axial strong-motion seismic sensors (ES-T) and 6-channel high resolution, IP-aware digitizer (Q330) with GPS antenna for data time stamp.
The digitizer converts the analog seismic signal to digital data at 100, 20 and 1 sample/second. The on-site storage device packet Baler PB14 (20GB RAM) records continuous data streams. A 2.4GHZ spread spectrum transmitter with radio and Yagi antenna (to send the online data to the communication provider (Etisalat) node as digital lease line) is provided.
Power is supplied to the equipment by a 12 Volt battery box with solar charger and a power inserter for radio and a 80W solar panel.

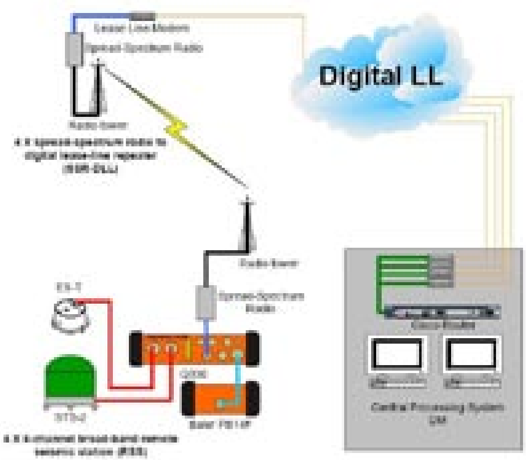


Fig. 2: Dubai Seismic Information System overview

Figure 2 shows an overview of Dubai seismic information system.

Central Processing System

The ASPEN **central processing system (CPS)** is located at the Survey Department of the Dubai Municipality. The CPS receives data from the RSS via the SSR-DLL.
The CPS consists of: a primary data acquisition sun workstation, one post-processing sun workstation, dual-host 365GB RAID for archiving data and acting as a database connected to workstations, a Magnetic tape (DAT72) unit connected to the primary workstation for backup data, a router with 8-port async/sync network module that establishes the connection with the 4 remote stations, 24-port Ethernet switch (Cisco system), network time server with in-line amplifier and GPS antenna, UPS provides pack up and 4 digital lease-line modem 19.2 kbps each provided by ETISALAT.
The network is completely based on TCP/IP communication which allows reliable data acquisition, commands and controls the remote sites from the data center where the SSR acts as network bridges.

Dubai Seismic Network uses the Antelope software version 4.8. It consists of ASPEN system's **Antelope Real-Time system (ARTS)** and **Antelope Seismic Information System (ASIS).**
ARTS refers to the real-time data acquisition, interactive control of field equipment, system state of health monitoring, and automatic data processing including detection, seismic phase picking, event association, location and archiving that are carried out by the software in real-time. It also provides automated import and export of raw data and processed results.
ASIS includes the underlying database of the software, which is based on the CSS v.3.0 schema for information organization.

Seismicity

The local seismic activity of UAE is low.
Historically there is no report or indication of any destructive earthquake in the country. Also, there is no national network to observe the microseismicity.

Recently a limited seismic activity has been observed in the northern part along the

Dibba-Masafi-AlFujairah area (Fig.3).

On March 11th, 2002 a moderate earthquake (M~5) occurred in the Masafi area and was recorded by seismic stations worldwide. The event was felt throughout the northern emirates and followed by many aftershocks for several months. A report on this event and accompanying damages is provided by *Othman, 2002*. *Rodgers et al., (2005)* studied the source mechanism of the Masafi 2002 event and reported a normal mechanism with a slight right-lateral strike-slip component consistent with the large-scale tectonics.

The focal mechanism provides for northeast trending steeply southeast-dipping normal faults similarl in orientation to an important pair of faults branching to the northeast from the Wadi Ham fault (Gnose and Nicolas, 1996).

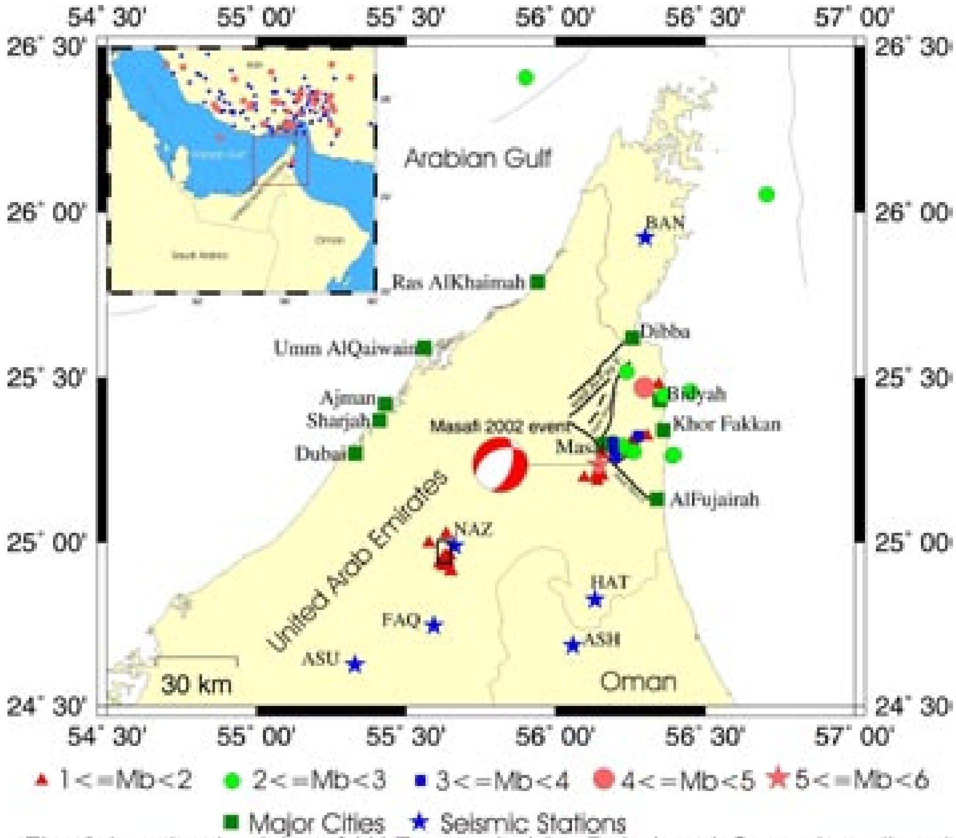


Fig. 3 Local seismicity of UAE recorded by Dubai and Oman broadband stations from June 2006 to February 2008. The betch ball represents the focal mechanism of 2002 Masafi earthquake, black rectangle represent the gas field in Dubai near to Wadi Nazwa.

Dubai seismic network has been running properly since June, 2006. The local seismic activity is concentrated along the northern part of UAE (Figure 3). The minimum and maximum local recorded earthquakes respectively had mb~1.2 to 4.5.

The seismic activity observed by Dubai and Oman seismic networks from June 2006 to February 2008 indicates a clustering of activity in the northern part of UAE along Dibba-Masafi-AlFujairah area and near to Wadi Nazwa gas field (Figure 3).

Acknowledgment

We thank the government of Dubai for supporting this project from the early stages till its completion.

We thank the staff members of EMC Sultan Qaboos University, Sultanate of Oman for their continuous collaboration to exchange online seismic data.

Also we thank the UCSD for providing links to import data online from 11 seismic stations in the region.

Maps were produced using the public domain Generic Mapping Tools (GMT) software (Wessel & Smith 1995).

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2) Kinemetrics, 222 Vista Avenue, Pasadena, CA 91107 U.S.A.

3) Seismology Dept., NRIAG, 11421, Helwan, Cairo, Egypt.

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New Member

YEMEN EARTHQUAKE MONITORING SYSTEM

by Jamal M. Sholan[1] and Hakim A. Ahmed[1]

Seismic instrumentation in Yemen started following the well-known 1982 destructive Dhamar earthquake through a special committee founded at the **Yemen Geological Survey and Mineral Exploration Board (YGSMEB)**, *currently known as the* **Yemen Geological Survey and Mineral Resources Board (YGMRSB)**, *which took the responsibility to purchase visual portable seismographic stations (MEQ-800) and started working to investigate the aftershocks of the Dhamar Earthquake.*

In 1984, an opportunity presented itself to Yemen when the country was accepted in the regional **Project for Assessment and Mitigation of Earthquake Risk in the Arab Region (PAMERAR)** *following what, the* **Arab Fund for Economic and Social Development (AFSED)** *agreed to fund a seismic monitoring system for Yemen. For this purpose a special project founded at the YGSMEB was formulated in 1987 for the organization, establishment and operation of a seismological network. This project was transferred to the* **Yemen Seismological Observatory Center (YSOC)**, *a governmental agency, which has the sole responsibility to monitor and study earthquake activity in the country.*
Since it was funded at YGSMEB in 1991, the YSOC has started a continuous program of activities aiming at installing observational networks used as the primary source of information for the scientific researches on earthquake phenomena, and targeting seismic hazard mitigation programs.

Seismological Networks

In 1993, **Strong Motion Network (SMN)** was installed in Yemen. The network was equipped with eighteen SSA-2 accellerographs distributed throughout the country: 12 stations were installed for free field monitoring in Sana'a, Dhamar, Taiz, Al-Bydhah, Al-Udayn, Zabid, Aden, Sadah, Hajjah, Mareb, Sayoon and Al-Hudyaidah areas (Figure 1); six stations were located on important structures for monitoring structural response during earthquakes.

This network is suffering from technical problems due to the lack of an Omega timing system signal but it is still working using a built-in clock manually adjusted to the correct date and time of a portable GPS timing instrument. The recorded data are stored in the station memory and collected using a portable computer running dos system.

In November 1994, the **National Seismological Network (NSN)** was installed. It consists of 12 short period and six Broad Band digital seismic stations. The network stations were sited in seismically advantageous areas of Yemen, primarily in different governorates where public telephone lines were available and safety guaranteed (Figure 1).
The Short period stations were equipped with LE-3D sensors, the Broad Band stations with Guralp CMG-40T sensors. Recording in the remote stations is currently being done in (STA/LTA) algorithm and the triggered seismic signals are digitized on-site by a Mars-88 digitizer with a 16 bit resolution. The triggered events are stored in the 4Mbyte memory of the stations which can be accessed and downloaded by the central station.

In 1997, **Visual Telemetry Network (VTN)** was established. This network is composed of three sta-

Fig.1: YSOC seismic networks configuration.

tions equipped with Kinemetrics SS-1 short period vertical component seismometers and located at the vertex of a triangle drawn around Dhamar City, namely in Ahram, Smarah and Addan areas with approximately a 50 Km-span between each adjacent stations as shown in Figure 1. Signals from these stations are sent either directly or through repeating stations to the data acquisition center in Dhamar. There, the data are recorded in visual continuous mode.

The main purpose of this network is classical monitoring and staff training.

Presently the central station of this network is connected to Mars-88/FD three channel instruments where the signals of all stations are digitally recorded on floppy diskettes, as soon as an event has been detected by at least two stations. With an 8-hour-interval or at the moment of a significant event, data are transferred to a PC where the processing takes place.

Seismic Data Analysis

By using an acquisition software utility provided by Lennartz and running on Sun Solaris workstation, triggered data at the remote NSN stations can be accessed from the central station at Dhamar, where recorded data are downloaded periodically in near real-time using public phone lines. Then the downloaded seismic data are registered and saved on the central station computer hard disk.

The data bank has been implemented both in ISAM and NORDIC formats. XPITSA and SEISAN software packages are being used for arrival picking, event location and magnitude calculation. Data analysis is being performed manually, which includes generation of earthquake reports, epicentral location map, uploading event information to the YSOC web site and sending the reports to different governmental authorities.

Printed annual seismological bulletins are produced and distributed both nationally and internationally along with a digital version on a floppy diskette containing arrival time readings, location and magnitude in HYPOCENTER file format.

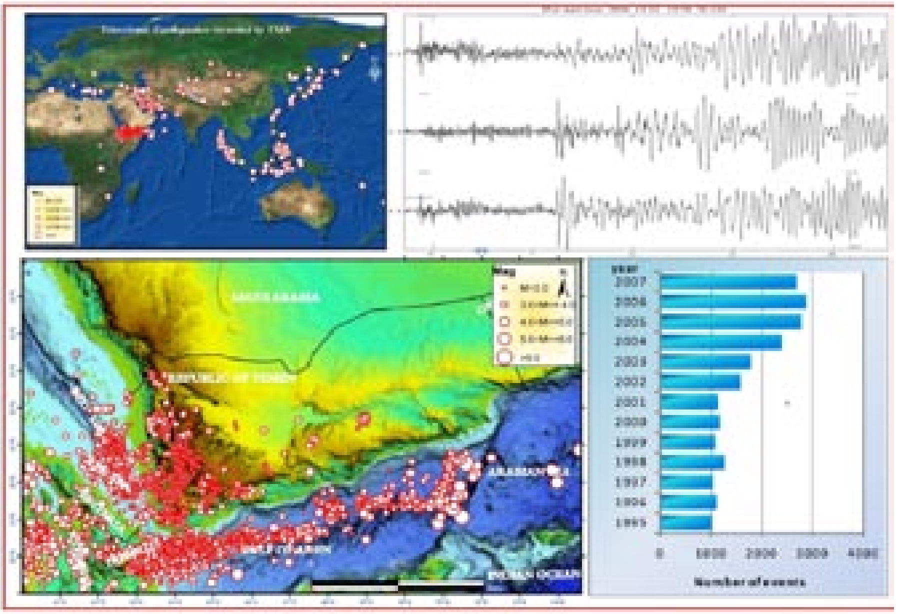


Fig.2: On the left, maps show regional and global seismic events recorded by the NSN seismic network in the 1995-2007 period. At the bottom right, a histogram shows the yearly number of earthquakes recorded by NSN, and at the top right corner the fig illustrates an example of waveform data.

Approximately 22,316 events have been detected and recorded during the 1995–2007 period by the NSN network, most of them from the Gulf of Aden, the Red Sea and Afar area as shown in the epicentral distribution map (Figure 2). More than one thousand teleseismic events have been detected and recorded at least by one station of the network. An example of the teleseismic waveform data is shown in Figure 2.

The average number of recorded events was around 1,000 events per year before 2003 and it has increased to 2,700 events per year for the 2004-2007 period because of the enhancement of the network configuration and triggering constrains, as shown in the histogram (Figure 2).

Ongoing improvement and upgrading of seismic networks

The overall effectiveness of the current seismic networks in Yemen faces some problems and challenges, the most notable being:

- Outdated, inadequate instrumentation,
- Separation of functions between strong and weak motion monitoring systems,
- Lack of real time digital data,
- Lack of uniform geographic coverage in areas with high seismic risk,
- Lack of full waveform data for triggered teleseismic events due to small storage capability,
- Lack of networked strong motion data.

Hence, the foremost need is a more modern digital seismic network equipped with Broad Band sensors, 24 bit continuous recording, real-time data transfer and automated analysis software.

To accomplish the YSOC goal of improving and upgrading the existing seismic networks, our plan considers the need for the following seismic stations across the country:

1. Deploy large aperture new seismic array equipped with broadband sensors and continuous real time information capability.
2. Develop the NSN ability to do real-time data transfer through dedicated phone lines.
3. Deploy new telemetric seismic stations with a single component vertical seismometer.
4. Improve the existing strong motion instruments with a GPS timing system and a dedicated phone line network system.

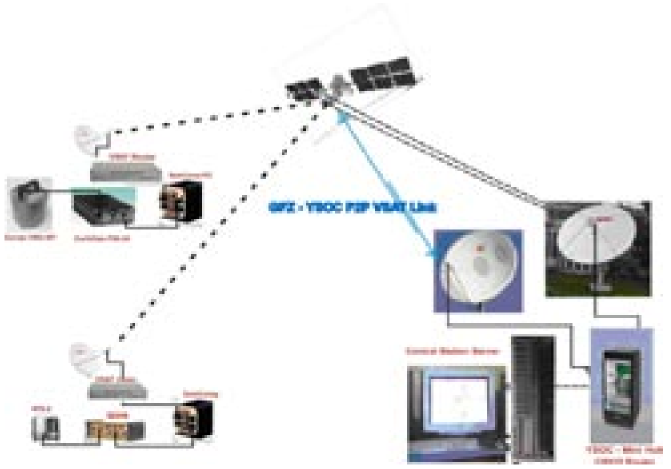


Fig.3: The diagram shows the layout of the new seismic monitoring system using VSAT communication.

In order to improve the existing earthquake monitoring system, a multi-phase upgrading plan has been submitted by the YSOC beginning of 2007. This plan has been approved and fully supported by the Ministry of Oil and Minerals. In the first phase of this plan and with the financial support of the Ministry of Oil and Minerals and the YGSMEB, 15 new strong motion stations will be deployed. The new stations will be equipped with Etna Accellerographs. The deployment is planned to be carried out in the first half of 2008.

As a part of this first phase of upgrading, YSOC and GFZ have signed a memorandum of understanding in 2006 for the deployment of a new state-of-the-art seismic network. This network will be the Yemen-German contribution to the Tsunami Early Warning System for the Indian Ocean. In the first stage, the new seismic network will be composed of five Broad Band digital stations. GFZ will provide 3 remote stations equipped with VBB STS-2 seismometers, Quanterra Q330 digitizers, Kinemetrics Episencors ES-T accelerometers, SeisComP data recorders and communication units, Warning center software and hardware and VSAT communication hardware. YSOC will provide 2 remotes seismic stations equipped with Guralp CMG-40T seismometers, Earthdata PS-24 digitizers, SeisComP data recorders, communication units and VSAT–communication hardware.

The central station will be equipped with iDirect private Hub and its accessories, a state-of-the-art Server (provided by YSOC), SeisComp software and a point-to-point VSAT communication hardware for data exchange between YSOC and GFZ (provided by GFZ). The final system layout is shown in Figure 3. The project was put out to tender during the last quarter of 2007. The local trading agency EYAB was the successful bidder. The deployment has been planned for the first quarter of 2008, but some delay is expected in the second quarter due to considerable difficulties.
The continuous data streams, that will be stored on the central computer hard disk, will be transferred in real time from the network remote stations to the central station at the head quarter of YSOC via a satellite communication system. The same data package will be transferred in real time to GFZ through point-to-point VSAT link. In case of strong earthquakes, a package of GFZ stations data can be transferred from GFZ to YSOC.

In the second phase of the upgrading plan, the number of remote BB stations of the new seismic network will be increased. The data transfer system for the national Seismic Network will be replaced by an ADSL line so that the network will be shifted from a triggered recording near-real-time monitoring system to a continuous recording real-time system.

Conclusion

Currently, YSOC monitoring system is composed of three groups of seismic stations, 18 SSA-2 accellerographs (Strong Motion Network), 12 LE-3D SP and 6 CMG-40T BB stations equipped with mars-88/MC dataloggers and 3 short period one component analog telemetry network (Week Motion Networks). In parallel, YSOC is now upgrading from the existing monitoring system to the installation of a new real-time seismic network equipped with 5 BB stations, 24 bit digitizers and VSAT communication system in the first phase of upgrading. The first phase of upgrading includes the installation of 15 new Etna accellerographic stations. It is an ongoing project for 2009.

1) Yemen Seismological Observatory Center – Dhamar.

New Member

REPUBLICAN SEISMIC SURVEY CENTER OF AZERBAIJAN NATIONAL ACADEMY OF SCIENCES (RSSC of ANAS)

by Vugar Farajov[1]

At the end of the 1970s, the **Experimental-Methodical Geophysical Expedition of the Institute of Geology of the Azerbaijan Science Academy (nowadays RCSS NASA)** *has been created following the decision of the directive bodies of the Republic in 1979.*

The RCSS NASA regroups all seismic stations of the Republic including «Baku» seismic station.

The creation of the RCSS ANAS began on the basis of the Experimental-Methodical Geophysical Expedition where seismological and seismic forecasting researches were led through an ever-extending network of seismic, geophysical and geochemical stations, equipped with modern means of registering seismic, geomagnetic, electromagnetic, gravitational and geochemical fields.

At the present the seismic station «Baku» is equipped with analog equipment such as СК-3, and ССР3-М.

Since 1981, an annual "Catalogue of earthquakes in the territory of Azerbaijan" is issued including earthquake coordinates, origin time, an magnitude for Azerbaijan and adjacent territories.
A catalogue of of scientific articles is also compiled including seismological, geophysical and geochemical scientific researches.

After the strong Caspian (Baku) earthquake of October 25th, 2000 (M6.2), and following the decree of the President of the Azerbaijan Republic, Mr.G.A.Aliev, about re-equipping seismic stations of the country with new, modern devices; tenders were invited and a network of 14 stations with satellite communication was purchased from Kinemetrics.

That was a significant contribution to the modernization of the network of the seismic stations of the Republic. It raised their activity to the level of international standards.

At the telemetric seismic stations of various regions, 11 sites were selected and equipped while 3 stations underwent upgrades. In «Academgorodok», the central "Baku" real time station has been constructed.

Locations of the seismic stations were chosen taking into account levels of seismicity geology, tectonic structure, and noise level in order to ensure an appropriate monitoring of the territory of Azerbaijan.

The three stations of Apsheron peninsula (NRD, GAL, GOB; figure 2) where Baku is located mo-

Table 1: Allocation of Seismic Stations Operated by the RSSC.

Station	ID	Latitude (Fi)	Longitude (La)	Elevation (m)
Ali-Bairamli	ALI	39.958	49.006	66
Barda	BRD	40.263	47.179	95
Gala	GAL	40.410	50.155	14
Ganja	GAN	40.646	46.322	603
Galilabad	GLB	39.242	48.393	156
Gobu	GOB	40.401	49.733	163
Ismailli	IML	40.792	48.182	711
Lenkaran	LKR	38.710	48.779	84
Nakhchivan	NAX	39.174	45.495	937
Nardaran	NDR	40.581	49.987	34
Pirkuli	PQL	40.789	48.593	1492
Quba	QUB	41.355	48.493	651
Seki	SEK	41.209	47.198	843
Siazan	SIZ	41.076	48.899	974

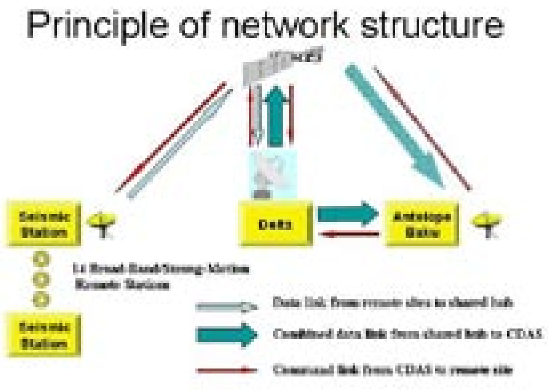


Figure 1: General scheme of the operations of the Azerbaijan digital seismic network.

nitor earthquake activity for the Greater Baku area, including small events in the water of the Caspian Sea. However, the location accuracy of offshore events will only be improved by the installation of new offshore seismic stations.
Processing of the current seismological information is carried out in real time with the help of a package of software: «Antelope, Panther».

The seismological information is collected through satellite communication with the 14 seismic stations, located in various regions of the Republic, before being gathered in the Center of gathering and processing (seismic station «Baku»).

Information on significant and strong earthquakes is transferred to the «Service of Urgent Reports», which is the operational contact with all directive bodies of the Republic and the media.

Because of the wide dynamic range (135dB) of the seismic stations, it was possible to lower the magnitude threshold down to M=2 and to increase the location accuracy which is estimated to be in the order of 5 to 6 km.

Such data have a great value for revealing active fault abnormalities in the seismically active regions of the Republic, but also their seismic potential, an estimation of their seismic potential, seismic zonation in terms of expected of maximum **peak ground acceleration (PGA)** that is very important for the construction of large engineering constructions.

Besides, because of the satellite communication between the stations and the center of gathering and processing of the information, probable research of dynamics of seismic process could now be done in real time and allow immediate reaction after an earthquake affecting any area of the Republic.

In seismoactive areas of Republic, the Seismological Center also operates geophysical and geochemical stations.

The seismic network of Azerbaijan operated by the RSSC ANAS

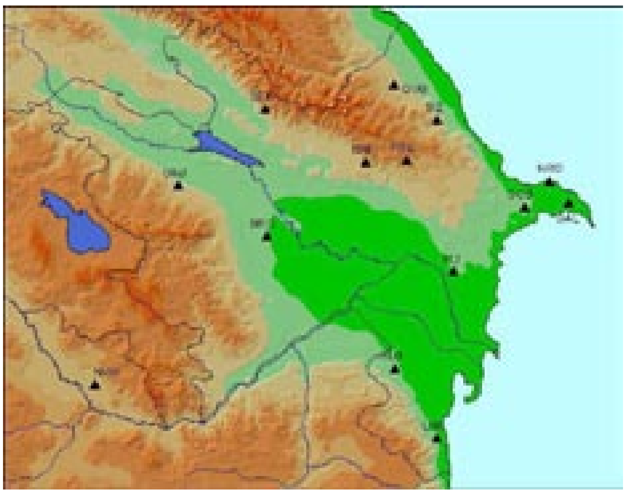
When part of the former Soviet Union, the seismicity in Azerbaijan was monitored by analog seismic stations equipped with common type seismometers of the Kirnos system.

From 1902 to 1988, the Experimental Methodical Geophysical Expedition (now **Republic Center of Seismological Survey**) had 18 analog seismic stations in Azerbaijan.

After 1990, the operations in one station had been fully stopped due to the economical crisis at that time in the Republic.
Furthermore, 3 stations have remained within territories occupied by the Armenians.

Despite the hardships and difficult conditions, 14 analog stations are still working up to now in the Republic.

Figure 2: Map of allocation of the new digital seismological network in Azerbaijan.



But of course, building a seismological network out of old stations didn't meet modern research needs. And it was necessary to renew our network.

In 1997, the Experimental Methodical Geophysical Expedition was renamed as the **Republic Center of Seismological Survey (RCSS)** under the Academy of Sciences of Azerbaijan.

Figure 3: Remote sites (stations).

Sta	Phase	Arrival time
SIZ	P	16:15:44.075
SIZ	S	16:15:51.649
PQL	P	16:15:47.111
PQL	S	16:15:56.627
QUB	P	16:15:49.082
QUB	S	16:15:59.782
NDR	P	16:15:49.880
NDR	S	16:16:03.582
IML	P	16:15:50.635
IML	S	16:16:04.086
GOB	P	16:15:50.817
ALI	P	16:15:55.972
SEK	P	16:16:00.826
BRD	P	16:16:03.158
BRD	S	16:16:26.909
GAN	P	16:16:08.518
GAN	S	16:16:34.878

Site selection was performed considering the level of seismicity and of noise.

The network comprises:
- 3 stations on the Southern slope of the Great Caucasus (Pirgulu, Ismailli, Sheki),
- 2 stations on the Northern slope of the Great Caucasus (Guba, Siyazan),
- 3 stations on the south-east part of the Republic (Ali-Bayramli, Jadlilabad, Lenkoran),
- 2 stations on the western part (Ganja, Barda),
- 1 station in Nakhchivan,
- 3 stations around Baku city, in the Apsheron peninsula.

Each station consists of a three-componential broadband seismometer STS-2 (manufactured by "Strekeisen",), one three-componential accelerometer Epi Sensor (manufactured by "Kinemetrics Inc.", USA), one 24-bit digitizer Quanterra-Q 330 (manufactured by «Kinemetrics Inc.», USA) and a communication system and a GPS clock.

The Epi Sensor accelerometer has a frequency-dynamic range up to 200Hz and 155 dB and the dynamic is set at +/- 2g.

Date	Time	Fi	La	H	M
11/01/2004	18:57:59	40.69	47.90	45.47	2.53
11/03/2004	19:15:37	40.35	46.99	32.34	2.16
11/03/2004	19:15:38	40.36	46.98	25.98	2.16
11/03/2004	20:12:56	40.47	49.12	42.13	3.39
11/03/2004	20:12:57	40.31	48.76	27.47	3.31
11/04/2004	05:50:12	41.44	47.89	10.11	2.08
11/04/2004	14:53:55	41.54	48.43	45.76	2.70
11/06/2004	20:51:03	39.16	49.96	60.00	3.70
11/07/2004	02:20:01	40.64	49.00	150.00	3.01
11/07/2004	17:18:33	38.38	49.38	40.71	3.71
11/07/2004	17:18:34	38.46	49.31	60.12	3.56
1/01/2005	16:15:34.053	41.0801	49.1367	58.2419	2.52

The center of data acquisition, equipped with satellite communication, is located in Baku, and the processing of all data from the 14 stations is done there.

The communication is provided by the "Delta" company via a satellite antenna in a real-time frame and stations are remotely controlled from the data centre.

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THE UNIVERSITY OF PATRAS SEISMIC NETWORK

New Member

by E.Sokos[1], A.Serpetsidaki[1] and G-A.Tselentis[1]

Introduction

The ***University of Patras Seismological Laboratory (UPSL)****, has a long history in seismicity monitoring in Western Greece, the area with the highest level of seismic activity in Europe.*

The first network was installed in the early 1990's around the city of Patras and it was based on short period sensors with analogue telemetry, (called ***PATras NETwork, PATNET****). This network monitored the regions of Patras and western Corinth Gulf for a few years; latter it evolved into a regional network for the entire area of western Greece.*

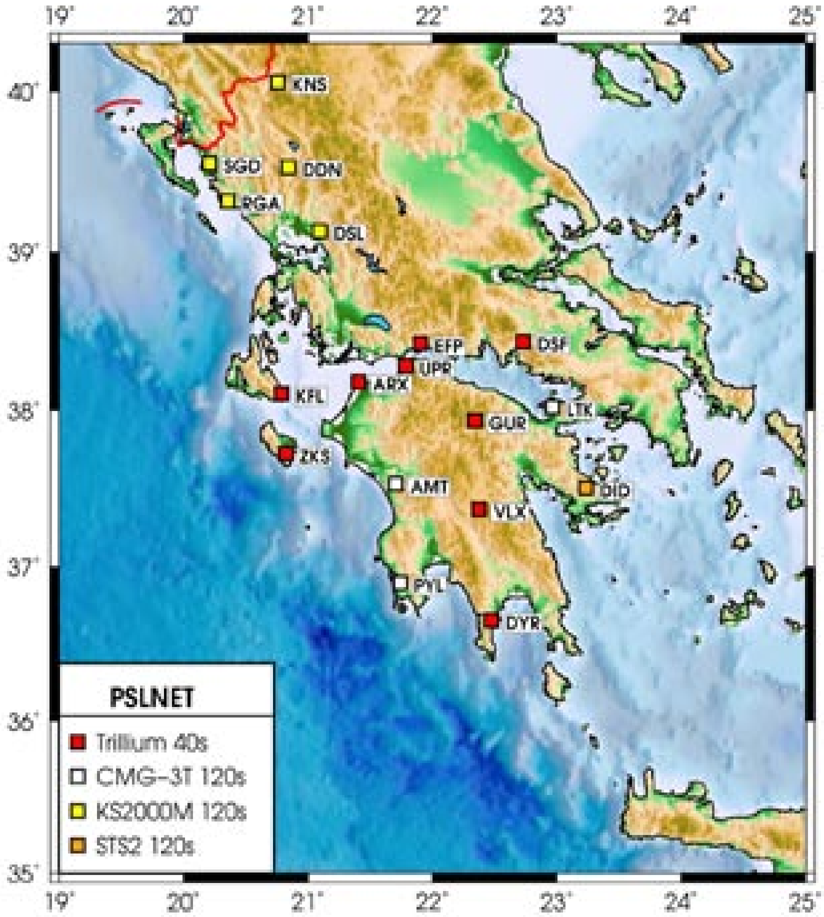

Figure 1: Map of present PSLNET stations distribution.

Recently the deployment of a new network started. It is called ***PSLNET (Patras Satellite Link NETwork)*** *and will substitute PATNET (Figure 1). It is based on three component broad band sensors and satellite telemetry. So far eighteen stations have been deployed and the plan is to have a total of twenty six stations by the end of 2009. Real time data are transmitted to the central station in Patras University and then stored and processed both automatically and manually. Phase picks, locations and moment tensor solutions are stored in our web page and also sent to EMSC. Recently PSLNET became a part of the newly established* **Hellenic Unified Seismic Network (HUSN)***, thus real time broadband data are shared among the four partners: Geodynamic Institute of National Observatory of Athens, Seismological Laboratory of National and Kapodistrian University of Athens, Seismological Laboratory of Aristotle University of Thessaloniki and Seismological Laboratory of the University of Patras. PSLNET and HUSN networks have a strong potential to improve studies of the seismic sources and reveal details of the complicated tectonic regime in Greece.*

Network description
Remote stations

PSLNET's first deployed station was LTK (Figure 1), this was done in 2003 and since then the installation of new stations is carrying on.

The majority of PSLNET's stations are equipped with Trillium 40 sec sensors but other sensors also exist (Figure 1). The two stations LTK and PYL are operated in cooperation with Charles University in Prague; these two are equipped with CMG-3T sensors and strong motion accelerographs, CMG-

5T, too. Real time data from LTK station are sent to ORFEUS. Acquisition at most stations is based on Trident digitizers and Libra VSAT telemetry system that incorporates the **TDMA (Time Domain Multiple Access)** access protocol. Libra system provides an efficient solution for seismological data transmission. Five stations are equipped with Geotech SMART24 digitizers and HellasSat satellite broadband internet.
Users have full control of the remote sites from the central recording site, allowing e.g. centering of the sensors and monitoring of the parameters health state. Remote sites are installed either in small houses or as underground vaults (Figure 2).
Considerable effort has been put towards the construction of low noise, reliable stations by careful shielding of electronics and sensors against electrical and environmental disturbances. Special care has been taken for the temperature isolation of the sensors.


Figure 2: View of Loutraki (LTK) station.

Network description
Central station

Remote stations transmit data (100Hz sampling rate, continuous records) to the central Hub located in the University of Patras campus.

This device is taking care of all data transmission by distributing the available bandwidth among remote stations, based on the TDMA protocol. The satellite system operates in Ku-band and currently the HellasSat satellite is in use. The performance of the telemetry system is very good and it efficiently balances costs with data retrieval. Similar to acquisition system, the user has full control on the telemetry system also, thus state of health monitoring and parameter change is quite easy. The central Hub receives data packets and then forwards them through local network to NAQS server acquisition software. This is an acquisition and data handling software package that performs the following tasks: data storage in ring buffer files, state of health data storage, waveform and state of health data real time display, data error handling and retransmission request, triggering of events and access to ring buffer data for clients like e.g. picking software. Ring buffer files store continuous data and are copied on backup disks once a day.

Network performance
Common problems

The network's performance is constantly monitored. As soon as an error occurs, the system sends email and SMS alerts to technical personnel. Monitoring is based on state of health data; on a daily basis plots of various parameters are created (data gaps, retransmissions, GPS status, seismometer mass status, voltage), and state of health data are stored in a MySQL database.

So far the main problems with data retrieval are thunderstorms (that can cause retransmissions and in extreme cases, data gaps), power failures at remote sites and local network problems. Overall the performance of the network is very good with minor problems and minor data gaps in a long period of time. Besides the technical parameters we also monitor the ambient noise levels at each station on a daily basis. The PQLX analysis software, by McNamara and Boaz 2005, is used for the noise level monitoring and plots are posted on Lab's web page.

Manual Processing

The Nanometrics Atlas software is used for manual data processing (Figure 3), this means phase picking, epicenter location and magnitude determination.
Results are stored in a MySQL database and are accessible through the Internet. The Hypoinverse program is used by Atlas for the determination of epicenter and the calculation of event magnitude. Two types of magnitudes are used; the duration and local magnitude using the Eaton, 1992 formula, implemented in Hypoinverse. Moment tensor solutions are calculated in the case of an event with M>4.0, using the ISOLA-GUI code (Sokos and Zahradnik 2008). The location and moment tensor results of the manual analysis are

posted immediately on the EMSC web page, while in case of strong events a small report is also prepared. Examples of these reports include the Leonidio earthquake (08/01/06, Mw6.2) and the Andravida earthquake (08/06/08, Mw6.4).

Automatic Processing

For the automatic detection and location of seismic events, the Hydra system is used (Figures 3, 4). This is a state-of-the-art automatic processing system that has been developed by USGS/NEIC. Hydra receives real time data from Naqs server and identifies, locates, and measures earthquakes. Thus, epicenter locations and seismic magnitudes (Ml, Mwp, mb, Ms etc) but also moment tensors are calculated automatically. Besides the automatic part, HYDRA is also providing tools for manual analysis.
The user has full control on the final results by

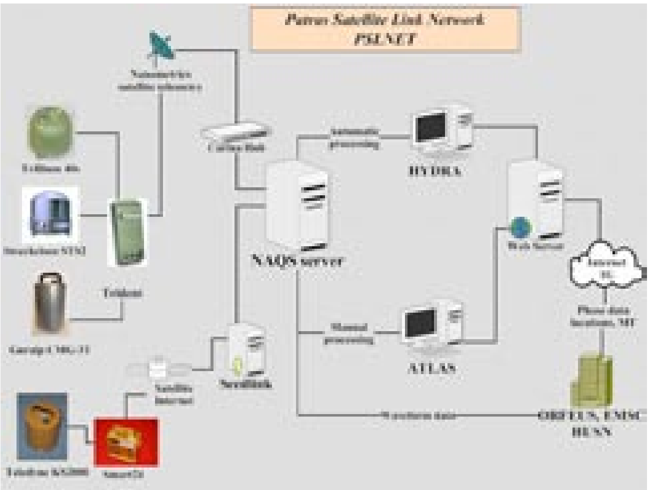

Figure 3: Flow chart of PSLNET operations (data transmission, acquisition and management).

e.g. correcting phase picks, or excluding/adding stations and reevaluating the location. Moreover, Atlas software can interact with HYDRA and load data and automatic phase picks for manual processing. All solutions, automatic and manual ones, are stored in a MySQL database and can be assessed using a Web interface.

Conclusions

PSLNET is a modern seismic network in Western Greece, operated by the Seismological Laboratory of the University of Patras.

The network now includes 18 stations and there are plans to install another three land stations and five OBS in 2009. All stations use satellite telemetry and the majority of them is based on the Nanometrics Libra system. PSLNET is part

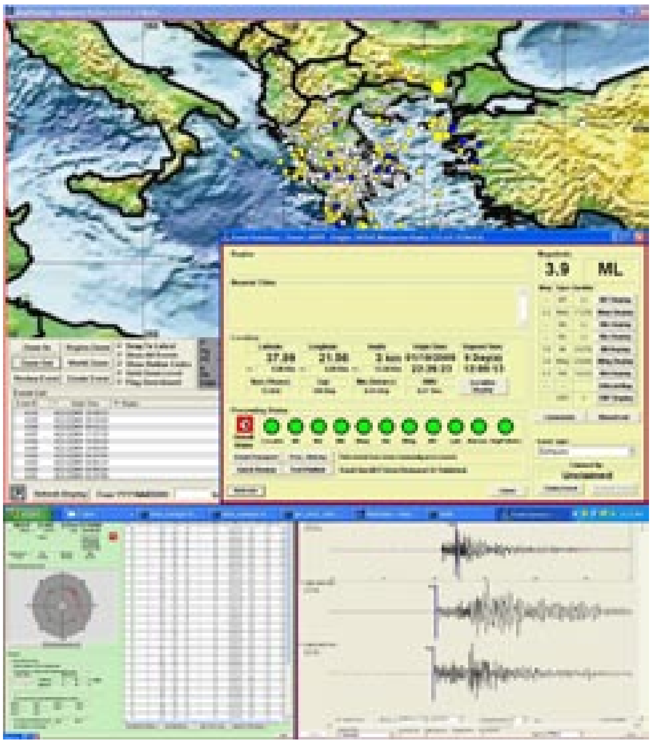

Figure 4: Example of Hydra system display. Location and phase picking windows are shown.

of the recently established Hellenic Unified Seismic Network, a national network with more than 80 broad band stations. So far performances meet expectations for PSLNET; the network is providing continuous high quality data with minimum telemetry costs.
Phase data as well as real time waveform data are sent to EMSC and ORFEUS, while focal mechanism solutions and reports about major earthquakes in Greece are posted on the EMSC web page soon after an event.

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ESC2010

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