Project N. 037110

NEAREST

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

Instrument: STREP

Thematic priority: 1.1.6.3 GOCE (Global Change and Ecosystems)

D38: Technological implementation plan

Due date of deliverable: May 20102009
Actual submission date: May 2010

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

Organisation name of the lead contractor for this deliverable: ISMAR

Revision:

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

D38: Technological implementation plan

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Introduction

Within the frame work of NEAREST a number of activities have been carried out which deserve further developments. These activities can be divided in three different typologies as consequence of a different degree of achievement reached during the life of the project: Some activities would concern the completion of a well established results and their application to a larger or different areas. This is the case of the Tsunami Detection Virtual Network, or the inundation maps or the simulated tsunami scenarios. Some other activities will require additional technical effort, because the stage of development reached during the NEAREST project was the testing of a first prototype, as for instance is the case of the tsunameter. Finally, some activities have been worked out at research level only and require further scientific development at theoretical, experimental and technological level, as is the case of the hydro-acoustic precursor.

1. The Tsunami Detection virtual Network, the Inundation Maps and the Simulated Tsunami Scenarios.

During the 42 months of activity of NEAREST it was carried out the development of an “Integrated Tsunami Detection Network” by establishing three data collectors for real-time automatic processing of the seismic data flow, one in Lisbon (Portugal), one in Granada (Spain) and one in Rabat (Morocco). The contractors involved were UGR, IM and CNRTS because they represent three national data collectors for the three nations listed above. The integration of the data-collectors, the harmonization of the recording and the processing procedures of the seismic data stream coming from different devices as tide gauges, buoys, obs, seismic stations, abyssal station was accomplished. The automatic procedures for rapid determination of seismic parameters and for effective tsunami detection methodology were also refined with further tests. The Moroccan partner, taking advantage of the coordination established by NEAREST between Spain and Portugal, had access to additional national funding allowing them to greatly improve the seismic network by adding several new land seismic station and tide gauges to the Network. At the end of the project the integration of the data-collector for each seismic node was completed and tested by using synthetic data streams. The Integrated Tsunami Detection Network developed within NEAREST was then able to share the data among the seismic node and to apply common procedures for earthquake fast-location. This Network can also easily integrate other external agencies allowing to define a Virtual Seismic Network for the Gulf of Cadiz region that could be dedicate to a future Tsunami Early Warning in SW Iberia margin and/or to support other possible focal points dedicated to the surveillance in other regions. The Virtual Seismic Network could locate and estimate real size of the seismic source in the SW Iberian margin in less than five minutes. By the end of the project, a prototype of Tsunami Early Warning System has been implemented in the Instituto of Meterologia (IM-Lisbon) able to release an alert in case of tsunamigenic seismic events. In addition, NEAREST carried out a feasibility study for a future Early Warning System. For this purpose NEAREST developed two types of simulators. The first simulator was designed to create synthetic data flows representing seismic information and water level data computed from realistic scenarios to be fed into the monitoring system and test its outcomes. The second simulator was designed to provide the Civil Protection authorities a software to be used either for training either as an operational add-to-decision tool in case of a simulated or true crisis. To improve the prototype and give more robustness to the system, the experience gained suggests that it would be highly desirable to include in the Virtual Seismic Network real time data from the source region, as for instance the bottom pressure recorder, bottom seismic recorder and meteo measurements acquired by the seafloor observatories deployed by NEAREST. A study carried out within NEAREST (Omira et al., 2009a) have shown that the deployment of at least three sea bottom pressure recorders in the Gulf of Cadiz would greatly improve the Tsunami Warning System in the Gulf of Cadiz (See Fig.1). The sensors at sea are in fact necessary either to shorten the warning times either to decrease the number of false alarms. It is worth to mention that, in addition to the "tsunamometer" tested by NEAREST, are available other open ocean devices, like DART or GITEWS sea bottom pressure recorders for this kind of measurements.

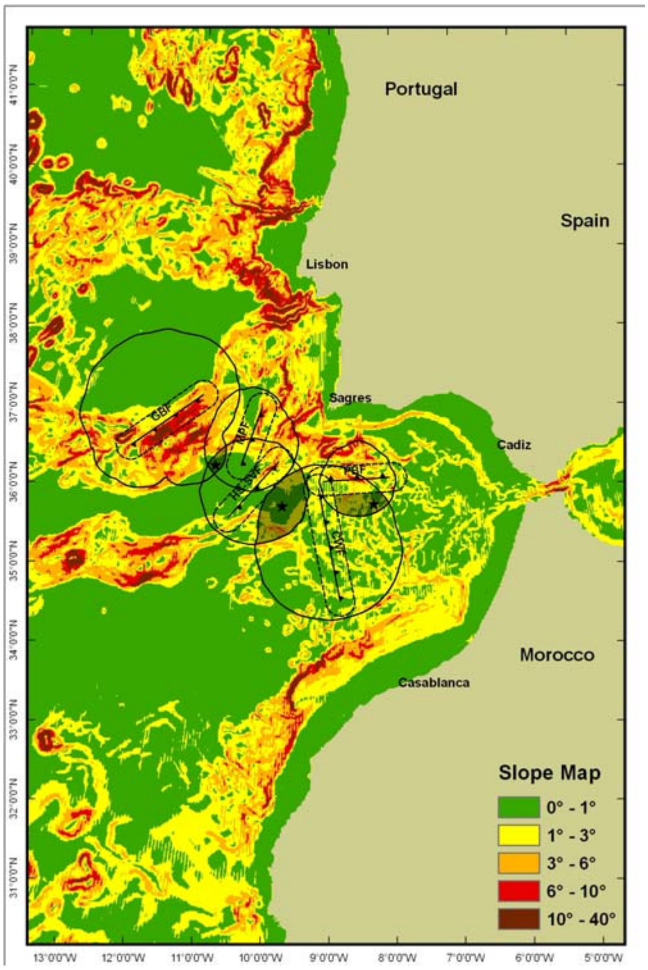

Figure 1 Location map of the proposed location of the three "Tsunami detector", courtesy of Luis Matias

Moreover, NEAREST computed the inundation maps for a test area located in the Algarve (South Portugal), along the Lagos and Sagres coastal areas. To extend the protection to the whole Gulf of Cadiz, inundation maps must be computed for all the main coastal cities and localities as well as the tsunami travel time scenarios The detailed bathymetries of these areas must be acquired in order to obtain the needed accuracy

The Tsunami Warning System developed for the Gulf of Cadiz on behalf of NEAREST, can be implemented also in other regions of the Mediterranean which are characterized by near-shore tsunamigenic sources and short warning times.

2. The Tsunameter

The common feature of the present day TEWS is the presence of the sea bottom pressure sensors used to decrease the number of false alarms by detecting the actual generation of a tsunami wave and to confirm or clear the tsunami warning. The tsunami signal has to be identified among other pressure perturbations, which can have greater amplitudes and are caused by various effects as barometric pressure changes, wind waves, tides, boats travelling nearby the sensor location, sea floor acceleration due to seismic events, salinity and temperature variations, and marine currents. All these effects are considered noise and have to be filtered out to obtain a detailed measurement of the tsunami wave. To succeed in the detection of tsunami parent signals the pressure sensors must be provided with dedicated software and/or hardware filtering devices. These filtering devices play a crucial role. This is especially true in tsunami generation area, where the pressure sensor may suffers accelerations that can completely mask the tsunami signal. All the tsunami warning systems make use of dedicated real time software algorithms, running on CPUs connected directly to the bottom pressure sensor (or based on land in the case of cabled system), to analyze and filter the pressure signal. Different devices are used to correct for the acceleration induced on the pressure sensors by the possible bottom motion in tsunami generation areas. For instance the GPS buoys installed by GITEWS are used to measure the displacement of the sea surface generated by the displacement of the sea bottom to account for this effect. In fact the tsunameter is equipped with a new and proprietary real-time tsunami detection algorithm, which is able, with low computational cost, to greatly reduce the dynamic range of the bottom pressure time series (from 3 m to few cm) and to detect tsunami signal with less than 1 cm amplitude with high reliability and earliness. The algorithm is also able to take into account, in real time, the effects due to the possible bottom motion by using the signal acquired by the accelerometers. These innovative technical solution place the tsunameter a step forward the other tsunami detection sensors concerning efficiency and costs.

To shorten the warning time the tsunameter is equipped with a three component broad-band seismometer, operated jointly with the bottom pressure sensor. The seismic signal is processed at the sea bottom with a short term over long term average algorithm (STA/LTA), and a warning message is issued and the pressure sensor "event mode" is activated if the given threshold is exceeded. In this way a double check on both pressure and seismic signal is achieved, improving the reliability and the readiness of the warning.

It must be underlined that the new instrument is in its very early stage of technological development. It has been tested as separated parts integrated and hosted on GEOSTAR abyssal observatory and buoy (developed in previous EU projects) which has been adapted to the tsunameter needs.

After the successful experimentation carried out within NEAREST, which have shown the full functionality of the tsunameter, the instrument now need to the completely re-engineered concerning the mechanical frame and the buoy The deployment also should be reconsidered, implementing a new dedicated deployment and recovering procedure.

3. The hydro-acoustic precursor

A challenging and very promising frontier for scientific research in the field of the Tsunami Early Warning is the "hunt" for a potential tsunami precursor. Starting from the pioneering work of Peltier and Hines (1976) and passing through the work of Artru et al. (2005) many attempts have been made to find the possible tsunami precursors induced in the atmosphere, while a first attempt to look for a hydro-acoustic precursor in the water column was made by Okal et al (2003), who proposed to use the T-waves for tsunami warning purpose. More recently, within the framework of NEAREST Chierici et al. (2010) developed a theoretical work concerning tsunami generation taking into account the water compressibility and the effect of a porous sea bed. They showed that modulated hydro-acoustic waves are generated in the water layer by the seafloor motion. The presence of the porous sediment acts as a "natural" low pass filter and allows the hydro-acoustic waves to propagate up-slope and outside the generation area with low attenuation. The main and surprising feature of these waves is their modulation, which carries information on the seafloor motion and source parameters. The existence of these waves was firstly observed during the Tokachi-Oki 2003 event (Nosov, 2007), when two pressure sensors, located within the generation area, detected a hydro-acoustic signal generated by the seafloor motion induced by the earthquake. The model of Chierici et al. (2010) correctly reproduces the measured frequency and amplitude of the signal. The results of this model showed the existence of a possible "hydro-acoustic tsunami precursor" , that could be integrated in a new generation of Tsunami Early Warning System.

It is important to remark that this result is valid in the framework of the theoretical model used for the study of the tsunami generation process. This linear model is solved in a 2-D vertical domain, with flat sea bottom and flat interface between water and porous sediment. From a theoretical point of view the presence of this hydro-acoustic precursor has to be validated also in the framework of more complicated models, taking into account the interferences which can occur in a 3-D domain, the effect of a bathymetric profile and the contribution of non-linear effects.

The full theoretical development of this model is still in progress. The experimental side should also be implemented with the measurement of the ocean hydro-acoustic environmental noise, with the design and the implementation of hydro-acoustic antennas able to measure the possible signal generated by the bottom motion and with the development of algorithms for the signal analysis devoted to tsunami warning.

In conclusion most of the work made within NEAREST can have useful, promising and interesting developments on scientific and technological side. This work can be used for the implementation and/ or the complementation of effective tsunami early warning services in near source and generation areas, as for instance the Mediterranean sea as well as for the possible development of new and more effective approaches to the tsunami early warning problem

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