Earthquake Early Warning System for Greece (HERMES)

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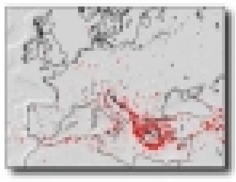
Introduction

Having in mind that 50% of the mean annual European seismic energy is expressed in Greece and that metropolitan areas located in the vicinity of major fault zones are becoming more vulnerable nowadays, the development of an Earthquake Early Warning System (EEWS) is of vital importance for Greece. In this respect, the design, development, testing and implementation of a pilot operational EEWS is one of the main targets of the related Greek Governmental Agencies and Seismological Community. The broader region of Gulf of Corinth and Athens (central Greece) has been selected for pilot deployment because:

- It directly affects the 65% the Greek population
- It affects indirectly all Greece (80% of Greek financial activities)
- It is a detailed studied area through numerous research projects with important existing infrastructure



European Seismicity distribution

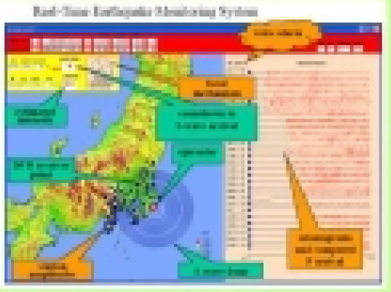
State-of-the-Art

The concept for the development of a system for earthquakes early warning is not new. It has been envisaged by J.D.Cooper in 1868 based on the fact that seismic waves generated at the source of the earthquake are propagated at relatively low speeds (3-8 km/sec) in relation to that of light. Based on this concept, if somebody would be in position to install detection sensors, around an earthquake prone area, estimate earthquake parameters in a few seconds and feed the estimates to a network of receivers, then it could be feasible to initiate early warning procedures with respect to the safety of the citizens, before seismic waves arrival at protected facilities. Since the time required for the initiation of early warning procedures is fluctuated with respect to the distance of the earthquake's source and can be of some seconds or tenths of seconds, it is implied that is not enough to allow manual handling.

In 1992 there was the first pilot system in Japan aiming to stop the fast trains in case of a destructive earthquake. The evolution of this initial system resulted to the REIS (Real-time Earthquake Information System) which is in operational mode for the last three years giving initial earthquake focal parameters just a few seconds after the occurrence of an earthquake. This is used operationally to Japan railways, schools, industries and moreover as an input to the tsunami warning system. Moreover a 5 years project was initiated on 2004 aiming the development of specific systems that will enhance the EW applicability in various areas.

A specific system exists in Mexico in order to protect Mexico city from the Guerrero gap seismic zone. Important efforts are conducted in California through TriNet, a pilot early warning and rapid response system. In addition, ElarmS methodology has was lately developed.

In Europe some initiatives have being conducted for the last two years in order to install some first pilot projects (Bucarest, Istanbul, Athens, Naples).



In Japan

An earthquake early warning system (EEWS) has been developed by using a spatially dense and high dynamic range seismic network that consists of 800 stations covering the Japanese Islands. The system is able to determine the hypocenter location, magnitude and a shaking intensity parameter within a few seconds from the P-wave arrivals at the closest stations and then transmits this information before the arrival of S-waves in areas of potentially serious earthquake damage. Since the available waveform data increases with time, the EEWS is designed to update the earthquake parameters every second.

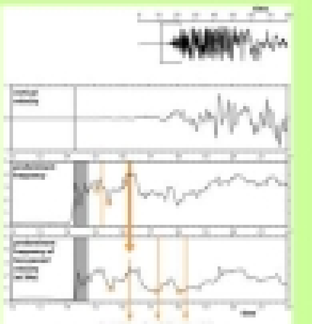
In California

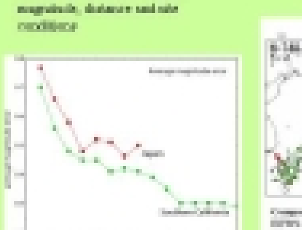
ElarmS goal

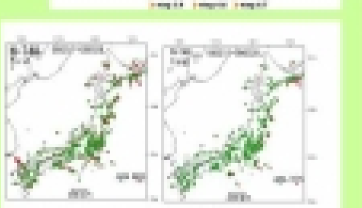
predict distribution and timing of peak ground shaking across the affected region

ElarmS methodology

1. Determine earthquake location
Using P-arrival times
2. Estimate warning time
Based on expected time of peak or significant shaking
3. Estimate magnitude
From frequency content of the P-wave
4. Calculate shaking intensity
Attenuation relations: require magnitude, distance and site conditions







Objectives / Expected impact

The HERMES concept addresses the design, development, deployment, public demonstration and operation of a pilot operational EEWS and rapid damage estimation system, for the alerting of local communities, public authorities (Ed Civil Protection, EPPO) and automated remote control of vital industrial installations (power plants, gas distribution, metro stations, generators, elevators etc). Our optimum target is to develop an end-to-end pilot operational system tuned for the broader region of Athens (Central Greece) where major installations of vital importance exist and then try to expand it all over Greece.

So in order to fulfil the four main elements of an operational early warning system, we can summarise that there is already important knowledge and infrastructure concerning the two first elements a) risk knowledge and b) technical monitoring

In the frame of this proposal we should:

a) upgrade the seismological infrastructure (dense sensors, satellite telecommunications, redundancy, etc)
b) establish the warning service (existing single station and network based algorithms (mainly from US and Japan) will be tested and tuned (ElarmS, hypocenter location using Tnow, shaking intensity magnitude etc, research on new approaches, array combination, shakemap product development)
c) alert dissemination based on new wireless technology (UMTS, satellite, WiMax).
d) Response capability in the sense of:
- Automated response on infrastructure (development of algorithms and interfaces (s/w and h/w) for automated control of infrastructures)
- Education in order to strengthen the knowledge and preparedness to act by those threatened, (production of educational material for all ages (video, presentations, leaflets, etc), in situ public awareness campaigns, evacuation plans)

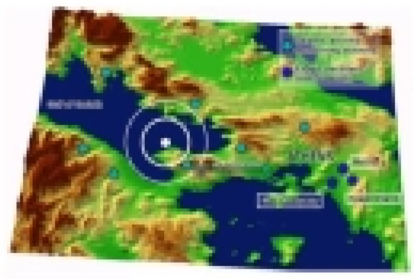
During the implementation testing of both existing and new techniques, special emphasis will be devoted on the assessment of errors on focal parameters estimation because it is closely related on their applicability. In addition, an EEW virtual implementation environment will be developed in order to simulate and evaluate automated response strategies before the final application according to specific end-users needs (EPPO-Earthquake Planning and Protection Organization, Greek Civil Protection, Public Gas Company, hospitals, industrial complexes etc).

The expected result is a fully operational earthquake early warning system that fulfils all four important elements of an effective early warning system as described in UN/ISDR recommendations. Moreover, the described system has the potential to cover a large part of the required infrastructure for the support of a tsunami warning system.

Our intention is at the end of the 5 years period to deliver a fully operational network. In order to reach operationallity, the following stages should be followed:

a) pilot deployment, b) pre-operational deployment, c) virtual implementation testing since pilot phase and continuous evaluation and d) Pilot operational implementation for specific applications

This process will enable reliable estimation and assessment of the potential impact of the operational system.



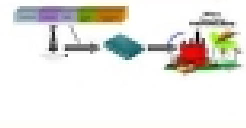
HERMES pilot area

Seismological network upgrade

Existing stations
New stations (every 20Km)

HERMES platform architecture

"Expert" decoder internal structure and control logic



Planned Activities

Network of seismic devices – acquisition – automated processing

In general, there are two different philosophies that could lead to the implementation of an earthquake early warning system. The network based philosophy that increase alarming information confidence level at the expense of lead time and the station based philosophy that could increase lead time, loosing thus parameter determination accuracy. As such, network based philosophy stations transmit the seismic data to a central processing unit (telemetry server) in the core network for post-processing, while single station philosophy does on spot data processing for the estimation of earthquake focal parameters (hypocentre, origin time, magnitude, errors of estimates) and sends the results to the early warning applications server.

The concept that will be followed will be to use the latest technology IP based seismological network infrastructure of the Seismological Laboratory of University of Athens, with the appropriate upgrades, in order to develop and implement both philosophies at the same time aiming to exploit the advantages of each procedure by building a **hybrid** system.

Existing single station and network based algorithms (mainly from US and Japan) will be tested and tuned (ElarmS, hypocenter location using Tnow, shaking intensity magnitude etc).

During the implementation testing of both existing and new techniques, special emphasis will be devoted on the assessment of errors on focal parameters estimation because it is closely related on their applicability. Both single station and network based algorithms estimates will be routed continuously to an "Earthquake early warning application server", which will be responsible to decide which earthquake data estimates will be forwarded at any given time to a database (EEW database) that will be developed in order to be used for comparative evaluation.

Shakemap like product will be developed by combining stochastic strong motion simulation results with Peak Ground Acceleration (PGA) values deduced from the real-time seismological and strong motion data-stream and integrating them to an automated webGIS s/w subsystem. PGA, PGV, PGD and estimated intensity contour maps will be created automatically following the occurrence of an earthquake. In order to achieve this, existing information (detail seismotectonic regime, site effect studies, attenuation laws, detail geology mapping, area DEM etc) deduced from previous research projects will be used. Additional studies on refining the attenuation relationships of seismic wavefield in both time and frequency domain as well as site effect studies have to be performed in an effort to create frequency depended "shakemap".

In addition, an EEW **virtual implementation** environment will be developed in order to simulate and evaluate automated response strategies before the final application according to specific end-users needs (EPPO-Earthquake Planning and Protection Organization, Greek Civil Protection, Public Gas Company, hospitals, industrial complexes etc). An **"expert" decoder** would receive and decode continuously the EEW data (magnitude, location, origin time and errors of estimates) before seismic energy release arrives. Such a decoder should be pre-programmed with the following information: a) Facilities' exact location (latitude, longitude), b)Local seismic amplitude amplification factor ("site effects" due to surface geological conditions - outcome of seismological site specific study), c) Local PGA (Peak Ground Acceleration) attenuation law (outcome of regional seismological study), d) Switching strategy. When the "expert" decoder receive earthquake early warning data, it would calculate immediately the hypocentral distance and estimated lead time till seismic energy arrives. Moreover, taking into account the PGA attenuation law and local site amplification factor, it can calculate the expected maximum PGA value and seismic intensity along with its confidence level. This means that we can have an automated estimation of maximum "shaking" **before** seismic energy release arrives at the decoders facilities. Then, according to the switching strategy that depends on specific infrastructure requirements in relation with the warning estimates and confidence level, intelligent control systems could automate responses according to infrastructure tolerance to the expected maximum "shaking".

EEWS applications for real-time risk reduction: algorithms, Interfaces automated control of lifelines/infrastructures

This concerns development of algorithms and interfaces (s/w and h/w) for automated control of infrastructures specific to real time early warning applications. As described above, incorporating EEWS information in the attenuation relationships for the area, event-specific control strategies may be adopted. Dealing with a lifeline, a safety issued shut down can be commanded either at the moment when a quake strikes at a selected location or when the effects of that quake exceeds given values. In both cases, the shut down could be too late to prevent damages of the infrastructures. If the magnitude of the quake as well as the expected PGA values at a selected location could be correctly estimated by an EEWS, the shut down procedures can be initiated in due time and the infrastructure could already stay in safe mode at the moment the quake strikes.

Education - strengthening the knowledge and preparedness to act

Production of educational material for all ages (video, presentations, leaflets, etc),In situ public awareness campaigns,Specific evacuation plans

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