Pilot Earthquake Early Warning for Athens

Diagourtas D[1], Horiuchi S[2], Makropoulos K[1]

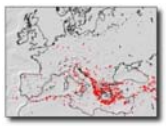
1. University of Athens, Department of Geophysics-Geothermics, Panepistimioupolis-Zographou 157 84, Athens, GREECE, diagourtas@geol.uoa.gr & kmacrop@geol.uoa.gr

2. National Research Institute for Earth Science and Disaster Prevention, 3-1, Tennodai, Tsukuba, Ibaraki, 305-0006, JAPAN, horiuchi@bosai.go.jp

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

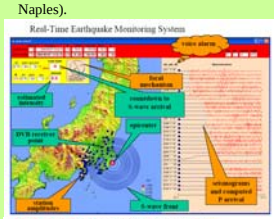
State-of-the-Art

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.

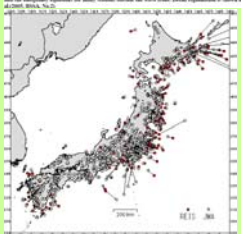
A specific system exists in Mexico in order to protect Mexico city from the Guerrero gap seismic zone. Important efforts are conducted in California through TriNet, a pilot early warning and rapid response system. In addition, ElarmS methodology has was lately developed.

In Europe in the frame of SAFER project, important initiatives have being conducted during the last two years in order to deploy several test sites with pilot implementations (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.

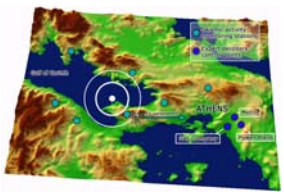


Comparison of Epicenter locations determined by our EEW (red) and those by manually picked data (white). The differences are shown by lines connecting two symbols. Events shown by only white circles indicate events without difference. Our EEW locates hypocenter when two stations detect large P waves for events inside the network and more than 4 stations outside the network. Our EEW locates 1332 events during three months and nearly 99 % of events except for the area of northeastern end are correctly located.

Objectives

In the frame of SAFER project, the Gulf of Corinth which represents one of the most important threats for the metropolitan area of Athens was selected as the area to deploy a dense network in order to provide the test-bed of implementing and testing several EW methodologies and especially the approach developed at NIED in Japan. For this purpose, a dense high dynamic range seismic network is installed in the area of Gulf of Corinth (Central Greece) since August 2007. We present the first results of testing this novel method of determining automatically earthquake focal parameters that was initially deployed at Hinet real-time system since 2002 and is capable of locating earthquakes in a few seconds after the first P-wave arrival.

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.



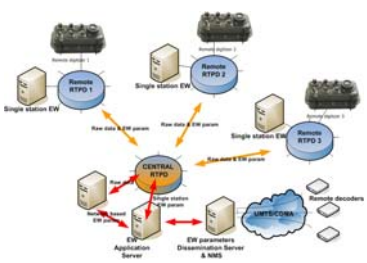
pilot area

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

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

Test Site Instrumentation

Green: Seismographs in real-time transmission,
Red: Seismographs in offline mode,
Yellow: Accelerographs in dial-up mode.

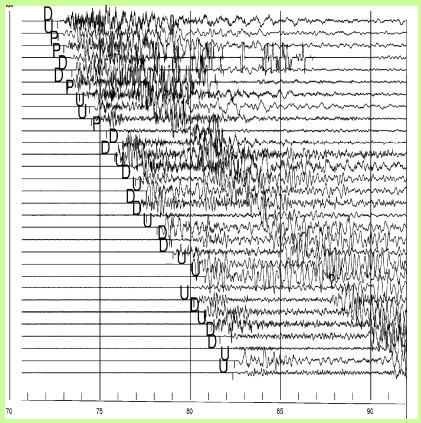


Hybrid platform architecture

First results

The earthquake location is calculated by using the arrival times of only a few stations in relationship with the fact that Pwaves have not arrived yet at other stations at a given time (Tnow). In addition by using a few ten parameters, a very efficient P-wave picking procedure is implemented that performs automatic event classification and on-the-fly phase picks association. The first tests performed on off line network triggered data by using the same parameters tuned for the Japanese network.

Picking and associating phases based always only on P -waves



Earthquake locations for earthquakes with M>3 for the period (September 2007 – March 2008)

White: manually picked data
Black: Automatic picked data

Work in parallel

- Establishing local PGA, PGV, frequency and site depended attenuation laws by using the RASMON database consisting of 4.212 records
- Detail Site effects investigation Real-time system implementation by using both event and ambient noise measurements

Next steps

- Event classification algorithms tuning
- Real-time system implementation
- Mi implementation
- Pilot operational system

Long-term plans include: a) supporting the developed system and its applications through national as well as end user funds b) applicability extension with additional end user funding c) extension of covered area to all Greece through a possible synergy of public and private sector funding and d) investigation of the most appropriate organization/structure that will support all the above

Acknowledgements

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