Efficiency of Earthquake Early Warning Systems

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With more early warning systems developed (Japan, Istanbul, Bucharest, Taiwan) and more systems evolving (California, Southern Italy, Greece,...) the issue of performance measurements becomes increasingly important.

Each early warning system is characterized by

- A given area that is characterized by a certain seismicity within the area, specifically a set of potential events (magnitude hypocenters) that represent the seismic hazard of the area.
- An network of seismological stations that communicate between each other or with a central processing unit; in extreme cases the ‘network 'consists of one station only.
- A specific methodology of early warning, which can range from onsite warning based on a single station to network type warnings and include all kind of intermediate approaches such as sub-networks, PreSEIS methodology, etc. The methodological aspects includes the issue of how and what kind of information is extracted to produce the alert. The first item (earthquake catalogue) must be considered as non-variable, whereas the station configuration and the warning methodology can be modified and adapted according to specific targets of early warning. These 'parameters' can and should be optimized for specific warning purposes. For instance, if the alert refers to a particular site (a city, parts of a city, facilities, etc.) and the information required is whether the ground motion level of an earthquake will be damaging (intensity > 5.5) one could attempt to optimize the station configuration (in terms of numbers and locations) but also the methodology to provide the required information, given a certain catalogue.

The optimization refers at least to two issues: (1) the effect of the entire set of earthquake events to which the system will respond has to be evaluated: The systems has to recognize whether an event will be such that the ground motion at the site of interest will be exceeded or not; (2) once this classification is appropriate (which means that there will be no false or miss-alarms) the warning times should be as best as possible.

We discuss some of these properties using the example of the Istanbul early warning system. We use a catalogue of events around the Marmara Sea ranging from magnitude 5 to 7.5, utilize two early warning methods and considerer the current configuration of early warning stations as well as potential extensions in the area. The two methodologies are: (1) the methodology currently being in practice that issues alarm levels based on threshold exceedance on at least 3 stations; (2) PreSEIS which we consider as a benchmarking method as it provides the best early warning performance given a particular station configuration and earthquake catalogue.

The optimization is then performed with a genetic algorithm which allows a systematic assessment of a large number of potential parameters. With this toolset we can address questions such as:

- Does the currently used early warning methodology based on 10 stations lead to proper identification of events and good warning times?
- Can parameters (threshold values to trigger alarms) be modified to improve the performance?
- Is the current station configuration optimal in the sense explained above?
- If stations are to be added, to what extend will the performance improve?
- If an OBS station can be positioned in the Marmara Sea, where is the best location and what performance improvement can be expected?