The Earthquake Early Warning System in southern Italy: Technologies, Methods and Performance Evaluation

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A real-time seismic monitoring infrastructure has been recently installed and it is actually operating in southern Italy, whose main purposes are to rapidly issue an earthquake alert, to provide near-real-time maps of the peak ground motion and intensity shaking and to test the feasibility of earthquake early warning following moderate to large earthquakes occurring along the southern Apenninic belt.

The monitoring system is based on a dense seismographic network (ISNet, Irpinia Seismic Network) deployed along the system of active normal faults of the Campania-Lucania region. This is the region where several large earthquakes in Italy have occurred during last centuries and there exist a significant probability for a M > 5.5 earthquake occurrence in the next decade. The 1980,*M*S 6.9 Irpinia earthquake, the most recent destructive earthquake to occur in the southern Apenninic belt, caused more than 3000 causalities and major, widespread damage to buildings and infrastructure throughout the region.

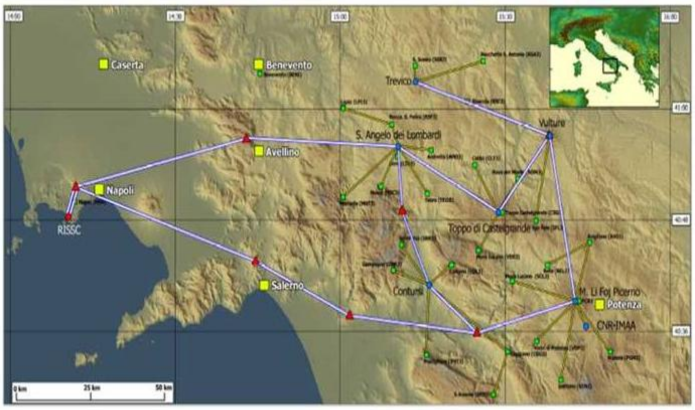

Figure 1 The figure shows the general layout of the Irpinia Seismic Network (ISNet). The network topology features multiple star shaped sub-networks, with several (maximum 7) seismic stations (green circles) and an LCC at their center (blue circle). The yellow lines are the radio link connecting the seismic station with LCC. The radio link backbone (under deployment) between LCCs and the NCC hosted at the RISSC-Lab in Naples is also shown. Red triangles represent the radio repeaters. The main cities are represented by yellow squares.

ISNet features 30 seismic stations and 5 data processing nodes (local control centers, LCC). All stations are equipped with three-component strong-motion accelerometer and 1-sec natural period velocity meter, to guarantee a relatively wide dynamic recording range (Figure 1). Five sites host broad band velocity sensors (30 sec of natural period), for the optimal recording of regional and tele-seismic events. The seismic data recorded at each station are transmitted to the nearest LCC, through a Wi-Fi directional antenna, where the data stream is real-time processed (e.g. to produce a bulletin of automatically detected events), archived and possibly visualized.

For early warning applications, a high bandwidth radio links backbone is being deployed, interconnecting the LCCs and the Network Control Center (NCC) in Naples, a hundred km distant from the network location. We developed a software application (PRESTo, Iannaccone et al., this issue) that processes the live streams of 3-component acceleration from the stations and, while an energetic event is occurring, promptly performs picking, event detection, event location, magnitude estimation and peak ground motion prediction at distant target sites.

Methodologies for earthquake early warning assume a point-source model of the earthquake source and isotropic wave amplitude attenuation. These assumptions may be inadequate to describe the earthquake source and wave amplitude attenuation effects and they can introduce significant biases in the real-time estimation of earthquake location and magnitude. This issue is critically related to the EEWS performances in terms of expected lead-time (i.e., the time available for earthquake mitigation actions before the arrival of damaging waves) and of uncertainties in predicting the peak ground motion at the site of interest.

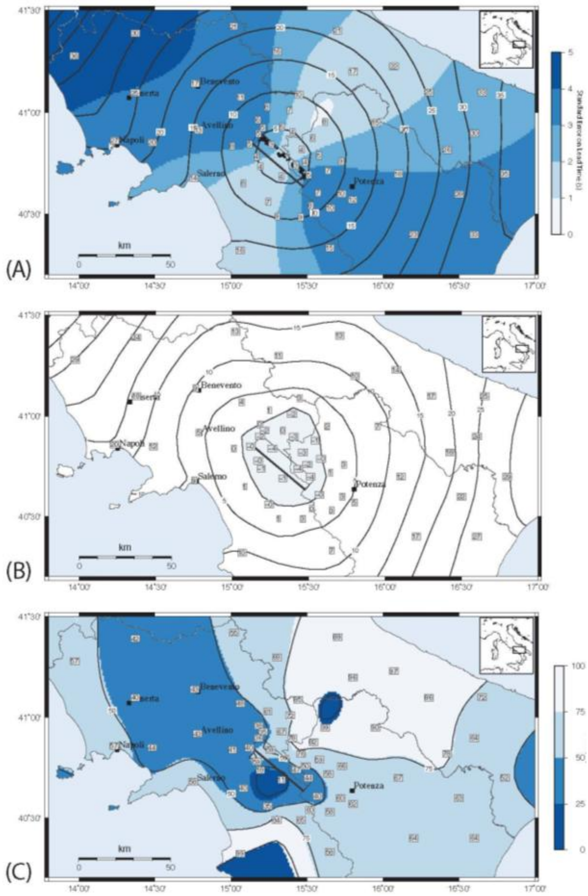

Figure 2 Regional maps of Early Warning System performance indicators. The maps are computed for 300 earthquake scenarios for an M 6.9 occurring inside the network. (a) Distribution of average Maximum Lead-Time (MLT) in seconds (isolines) and the associated range of variation (shaded scale). (b) Distribution of the Effective Lead-Time (ELT) in seconds. The shaded area inside the network indicates a zone with negative ELTs, where S-waves arrive before the distribution of PE becomes stable. (c) Distribution of PPE, the Probability of Prediction Error on parameter log(PGV) (see text for details). Shaded areas are obtained from a discrete representation of PPE, where lighter regions indicate a better efficiency of the EEWS to predict the PGV relative to darker regions.

In this note we investigate the effect of extended faulting processes and heterogeneous wave propagation on the early warning system capability to predict the peak ground velocity (PGV) from moderate to large earthquakes occurring within and outside the ISNet network. Simulated time histories at the early warning network have been used to retrieve early estimates of source parameters (earthquake location and magnitude) and to predict the PGV, following an evolutionary, probabilistic approach.

The system performance is measured through the Effective Lead-Time (ELT), i.e., the time interval between the arrival of the first S-wave and the time at which the probability to observe the true PGV value within one standard deviation becomes stationary, and the Probability of Prediction Error (PPE), which provides a measure of PGV prediction error (Figure 2).
The regional maps of ELT and PPE show a significant variability around the fault up to large distances, thus indicating that the system's capability to accurately predict the observed peak ground motion strongly depends on distance and azimuth from the fault.

Concerning the southern Italy EEWS the effectiveness of prediction depends on the specific scenario, whose real-time characterization becomes crucial for issuing an alert. As an example, for the densely populated Naples urban area, ELT can range between 8s and 16s, and PPE between 50% and 60%, indicating that several mitigation actions could be effective before S-waves shake the town.