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A probabilistic evolutionary approach for the real-time magnitude estimation from the early P and S wave displacement peaks.

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A regional EEWS is based on a dense sensor network covering a part of or the entire seismic source area. The relevant source parameters (event location and magnitude) are estimated from the early portion of the recorded signals and are used to predict, with a quantified confidence, a ground motion intensity measure at a distant location where a target site of interest is located. The success of a regional EEWS critically depends on the capability to provide in a fast, secure and reliable way the size and location of an earthquake while it is still occurring.

Standard techniques used to determine the source parameters of an earthquake are generally not suited for early warning applications, since they typically use the complete event waveforms from all the stations of a local seismic network, with a consequent large time delay for data transmission and analysis. For this reason, a different strategy is required, where the computation starts when few seconds of data from a small number of recording stations are available, and the source parameters estimates are progressively updated with time.

Assuming that a dense seismic network is deployed around the earthquake source zone, an evolutionary estimation of source parameters requires that earthquake location and magnitude, and their associated uncertainty, are determined as a function of time, i.e. of the number of recording stations and of the length of ground motion signal recorded at each station.

The technique is based on empirical prediction laws correlating the low-frequency peak ground displacement measured in a few seconds after the P and/or S phase arrival and the final event magnitude.

Based on the analysis of the Mediterranean, near source strong-motion database, Zollo et al. [2006] showed that the peak displacement amplitude of initial P and S scales with magnitude in the moment magnitude range $4 \leq M\omega \leq 7$. Such a correlation has been confirmed through the analysis of 256 shallow crustal events in the magnitude range Mjma 4-7.1 located over the entire Japanese archipelago. The peak displacement measured in a 2 seconds window from the first P-phase arrival correlates with magnitude in the range M = [4 - 6.5]. While a possible saturation effect above M = 6.5 is observed, it is no more evident in an enlarged window of 4 seconds.

The scaling of S peaks with magnitude is instead observed also at smaller time lapses (i.e., 1-sec) after the first S-arrival. The different scaling of P-and S-peaks with magnitude when measured in a 2 seconds window is explained in terms of different imaged rupture surface by the early portion of the body wave signals.

We developed a technique to estimate the probability density function (PDF) of magnitude, at each time step after the event origin. The predicted magnitude value corresponds to the maximum of PDF, while its uncertainty is given by the 95% confidence bound. The method has been applied to the 2007 (Mjma = 6.9) Noto-Hanto and 1995 (Mjma = 7.3) Kobe earthquakes.

The results of this study can be summarized as follow:

-The probabilistic algorithm founded on the predictive model of peak displacement vs final magnitude is able to provide a fast and robust estimation of the final magnitude.

-The information available after few seconds from the first detection of the P phase at the network is useful to predict the peak ground motion at a given regional target with uncertainties which are comparable to those derived from the attenuation law.

-The near-source, S-phase data can be used jointly with P data for regional early warning purposes, thus increasing the magnitude estimation accuracy and reliability.