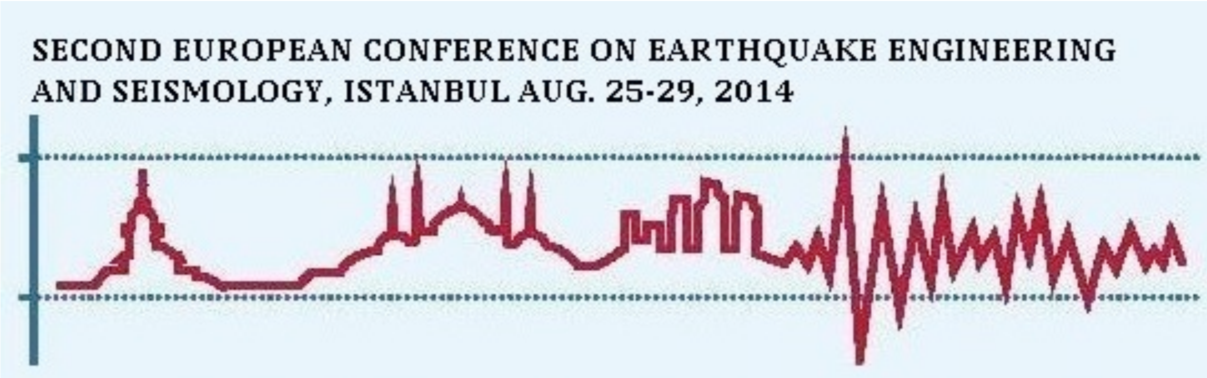

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EARTHQUAKE PARAMETERS DETERMINATION FROM SINGLE STATION RECORD

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Evaluating the effectiveness of real time-earthquake risk reduction systems focused on the decrease of the building vulnerability and people exposure, are important issues of the EU projects REAKT (Strategies and tools for Real Time Earthquake RisK ReducTion) and NERA (Network of European research infrastructures for earthquake risk assessment and mitigation). As part of these projects five schools in Southern Italy have been equipped with strong-motion seismic stations: ITIS "E. Majorana" in Somma Vesuviana (NA) (station MAJI); the Liceo Statale "Rinaldo D'Aquino" in Montella (AV) (station MOTI); the Department of Physics of the University of Naples "Federico II" in Naples (station NAPI); the IISS "The Sanctis" in Sant'Angelo dei Lombardi (AV) (station SALI); the IIS "Pomponio Leto" in Teggiano (AV) (station TEGI). These stations are integrated in the earthquake Early-Warning System (EWS) network deployed along the Southern Italian Apenninic chain.
In order to increase both the scientific knowledge and the consciousness about seismic hazard and risk educational activities involving both teachers and students are planned for the schools. These activities including the management and maintenance of the instruments installed in the schoolhouses and are disseminated through the portal www.sismoscholar.it. In particular, this work is dedicated to present how it is possible to use and process data available at each single-station for the earthquake source parameters estimation of local and regional seismic events through the analysis of the recorded waveforms.
Here we introduce the key concept of the single station methodology and present preliminary results of its application using both simulated data and real earthquake recordings. The methodology is suitable for small-to-moderate earthquakes and in the point source approximation is expected to provide the main source parameters: earthquake location, seismic moment, local, moment and duration magnitude and possible focal mechanism.
The travel-time difference between P and S-waves at a given station depends on the source-to-receiver distance and on the P and S-wave velocity of propagation. Assuming a simplified velocity model (homogenous or 1D), an approximate estimate of the source-to-receiver distance (i.e., the hypocentral distance) can be obtained from the observed P and S-wave arrival times at the station. This allows to define a half-spherical surface, centered at the station, with a radius given by the hypocentral distance, which includes all the possible hypocenter positions (Figure 1a).
To reduce the space of possible solutions, a further constrain can be added. The P-wave amplitude is measured both along the vertical component and on the modulus of the 3-component displacement vector. The ratio between the vertical component and the modulus amplitude is then used to compute the take-off angle between source and receiver. The P-wave amplitude ratio between the East-West and the North-South component is used, instead, to approximately compute the station azimuth. When these two additional parameters (take-off angle and azimuth) are available, the space of possible hypocentral solutions can be restricted to a single half-circle (Figure 1b). The sign of the ratio between the vertical and the horizontal P-wave amplitude can be used to discriminate to which quadrant (along the semi-circle) the hypocenter belongs (Figure 1c,d).

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Finally, once that the possible hypocentral solutions are limited to a circular arc, the source depth can be approximately estimated using the take-off angle value, so that the hypocenter position is univocally identified.

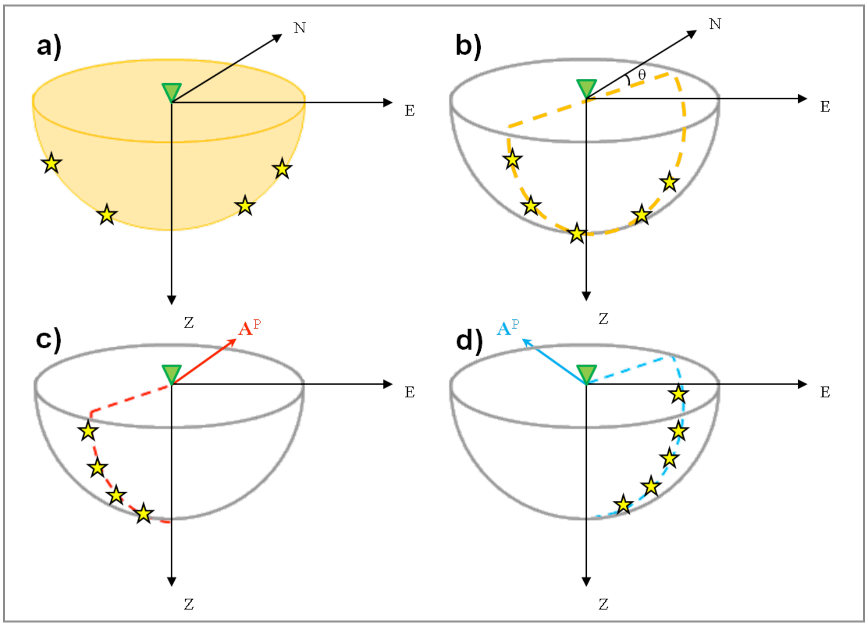

Figure 1. Scheme of the multi-step approach for the earthquake location using single station records.

Another piece of information that can be obtained using single station records is an estimate of the earthquake magnitude (local, moment and duration magnitude).
Once the P and S-waves are identified along the seismogram, a short time window (i.e., a few seconds) around the phase arrivals is extracted from the records and is used to compute the displacement spectra. Assuming the theoretical source model of Brune (1970), the plateau level and the corner frequency can be measured both from the P and the S-wave displacement spectra, through a fitting procedure. The plateau level of displacement spectra provides a measure of the seismic moment, which can be, in turn, converted into a moment magnitude value, using the relationship of Hanks and Kanamori (1979). Furthermore, the measure of the corner frequency from the spectra provides an estimate of the source radius, under the assumption of a small, circular fracture.
Given the hypocentral distance, the local magnitude can be also obtained by measuring the peak-to-peak Wood-Anderson displacement amplitude.
Finally, an independent estimate of the earthquake magnitude can be also obtained from the total duration of the seismogram. The duration of the seismogram is measured as the time elapsed between the P-wave arrival and the moment along the record where the signal amplitude is decreased to the pre-event noise level. The duration magnitude depends on the ground-shaking duration and, for small epicentral distances, is approximately independent on the source-to-receiver distance. Following the approach proposed by Colombelli et al. (2014), the signal duration can be measured along the squared signal envelope of a single component (for example the vertical component), after applying a smoothing filter to enhance the signal.
While location and magnitude are quite easy to be computed, a more challenging problem is the definition of the focal mechanism, using single station data. In theory, the spectral amplitude of P and S-waves and the P-wave polarity are related to the three angles composing the focal mechanism,

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through the radiation pattern coefficients. Through a grid search procedure the full space of possible focal mechanism solutions is explored. For each solution the agreement between theoretical and observed radiation pattern coefficients is evaluated. The optimal solution is the one providing the minimum *mistfit*.
The methodologies presented so far have been tested first using a database of synthetic waveforms and then using the recorded waveforms of a real event. Synthetic seismograms have been generated using Axitra code (Bouchon 1981) and for each given source, a series of stations, azimuthally well distributed have been also reproduced. The application of the proposed methodologies for earthquake location and magnitude computation provided excellent results for the simulated cases.
Then, the real 2013, December 29th, magnitude 4.9 Monti del Matese earthquake has been chosen as a testing case to validate the proposed single station procedures. The station of LIO3 (LIONI, station belonging to the ISNet network) has been chosen for the test. Figure 2 shows an example of waveforms recorded at LIO3 station and of the fitting procedure of S-wave displacement spectra. Even for the real case, the agreement between theoretical and observed earthquake parameter turned out to be excellent, both in terms of source location, moment and fochal mechanism.

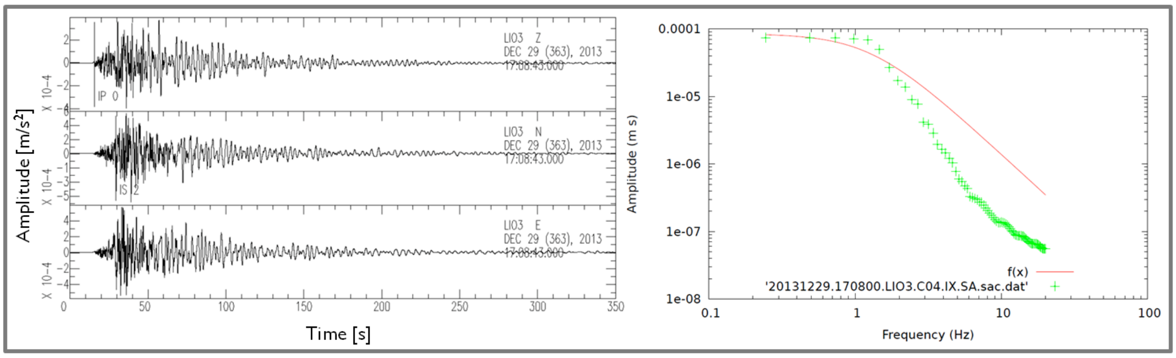

Figure 2. Left panel: example of seismogram recorded at LIO3 station during the December, 29th, 2013, M 4.9 Matese earthquake. Right panel: example of fitting procedure of displacement spectra.

The final purpose of the whole project would be to develop simple and user friendly tools to be provided to students, so that they could apply the proposed methodology by themselves. The idea is that teachers and student of the schools can download data from the www.sismoscholar.it website and apply the single station methodology using data recorded at their own school.

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