Real-time monitoring of seismic moment and radiated energy

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Understanding the dynamics of faulting is a crucial target in earthquake source physics (Yoo et al., 2010). To study earthquake dynamics it is indeed necessary to look at the source complexity from different perspectives; in this regard, useful information is provided by the seismic moment (M₀), which is a static measure of the earthquake size, and the seismic radiated energy (ER), which is connected to the rupture kinematics and dynamics (e.g. Bormann & Di Giacomo 2011a). Studying spatial and temporal evolution of scaling relations between scaled energy (i.e., e = ER/M₀) versus the static measure of source dimension (M₀) can provide valuable indications for understanding the earthquake generation processes, single out precursors of stress concentrations, foreshocks and the nucleation of large earthquakes (Picozzi et al., 2019). In the last ten years, seismology has undergone a terrific development. Evolution in data telemetry opened the new research field of real-time seismology (Kanamori 2005), which targets are the rapid determination of earthquake location and size, the timely implementation of emergency plans and, under favourable conditions, earthquake early warning. On the other hand, the availability of denser and high quality seismic networks deployed near faults made possible to observe very large numbers of micro-to-small earthquakes, which is pushing the seismological community to look for novel big data analysis strategies. Large earthquakes in Italy have the peculiar characteristic of being followed within seconds to months by large aftershocks of magnitude similar to the initial quake or even larger, demonstrating the complexity of the Apennines' faults system (Gentili and Giovanbattista, 2017). Picozzi et al. (2017) estimated the radiated seismic energy and seismic moment from P-wave signals for almost forty earthquakes with the largest magnitude of the 2016-2017 Central Italy seismic sequence. Focusing on S-wave signals recorded by local networks, Bindi et al. (2018) analysed more than 1400 earthquakes in the magnitude ranges 2.5 ≤ Mw ≤ 6.5 of the same region occurred from 2008 to 2017 and estimated both ER and M₀, from which were derived the energy magnitude (Me) and Mw for investigating the impact of different magnitude scales on the aleatory variability associated with ground motion prediction equations. In this work, exploiting first steps made in this direction by Picozzi et al. (2017) and Bindi et al. (2018), we derived a novel approach for the real-time, robust estimation of seismic moment and radiated energy of small to large magnitude earthquakes recorded at local scales. In the first part of the work, we describe the procedure for extracting from the S-wave signals robust estimates of the peak displacement (PDS) and the cumulative squared velocity (IV²S). Then, exploiting a calibration data set of about 6000 earthquakes for which well-constrained M0 and theoretical ER values were
available, we describe the calibration of empirical attenuation models. The coefficients and parameters obtained by calibration were then used for determining ER and M0 of a testing dataset.