Rapid determination of the energy magnitude Me

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The magnitude of an earthquake is one of the most used parameters to evaluate the earthquake's damage potential. Among the non-saturating magnitude scales, the energy magnitude Me is related to a well defined physical parameter of the seismic source, that is the radiated seismic energy E_S (e.g. Bormann et al., 2002): Me = 2/3($\log_{10} E_S$ – 4.4). Me is more suitable than the moment magnitude Mw in describing an earthquake's shaking potential (Choy and Kirby, 2004). Indeed, Me is calculated over a broad frequency range of the source spectrum and represents a better measure of the shaking potential, whereas Mw is related to the low-frequency asymptote of the source spectrum and is a good measure of the fault size and hence of the static (tectonic) effect of an earthquake.
We analyse teleseismic broadband P-waves signals in the distance range 20°-98° to calculate E_S. The correction for the frequency-dependent energy loss experienced by the P-waves during the propagation path is performed by using pre-calculated spectral amplitude decay functions for different frequencies obtained from numerical simulations of Green's functions (Wang, 1999) given the reference Earth model AK135Q (Kennett et al., 1995; Montagner and Kennett, 1996). By means of these functions the correction for the various propagation effects of the recorded P-wave velocity spectra is performed in a rapid and robust way, and the calculation of E_S, and hence of Me, can be computed at the single station.
We show that our procedure is suitable for implementation in rapid response systems since it could provide stable Me determinations within 10-15 minutes after the earthquake's origin time, even in case of great earthquakes. We tested our procedure for a large dataset composed by about 770 shallow earthquakes globally distributed in the Mw range 5.5-9.3 recorded at the broadband stations managed by the IRIS, GEOFON, and GEOSCOPE global networks, as well as other regional seismic networks.
The suitability of the proposed approach is discussed by comparing our rapid Me estimates with Mw published by GCMT as well as with Mw and Me reported by the USGS. Mw is on average slightly larger than our Me for all types of mechanisms. No clear dependence on source mechanism is observed for our Me estimates. In contrast, Me from the USGS is generally larger than Mw for strike-slip earthquakes and generally smaller for the other source types. For ~67% of the event dataset our Me differs ≤ ±0.3 magnitude units (m.u.) from the respective Me values published by the USGS. However, larger discrepancies (up to 0.8 m.u.) may occur for strike-slip events. A reason of that may be the overcorrection of the energy flux applied by the USGS for this type of earthquakes. We follow the original definition of magnitude scales which does not apply a priori mechanism corrections to measured amplitudes, also since reliable fault-plane solutions are hardly available within 10-15 min after the earthquake origin time. Notable is that our uncorrected Me data show a better linear correlation and less scatter with respect to Mw than Me of the USGS.
Finally, since Me and Mw express two different aspects of the seismic source, it will be shown by means of representative case studies that their joint use in the characterization of the seismic source would allow a better assessment of the tsunami and shaking potential of an earthquake.

References

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