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A generalized time-domain approach for routine moment magnitude estimation from S-wave peak displacement amplitudes

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Local magnitude (M_L) is widely used for reporting the size of small earthquakes, but to achieve consistent physical scaling and cross-regional comparability, moment magnitude (M_W) and related source parameters such as corner frequency (f_c) are required. Routine M_W estimation for small events is often hampered by low signal-to-noise ratios and unstable spectral fitting in conventional frequency-domain approaches. Recent time-domain approaches have therefore estimated M_W from peak S-wave displacement amplitudes measured in multiple narrow-band filters, but commonly rely on frequency and distance-dependent empirical attenuation curves that are inherently region specific. We present a generalized time-domain method that estimates moment magnitudes from peak S-wave displacement amplitudes measured on vertical-component seismograms filtered into ten fixed narrow bands with center frequencies spanning 0.1-30 Hz.

The method applies one-way Butterworth bandpass filters with constant bandwidth (0.2 Hz) and three poles, selected to provide stable spectral equivalence across center frequencies. For each band, the peak S-wave displacement is converted to an equivalent displacement spectral amplitude using a constant factor calibrated against Fourier displacement spectra. Source and path effects are corrected using geometrical spreading and intrinsic anelastic attenuation. Multi-band amplitudes are interpreted with a Brune source model (Brune, 1970) using a nested grid search to retrieve the long-period level (Ω_0) and corner frequency (f_c). M_W is then calculated from the resulting seismic moment.

We validated the approach using 12,025 records from 490 earthquakes in and around the southern Korean Peninsula (2017–2022). The time-domain M_W agrees closely with reference M_W from displacement-spectral fitting with uncertainty assessment (R^2 = 0.97). To validate the generalization of our method, we applied it to a two-week subset of the 2019 Ridgecrest sequence (4–18 July 2019), comprising 115,309 seismograms from 5,073 earthquakes. The resulting magnitudes also showed strong agreement with Trugman (2020) (R^2 = 0.91) without a region-specific correction curve.

The proposed method is directly compatible with real-time workflows, and we are integrating it into an Earthworm-based pipeline to output source parameter estimates shortly after S-wave arrival. To support this implementation, we developed modules for real-time IIR filtering and

moment-magnitude estimation by adapting and extending Earthworm modules. This provides an efficient and practical route to real-time M_W estimation in operational settings.