Multi-Array Multi-Phase Back-Projection: Improving the imaging of earthquake rupture complexities

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We present a teleseismic earthquake back-projection method parameterized with multiple arrays and combined P and pP waveforms, improving the spatiotemporal resolvability of rupture complexity. The contribution of each array to the rupture image is weighted depending on the multi-array configuration. Depth phases also contribute effectively to earthquakes at 40 km depth or deeper.

We examine 31 large earthquakes with moment magnitude greater than 7.5 from 2010-2020, which were back-projected in the 0.5-2.0 Hz band, giving access to the high-frequency rupture propagation. An algorithm estimates rupture length, directivity, and speed based on the back-projection results.

Thrust and normal earthquakes showed similar magnitude-dependent lengths and consistent subshear ruptures, while strike-slip earthquakes presented longer ruptures (relative to their magnitude) and frequently reached supershear speeds. The back-projected lengths provided scaling relations to derive high-frequency rupture lengths from moment magnitudes. The results revealed complex rupture behavior, for example, bilateral ruptures (e.g., the 2017 Mw 7.8 Komandorsky Islands earthquake), evidence of dynamic triggering by a P wave (e.g., the 2016 Mw 7.9 Solomon Islands earthquake), and encircling asperity ruptures (e.g., the 2010 Mw 7.8 Mentawai and 2015 Mw 8.4 Illapel earthquakes). The latter is particularly prevalent in subduction megathrust earthquakes, with down-dip, up-dip, double encircling, and segmented patterns. The automated choice of array weighting and the extraction of basic rupture parameters makes the approach well suited for near-real-time earthquake monitoring.