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Multi-scale Slip Inversion – Development and Application

T. Uchide and S. Ide
The University of Tokyo, Japan (uchide@eps.s.u-tokyo.ac.jp)

To analyze an initial rupture process on a small scale and a whole rupture process on a large scale systematically, we present a multiscale slip inversion method for earthquakes as a first attempt. A multiscale source model is constructed by renormalizing slip rate distributions on different scales as same as Aochi and Ide [2004]. A multiscale observation equation includes a renormalized kernel matrix.

Using the new method and employing theoretical and empirical GreenĄfs functions with two small events (M_W 2.3 and 3.3), we analyze the 2004 mid-Niigata prefecture earthquake (M_W 6.6). Following a preliminary deconvolution analysis suggesting a complexity of the initial phase, the multiscale analysis reveals details of the initial rupture process (the first 1 s) successfully. In the multiscale model, the estimated source process is consistent for all scales, while independent slip inversion analyses on three scales (monoscale analysis) result in inconsistent slip distributions with large errors.

The summary of the result is as follows: The maximum slip rate ($\sim$ 1.0 m/s) and the rupture velocity (2.5 – 3.0 km/s) in the initial rupture process are comparable to those in the main rupture processes of earthquakes. Four stages of rupture growth with different rupture directivities are found: the first 0.4 s with northeastward directivity; from 0.6 s to 1.0 s with southward directivity; until 2.0 s with northeastward directivity again; and after 2.0 s with southwestward directivity. These stages may represent cascading ruptures, evolving into a large earthquake. This first image of the whole rupture process of an earthquake implies self-similarity of the dynamic rupture process and is a breakthrough in the complete realization of earthquake source scaling.