Directivity moment tensor inversion toward automated estimates of earthquake rupture properties

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Rupture directivity is a first-order characteristic of the seismic source finiteness and observed ubiquitously for not only large but also small magnitude earthquakes. With directivity effect, seismic waves radiated in the direction of rupture could be greatly amplified, and even moderate magnitude earthquakes can sometimes cause serious damage. Thus, knowing directivity information of earthquakes is fundamentally important for ground shaking prediction and hazard mitigation, and is also useful for discriminating which nodal plane corresponds to the actual fault plane as if the event lacks aftershocks and outcropped fault traces. While the detailed rupture process of large earthquakes is commonly imaged by finite fault inversion and backprojection methods, for the small-to-moderate earthquakes the methods that utilize single source parameter (e.g. source duration, corner frequency, etc.) determined at stations at different azimuths to determining directivity are usually employed. However, these methods usually require sophisticated processing and good station distribution to obtain reliable results. Here, we propose a directivity moment tensor inversion method through direct waveform fitting with source time functions stretched for each station according to given rupture vector. By grid searching the rupture vector (i.e. directivity) in 3-D space, this method provides uncertainty estimation and is easily to be automated. The byproducts of derived rupture velocity and source duration can then be used for further estimates of rupture extent and stress drop. We perform extensive synthetic tests and real applications to the MW 6.2 Nantou, Taiwan earthquake, MW 7.0 Kumamoto, Japan earthquake, and MW 4.7 San Jacinto fault earthquake in southern California to validate the method. The obtained results show good agreement with previous studies and demonstrate the applicability of this method to a wide magnitude range of earthquakes.

Keywords: Rupture directivity, Rupture velocity, Stress drop, Realtime application