Simultaneous estimation of stress drop and rupture directivity of small to medium earthquakes around the Fukushima-Ibaraki border

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Stress drop is key to understanding the earthquake cycle. Although stress drops of small and medium-size earthquakes have long been estimated by assuming some simple source processes (e.g., Brune, 1970; Sato & Hirasawa, 1973; Madariaga, 1976), developments of recent seismic networks allow us to estimate the rupture propagation process even for small and medium-size earthquakes. In this study, we simultaneously estimated rupture directivities and stress drops of small to medium-size earthquakes (Mw 3.3-5.2) which occurred around the prefectural border between Fukushima and Ibaraki from 11th March 2011 to 31st October 2018.

We first estimated apparent moment rate functions of 348 earthquakes using an empirical Green’s function method. Apparent moment-rate functions were determined at respective seismic stations by the waveform deconvolution method (Ligorria & Ammon, 1999). We used waveforms of nearby smaller earthquakes as empirical Green’s functions. As a result, we found that many of the analyzed earthquakes showed strong directivities of the durations and the amplitudes of apparent moment-rate functions.

Then, by using a generalized rupture model (Dong & Papageorgiou, 2003) that can account for elliptical asymmetry ruptures, we estimated fault sizes, stress drops and rupture directions from the directional dependence of corner frequencies. Introducing asymmetrical rupture of elliptical fault, we succeeded to significantly decrease residuals between observed and synthetic corner frequencies in comparison with analysis assuming symmetrical rupture of circular faults. We found that 306 of 348 earthquakes we analyzed had significant rupture directivities. We also found that fault ruptures tend to propagate in the southeast direction. Stress drops and fault size were systematically larger than those estimated by assuming a symmetrical rupture model.

The median value of the estimated stress drops is 20.2 MPa, which is almost the same as the maximum shear stress estimated by the previous studies in this area (Yoshida et al., 2015a and b). It may suggest that each earthquake released most of the shear stress around its fault plane.

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