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Source Characteristics of Outer Rise Earthquakes

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An outer rise earthquake occurs in an oceanic plate beyond a trench axis. Due to the bending stress of the oceanic plate and the seismic stress transfer from a continental plate, normal and reverse faulting events are often observed (Lay et al., 1987). The focal depths of outer rise events are generally shallower than 30 km, therefore it well generates tsunami as seen during the 2009 Samoa earthquake (Mw 8.1). Around the Japan Islands, the 1933 Sanriku earthquake (Mj 8.1) is one of disastrous and significant examples, where the maximum tsunami height was 28.7 m and 3,064 people were dead or missing. The most recent outer rise earthquake is the 2010 off Chichijima earthquake (Mj 7.4), and tsunami 0.5 m high was observed after this event.

We performed source inversions of teleseismic body-wave data for outer rise earthquakes (Mw $>$ 7.0) around the Japan Islands in 1990 or later, then investigated rupture areas and average slips derived from the results of the source inversions and compared them with those of other kinds of earthquakes. Since outer rise earthquakes occur offshore, it is hard to obtain records observed in a near-source region, and therefore it is effective to analyze global data. We chose seven outer rise earthquakes. Those in the Pacific plate are the 2005 off Sanriku (Mw 7.0, 18.0 km deep, normal faulting), 2007 eastern Kuril Islands (Mw 8.1, 12.0 km deep, normal faulting), and 2009 eastern Kuril Islands (Mw 7.4, 45.2 km deep, reverse faulting), and 2010 off Chichijima (Mw 7.4, depth 18.6 km, normal faulting) earthquakes. The 1998 south off Ishigakijima (Mw 7.4, 22.9 km deep, strike-slip faulting), 2004 off Kii peninsula (Mw 7.2, 16.0 km deep, reverse faulting), and 2004 off Tokaido (Mw 7.4, 12.0 km deep, reverse faulting) earthquakes occurred in the Philippine Sea plate (The magnitudes and depths are reported by the Global CMT Project).

We used teleseismic data obtained from global observation networks through IRIS DMC. The velocity structure used is based on the Jeffreys-Bullen model, and we replaced a part of the top layer with the water layer of CRUST 2.0 in the source region. We first performed point source analyses, and then inversions for slip distributions on the finite faults determined from the results using the method of Kikuchi et al. (2003). Due to the low accuracy of the aftershock distribution, we used the residuals of an inversion for choosing the actual source fault out of two conjugate fault planes. The slip distributions of most outer rise earthquakes provided large slips above the hypocenters, and no systematic difference in source characteristics is found according to focal mechanisms and plates.

We extracted rupture areas and average slips from the resultant slip distributions using the method of Somerville et al. (1999). The results were compared to the scalings of crustal earthquakes (Somerville et al., 1999), plate-boundary earthquakes (Murotani et al., 2008), and intraslab earthquakes (Iwata and Asano, 2011). The rupture areas of outer rise earthquakes are similar to those of crustal and intraslab earthquakes, and the average slip of outer rise earthquakes are similar to those of crustal earthquakes. Therefore, the source characteristics of outer rise earthquakes are different not only from those of plate-boundary earthquakes (Ammon et al., 2008) but also those of intraslab earthquakes, though both outer rise and intraslab earthquakes belong to a category of intraplate earthquakes. In addition, shallow outer rise earthquakes such as the 2007 eastern Kuril Islands earthquake have obviously different source characteristics from those of intraslab earthquakes. Further investigation is necessary for outer rise earthquakes with smaller magnitudes.

Keywords: outer rise earthquakes, source characteristics, source inversion, slip distributions