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Development of Complex Seismic Source Inversion Method: Application to December 7, 2012 Sanriku-oki Earthquake

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Good knowledge of the seismic source process is important for understanding the stress regime and physical properties in and around the seismic source area. However, it is difficult to directly observe the co-seismic behavior on a fault in the interior of the Earth. Hence, many seismic source inversion methods have been developed, since the pioneering study of Trifunac (1974), to estimate the seismic source process using geophysical observations available on the earth's surface, under the assumption that the seismic energy was released by a hypothetical fault plane. Usually a simple planar fault is assumed and its geometry is decided from one of the nodal planes of the corresponding Centroid Moment Tensor (CMT) solution. However, it is well known that surface traces of faults are bending and branching; moreover, the complexity in fault geometry is also supported by the existence of earthquakes whose focal mechanism solution, determined using P-wave first-motion polarities, is different from their CMT solution and events for which the CMT solution contains large Compensated Linear Vector Dipole components.

Inversion with inappropriate fault geometry could result in a biased solution and increase the risk of misinterpretation. To mitigate the problem, it is better to estimate not only the seismic source process but also the fault geometry at the same time.

We developed a seismic source inversion method that does not require prior information of detailed fault geometry. In this approach, the seismic rupture process is formulated as a moment release function in a volume around the seismic source and the fault location is represented as a region of high moment release density within the rock volume.

First, we performed a synthetic test for the new method. In the test, both mechanism solution distribution and moment release were well recovered through the method. Next, we applied the method to real data from an earthquake occurred on Dec 7, 2012 at Far East of Honshu, Japan. We found that both a thrust type and a normal type earthquake occurred closely in space and time. The earthquake ruptured mainly two patches, one was a reverse faulting patch in deeper part, east of the hypocenter, the other was a normal faulting patch in the shallow part, west of the hypocenter. The normal faulting patch extended down to about 40 km, which is consistent with the deepest normal faulting events observed after the 2011 Tohoku earthquake in the region (Obana et al., 2012). The hypocenter was located between the reverse faulting patch and the normal faulting patch, where the stress state seems to be approximately neutral. The rupture seems to have propagated bidirectionally from the hypocenter towards both the reverse and normal faulting regions.

Keywords: source process, inversion, December 7, 2012 Sanriku-oki earthquake