**Effects of Rupture Processes in an Inverse Analysis of the Tsunami Source of the 2011 Off the Pacific Coast of Tohoku Earthquake**

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An inverse analysis of the tsunami source of the 2011 earthquake off the Pacific coast of Tohoku (Mw 9.0) was conducted on the basis of offshore sea-level observation near the source area. The effects of the rupture process on tsunami source inversion were investigated by comparing tsunami source models that assumed either infinite or finite rupture velocities.

**INTRODUCTION**

On 11 March 2011, the Tohoku earthquake occurred along the Japan Trench subduction zone. The Japan Meteorological Agency (2011) reported that the moment magnitude (Mw) of the earthquake was 9.0 and that the epicenter was at N38° 6.2′, E142° 51.6′ and 24 km deep. A tsunami was generated by the earthquake, causing severe damage and loss of life over wide areas along the Pacific coast of Japan. This event was successfully observed at offshore tsunami observation stations around Japan, using GPS buoys (e.g., Kato et al., 2005) and cabled ocean-bottom pressure gauges (e.g., Meteorological Research Institute, 1980). Tsunami heights exceeded 5 m at offshore observatories near the tsunami source, including a water rise of 6.7 m at the Central Iwate GPS buoy (Fig. 1).

The identification of a tsunami source is important for understanding the mechanisms of tsunami genesis and for improving the accuracy of tsunami forecasts. According to seismic wave analyses, a 450-km-long and 200-km-wide megathrust earthquake occurred for about 3 minutes (Japan Meteorological Agency, 2011). For tsunamis generated by a spatially and temporally large tectonic deformation, both the spatial distribution and the temporal development of the rupture motion are critical. For the 2004 Sumatra-Andaman earthquake and tsunami, the rupture and tsunami source extended 1200–1400 km (Ammon et al., 2005; Ishii et al., 2005; Fujii and Satake, 2007), twice that of the 2011 Tohoku earthquake. The rupture process and related time-lag effects on tsunami source generation were broadly discussed (e.g., Ammon et al., 2005; Ishii et al., 2005; Lay et al., 2005; Hirata et al., 2006; Fujii and Satake, 2007; Piatanesi and Lorito, 2007; DeDontney and Rice, 2012). By examining the time-lag and/or temporal development of a specific rupture, the reproducibility of observed tsunami waveforms has improved. Many previous studies on tsunami source inversion made assumptions regarding the geometry of the fault plane (e.g., Satake, 1987; Lay et al., 2005; Hirata et al., 2006; Fujii and Satake, 2007; Piatanesi and Lorito, 2007; DeDontney and Rice, 2012) and estimated the slip distribution along the fault plane. Our inversion method instead estimates the distribution of sea-surface displacement (e.g., Aida, 1972; Baba et al., 2005; Tatsumi and Tomita, 2008; Tsushima et al., 2009, 2011, 2012), allowing for the estimation of the tsunami source even when the geometry of the fault that initiated the tsunamigenic earthquake is unknown (Tsushima et al., 2009). Most large tsunamis are generated by megathrust earthquakes. It is generally assumed that their sources are at the upper surface of the subducting plate, where the geometry is well-defined. However, tsunamis generated by earthquakes originating from normal faults in the trench outer slope region, which occurred during the 1933 Sanriku earthquake (e.g., Kanamori, 1971) and the 2007 Kuril earthquake (Ammon et al., 2008), must also be considered. Even for megathrust earthquakes, splay faults may produce a substantial amount of tsunami energy (e.g., Fukao, 1979), but little is known about the geometry and orientation of these faults. Submarine landslides should also be taken into account. Our approach, which uses source inversion methods to forecast tsunamis, avoids undesirable biases that can occur with incorrect assumptions of fault geometries and/or a lack of knowledge about the physical mechanisms of tsunami generation.

In this study, we incorporated time-lag and temporal development effects into the direct inversion method for the distribution of sea-