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Fault modeling and stress drop estimation based on millimeter-scale tsunami records of an M6 earthquake detected by the dense and wide pressure gauge array

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Tsunamis observed by offshore ocean-bottom pressure gauges have been used to infer fault models and stress drops for major (M > 7) offshore earthquakes, to understand the earthquake and tsunamigenesis (e.g., Satake et al. 2013). However, it is challenging to observe tsunamis due to moderate (M ~6) earthquakes with reasonable quality by those, previous, few and remote pressure gauge arrays. Recently, a new, dense and wide pressure gauge network, the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net), was constructed off eastern Japan (Kanazawa et al. 2016). This array observed tsunamis associated with a moderate (M~6) earthquake which occurred inside the array, with amplitudes of less than one cm. We analyzed these millimeter-scale tsunami records to infer the finite fault model and stress drop, and to examine its relationship with other interplate earthquake phenomena.

We analyzed the pressure data associated with an Mw 6.0 earthquake off Sanriku on August 20, 2016. This earthquake was located at the shallowest part of the plate boundary off Sanriku, Japan, near the northern edge of the rupture area of the 1896 Sanriku tsunami earthquake (Kanamori, 1972). Although the signal-to-noise ratio is not high, the westward tsunami propagation with the velocity of ~0.1 km/s could be recognized when the waveforms were aligned according to the station locations. Using these data, we constrained the rectangular fault model with a uniform slip across the fault. As a result, the fault model was located ~10 km to the west of the Global CMT centroid (a seismic moment M_0= 1.4 × 10^{18} Nm, Mw 6.0, and a stress drop of Δσ = 1.5 MPa). The stress drop seems not so small as expected in tsunami earthquakes such as the 1896 Sanriku tsunami earthquake (□ ~1 MPa, e.g., Kanamori 1972) even if the uncertainty of the stress drop estimation is considered (Δσ > ~ 0.7 MPa). We also found the rupture area was unlikely to overlap with regions where slow earthquakes are active, such as low-frequency-tremors and very-low-frequency-earthquakes (e.g., Matsuzawa et al. 2015; Nishikawa et al. 2019; Tanaka et al. 2019).

This result demonstrates that the S-net new dense and wide pressure gauge array dramatically increases the detectability of a millimeter-scale tsunami and the constraints on earthquake source parameters of moderate earthquakes off eastern Japan. It is expected that more tsunamis due to minor-to-moderate offshore earthquakes are recorded by this new array, which will reveal the spatial variation of the stress drops, or mechanical properties, along the plate interface with much higher resolution than previously possible.