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Twin-peaks slip distribution of the 2011 Tohoku Earthquake and its relation to the fore-shock and aftershock activities

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Previously, Hiratsuka and Sato (2011) investigated the Coulomb stress change for the hypothetical receiver faults to evaluate the effect of the 2011 Tohoku Earthquake on aftershocks and future earthquake probabilities. They assumed the slip distribution determined immediately after the event using the GEONET data by the Geospatial Information Authority of Japan (GSI). The slip distribution gives the area of maximum slip lying almost halfway between the coast line and trench. Based on the calculated Coulomb stress changes, Hiratsuka and Sato (2011) suggested that the normal-fault aftershocks near the Japan Trench should occur within the subducted Pacific plate whereas the normal-fault aftershocks on the west of approximately 20 km depth contour of the plate interface should occur in the crust above the plate interface. Later, Sato and Hiratsuka (2011) evaluated the Coulomb stress change for the 81 larger aftershocks of which fault plane solutions are provided by Nettles et al. (2011). There they used the slip distributions determined using the GEONET data by themselves. As different slip distributions were obtained from inversion of the GEONET data depending on the strength of constraints put on the initial slip distribution, they compared the Coulomb stress change calculated for two extreme cases, that is, a slip distribution with the area of maximum slip shifted toward the land and a slip distribution with the area of maximum slip shifted toward the trench. The comparison indicated that the aftershock focal mechanism distribution is better explained by the slip distribution with the area of maximum slip shifted toward the trench. During the course of these previous studies, it was suggested that the slip distribution of the 2011 might be better constrained by considering the aftershock focal mechanism distribution as well.

In this paper, we investigate the level of consistency between the slip distribution of the 2011 Tohoku Earthquake and the aftershock distribution more closely. Since more accurate slip distribution is desirable for that purpose, we determine the slip distribution by using the coseismic displacements observed at the ocean bottom sites as well as the GEONET data. The fault geometry is assumed to be the same as that of Sato and Hiratsuka (2011). The slip distribution thus obtained is characterized by the two peaks of slip separated by a relatively low-slip zone extending in east-west direction off the border of Miyagi and Iwate Prefectures. This feature is robust and well constrained by the combination of the GEONET and ocean-bottom observations. Looking closely at the aftershock distribution near the trench, we find the place where the aftershock distribution protrudes from the trench toward the land (not towards the sea). This place coincides with the low-slip zone sandwiched by the two peaks of slip. Moreover, major seismic activities prior to the 2011 Tohoku earthquake since 1978 Off-Miyagi earthquake are distributed along the low-slip zones sandwiched by the two peaks of slip. Based on the analyses of stress field due to the slip distribution with the two peaks of slip, we investigate the cause of the interesting correlation described above.

Keywords: Subduction zone, Great earthquake, Coulomb stress change, Aftershock activity, Foreshock activity