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Slip distribution and Coulomb stress change of the largest foreshock (Mw 7.3) of the 2011 Tohoku earthquake

Aditya Gusman[1*], Yuichiro Tanioka[1], Shin'ichi Sakai[2]

[1]Institute of Seismology and Volcanology, Hokkaido University, [2]Earthquake Research Institute, University of Tokyo

The largest foreshock of the 2011 Tohoku earthquake occurred off the coast of Miyagi at 02:45:12 on 9 March 2011 UTC. The epicenters of the largest foreshock (143.28 E and 38.328 N) and the mainshock of the 2011 Tohoku earthquake (Mw 9.0) are separated by approximately 45 km. The tsunami waveforms generated by the largest foreshock were recorded by pressure gages (TM1 and TM2) and GPS buoys (GPSB802, GPSB803, and GPSB804) deployed off the coast of Miyagi. We apply tsunami waveform inversion method and include a spatial smoothness constraint to estimate slip distribution of the largest foreshock. Earthquake parameters of strike = 192, dip = 14, and rake = 81 (USGS W phase centroid moment tensor solution) are used in this study. Then we predict the Coulomb stress change from the slip distribution and evaluate how the largest foreshock led to the rupture of the great 2011 Tohoku earthquake.

The inferred slip distribution has a major slip region with dimension of 45 km x 45 km which is located on the down-dip side of the hypocenter. The slip amounts on the major slip region range from 0.6 to 1.5 m. The major slip region is centered at a depth of approximately 19 km. The center of the major slip region is located near the centroid for this event that was determined by the USGS. By assuming the rigidity of 4 x 10ˆ10 N mˆ-2, the seismic moment calculated from the slip distribution is 1.2 x 10ˆ20 N m which is equivalent to Mw 7.3. The slip distribution indicates that the largest foreshock did not rupture the plate interface where the rupture of the mainshock was initiated. From the slip distribution, we calculated the Coulomb stress change on thrust faults with the same geometry as the largest foreshock. Friction coefficient of 0.4 and rigidity of 4 x 10ˆ10 N mˆ-2 are assumed. The calculation shows that the Coulomb stress increased by 1.6-4.5 bars within a 4 km radius of the hypocenter of the mainshock (depth = 23.7 km). This indicates that the 2011 Tohoku earthquake was brought closer to failure by the largest foreshock.

Keywords: Foreshock, the 2011 Tohoku earthquake, slip distribution, Coulomb stress change, tsunami waveform