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Aftershock activity of the 2008 Iwate-Miyagi inland earthquake suppressed by stress shadow of the 2011 Tohoku earthquake

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The 2011 Tohoku-oki M9 earthquake has increased seismicity rates in many areas in eastern Japan. Several papers already sought the triggering mechanism to static stress change (Toda et al., GRL, 2011), dynamic stress change (Miyazawa et al., GRL, 2011) and pore fluid pressure change (Terakawa et al., EPSL, 2013). In contrast, areas where seismicity rate evidently dropped are restricted to the vicinity of the 2011 rupture zone (Kato & Igarashi, GRL, 2012), the 2004 Chuetsu aftershock zone (Hirose & Toda, SSJ fall meeting, 2011) and the 2008 Iwate-Miyagi inland earthquake aftershock zone (Suzuki & Toda, AGU fall meeting, 2013). Suzuki and Toda (2013) claim that the cause of seismic quiescence is Coulomb failure stress (CFF) decrease due to the 2011 event. However, a small quantity of focal mechanisms prevents them to confirm the mechanism.

In this study, we determine 4106 newly focal mechanisms in the area and develop a model to explain spatio-temporal seismic evolution. To estimate the focal mechanisms, we employ the method of Hardeback & Shearer (BSSA, 2002) using first motion of P-wave, provided by the campaign data by the Group for the Aftershock Observations of the 2008 Iwate-Miyagi inland Earthquake and Japan Nuclear Energy Safety Organization (JNES) in addition to the stationary data from Hi-net and F-net by NIED. Besides, we use F-net moment tensor solutions (VR?80%) and JMA focal mechanisms together with our estimates. Most of the focal mechanisms are strike-slip or thrust fault type and the distribution of ratio of strike-slip type to thrust type is spatially heterogeneous. We find several distinctive seismic clusters from all the distribution. Seismicity in two clusters in southern rupture zone of the 2008 event has been clearly decreased by the 2011 event. We calculate $\triangle$CFF on all nodal planes as a proxy for background faults using a Tohoku-oki coseismic slip model given by Iinuma et al. (JGR, 2012) in an elastic half-space of Okada (BSSA, 1992). Apparent friction coefficient, μ', is assumed to be 0.0, 0.4 or 0.8. In the case of μ' =0.0, 80% of $\triangle$CFF resolved on all nodal planes are negative and over 50% $\triangle$CFF are negative in the case of μ' =0.8. In the distinctive clusters mentioned above, ratios of the negative $\triangle$CFF far exceed above overall average.

Seismic response to $\triangle$CFF is formulated by Dieterich (JGR, 1994) based on the rate-and state-dependent friction law. The physics-based model can reproduce the empirical Omori's aftershock decay after a stress step controlled by several parameters. In this study, we estimate reference seismic rate from an average number of earthquakes from 2000 to the 2008 mainshock, $\triangle$CFF associated with the 2008 mainshock, stressing rate, product of constitutive parameter and normal stress on a fault plane (Aσ) estimated from the aftershocks occurred until the Tohoku-oki earthquake. Using these parameters, we calculate seismic time series from all the calculated $\triangle$CFF by the Tohoku-oki earthquake, and then compare the observation with the average of all time-series curves. As a result, the models increase seismicity rate at the Tohoku-oki earthquake, which is inconsistent with the observation. We seek that reasons for mismatch between our model and observation to (i) the paucity of aftershock hypocenter data because of detectability decrease immediately after the Tohoku-oki earthquake, (ii) change in stressing rate due to the post-seismic deformation of the Tohoku-oki earthquake, (iii) reduction of friction coefficient due to fluid injection and/or pore pressure change on fault planes.

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Keywords: induced earthquake, static Coulomb failure stress change, rate-and state-dependent friction law, seismic quiescence