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2011 年東北地方太平洋沖地震による地震の静的・動的トリガリング
Static and dynamic earthquake triggering associated with the 2011 Tohoku earthquake

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The 2011 Tohoku earthquake (M9.0) was followed by large aftershocks and seismicity activation at locations up to several hundred kilometers away from the mainshock. Our present study is divided into two parts. In the first part we analyze the effect of static stress changes due to the 2011 Tohoku event on the occurrence of relatively large aftershocks, using their CMT focal mechanism solutions. In the second part, we investigate the possible role of both dynamic and static stress transfer mechanisms on the occurrence of remote seismicity.

a) Static stress changes resolved on the nodal planes of large aftershocks.
We used the Tohoku slip distribution of Suzuki et al. (2011) and the CMT focal mechanism solutions of aftershocks determined by Asano et al. (2011). The aftershocks (M >= 3.8) are located in an area of slightly larger extent compared to the fault plane of the mainshock and the depth ranges between 0 and 60 km. We divide the focal mechanisms into two groups: consistent (i.e., thrust faulting) and non-consistent (mainly normal faulting) with the mainshock focal mechanism, based on the rotation angle defined by Kagan (1991). We resolve the Coulomb static stress changes on both aftershock nodal planes and select the nodal plane with the largest stress change as the likely fault plane. We show that 71% and 78% of earthquakes from the two groups, respectively, occur at locations of increased stress. To test the statistical significance of this result, we have selected 1800 F-net focal mechanisms for earthquakes occurred in the same region as the analyzed aftershocks, before the occurrence of the Tohoku earthquake (2003.01.01 - 2011.03.11). The percentage of earthquakes that occur at locations of increased stress is about 46%. Several other slip models for the Tohoku mainshock produce similar results. This indicates a high correlation between the occurrence of the aftershocks and the co-seismic static stress changes.

b) Triggering of remote seismic activity.
The 2011 Tohoku earthquake was followed by an unprecedented increase of seismicity at remote locations (i.e., at distances up to several hundred kilometers away from the mainshock). Examination of Hi-net waveform data and the JMA earthquake catalog reveals triggered local events in southern Kyushu, close to the Ibusuki volcanic field, at about 1000 km from the south-western edge of the Tohoku fault. The onset of increased seismic activity correlates very well with the arrival of the surface waves. We detect local, high-frequency tremor-like signal (i.e. not clearly defined P- and S-arrivals) correlated with the arrival of the mainshock surface waves at several Hi-net seismic stations in Shikoku region, at distances of about 700 km from the SW edge of the Tohoku fault. We also detect a rather clear correlation between the arrival of the surface waves and the seismicity increase close to Yakedake volcano, in Hida Mountains, at about 300 km from the fault edge. A cluster of seismicity close to the Hakone geothermal area and in the northwestern part of the Miyakejima volcano could be explained by both static (Coulomb stress changes of about 0.2-0.3 Bar) or dynamic stress changes. The 15th March 2011, M6.4 Shizuoka Prefecture earthquake occurred in an area of static stress change of about 0.4 Bar. In contrast, there was no clear activation of seismicity on the nearby Tokai subduction zone, where the static stress changes resolved on the plate interface show values of less than 0.1 Bar. The passage of surface waves from the Tohoku mainshock appears to be responsible for the activation of seismicity in some volcanic and geothermal areas, however it is more difficult to detect or confirm such a correlation at other locations.
Keywords: 2011 Tohoku earthquake, stress triggering, seismicity activation, aftershocks, focal mechanisms