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Triggered seismicity in Northern Nagano region at short times after the 2011 M9.0 Tohoku-Oki earthquake

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The changes in seismicity after the 2011 Tohoku-Oki earthquake can be explained in most cases by the Coulomb static stress transfer mechanism (Toda et al., 2011). However, one exception seems to be the seismicity activation in a few inland regions of northeast Japan. Given the compressional tectonic regime in northeast Japan, the seismicity in such areas, after the megathrust event, should have been inhibited rather than activated, if we assume the Coulomb failure criterion. Thus the static stress transfer from the Tohoku-Oki earthquake cannot explain this seismicity increase. It may be possible to relate such activation with dynamic stress changes caused by the passage of surface waves from the 2011 Tohoku-Oki earthquake.

In this study we investigated the possibility of dynamic earthquake triggering in the northern Nagano region, where the seismicity was clearly activated following the 2011 Tohoku-Oki earthquake. An Mw6.2 event occurred here after about 13 hours from the Tohoku-Oki earthquake. According to the Japan Meteorological Agency (JMA) earthquake catalog, there was no recorded earthquake in this region in the first 7 hours after the 2011 Tohoku-Oki event. However, in many cases after large events, the seismicity immediately after the mainshock is incompletely recorded in earthquake catalogs (Kagan, 2004). We used event-waveform data and continuous waveform data recorded at Hi-net stations in Nagano region and apply the Matched Filter Technique (Peng and Zhao, 2009) to detect as many earthquakes as possible in the first hour after the Tohoku-oki earthquake. As a result, we have detected new events (i.e. events that are not in the JMA earthquake catalog) occurring in the first hour after the Tohoku-Oki earthquake. Some of these events are located close to the hypocenter of the Mw6.2 Nagano earthquake (which occurred about 13 hours after Tohoku-Oki earthquake), some others locate to the south, in an area where an Mw5.4 earthquake occurred about one month later. The analysis of F-net Centroid Moment Tensor (CMT) focal mechanism solutions shows that the majority of earthquakes from 2001 until the occurrence of the Tohoku-Oki earthquake differ from those after the M9.0 event. In detail, the thrust fault events are predominant in the region before the Tohoku-oki earthquake, while the dominant mechanism becomes strike-slip after the M9.0 event. The Coulomb failure stress changes cannot explain the focal mechanism changes. Note that the ”anomalous” focal mechanisms in the triggered areas are consistent with a fluid-driven seismicity activation (Terakawa et al., 2012).

Based on the above results, we can speculate that the passage of surface waves from the Tohoku-oki earthquake caused enhanced fluid transport and pore pressure changes. These fluid-related changes may have modified the Coulomb failure function in such a way that the effective normal stress is decreased sufficiently to trigger failure (e.g., Cocco and Rice, 2002). We can further speculate that the seismicity occurred at early times after Tohoku-Oki earthquake in the Nagano region contributed through dynamic stress transfer to the occurrence of the nearby Mw6.2 Nagano earthquake.

Keywords: The 2011 M9.0 Tohoku-Oki earthquake, Northern Nagano seismicity, dynamic triggering, cross-correlation, focal mechanism data