Nucleation Process of the 2011 M_w 6.2 Northern Nagano earthquake

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Introduction. Previous research.
An M_w6.2 inland earthquake occurred in northern Nagano region, central Japan, about 13 hours after the M_w9.0 Tohoku-oki megathrust earthquake. The regional seismic activity recorded in the Japan Meteorological Agency (JMA) catalog in the first hours following the megathrust event was highly incomplete, thus not allowing a detailed analysis of triggering mechanisms. By applying a Matched Filter Technique (MFT) to the continuous Hi-net (NIED) waveform data, Shimojo et al. (2014) revealed an immediate post-Tohoku seismicity activation in an area located about 10 km south of the M_w6.2 Northern Nagano source region. They also detected a few foreshocks close to the hypocenter of the M_w6.2 mainshock, within one hour before the occurrence of the moderate-size event. However, the physical processes that led to the occurrence of the M_w6.2 earthquake remained unclear. In this study we take advantage of the data recorded by a dense temporary seismic network operated by NIED from 2008 to 2012 to reveal with an unprecedented resolution the nucleation process that culminated with the occurrence of the Northern Nagano earthquake.

Data and Method
We use the waveform data of the NIED “Hizumi” temporary network, with station spacing of about 5 km or less in the study area. The data recorded by the permanent Hi-net stations (spacing of about 20 km) complements that of the dense regional network. We have first picked P- and S-wave arrivals of earthquakes on the continuous seismograms and use the pick data to locate the events. The earthquakes were then relocated using the tomoDD software (Zhang and Thurber, 2003). The newly located earthquakes were further used as MFT templates to search for new events within the 13-hour time interval, in the hypocentral region of the M_w6.2 earthquake.

Results and Discussion
We have detected a total of 285 earthquakes in the source region of the M_w6.2 event. The earthquakes are relatively small, with magnitudes less than 2.5, and distribute within two spatially distinct clusters: one of these clusters was located close to the hypocenter of the M_w6.2 event (western cluster), the other about 5 km to the east (eastern cluster).
In the eastern cluster the seismicity starts within one hour after the Tohoku-oki earthquake. The events occur off the M_w6.2 fault and expand with time from shallow towards deep locations. In the western cluster the seismicity starts immediately after the passage of surface waves excited by a moderate earthquake in the Tohoku-oki aftershock area, which occurred 21 minutes after the M_w9.0 megathrust; most of these events distribute along the fault line of the Mw6.2 mainshock. Within the western seismicity area, a tight sub-cluster that occurred in the immediate vicinity (within about 2 km) of the M_w6.2 hypocenter was strongly activated thrice: about 9 hours before, 3 hours before and 50 minutes before the mainshock, respectively. In particular, about 9-hours before and 3-hours before the Nagano earthquake, micro-seismicity migrated towards its epicenter, and just about 1-hour before, micro-seismicity accelerated within about several hundred meters of the M_w 6.2 epicenter. Migration speeds indicate potential underlying slow-slip culminating with the occurrence of the large inland earthquake, but fluids might have also played a triggering role at a broader, regional scale.

In both western and eastern cluster some events occured immediately after the arrival of surface waves from some M_{JMA}≧5.5 Tohoku-oki aftershocks. We show that the local seismicity continued intermittently until the occurrence of the M6.2 event, being likely ‘modulated’ by the arrival of surface waves from larger teleseismic aftershocks off-shore Tohoku.

Keywords: Mw 6.2 Northern Nagano earthquake, nucleation process, Matched-Filter Technique, dynamic stress changes, fluid flow, aseismic slip

