The 2016 Northern Ibaraki Prefecture Earthquake (M_j 6.3) Rupturing the Fault of the Large Earthquakes in 2011 Again

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The 2011 Tohoku-oki earthquake (M_w 9.0; hereafter referred to as "mainshock") activated the seismicity in many areas not only in Japan but also all over the world. In particular, in the Fukushima Hamadori and the northern Ibaraki prefecture (hereafter, "N. Ibaraki") areas, northeast Japan, the rate of the seismicity with normal faulting mechanisms jumped to high, although the seismicity had been inactive before the mainshock. This is because the preexisting east-west extensional stress regime was significantly strengthened by the mainshock [*Imanishi et al.*, 2012]. In the N. Ibaraki area, a large earthquake with Japan Meteorological Agency magnitude (M_j) of 5.7 ("Event 2011a") occurred just 8 minutes after the onset of the mainshock. Another large earthquake (M_j 6.1; "Event 2011b") struck on March 19, 2011, 8 days after the mainshock. On April 11, 2011, an M_j 7.0 earthquake struck the Fukushima Hamadori area, on the north of the N. Ibaraki area. Afterward the seismicity has been attenuating with time.

On December 28, 2016, a large earthquake (M_j 6.3, "Event 2016") occurred in the N. Ibaraki area. The interferograms of the SAR data for Events 2011a and 2011b [*Kobayashi et al.*, 2011] and Event 2016 [*Geospatial Information Authority of Japan (GSI)*, 2017] are very similar to each other, implying the similarity in earthquake rupture processes.

We analyzed rupture processes of the Events 2011a, 2011b, and 2016 by finite-fault slip inversion analyses using strong-motion data from KiK-net, K-NET, and F-net. Our fault models indicate that the Events 2011a and 2016 ruptured the ground surface as reported by field observations [*Aoyagi et al.*, 2015; *Geological Survey of Japan*, 2017], whereas Event 2011b did not. Note that this does not contradict the SAR analysis [*Kobayashi et al.*, 2011] and the field observation [*Aoyagi et al.*, 2015], because they have no temporal resolution to distinguish the deformation occurred on March 11 (Event 2011a) and 19 (Event 2011b). Overall the rupture areas of two events in 2011 and the Event 2016 are overlapping and similar to each other.

Why could the large earthquakes occur on the same fault twice in such a short time, almost 6 years? Since the fault strength recovers quickly [e.g., *Dieterich*, 1972], a stress loading and/or a fault weakening are required. According to the strain change inferred from the GNSS data by GEONET of GSI, the east-west extensional plain strain on the ground surface was rapidly increased after the mainshock, however afterward the east-west compressional strain rate has been observed, which seems to contradict the occurrence of the normal faulting large earthquake. Detail will be studied by a seismicity analysis based on the ETAS model [*Uchide*, this meeting].

It is probable that the large earthquakes in the N. Ibaraki area occurred due to the coseismic and postseismic deformation of the Tohoku-oki mainshock. Since the postseismic deformation generally attenuate with time, the seismic activity will also be decay. A quantitative assessment will require numerical simulations with a precise rheology model as well as seismic and geodetic observation to monitor the seismicity and crustal deformation.

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