Source processes of the M 6 class earthquakes which occurred in northern Ibaraki Prefecture on 2011 and 2016

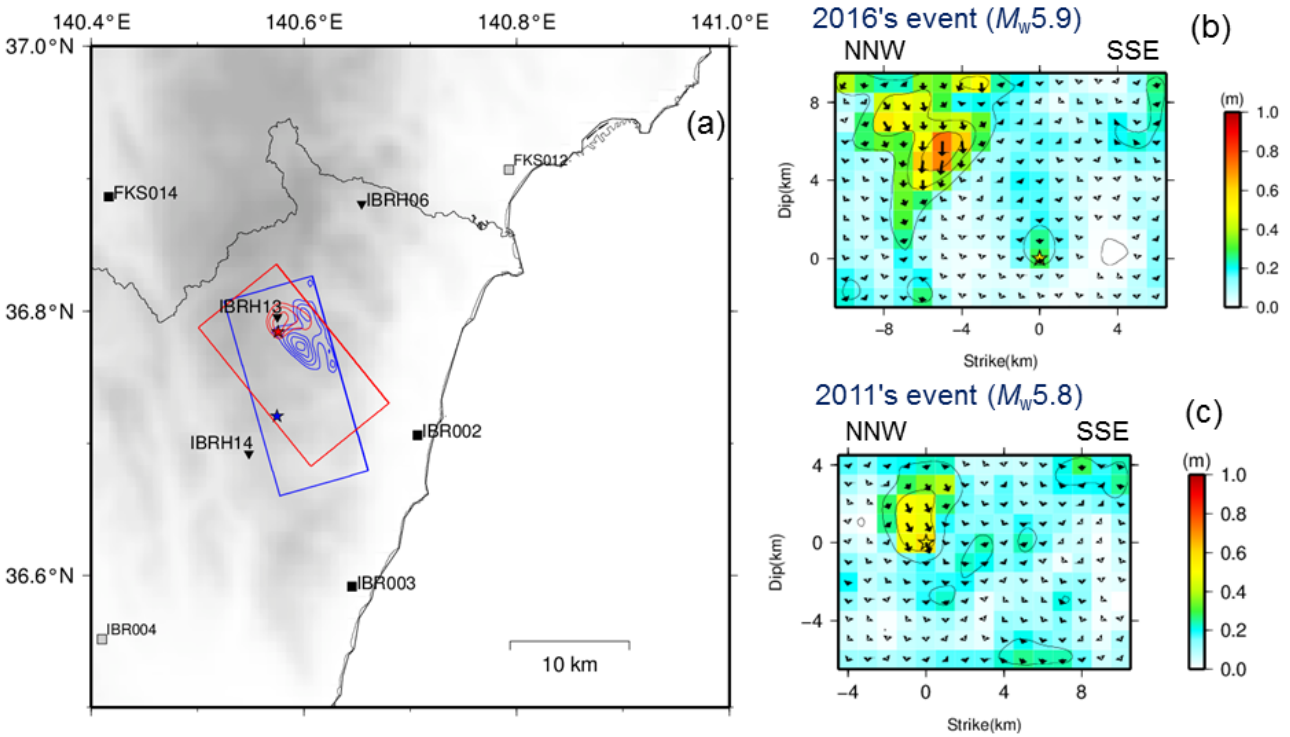
*Kazuhito Hikima[1]

1. Tokyo Electric Power Company Holdings, Inc.

<INTRODUCTION>
An M 6.3 earthquake occurred at 21:38 on December 28, 2016 in northern Ibaraki Prefecture. Since just after the 2011 off the Pacific coast of Tohoku Earthquake(M9.0), a significant increase in the shallow normal fault type seismicity, which had been extremely rare before the 2011 Tohoku earthquake, has been observed. Furthermore, the M 6.1 earthquake had occurred on March 19, 2011, within the area. According to the analyses of InSAR data, the crustal deformations of the 2016 and the 2011 earthquakes are observed in almost same area (GSI, 2017), so, it suggests that comparable size earthquakes have repeated in the interval of only about 5.7 years.
In addition, strong ground motions, those peak accelerations are about 1G, have been recorded during both earthquakes at the KiK-net station (IBRH13, Takahagi), therefore, those records are important to consider the ground motion level at the near faults. To consider these issues, the source process inversion analyses for the 2016 and the 2011 earthquakes are performed in this study.
<OUTLINE of ANALYSES>
The 16 stations of the K-NET and KiK-net (NIED) were used in these inversion analyses. Basically, identical stations were selected for the 2016 and the 2011 earthquakes. The acceleration waveforms were filtered between 0.03 and 0.8 Hz, and were integrated to velocity waveforms for the inversion analyses.
The source processes were inverted by the multi time window analysis (Yoshida et al., 1996, Hikima, 2012). The Green’ s functions were calculated using 1-D velocity models, which were tuned by the waveform inversion method using the records of a small event (Hikima and Koketsu, 2005).
The fault planes for the initial models were configured by referring to the F-net mechanism solutions and distribution of the aftershocks, those were relocated using DD method (Waldhauser and Ellsworth, 2000). The parameters of the final models were determined by considering the degree of fitness between the observed and synthetic waveforms. The size of subfaults for the inversion analyses were set in 1 km.
<RESULT: 2016's earthquake>
The fault parameters are given as follows: the strike and the dip are 164 and 50 degree, and the length and width are 17 and 12 km, respectively. The focal depth is 10.3 km. The inversion result shows that the seismic moment is 9.7e17 Nm (Mw 5.9), and the maximum slip is about 0.7 m and the dominant focal mechanism is the normal fault type. The rupture propagated toward the northern shallow part mainly, and a large slip area (asperity) exists at 6 - 7 km apart from the hypocenter.
<RESULT: 2011's earthquake>
The fault parameters are set as follows: the strike and the dip are 141 and 40 degree, and the length and width are 15 and 11 km, respectively. The depth of hypocenter is 5.9 km. Dominant focal mechanism is normal fault type, and the estimated seismic moment is 7.0e17 Nm (Mw 5.8). The maximum slip is about 0.6 m and it is located near the hypocenter. The asperity covers the hypocenter and its slightly northern part. The amount of final slip on southern part of the fault plane is small.
<DISCUSSION>
The epicenter of the 2016's event is located at about 7 km south of the 2011's event. Though, it was revealed that the rupture of the 2016's event propagated toward the north and its asperity stands fairly near an asperity of the 2011's event. However, the strike and the dip of these events are different and it means that the fault planes of the events are not identical. Furthermore, the estimated slip distributions

show that the asperities of two events scarcely overlap each other. According to these results, it is deduced that the dominant slip areas of the 2016's and the 2011's events are different.
The KiK-net station (IBRH13), at which high accelerations were observed, is located adjacent to the asperities of these events. Especially, the asperity of 2011's event was recovered just below the IBRH13. The PGA of the 2011's and 2016's events was 1084 gal and 887 gal, respectively (3 components synthesized, from NIED's HP). This higher PGA of the 2011's event, although the magnitude is smaller than the 2016's event, is thought to be due to its closer distance from the asperity.

Keywords: Source process, Crustal earthquake, Strong motion, Repeating earthquake, Northern Ibaraki Prefecture earthquake



(a): Surface projection of the final slip distribution of 2016's and 2011's events. Blue denotes the 2016's event and red denotes the 2011's event. Squares and stars indicate set fault planes and epicenters, respectively. Contour shows slip area larger than 0.3 m, with interval of 0.1 m. Black marks denote KiK-net and K-NET stations.
(b), (c): Final slip distributions on fault planes of 2016's and 2011's events. The yellow stars mean hypocenters.

