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# Episodic slow slip after the 2011 Tohoku-oki earthquake: estimation from repeating earthquakes, very low frequency earthquakes, and seafloor geodetic measurements

Naoki Uchida (1), Chie Honsho (1), Fumiaki Tomita (2), Takanori Matsuzawa (3), and Roland Bürgmann (4)

(1) Graduate School of Science, Tohoku University, Sendai, Japan, (2) Faculty of Science, Hokkaido University, Sapporo, Japan, (3) National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, (4) Berkeley Seismological Laboratory and Department of Earth and Planetary Science, Berkeley, USA

Along the Japan trench, quasi-periodic slow slip was found from repeating earthquakes (repeaters) and on-land GPS data before the 2011 Tohoku-oki earthquake. After the earthquake, the occurrence of Very Low Frequency Earthquakes (VLFEs) was recognized and new GPS-Acoustic (GPS-A) stations were deployed along the shallow plate boundary. In this study, we examine the postseismic activity of the slow slip from repeater, GPS-A and VLFE data. The repeaters are selected form their inter-event waveform similarity and the VLFEs are selected by waveform similarity with template matching at low-frequency range (0.02 – 0.1 Hz). Both data analysis periods were extended from previous studies to until the end of 2016. The GPS-A data from 2012 to 2016 was also re-analyzed to obtain better positions by incorporating the effect of horizontal variations in the sound speed of the ocean. The repeater analysis shows that the plate-boundary slip rate in the area close to the trench off Sanriku (to the north of the coseismic slip area) has large temporal variations with overall decay after the Tohoku-oki earthquake. On the other hand, the slip rate decreased monotonically with time in the area close to the trench off Fukushima (to the south of the coseismic slip area). In the off-Sanriku area, a slip-rate peak in 2015 correlated well with an active period of the VLFEs and a period of trenchward movement of the GPS-A stations. These observations suggest the occurrence of episodic slow slip caused the surface trenchward movement and repeater and VLFE activities. The amount of the inferred fault slip from the repeater activity was $\sim$27 cm for the 2015 event, consistent with the seafloor GPS-A station movements (7$\sim$16 cm). The largest 5 earthquakes in the region during the 2015 episode were M5.5 to 6.9, but the total surface deformation expected from these earthquakes is too small ($\sim$2 cm) to explain the GPS-A station movements. This suggests the event was mostly aseismic. We also found the distribution of the VLFEs and repeaters are spatially complementary, suggesting that variations in local fault material properties near the plate boundary control the differences in slip mode.