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Slow slip event within a gap between tremor and locked zones in midwestern Shikoku

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Episodic tremor and slip (ETS), a slow slip phenomenon on the plate interface, occurs at downdip region of seismically locked zone in the Nankai subduction zone. The locked zone has potential to be ruptured by great earthquakes. However, there is a gap between ETS and the locked zones. In the present study, we detected a slow slip event (SSE) within the gap from GNSS data by subtracting steady state component and postseismic effect of large earthquakes.

We analyzed GNSS daily coordinates at GEONET stations in southwest Japan provided by GSI. After removing offsets due to large earthquakes and equipment repairs, we applied the spatial filtering proposed by Nishimura et al. (2013) to reduce spatially coherent noise. Then, we estimated trend and seasonal components from the displacement time series during two years from 2007 to 2008, and subtracted those from entire time series. The displacement field after 2011 contains short wavelength variation at midwestern Shikoku in addition to long wavelength variation due to the postseismic effect of the 2011 Tohoku-Oki earthquake. Thus, we estimated the long wavelength variation from the displacement data without midwestern Shikoku by assuming the long wavelength variation as a bivariate quadratic function of horizontal space. Finally, subtracting the estimated long wavelength variation from displacement filed, we extracted the short wavelength variation.

The short wavelength variation in midwestern Shikoku shows displacements toward southeast and it may be attributed to a thrust fault slip in the plate convergence direction. Modeling with a rectangle fault using the equation by Okada (1992) reveals that a dip slip of 2 cm/year within the gap between ETS and the locked zones well explains the observed displacements. The dip slip event lasts at least 1.5 years. The rectangle faults estimated from annual displacements for the periods starting from Apr. 2011, Oct. 2011, Apr. 2012, and Oct. 2012, are located between mid Shikoku and the Bungo channel with dimensions of 150-180 km length and 20-40 km width. The strikes of the faults are almost parallel to isodepth contours of the subducting plate. A similar SSE is detected in 2004 and 2005, which was partly reported by Kobayashi (2010), while the fault length of the 2004-2005 event is shorter than that of the 2011-2012 event. These SSEs within the gap follow the 2003 and 2010 long-term SSEs in the Bungo channel and are located just east of the long-term SSEs. Therefore, after the long-term SSEs in the Bungo channel, the slip may migrate east and small slip last within the gap between ETS and the locked zones.

Tremor in western Shikoku occurs at intervals of about a half years, and migrates along the strike direction with durations of a few days to a week. After 2011, the migration pattern has been changed. Some episodes show migrations with length longer than 120 km, while such long migration has not been observed before 2011. Since the long-term SSE detected by the present study is located shallow part of the tremor episodes with the long migration, it is suggested that the shallower long-term SSE facilitates the migration of the deeper short-term SSEs.

In Cascadia subduction zone, there is also a gap between ETS and locked zones. Understanding slip behavior in the gap zone is of importance for estimating downdip limit of grate earthquake rapture (Hyndman, 2013) and understanding stress accumulation for great earthquake (Wech and Creager, 2011; Yokota and Koketsu, 2015). In the present study, we detected the long-term SSE within the gap from GNSS data by removing trend components and postseismic effects of large earthquakes. We suggest that, between ETS and the locked zones, the long-term SSE slowly releases accumulated strain due to plate convergence.

Keywords: slow slip event, slow earthquake, GNSS, non-volcanic tremor, subduction zone