Variability of the space-time evolution of slow slip events off the Boso Peninsula, central Japan, from 1996 to 2018

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Continuous geodetic measurements over the past two decades have identified numerous recurrent slow slip events (SSEs) in subduction zones and other tectonic settings. Many previous studies revealed static source characteristics of SSEs, including the magnitudes, durations, recurrence intervals, and spatial slip distributions. However, our current knowledge of the time-dependent evolution of SSEs and their variability is much more limited.

In this study, we focus on a series of SSEs that occurred off the Boso Peninsula, central Japan. Since the installation of a dense GNSS network in Japan in the early 1990s, six Mw 6.6-6.7 SSEs, accompanied by swarms of regular earthquakes, have been identified on the subducting Philippine Sea Plate interface offshore of the Boso Peninsula in 1996, 2002, 2007, 2011, 2013-2014, and 2018. We invert GNSS time series to estimate the space-time evolution of the six SSEs using a modified version of the Network Inversion Filter (NIF) [Fukuda et al., 2008]. Our analyses reveal the similarities and differences in the time-dependent evolution of the six SSEs. We find that the nucleation style and space-time evolution of slip vary among the SSEs. The 2002, 2007, and 2011 SSEs nucleated more rapidly, with slip accelerations significantly higher than those of the 1996 and 2013-2014 SSEs. Furthermore, the 2002, 2007, and 2011 SSEs exhibited more rapid temporal variations in their slip and slip rates, and showed larger seismic moments and higher maximum slip rates than the 1996 and 2013-2014 SSEs. The along-strike expansion/propagation of slip is identified for the SSEs, revealing that the expansion/propagation patterns vary from event to event. Our results also show that the swarm seismicity accompanying the SSEs is highly correlated in space and time with slip rate, and seismicity only occurred after the slip rate exceeded ~4 m/yr, suggesting that the evolution of seismicity is controlled by the instantaneous stressing rate determined by slip rate.

Finally, we show that the space-time evolution of slow slip obtained here can potentially be used to study mechanisms governing the SSEs. We model the spatiotemporal evolution of shear stress on the plate interface due to slow slip obtained in the NIF analysis using the rate-and-state friction law. The rate-and-state friction parameters and initial state variable are adjusted to reproduce the stress histories. Results show that the rate-and-state friction law well reproduces the spatiotemporal evolution of stress on the plate interface during the SSEs. The critical fault size calculated from the estimated friction parameters is similar to the size of the SSE region, suggesting that the evolution of slow slip is governed by frictional properties near the stability boundary between stable and unstable slip.

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