What controls along-strike variations in Long term SSE recurrence intervals in the Western Nankaui Subduction Zone?

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There have been observed a variety of slow earthquakes. Recent simulation studies based on rate and state friction (RSF) laws have showed that these activities can be changed before occurrence of megaquakes (e.g., Matsuzawa et al., 2010). In this respect, it is important to understand frictional properties controlling slip evolution of these slow earthquakes in relation to megaquake forecasting. Here we focus on Long-term Slow Slip Events (L-SSEs) among these slow earthquakes. SSE simulations have so far been executed by trial-and-error assignments of RSF parameters. In these situations, Hirahara and Nishikiori (2019) executed numerical twin experiments of a simple Bungo channel L-SSE patch with Ensemble Kalman Filter (EnKF) to show a potential of determining frictional parameters from synthetic GNSS data. Further, Fujita (2020) showed a capability of short-term forecasting L-SSE activity using the slip rate data on the SSE fault inverted from actual GNSS data. However, it was also found that we need quite good pairs of initial parameters to obtain converged parameters even with EnKF.

Recent study revealed along-strike variations of recurrence interval (Tr) of L-SSE in the Western Nankai Subduction Zone; in the Southern Hyuga-nada, 2-3 years, the Bungo channel, 3 years, and the Northern Hyuga-nada and Western Shikoku, 5-6 years. Takagi et al. (2019) proposed that the up-dip locked region controls these variations. That is, at the down-dip of the locked region, Tr of L-SSE tends to be longer because of the low accumulation of the stress. To confirm this idea, we make a numerical model with the actual 3-D geometry of PHS slab to simulate such L-SSE behaviors. In our model, we set kinematically slip deficiency rate in the locked zone, and RSF parameters in the depth-dependent SSE zone and creep zone where slip evolution is quasi-dynamically simulated. We found that along-strike Tr variations cannot be fully explained only by the along-strike difference of slip deficiency rate. Thus, we need to consider another model.

In our RSF model without cut-off velocities, slip instability of a L-SSE zone with velocity weakening frictional property is basically controlled by the ratio of the width of the L-SSE zone and the critical nucleation size (W/h*) (e.g., Liu and Rice, 2007). Other parameters, however, possibly control SSE slip behaviors (e.g., Ampuero, 2019). Therefore, it is necessary to understand which parameters control the observed along-strike Tr variations and the physical meanings. First, we make a simple dipping plain model composing three zones of locked, SSE and creep in the down-dip direction, each of which has uniform parameters. Then, we execute experiments by changing parameters to examine produced Tr, maximum SSE velocity (Vmx) and duration (Td). These simulations showed that almost all parameters, such as frictional parameters, effective normal stress, width of the L-SSE zone, and slip deficiency of the locked region, make effects on Tr by roughly the same weight. Especially, we note that simulations with a constant W/h* produce considerable different slip behaviors. Second, we construct a plane model including several SSE zones with different parameters to reveal the along-strike interactions. We found that the heterogeneous distribution of parameters, such as width of the SSE zone and effective normal stress, can produce along-strike variations of Tr, Vmx and Td. It was also recognized that the boundary conditions assigned in the both sides of SSE zones affect slip behaviors such as along-strike slip propagations.

Keywords: SSE, Rate and State Friction Law, Recurrence interval, Nankai Subduction Zone

