Numerical simulation of slow slip events, considering the effect of earth tide

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Several studies reported that occurrence of slow slip events (SSEs) in the Nankai region is affected by earth tide (e.g., Nakata et al., 2008; Tanaka and Ide, 2014). The effect on the SSEs is also examined by numerical studies (e.g., Hawthorne and Rubin, 2013). We have studied the behavior of SSEs during seismic cycles in numerical simulations (e.g., Matsuzawa et al., 2010), and suggested that recurrence intervals may decrease at the later stage in a seismic cycle. In this study, we examined the behavior of SSEs during seismic cycles, considering the effect of earth tide.

Our numerical model is similar to our previous study with a flat plate interface (i.e., Matsuzawa et al., 2010). A plate interface is expressed by 40,000 small rectangular elements. A rate- and state-dependent friction law with a cutoff velocity is adopted as the friction law on each element. In the region deeper than short-term SSEs, low cutoff velocity ($10^{-6.5}$ m/s) and low effective normal stress are assumed. In the following section, we show an example in the case of sinusoidal stress perturbation at the period of M2 tide (i.e. 12.42 hours) with 2 kPa peak-to-peak amplitude, which has the phase that maximum shear stress coincides with minimum normal stress.

In the numerical result, introduction of earth tide slightly decreases recurrence interval of megathrust earthquakes, for example, from 106.5 years to 106.2 years between first and second large earthquakes, and from 106.5 years to 105.9 years between second and third large earthquakes. This suggests that the earth tide can also affect the recurrence intervals of large earthquakes.

In terms of short-term SSEs, the recurrence intervals decrease during a seismic cycle both in the cases with and without tidal effect. The difference between these two cases is not clear. We note that SSEs are detected on each rectangular element, if displacement exceeds 5 mm during episodic slip with more than twice of subduction velocity. In terms of the relationships between the occurrence of SSEs and phase of tides, the distribution of occurrence times of SSEs shows a peak around the phase with maximum shear stress and minimum normal stress. The SSEs, which occur between -30 and 30 degrees from this phase, are 22.7%, 22.7%, and 22.2% of the total number of SSEs, during the period of 5-35 years, 35-65 years, and 65-95 years after large earthquakes, respectively. These values are higher than the identical ratio of 16.7% with no relevance. Our numerical simulation also suggests that the stress perturbation by earth tide can affect the occurrence of SSEs, although the change during seismic cycle is not clear in this case.

Keywords: Slow slip event, Numerical simulation, Earth tide

