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Numerical model of slow slip events in the Nankai trough -Reproduction of observations and expectations from the model-

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Slow slip events (SSEs), low-frequency tremors, and very low frequency earthquakes have been found in several subduction zones. These events are interpreted as a slip on the plate interface based on geodetic observations of SSEs and the focal mechanisms (e.g. Hirose and Obara, 2005; Ide et al., 2007; Ito et al., 2007, 2009). As recent studies have reported the detailed characteristics of these slow earthquakes (e.g., Obara, 2010; Ide, 2010; Hirose et al., 2010), a numerical model is necessary to interpret those observations and understand the stress state at the deeper extent of the major slip region of megathrust earthquakes. We have developed a numerical model of SSEs and reproduced the behavior of SSEs observed in the Nankai subduction zones.

SSEs occur at the transitional area of frictional property from stick-slip behavior to ductile deformation. To model such frictional behavior, we adopted a rate- and state-dependent friction law with cut-off velocities, which approximates the experimental result (Shimamoto, 1987). In addition, as high Vp/Vs around SSE region suggests the existence of water (e.g., Shelly et al., 2006; Matsubara et al., 2009), we assumed high pore pressure in the SSE region. We modeled a plate interface within a semi-infinite elastic medium, and calculated the temporal evolution of slip, assuming the above frictional properties and loading velocity on the interface.

At first, we simulated a simple case of a flat plate interface (Matsuzawa et al., 2010). In this model, long- and short-term SSEs were successfully reproduced in each model with different pore pressure distribution. Changing pore pressure distribution along the strike direction, both of long- and short-term SSEs were also simulated in the same model. In our result, the recurrence interval of SSEs shortened during an inter-seismic period. The shortening of the recurrence interval of SSEs was also found with the increase of the slip velocity between the SSE region and the locked region of megathrust earthquakes. These suggest that the recurrence behavior of SSEs may be affected by the stress accumulation process of megathrust earthquakes.

To reproduce the observed segments of tremor and SSEs, we constructed more realistic model introducing the shape of the subducting plate and the actual distribution of tremor in the Nankai trough. We assumed transitional friction around the tremor region, and stable sliding behavior outside of the region. This numerical model successfully reproduced the characteristics of the segments and recurrence intervals of SSEs. For example, in the model of the Kii and Tokai region, the reproduced interval in the southern Kii region was shorter than those in the northern Kii and Tokai region, as in observations (e.g., Obara, 2010).

In our result, the segmentation of the SSE regions is reproduced with the actual shape of the plate interface and tremor distributions. As suggested in Shibazaki et al. (2010), this segmentation is characterized by the width of SSE region in the dip direction. Shortening of the recurrence intervals during an inter-seismic period may reflect the stress accumulation process of megathrust earthquakes, as discussed in Matsuzawa et al. (2010). In the early stage of a seismic cycle, recurrence intervals of SSEs are relatively long as the locked region is close to the SSEs. In the later stage, recurrence intervals of SSEs shorten reflecting accelerated slip velocity at the bottom of the locked region. In the model considering the actual shape of plate interface and tremor distribution, however, this shortening behavior is less clear, although the tendency still remains.

Numerical studies to reveal the relationship between SSEs and megathrust earthquakes may be in the developing stage, as new findings are reported constantly. Reproduction of such observations and examining the expectations from the numerical model may lead to the further understanding of the subduction process and megathrust earthquakes.

Keywords: slow slip event, numerical simulation, seismic cycle, Shikoku