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Numerical models of slow slip events in Shikoku based on observed distribution of tremor and plate configuration

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Recent studies revealed that slow slip events (SSEs), low-frequency tremors, and very low frequency earthquakes occur in several subduction zones. In the subduction zone of the Nankai trough from Shikoku to Kyushu, shallow very low frequency earthquakes are found along trench axis, and episodic low-frequency tremor and short-term SSEs (ETSs) are found at the deeper extent of the locked region of megathrust earthquakes. In addition, long-term SSEs repeatedly occur in the Bungo channel, and locate at the shallower extent of the ETS region. We successfully reproduced recurrence of short- and long-term SSEs in the flat plate model (Matsuzawa et al., 2010, JGR). Recently, we also reproduced recurrence and segments of short-term SSEs in the Kii-Tokai region, incorporating the actual distribution of tremor and the shape of the subducting Philippine Sea plate. In this study, we aim to reproduce the recurrence of short- and long-term SSEs in the Shikoku region, incorporating the actual distribution of tremor and the shape of the plate.

The ETSs occur at the transitional zone of friction from brittle behavior of megathrust earthquakes to ductile deformation of stably subducting plate. To model such transitional frictional property, we adopted a rate- and state-dependent friction law with cut-off velocities based on the experiment of halite (Shimamoto, 1987), as in Shibazaki and Shimamoto (2007). In the ETS and long-term SSE region, high Vp/Vs is reported (Shelly et al., 2006; Matsubara et al., 2009), which implies high pore pressure. Therefore, we assumed low effective normal stress in those regions. We modeled the shape of the subducting Philippine Sea plate based on Shiomi et al. (2008) and Baba et al. (2006). In our numerical simulation, the plate interface is modeled by ˜65,000 triangular meshes within a semi-infinite elastic medium. In our model, we defined ETS regions with transitional frictional property, based on the actual distribution of tremor (Obara et al., 2010). Outside of the ETS regions below the locked region, velocity-strengthening friction is assumed. A long-term SSE region is introduced in the Bungo channel as a low effective normal stress region, as modeled in Matsuzawa et al. (2010). Assuming the above frictional parameters and the shape of the subducting plate, we calculated the temporal evolution of slip on the plate interface.

In our numerical result, recurrences of short- and long-term SSEs are reproduced. The typical scale of activities is larger in western Shikoku than that in eastern Shikoku, as observed in tremor. Our numerical simulation also reproduced the observed characteristics that the major tremor activity usually starts from the deeper part of ETS region (Obara et al., 2011). However, there exist differences between observation and our simulated results. For example, transient slow events are found between the ETS region and the locked region of megathrust earthquakes in central Shikoku, though no transient event has reported at that region. Comparison of such differences may lead us to a more realistic numerical model, and may be a key to further understanding of subduction processes.

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