

Numerical modeling of concurrent occurrence of shallow very low frequency earthquakes and long-term slow slip events

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Concurrent occurrences of shallow very low frequency earthquakes (VLFs) and long-term slow slip events (SSEs) are found in the Bungo channel (Hirose et al., 2010, Science). This region is located at the western rim of the area where a large slip of megathrust earthquake is expected. Thus, the understanding of such behaviors will help us to reveal the preparation process of megathrust earthquakes. We aim to numerically reproduce the concurrent slip at the shallow VLFE and the long-term SSE region.

In our numerical model, a subducting plate interface is modeled as a flat plane within a semi-finite elastic medium. Frictional stress on the plate interface is given by a rate- and state-dependent friction law with cut off velocities (e.g., Matsuzawa et al., 2010, JGR). To reproduce long-term SSEs, a region with a cutoff velocity of $10^{-6.5}$ m/s and low effective normal stress is assumed below the depth of 10 km. In terms of shallow VLFs, result of rock experiments shows that velocity-weakening and strengthening behaviors are found at low and high slip velocity, respectively (Saito, et al., 2013, GRL). In addition, it is estimated that a radius of shallow VLFs is 5-10km from seismic data analysis (Ito and Obara, 2006, GRL). Based on these results, we assume circular regions for VLFs with a cutoff velocity of 10^{-4} m/s and a radius of 6 km. In addition, we pose a stable sliding region beside the long-term SSE region, as more stable sliding behavior is expected in the Hyuganada region where shallow VLFs frequently occur even in the period without long-term SSEs. In this study, some cases are calculated to examine the effect of the distribution of frictional parameters. Model 1 is a model based on the above assumptions. Model 2 is a model without a stable sliding region beside the long-term SSE region. In Model 3, the top of the long-term SSE region is set to the depth of 18 km.

In the numerical results of these three models, recurring slip at shallow VLFE and long-term SSE regions are reproduced. Concurrent occurrence of shallow VLFs and long-term SSEs are reproduced in Model 1 and 2, while the concurrent occurrence is not clear in Model 3. In addition, slip events at the VLFE region are also found during the period without long-term SSEs in Model 2, while most of slip events at the VLFE region are found with long-term SSEs in Model 1. Our results suggest that the top of the long-term SSE region are close to the VLFE region, and the model with stable sliding region beside the long-term SSE region (Model 1) is more preferable to reproduce observed results than the model with fully locked surrounding region (Model 2).

Keywords: very low frequency earthquake, slow slip event, numerical simulation, Bungo Channel