A numerical simulation of long- and short-term slow slip events on the subducting plate in Southwest Japan

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Recent studies revealed the existence of various 'slow' earthquakes on a subducting plate interface. In these 'slow' earthquakes, slow slip events (SSEs) are detected and analyzed using GPS or tiltmeters, and have the largest seismic moment. SSEs in western Shikoku and Tokai regions have two typical recurrence intervals, and are called as long-term slow slip events (L-SSEs) and short-term slow slip events (S-SSEs) by their intervals. L-SSEs have several years of a recurrence interval and several months of source duration. On the other hand, S-SSEs have 6 months of a recurrence interval and several days of source duration. Hirose and Obara (2005) analyzed SSEs in the western Shikoku region, and revealed that the slip areas of SSEs are distributed as patches along the subducting plate. They also found that the recurrence interval of S-SSEs became shorter than the regular interval during the L-SSE. This suggests that the SSEs interact with each other. A physical mechanism of such slow slips with different characteristic intervals is still not clear. Understanding of this mechanism is important to discuss the stress build-up process during the inter-seismic period of large earthquakes along the Nankai Trough subduction zone.

We numerically simulated the SSEs with two different characteristic recurrence intervals on 1- and 2-D flat fault planes in a semi-infinite elastic medium. As Shibazaki and Shimamoto (2007) adopted, we used a rate- and state-dependent friction law with a cut-off velocity to an evolution effect, and assumed the pore pressure rise between 26 km and 40 km in depth (i.e. effective normal stress (S_e) decreases at 26-40 km due to the high pore pressure). Though Shibazaki and Shimamoto (2007) assumed that the effective normal stress and critical slip length (d_c) are almost homogeneous in this region, we pose another region immediately below the 26 km of depth, where S_e and d_c are larger than these of the deeper part (40 km) but much smaller than the shallower part (20 km). Hereafter, we call this shallower transient region as L-SSE region, and deeper one as S-SSE region, because SSEs in the L-SSE region have a longer recurrence interval than the SSEs in the S-SSE region.

In a 1-D fault model, we assumed that the slip behavior is homogeneous along the strike of a subducting plate, and calculated the time evolution of slip behaviors. For example, recurrence intervals of L-SSE and S-SSE become 6 years and 6 month, when S_e and d_c are 3.2 MPa and 2mm in the L-SSE region (26-30 km) respectively, and S_e and d_c are 0.32 MPa and 0.2 mm in the S-SSE region (deeper than 32 km) respectively. A recurrence interval of S-SSE becomes shorter than the regular interval when L-SSE occurs. This is similar to the SSE activities observed in the western Shikoku region. We note that the widths of the L-SSE and S-SSE regions are also important parameters to the recurrence interval. Actually when the L-SSE region is extended to 32 km of depth, the interval of S-SSE decreases to 3 months.

In the case of a 2-D fault model, we pose a patch-like L-SSE region at the center of the calculating area, and assume that there is no transient rise of S_e and d_c (i.e. L-SSE region) in the other area. As well as the 1-D model, SSEs with two characteristic intervals are reproduced in the 2-D model. Our study suggests that the anomalies in d_c and S_e along a subducting plate can also control the recurrence intervals and the size of patches of SSEs. This also implies that the dehydration and diffusion of water around the plate boundary may be essential mechanisms to govern the behavior of SSEs, because S_e is controlled by pore pressure and d_c seems to be affected by S_e and hydrologic conditions.

References:

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