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Rate and state simulation of Yaeyama slow slip events in the southwestern part of the Ryukyu Arc, Japan

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Slow slip events (SSEs) are recurring on the plate interface beneath the source regions of the interplate large earthquakes. It has been proposed that the activity of SSE possibly changes before the occurrence of large interplate earthquakes. Hence, it is essential to know the frictional properties for producing SSEs to predict the occurrence of large earthquakes. Our final goal is to optimize frictional parameters on the fault related to SSE through a data assimilation method which combines the observational data and the forecast ones derived from a simulation model, and then to give information on the occurrence of large interplate earthquakes. In this paper, as a first step of such a data assimilation, we construct a simulation model reproducing the observed spatio-temporal slip evolution of SSE.

In this paper, we consider the Yaeyama SSEs. Around the Yaeyama islands in the southwestern part of the Ryukyu Arc, Japan, GPS observations have caught the frequent recurrence of SSE activity. Around there have occurred almost no large earthquakes that affect the SSE activities during the observational period, which leads to a relatively simple simulation model of SSE. Those are the reasons that we select SSE on this area.

Heki and Kataoka(2008) reported the following features of Yaeyama SSEs; 1) SSEs recur on a plate interface at depths of 20-40km, 2) the average recurrence interval is 6.3 months, 3) its standard deviation is 1.2 months, 4) the slip rate released by SSEs is 11.0 cm/yr, in spite of the estimated convergence rate of 12.5 cm/yr.

We construct a simulation model which reproduces the above mentioned features of SSE. We set a dipping fault embedded in a homogeneous elastic half space. The friction on the fault is assumed to obey a rate-and state-dependent friction law, and the slowness law of state evolution (Dietrich, 1979). To simulate SSE, following Kato(2003), we set an asperity at depths of 20-40 km on a stable sliding plate interface, whose frictional properties are characterized by frictional parameters A, B and L. The asperity has the rate weakening frictional property of $A-B<0$ and its radius is nearly equal to or less than the nucleation radius determined by frictional parameters. We also consider the possible presence of a locked zone, namely an asperity, at the shallow portion of the plate boundary close to the Ryukyu Trench, which might cause the 1771 Meiwa tsunami (Nakamura, 2009). Dating of tsunami stones suggests a possible recurrence of 150-400 years of large tsunami (Araoka et al., 2013), and the large tsunami events close to the Ryukyu Trench might have recurred in several hundred years.

It is found that the interval of SSE can be adjustable by changing the friction parameters. For example, if a single asperity with the size of 80 km has frictional parameters of A=50 kPa, B=56kPa, and L=2.2 mm, the interval is about 6 months. Further, if we add another asperity with 40 % slip deficit rate of the convergent rate of 12.5 cm/yr just above the SSE asperity zone, the slip rate released by SSEs reduces to the observed rate of 11.0 cm/yr. The released slip rate depends on the location, size and assigned slip deficit rate of the shallow asperity. The locking state at the shallow portion is important to give information on the occurrence of possible tsunami earthquake, and we need the further investigation. For reproducing the observed fluctuation of recurrence intervals of SSE, we need to consider the interaction among multiple asperities or the hierarchical asperity model where a large asperity has small asperities with different properties inside itself.

Keywords: slow slip events, Yaeyama, a rate- and state-dependent friction law