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The properties and variations of repeating slow slip events near Hateruma Island, southwestern Japan

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Slow slip events (SSEs) are a kind of transient motion related to slow fault rupture at the plate interface (Heki and Kataoka, 2008). These events are classified into slow earthquake series due to their long periods than regular earthquakes. SSEs are usually detected on intensely coupled plate boundaries such as Cascadia subduction zone (Dragert et al., 2001), Alaska (Ohta et al., 2007) and central Japan (Ozawa et al., 2002, 2003). For this reason, SSEs are considered to relate to large thrust earthquakes and can be evidence for seismic coupling on subduction zones. However, in the southwestern Ryukyu trench where most researchers believe that it should be a creeping and aseismic plate boundary. Nevertheless, Heki and Kataoka (2008) identified more than 20 SSEs near Hateruma Island using ten-yrs GNSS (Global Navigation Satellite Systems) data and found that repeated intervals are approximately 6 months regularly. Moreover, the events occurred at a fault patch that is as deep as 20 to 40 km, and their release seismic moments are Mw 6.6 on average. In addition, Nakamura (2009) identified a slow crust deformation near Yonaguni Island that was induced by an Mw7.1 earthquake, and the duration of this event is longer than 5 yrs. These phenomena describe that the southwestern Ryukyu subduction zone could be a coupled plate boundary and have potentials to cause large thrust earthquakes.

In order to understand the properties and variations of SSEs in this area, GEONET GNSS daily coordinate solutions of 16-yrs (1997-2014) are used in this study. During this period, a total of 33 SSEs are identified from Hateruma station through visual inspection. The average recurrence interval (6.3 mos) and the average release seismic moment (Mw 6.6) consistent with the results of Heki and Kataoka (2008). However, the interval and slip of SSEs vary in a short time. For instance, from 2005 to 2007, the interval decreases suddenly from 6 to 4.5 mos without specific causes, and then turns back to the previous level. Moreover, the slip rate (cumulative slip/ lapse time) of SSEs in this area is 8 cm/y on average. From 1997 to 2001, the slip rate is 10 cm/y; and during 2003 to 2006, the slip rate increases slightly to 11 cm/y. Afterward, between 2007 to 2013, it drops remarkably to 6 cm/y, and then increases again to 12 cm/y near the end of 2013.

Although the slip rate significantly increases in 2002 and 2013, the mechanisms of the variations are still uncertain. For this issue, Heki and Kataoka (2008) indicated the slip rate variation of SSE in 2002 could relate to nearby large earthquakes (Mw $>$7). Subsequently, Nakamura (2009) calculated the $\triangle$CFS on the fault of SSEs and proposed the slow crust deformation near Yonaguni Island induced by one thrust earthquake might affect the slip rate variation. However, above idea cannot explain the slip rate change in 2013, since no significant earthquake occurred near the southwestern Ryukyu trench in this period. On the contrary, one earthquake swarm activity in the Okinawa trough, approximately 50km north of the SSE fault patch, started simultaneously. On the basic of displacement data of Yonaguni and Hateruma stations, we infer that the earthquake swarm was generated by a dyke intrusion which relates to the Okinawa trough spreading. Through Coulomb failure stress calculation, the positive $\triangle$CFS confirms the dyke intrusion triggered the slip rate change of SSEs in 2013.

Keywords: SSEs, Hateruma Island, variations, Ryukyu subduction zone