Nucleation of the characteristic earthquake in simulated cycles involving huge SSEs on the deeper extension

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The 1944/1946 Showa Tonankai/Nankai earthquakes may have been preceded by a huge, fast precursory aseismic slip event (SSE) in the brittle-to-ductile transition zone (Linde and Sacks, 2002). Kato (2003) reproduced such precursory SSEs using a fault model obeying the rate- and state- friction law. He introduced the friction law with cut-off velocity V_{cx} above which the friction changes from velocity-weakening to velocity-strengthening. The depth-dependent V_{cx}, decreasing with depth in the transition zone, produces both earthquakes and precursory slip.

In this study, we focus on the nucleation of the characteristic earthquake (CE) in the simulated earthquake cycles involving repeating huge SSEs. Our model is similar to Kato (2003), but we conducted systematical simulations with the variation of characteristic slip length *L*, and we further classify the earthquake nucleation (EN) into the three patterns: (P1) When *L* is small, the huge SSE in the transition zone directly grows into an earthquake without experiencing a separate nucleation at the brittle zone (brittle nucleation; BN), i.e., EN = SSE. (P2) With moderate *L*, huge SSE triggers BN, which develops into an earthquake; EN = SSE + BN. (P3) When *L* is large, an SSE ceases without triggering an earthquake or BN. Then, the accumulation of slip deficit resumes to finally cause a BN and an earthquake without a large precursor; EN = BN. With the intermediate *L*, different nucleation patterns can emerge in a single simulation. In our simulation, the SSEs, which sometimes lead to EN, can grow huge because of its slip profile resembling the cross-section of *Stollen*, characterized by the slip and stress concentration smaller than expected from the ordinary elliptic profile with the same moment.

EN in P1 and P2 are the cases where huge SSEs trigger an earthquake. However, EN in P3 is not preceded by a huge precursory SSE so that the CE occurs without a short-term warning except a smaller signal from the BN, which might be skipped by cascade-up (Noda et al., 2013). However, in our systematic simulations with different *L*s, 80% of CEs were preceded by a huge SSE within three days, an excellent alarm rate. On the other hand, in many cycles, one or two huge SSEs occur without triggering the CE, causing false alarms albeit the huge size of the SSE. Still, a huge SSE “succeeds” to trigger the CE within three days at a 43 % chance, not too bad at all. It looks like a huge SSE would deserve the gravest alert if our simulation is pertinent to natural faults.