Simulation of the Nankai earthquake cycle -Quasi-dynamic discrete-cell model incorporating rate-weakening due to thermal pressurization-

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Along the Nankai Tough, great earthquakes have historically recurred, causing devastating disasters in southwest Japan, and the next Nankai earthquake is anticipated to occur in the first half of this century. The recurrence times of the Nankai earthquakes vary from 90 to 250 years. The source region extending from off-Shikoku to off-Tokai regions is divided into five segments. The segments complicatedly slip at each event; all five segments seismically slip, and some segments seismically slip with delays or sometimes not slip (Ishibashi, 2004). Moreover Seno [2012] re-examined the historical sequences and proposed that the source region is characterized into a seismic-b, tsunami-b and geodetic-b areas where seismic waves, tsunamis and crustal deformations are dominantly generated, respectively, and the historical events are grouped into the Ansei-type or the Hoei-type. His model might explain the complexity of historical sequences, but we need some verification. We execute earthquake cycle simulations to reveal the complexity.
In this study, we take a boundary element method to simulate earthquake cycles following the rate- and state-dependent friction law. Setting spatially heterogeneous friction parameters on the fault may not reproduce the complex historical sequences, and another factor should be introduced in the numerical model. Noda and Lapusta [2010] focused on the thermal pressurization (TP) that the increases pore fluid pressure at the shear zone due to frictional heating and showed that the interaction of two patches with spatially heterogeneous hydraulic parameters produces complex earthquakes cycles. The goal of this study is to reproduce the complex sequences by introducing TP in addition to spatially heterogeneous frictional parameters in the model. Their simulation include the dynamic rupture process, but in this study we use the radiation damping (Rice,1993) to simulate quasi-dynamically for reducing the computational cost. The quasi-dynamic approximation may cause the underestimation of TP effect, which should be examined in future.
TP increases the effective normal stress, and then the friction drops coseismically. Therefore the amount of coseismic slip increases and the recurrence interval gets longer than that without TP. For calculating the temporal change in pore fluid pressure by TP, we use the convolution form proposed by Bizzari and Cocco [2012] which enables us to take a longer time step than that in the case solving numerically the diffusion equation. However, the numerical cost of convolution calculation is also enormous. Accordingly, it is quite difficult to execute cycles of great earthquakes such as Nankai earthquakes as in a continuum medium, considering also the numerical cost of calculating interaction between a huge number of cells. Hence we consider a conceptual model similar to the block and spring model [Mitsui and Hirahara, 2004]. The numerical cost using their model is relatively smaller even when taking account of thermal pressurization. They set five blocks corresponding to five segments and assign properties to respective blocks; for example, dip angles, plate convergence rates and frictional parameters. In this study we calculate slip response functions by the code of Okada [1992] for elastic interactions between cells instead of springs, which is called a discrete cell model. Because we found only five cells produce almost no interactions, we divide each cell to a number of cells along its subduction direction. In addition to a variety of frictional parameter settings, we apply TP to specific cells and we compare the calculated patterns of earthquake cycle with the historical sequences of the Nankai earthquakes. This conceptual model and the resultant earthquake cyclers are expected to contribute to the actual reproduction of the Nankai earthquake sequences by simulating not as a discrete cell model but as a

continuum model.

Keywords: Nankai Trough, simulation of earthquake cycle, a boundary elementary method, pore fluid pressure, thermal pressurization

