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3-D cell model simulation of earthquake generation cycles in Southwest Japan in a layered viscoelastic medium

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At subduction zones, great interplate earthquakes repeatedly occur. In most cases, the magnitude and recurrence time of the interplate earthquakes are not constant even in the same plate boundary. One of the reasons of the complex history of great earthquakes is that the stress accumulation/release processes interact with each other among multiple fault segmentation of the plate interface. In addition, stress accumulation/release at the plate interface change the stress distribution in the overriding plate and affect the earthquake generation at the inland active faults. In this study we simulate earthquake generation cycle in and around Southwest Japan with cell model to clarify the stress accumulation/release process and also evaluate its effect to the earthquake generation cycle of plate interface and inland active faults in this region.

Earthquake generation cycles at subduction zones can be regarded as the stress accumulation/ release process due to slip deficit at the plate interface and locking at the inland active faults. Based on the concept, numerical simulations have been made to model earthquake generation cycle at a subduction zone by solving the boundary value problem. The governing equations are the slip response function at a fault plane, with which we can obtain the change of stress due to the accumulation/release of slip deficit and locking, and the friction constitutive law, which gives the relation between stress or strength and slip at the fault plane. The boundary conditions are relative plate motion and geometry of plate interfaces and inland active faults.

In this study, we compute the slip response function in elastic-viscoelastic stratified medium. We assume the effects of negative and positive buoyancy due to surface uplift and subsidence. Under these conditions and quasi-static assumption, we obtain slip response function. In this study, we employ viscoelastic slip response functions for point sources by Fukahata & Matsu'ura (2005). To obtain accurate slip response functions for rectangular sources effectively, we apply the Gauss-Legendre integration scheme. In addition, we use the approximate solutions under the assumption that slip response exponentially reduces with time, since it is difficult to calculate viscoelastic slip response functions for all time steps. To approximate quasi-dynamic slip behavior during earthquakes, the radiation damping term (Rice, 1993, JGR) is introduced to the stress evaluation equation.

As for the friction constitutive law, we employed the laboratory-derived rate- and state-dependent friction law (Dietrich, 1979, JGR). The parameter distribution of the friction law decides the distribution of slip behavior on the fault plane (the stick-slip or aseismic sliding). Using the friction law, we can uniformly deal with the decrease of stress and strength at the coseismic period and the fault strength restoration during the interseismic period.

We apply the present earthquake generation cycle model to the region in and around Southwest Japan. As a conceptual model, we here employ the cell model and divide the plate interface in and around Southwest Japan into dozens of cells. We set segments from the Sagami trough to the

Bungo channel for subduction boundary of the Philippine Sea plate and from Southern Tohoku to the Izu Islands for subduction boundary of the Pacific plate. We divide these segments into several segments for the dip direction and set different friction parameters for each cell. We also set stick-slip cells to represent inland active faults and aseismic cells at downward extension of the faults. The subduction rate at the Philippine Sea plate is decreasing at around the root of the Izu Peninsula, which corresponds to the partial collision in this region. Under this setting we simulate earthquake generation cycles at plate interface and inland active faults in and around Southwest Japan.

Keywords: subduction zone, numerical simulation, viscoelasticity, friction constitutive law, earthquake cycle, active fault