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Simulation of the Complicated Patterns of Great earthquakes along the Nankai Trough

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Hirose and Maeda (2010, SSJ) numerically simulated that the Tokai region did not rupture during the most recent Tonankai earthquake in 1944, and that long-term slow slip events (LSSE) in the Tokai region and Bungo channel occurred periodically, by using a three-dimensional earthquake cycle model on the basis of the rate- and state-dependent friction law. By assuming large characteristic displacements for areas where ridges are being subducted beneath the Tokai district [Kodaira et al. (2004, Science)] and Hyuganada, they developed a model for which recurring ruptures of both the Tonankai and Nankai segments occur approximately every 110 years, but rupture on the Tokai segment occurs on average during only every second earthquake cycle. Their modeling also successfully reproduced the recently observed recurring LSSE by assuming low normal stress and small characteristic displacement in areas where the LSSE occur. Their simulation showed that the amplitudes of the LSSE increased following earthquakes that did not rupture the Tokai segment.

However, in their model, great earthquakes along the Nankai trough always initiate off Kii Peninsula and the ruptures then propagate bilaterally; that is, the Tonankai and Nankai segments always rupture at the same time. These simulated results are not completely consistent with the complicated historical record of great earthquakes along the Nankai trough. On the other hand, the Tokai segment ruptures every second time the Tonankai segment ruptures because large L plays a role of barrier. In this study, we attempt to simulate intervals between the ruptures of the Tonankai and Nankai segments by introducing large L in area of the subducted Kinan seamount chain which may play a role of barrier.

As for the simulation method, we assumed that the shear stress on the fault obeys a rate- and state-dependent friction law derived from laboratory experiments. We used here the composite law [Kato and Tullis (2001, GRL)]. Assuming that equilibrium between shear stress and frictional stress remains quasi statically, we numerically solved differential equations by the fifth-order Runge-Kutta method with an adaptive step-size control [Press et al., 1992]. For simplicity, we considered that frictional parameters a and b depend only on depth and that the seismogenic zones for which (a ? b) is negative is within the depth range from 10 to 30 km [cf. Hyndman et al., 1995]. We assumed that a = 0.001 for the entire depth range, and b = 0.00165 for depths from 10 to 30 km. The characteristic displacement L was taken to be 0.1 m, except for 0.5 m at subducted ridges beneath the Tokai region, Hyunagada, and Kinan seamount chain, and 0.019-0.035 m at area of the LSSE. We believe that the dehydration process is especially active in the subducting slab beneath area of the LSSE [Hirose et al. (2008, JGR)], so we used smaller effective normal stresses (30-60 MPa) at the plate interface beneath area of the LSSE than the 100 MPa we used elsewhere. The plate convergence rate we used along the Nankai trough was 6.5 cm/y in the western part of the study area, decreasing eastward from the Kii Peninsula to 1.5 cm/y in the eastern part of the study area [Heki and Miyazaki (2001, GRL)].

The results show that a great earthquake that ruptures the Tonankai segment occurs about every 110 years, then after a few years a Nankai earthquake occurs. Furthermore the rupture propagates into the Tokai segment for only every second earthquake. By setting the large L which plays a role of barrier at the Kinan seamount chain, we can simulate the time interval between the Tonankai and Nankai earthquakes. However, the simulation holds the interval time at every earthquake cycle and does not produce the pattern like the 1707 Hoei earthquake which ruptured all segments along the Nankai trough at the same time. We will try to make a model which is consistent with the complicated historical record of great earthquakes along the Nankai trough.

Keywords: Nankai trough, Great earthquake, Simulation