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Simulation of the Complicated Patterns of Great earthquakes along the Nankai Trough: Part 2

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1. Introduction

We have developed and improved a three-dimensional earthquake cycle model on the basis of the rate- and state-dependent friction law. Hirose and Maeda (2011, JpGU, SSJ) numerically simulated great earthquakes along the Nankai trough and produced some occurrence patterns such as (A) all region ruptured, (B) the Tokai region did not rupture occasionally, which is the case of the most recent Tonankai earthquake in 1944, (C) a part of or all part of the Nankai earthquake occurred two to five years after the Tonankai earthquake, and (D) long-term slow slip events (LSSE) in the Tokai region and Bungo channel occurred periodically. They distributed characteristic displacements (L) and effective normal stress (sigma) heterogeneously considering locations of asperities of the 1944 Tonankai and 1946 Nankai earthquakes (Kikuchi et al., 2003, EPS; Murotani et al., 2007, SSJ), subducting ridges beneath the Tokai district (Kodaira et al., 2004, Science) and Hyuganada, the existence of water due to dehydration from the slab (Rice, 1992; Hirose et al., 2008, JGR). In addition, their model simulated also a pattern that only the Tonankai earthquake occurred. However, further inspection is necessary about the reliability of the model because we do not know that pattern in history.

By the way, it is suggested that the shallow region of the plate boundary slipped largely in the 2011 off the Pacific Coast of Tohoku Earthquake (Mw9.0, hereinafter 2011 Tohoku earthquake) (e.g., Yoshida et al., 2011, EPS). So far, it had classically been considered that aseismic slips had occurred constantly and coseismic slips had not occurred in the shallow region of the plate boundary off the Tohoku district (Uyeda and Kanamori, 1979, JGR). However, it was shown that this assumption was wrong by analysis of the 2011 Tohoku earthquake. In this study, taking above points into consideration, we tried to make a model that the shallow zone along the Nankai trough can sometimes slips largely when an earthquake occurs.

2. Method

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 (Rice, 1993, JGR). 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 the Nankai trough to 30 km (cf. Hyndman et al., 1995, JGR). We assumed that a = 0.001 for the entire depth range, and b = 0.0015 for depths from 0 to 30 km. The characteristic displacement L was taken to be 2.0 m at shallower zone than 10 km; 0.5-1.0 m at subducted ridges beneath the Tokai region, Hyunagada, and intermediate region of the 1944 Tonankai and 1946 Nankai earthquakes; and 0.1 m elsewhere. By following the excess pore pressure model suggested by Rice (1992), (sigma) is given by rgz for z <= 5.66 km and 100 MPa for z > 5.66 km, where z is depth, r = 1.8×10^3 kg/m^3 , and g = 9.8 m/s^2. 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). Difference from the model of Hirose and Maeda (2011, JpGU, SSJ) is as follows: we set negative a-b, large L (= 2.0 m) in the shallower zone than 10 km.

3. Results and discussion

By setting above parameters, we made the model which shows complicated patterns. We simulated great earthquakes which ruptured up to shallow zones once in a few cycles by setting a barrier with large L at shallower zones than 10 km in depth.

Keywords: Nankai trough, great earthquake, simulation, characteristic displacement