Development of Mechanical Coupling Model on Subducting Plate Interfaces

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Introduction

Interplate earthquakes occur at regions where the interplate strain has been accumulated by plate convergence. To evaluate the interplate seismic potential, many previous studies have tried to estimate the spatial distribution of interplate "coupling" [e.g., Loveless and Meade (2010); Yokota et al. (2016); Nishimura et al. (2018); Kimura et al. (in prep.)]. In their models, "coupling" is defined as the ratio between slip deficit rate and convergence rate, based on the kinematic concept. However, the actual situation of plate interface should be treated as mechanical "locking" (sometimes called as asperities) or "creeping". It is considered that the seismic ruptures at asperities can generate the strong-motion that gives constructions serious damages. Thus, it is essential to comprehend the spatial distribution of the mechanical "locking" region on the plate interface. We then introduce the two kinds of back-slips to develop the mechanical coupling model on the basis of the geodetic observation data. Using this model, we test several scenarios of mechanical coupling distributions along the Nankai Trough for forward simulation.

Modeling of Mechanical Coupling

The mechanical coupling model we developed in this study is similar to the "pinned asperities" model presented by Bürgmann et al. (2005). We consider two kinds of back-slip on the plate interface: active back-slip and passive back-slip. The first one is applied on the mechanical coupling region, that is the mechanically locked region to the plate interface between subducting and overriding plate. We calculate the active back-slip rate from the relative block motion rate based on the Euler vectors of each block. The second one is the slip around the mechanical coupling region generated to completely relieve the along-dip and along-strike shear strain due to the active back-slip. We model the relationship between shear strain concentration $\boldsymbol{\varepsilon}$ and passive back-slip rate $\boldsymbol{v}$ around the mechanical coupling region with a linear equation $\boldsymbol{\varepsilon} = G\boldsymbol{v}$, where G is the Green's function matrix. To estimate the passive back-slip, we first calculate the shear strain due to the given active back-slip on the mechanical coupling region. Then, we inverse the passive back-slip rate using the linear equation above. We repeat these two procedures until the shear strain concentration becomes zero. We call the region where the active or passive back-slip is observed as kinematic coupling region. The elastic component of crustal displacement at the surface can be calculated from the total back-slip on the kinematic coupling region.

Forward Simulation

We conduct the forward simulation using our mechanical coupling model for some scenarios of mechanical coupling distributions along the Nankai Trough. We divide the test region into 12 rigid blocks and calculate the active back-slip rate on mechanical coupling regions using the Euler vectors referring to Kimura et al. (in prep.). Figure 1 shows one example of (a) given mechanical coupling distribution and (b) spatial distribution of the simulated passive back-slip rate. Blue lines mean the edges of mechanical coupling regions. Because the relative block motion rate is about two times faster in the western region than that in the eastern region, the passive back-slip area is larger around the western mechanical coupling region, extending down to ~50 km in depths. In this presentation, we discuss for the other cases of mechanical distributions. In this study, we give the mechanical coupling distributions and Euler vectors for forward simulation. Because of this, the estimated passive back-slip rate depends on the given distribution, and we could not know other scenarios of mechanical coupling distributions. To resolve this problem, we will estimate the spatial distributions of mechanical coupling and Euler vectors simultaneously as a non-linear problem in future studies.

Keywords: Mechanical Coupling, Passive Back-slip, Strain Concentration, Crustal Deformation Observation Data, Plate Subduction Zone

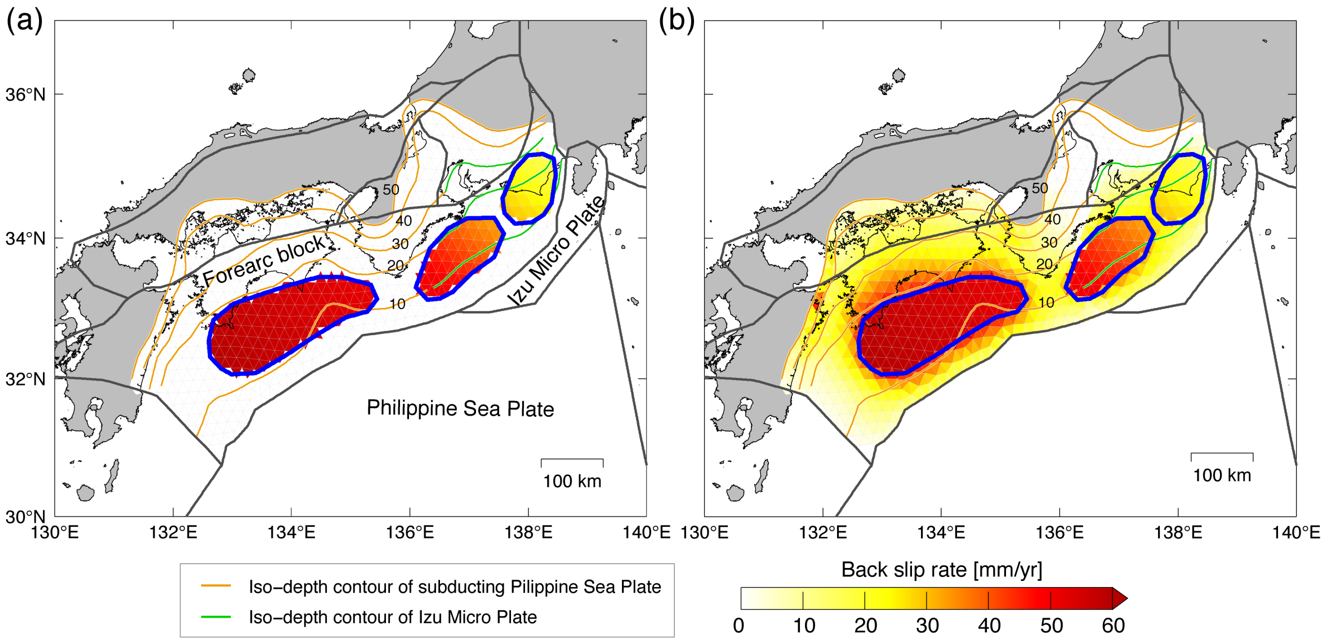

Figure 1: Map showing the spatial distribution of back-slip rate of (a) given active back-slip, and (b) calculated passive back-slip as well as given back-slip.