Interplate Mechanical Locking Distribution along the Kuril - Japan Trench in NE Japan based on Onshore and Seafloor Geodetic Observations

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Interplate earthquakes occur at regions where the interplate strain has been accumulated by plate convergence. Many previous studies tried to evaluate the interplate seismic potential by estimating the interplate coupling, that is defined as the ratio between slip deficit and plate convergence rate [e.g., Loveless and Meade., 2016; Watanabe et al., 2018; Kimura et al., 2019]. However, the actual situation of plate interface should be treated as “mechanical locking” (sometimes called as asperities) or “creeping” (sliding state). As seismic ruptures at asperities can be considered to generate the strong-motion that gives constructions serious damages, it is essential to comprehend the interplate mechanical locking distribution prior to the earthquake. In this study, we constructed a model expressing the relation between interplate mechanical locking and crustal deformations; and estimated the interplate mechanical locking distribution along the Kuril and Japan Trench in NE Japan using onshore and seafloor geodetic observations, adopting the above model.

We describe the observed surface displacement as sum of the rigid block motion, surface responses from the interplate slip deficits, and the internal strain of blocks. In this study, the slip deficit is distinguished into two types: one is imposed on mechanical locking patches, the other one is induced on creeping area that is surrounding the mechanical locking patches to release the shear strain concentration around the mechanical locking patches. To estimate the mechanical locking distributions, we parameterized the slip deficit with the limitation of up-dip and down-dip depths of mechanical locking areas. The observation equation is non-linear that contains three kinds of unknown parameters: Euler vectors of each block, down-dip and up-dip limitation depths of mechanical locking, and internal strains. We used the Replica Exchange Monte Carlo method [e.g., Swendsen & Wang, 1986] to obtain the probability density functions of all unknown parameters. We considered two plate interface geometry models: Hirose plate model [Hirose et al., 2008] and Iwasaki plate model [Iwasaki et al., 2014]. Input data set is surface velocities at onshore GEONET (from 1997 to 2003) and seafloor GNSS/Acoustic observation sites (from 2002 to 2011) [Yokota et al., 2018]; the total number of sites is 497.

We estimated four mechanical locking segments with M > 7 (30 –40 km in lengths) inside of the target area. Besides, some smaller mechanical locking segments are found around the M > 7 segments. Estimated mechanical locking distributions are roughly equal between Hirose and Iwasaki plate models, whereas some discrepancies in the mechanical locking distributions between the two plate models were found: mechanical locking segments off Tohoku of Iwasaki plate model were estimated ~50 km north to that of Hirose plate model; only one mechanical locking segment was estimated off Nemuro in Hirose plate model, while two segments were estimated in Iwasaki plate model. We found that the mechanical locking distributions roughly correspond to the strong-motion generation areas (SMGAs) of 2003 M8.0 Off Tokachi Earthquake [e.g., Nozu & Irikura, 2008; Kamae & Kawabe, 2008] and 2011 M9.0 Off Tohoku Earthquake [e.g., Asano & Iwata, 2012; Kurahashi & Irikura, 2013] for both plate models. However, the mechanical locking area corresponding to the southern part of SMGAs of 2011 Off Tohoku Earthquake was not estimated in Hirose plate model. These results suggest that our model can roughly detect SMGAs

before the earthquakes but the estimates of mechanical locking distributions depend on the plate interface geometries. In the future study, we will estimate the interplate mechanical locking distribution along the Nankai Trough employing the model developed in this study, using onshore and seafloor geodetic observation data.

Keywords: Mechanical Locking, Onshore and Seafloor Geodetic Observations, Plate Interface Geometry model, Strong Motion Generation Areas