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Fault stressing in the overriding plate due to megathrust coupling along the Nankai trough, Japan

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The Nankai trough has hosted ~M8 interplate earthquakes with the interval of 100-200 years. The crustal activity in southwest (SW) Japan in the overriding plate was relatively quiet after the last coupled megathrust ruptures occurred in 1944 and 1946. In the recent 20 years, however, SW Japan has experienced ~M7 earthquakes such as the 2016 Kumamoto earthquake. Similar activation of crustal earthquakes in the later stage of the megathrust earthquake cycles can be found in the historical earthquake occurrence based on paleogeographical studies. Such a change cannot be resolved by the probabilistic approaches, which usually rely on paleo-seismological data on longer timescales. Here, we show a deterministic way to quantify the current stressing state on the source faults due to megathrust coupling at the Nankai trough, making use of the data captured by the dense, modern geodetic network in Japan.

We constructed a 3-D finite element model (FEM) around the Japanese islands including the viscoelastic feature in the asthenosphere. The geometry of plate boundary on the Philippine Sea slab is based on earthquake distributions determined by the previous studies. In particular, the bended geometry at the junction of the Nankai trough and the Ryukyu trench is crucial for calculating stress. The plate boundary is divided into 8 x 27 patches to generate Green's functions. The model region is divided into about 1000,000 tetrahedral elements with dimension of 5-100 km. We revised the source fault model by the Headquarters for Earthquake Research Promotion based on recent geophysical and geological data and added new faults in the Sea of Japan.

Our inter-seismic inversion suggests ~8 cm/year slip-rate deficit, which is consistent with the previous studies. Using the slip distribution, we calculate stressing rates on the source faults over SW Japan. In particular, positive Coulomb stressing rate on the source faults of the 2016 Kumamoto earthquake and the other M7 earthquakes is consistent with their occurrence. The crustal earthquakes before the 1944 and 1946 megathrust events also occurred in the region with source faults with positive Coulomb stressing rate.