Self-similar and random slip distributions on a non-planar fault for tsunami scenarios for megathrust earthquakes

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Megathrust earthquakes along the Nankai trough in southwest Japan, such as the 1944 Tonankai and 1946 Nankai events, have caused severe damage due to strong ground motion and the generation of large tsunamis. Since such devastating earthquakes have repeatedly occurred throughout history in this region, we should prepare for future large earthquakes. However we cannot exactly predict slip distributions of future earthquakes and ensuing tsunamis. Previous efforts to characterize tsunami damage have involved the computation of theoretical tsunamis based on a set of scenario earthquakes. Additionally, tsunami early warning systems have also been developed based on correlations of coastal tsunami heights and offshore tsunami observations (Baba et al. 2014; Igarashi et al. 2016). These studies also involved the computation of theoretical tsunamis where thousands of earthquake scenarios of various magnitude earthquakes with uniform slip distributions are considered. However, actual earthquakes have heterogeneous slip distributions which affect coastal tsunami heights and distributions. In general, fault slip distributions have fractal dimension of about 2 (Herrero and Bernard, 1994) with a corner wave number depending on earthquake magnitude, but we cannot exactly estimate the distributions in future earthquakes. One of possible solution to resolve this difficulty is to create a set of scenario earthquakes based on a slip probability density function (SPDF, Murphy et al., 2016), in which heterogeneous slip distributions on the source fault are stochastically generated based on a given probability density function. The generated earthquake slip distributions differ from event to event, but their average for a large ensemble of models converges to a predefined SPDF.

In this study, we create a set of scenario earthquakes considering self-similar slip distributions based on the composite source model (Herrero and Murphy, 2018) on the Nankai trough. We also consider surface ruptures, where the fault slip is not tapered to zero at the free surface. The location of the rupture area is assigned according to the probability defined by SPDF; and the extent of the source area is based on an empirical relation obtained for subduction zone earthquakes (Strasser et al. 2010). Families of asperities which contain a power law distribution of sizes given by Zeng et al. (1994) are placed based on the same SPDF in the defined source area to obtain a self-similar slip distribution.

Assuming the SPDF is similar to the slip deficit rate (SDR) obtained by Yokota et al. (2016), which may represent long-term average of slip on the target fault, we generated sets of 200 scenario earthquakes for Mw >= 8.0. We found that the average slip for a family of Mw 8.5 mostly converges to the SDR. For Mw 8.0 more earthquakes are required to observe a similar convergence due to its smaller source area.

The next step is to compute tsunamis based on the scenario earthquakes generated in this way in order to create a tsunami database which will be used to forecast potential tsunami damage and improve the accuracy of the tsunami early warning systems in Nankai region.

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