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Tsunami scenarios for megathrust earthquakes: mechanics of multi-segment ruptures and elastic-fluid dynamics of wave propagation

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Great earthquakes repeatedly occurred with different rupture processes in the Nankai trough, southwestern Japan. The 1944 Tonankai and the 1946 Nankai earthquakes (M ~8) caused serious tsunami damage over many areas along the coastline. The greatest earthquake in this region is the 1707 Hoei earthquake (M 8.4) that is believed to have ruptured the whole region (~600 km) of the Nankai Trough. The purpose of this study is to theoretically assess the tsunami height along the coasts excited by great earthquakes that can possibly occur in future in this region and simulate observable tsunami records during the earthquakes.

This study employed a new method for making various rupture scenarios. Based on a shear-stress distribution along the plate boundary estimated by the GNSS data analyses (Noda et al. 2018 JGR), we calculated coseismic slip distributions to release the accumulated stress for possible multi-segment rupture scenarios. Then, we used the strain energy released by the rupture to evaluate the possibility of each event. The released strain energy should be larger than the energy dissipated on the fault. However, for some scenarios, the released strain energy was smaller than the dissipated energy under the assumptions of friction laws. Such rupture scenarios are not likely to occur in the viewpoint of earthquake mechanics. This approach can provide necessary conditions of the strain energy or the accumulated stress levels for multi-segment rupture processes, while methods based on empirical or kinematic approaches do not treat stress or interseimsmic stress-accumulation periods required for ruptures.

Another distinctive point in our approach is that we theoretically synthesize ocean-bottom pressure changes caused by both seismic waves and tsunamis using a simulation method based on elastic and fluid dynamics (Saito and Tsushima 2016 JGR; Saito et al. 2019 Tectonophysics). Seismic wave contributions to ocean-bottom pressure changes are critically important for the synthetics in near-field or inside rupture areas because the seismic waves overlap with tsunami signals and work as noise for real-time tsunami monitoring. The records simulated in this study can be used to examine the monitoring ability of a deep-ocean observation network for megathrust earthquakes and tsunamis in this region.