Sea-surface Displacement and Tsunami Inundation Including Seismic Waves and Tsunami for Anticipated Nankai Trough Earthquakes, Southwest, Japan

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When observation stations are located apart from an earthquake hypocenter, tsunami arrives much later than seismic waves because tsunami propagates considerably slower than seismic waves. Hence, we effortlessly exclude seismic waves by just setting an appropriate time window when we analyze tsunami signals. However, when analyzing the waveforms recorded inside the focal area, it is difficult to decompose the wavefield into seismic waves and tsunami. We need to employ a theory that describes seismic waves and tsunami simultaneously. For example, Saito and Tsushima (2016) proposed a method for synthesizing ocean-bottom pressure records considering both seismic waves and tsunami. They evaluated the performance of a real-time tsunami forecasting algorithm called tFISH (e.g., Tsushima et al. 2012) by using the synthesized records.
New observation networks such as DONET and S-net are designed for the observation inside the focal area. Therefore, it is fundamentally important to investigate the contributions of seismic waves in tsunami waveforms. Recent development of tsunami observation technology enables us to observe tsunami not only by sea-bottom pressure change but also by sea-surface displacement by using GPS buoys. Inazu et al. (2016) showed that real-time tsunami source estimation is possible if we utilize high-precision, real-time GPS height observations equipped with cargo ships and tankers. At present, a method for synthesizing ocean-surface displacement including both seismic waves and tsunami is urgently required.
The present study proposes a method that calculates both the sea surface displacement including seismic waves and tsunami in addition tsunami inundation along coasts. Taking the anticipated Nankai-Trough huge earthquakes as example, we theoretically created the sea-surface displacement waveforms and the inundation. We used the scenarios proposed by Hok et al. (2011) where the earthquake ruptures were simulated based on the friction law established in laboratory experiments and the slip deficit distribution estimated by geodetic-data analysis. By using their rupture scenarios as seismic sources in 3-D seismic-wave propagation simulations, we calculated spatial and temporal variation of the sea-surface displacement field without considering gravity (e.g., Takemura et al. 2016). Then, we included the contribution of gravity to the displacement field (in other words, simulated surface-height propagation as tsunami) by numerically solving nonlinear long-wave tsunami equations. We successfully simulated the inundation process with high-resolution topography data (minimum grid-spacing is ~6 m) by integrating a code referred to as JAGRUS (Baba et al. 2015) to the scheme proposed in this study.
Seismic waves and tsunami simultaneously appeared in the sea-surface displacement during the earthquake rupture, which can be noise for tsunami analyses. The seismic wave contribution to sea-surface displacement was smaller than to the sea-bottom pressure change. Since the moment rate becomes larger when the rupture duration gets shorter, seismic wave contributes more due to shorter rupture duration. On the other hand, tsunami inundation is mainly controlled by the moment but not the moment rate. The data sets created in this study would be useful for practical tests of tsunami-prediction algorithms using sea-surface displacement waveforms.

Keywords: Seismic Wave, Tsunami, Simulation

