Predictions of tsunamis caused by possible outer-rise earthquakes in the Japan Trench

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Great interplate earthquakes often induce outer-rise earthquakes in the subducting plate. An M8-class outer-rise earthquake which will be a pair of the 2011 Tohoku earthquake has not occurred yet, so it is anticipated to occur. We have conducted detailed seafloor topographic surveys, passive and active seismic observations to create possible 33 faults of outer-rise earthquakes near the Japan Trench axis in an area from 36.5 to 40.5 degrees north latitude. In this study, we predicted tsunamis caused by these outer-rise earthquakes using numerical simulations. Actual earthquakes do not exactly match the fault parameters of the assumed faults. Therefore, variations on the predictions due to the uncertainty of the assumed parameters were evaluated using the values of K and kappa of Aida (1978).
Each fault was modeled by one rectangular plane connecting endpoints of corresponding horst-and-graven structure on the seafloor. This defined fault length (L) and strike of the fault plane. The upper depth of the fault was set to be 0.1 km below the seafloor. Dip and rake angles were 60 and 270 degrees, respectively. An earthquake scaling law complied by outer-rise earthquakes around the world (Á lvarez-Gómez et al., 2012) determined earthquake magnitude from the fault length. The fault width was the same as the fault length (L=W). But when the lower edge of the fault was deeper than the bottom of the seismogenic zone (40 km), the width was shortened to match the depth of the bottom. The slip amount on the fault was determined by fault area (L x W) and magnitude assuming rigidity of $5x10^{10}N/m^2$.
In tsunami calculations, initial sea surface displacements were calculated assuming that the crust is a homogeneous elastic body in half-space (Okada, 1985). Additionally, horizontal movement effects (Tanioka and Satake, 1996) and a hydraulic filter based on the linear potential theory (Kajiura, 1963) were applied to the tsunami generation. The nonlinear long-wave equations were solved on a uniform finite-difference grid using JAGURS (Baba et al., 2015; 2017) for tsunami propagations. The interval of the grid points was 18 arc-sec. A nesting algorithm was not applied in this study. The large outer-rise fault model (No. 9, L=332 km, Mw=8.66) caused the maximum tsunami which reached 27 m at the coast in northeast Japan.
We repeated tsunami calculations using the fault parameters with variations. The marine seismic surveys showed that the dip angle of the outer-rise faults changed in a range from 45 to 75 degrees. Tsunamis from fault models with a dip of 45 and 75 degrees were calculated by the same method described above. Besides, a compound fault model consists of the upper half with 75 degrees and the lower half with 45 degrees was examined. Rake angle was changed in a range of ±15 degrees. We also performed calculations with models consisting of small subfaults with dimensions of about 60 km instead of a single large rectangular fault, other earthquake scaling laws and dispersive tsunami effects. The strike angle was unchanged because it can be determined from the seafloor topography. In results from the numerical tsunami simulations, using the difference earthquake scaling laws showed the most significant effect on the predicted tsunami heights which were changed by about 50 % on average of the 33 faults. The predicted tsunami heights were changed by a range from 5 to 10 % for changing the dip angle, about 5% for considering tsunami dispersion, about 2% for changing the rake angle, and about 1% for using the subfaults.
Acknowledgments: This work was supported by JSPS KAKENHI Grant Number 15H05718 and 19H02409.

Keywords: Tsunami, Outer-rise earthquakes, Japan Trench