Dependence of calculation parameters on tsunami height from the outer-rise earthquakes

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Huge subduction zone earthquakes often induced outer-rise earthquakes occurring on the sea side from the trench axis. An outer-rise earthquake of M8 class which becomes a pair of the 2011 Tohoku earthquake has not yet been occurred. We should pay much attention on the next outer-rise earthquakes and resulting tsunamis in the Japan Trench. A data base (DB) retrieval type system is common for real-time tsunami prediction. It is necessary to incorporate various kinds of earthquake scenarios into DB without deficiencies. However, we have no clear answer to questions such as to how many every kilometer to be set in the depth of the fault stored in the DB in order to guarantee the prediction accuracy of a tsunami. Therefore, in this study, sensitivity analysis of calculation parameters was carried out for tsunamis caused by the outer-rise earthquakes.
We set nine basic fault models of the outer-rise earthquakes with reference to the results of crustal structure surveys and ocean bottom seismic observations. Each basic fault model was composed of multiple small subfaults of about 20 km in length, and the top end of the small subfaults were all set to be 0.1 km under the seafloor, the slope angle was 60 °, and the rake angle was 270 °. The strike angle of the subfaults were based on seafloor topography and crustal structure surveys. Magnitude (M) of the modeled outer-rise earthquake was calculated from the total fault length (L) using an outer-rise earthquake scaling law complied by Álvarez-Gómez et al. (2012). The fault width (W) was constrained at the lower end of the seismogenic layer, but it was given as L/W = 1 until reaching the lower end. The thickness of the seismogenic layer was set at 35 km. Slip amount was calculated from the fault area and M. Crustal deformation due to the faulting was calculated assuming a semi-infinite homogeneous elastic medium (Okada, 1985). The initial sea surface distribution was obtained considering the effect of tsunami excitation by horizontal movement of the slope (Tanioka and Satake, 1996) and the hydraulic filter (Kajiura, 1963) on the calculated seafloor crustal deformation. For tsunami calculations, the nonlinear shallow water equations were solved on a finite difference scheme.
Tsunamis were calculated by changing the calculation parameters and methods of the basic model one by one. The investigated cases were when using the dip angle of (1) 45 °or (2) 75 °against the dip angle of 60 °of the basic model, (3) when using the model approximated by single subfault, (4) when ignoring the effect of horizontal movement of the slope , (5) when ignoring the hydraulic filter, (6) when using different fault scaling laws, and (7) when using the nonlinear dispersive equations in the tsunami calculations. For the coastal tsunami height, the residuals from the basic model were evaluated by the root mean square error normalized by average tsunami height (NRMSE).
In this study, the difference in the coastal maximum tsunami height between the basic model and the derived model was large when (6) the fault scaling law was different (NRMSE ~ 0.50). This is followed by (7) without dispersion (NRMSE = 0.28), (5) without hydraulic filter (NRMSE = 0.21), (1)(2) when using the different dip angle in the subfault (NEMSE ~ 0.15), and (3) when approximating with a single fault (NRMSE = 0.10). Since the outer rise earthquake is a high-angle fault occurring in the relatively flat ocean, the effect of horizontal movement of the slope is relatively small (NRMSE = 0.025).
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