Should we consider sea in ground motion simulation for subduction earthquakes?

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There exists the sea with a depth of several hundred meters in the source regions anticipated along the Pacific trenches near Japan and the sea might have serious influence on seismic ground motion observed on the land. It is nevertheless usual to ignore the sea in ground motion simulation for assessment of loss caused by earthquakes. This is against a background that effects of the sea have not been examined in fear of numerical instabilities that can arise when the finite difference method (FDM), which is most frequently used in ground motion simulation, applies to subsurface structures including fluid.

Hatayama (2002) compared 2-D P-SV waveforms calculated for subsurface structure models with and without the sea by using the boundary element method (BEM) and specified the following effects of the sea with a depth of several hundred meters on ground motion with periods of 1.5 to 3 s: (1) Rayleigh waves are strongly affected by the sea; (2) As the sea is deeper, its effects extend to longer-period ground motion; if the depth is 400 m, around-1.5-s-period ground motion is influenced; if the depth is 800 m, 1.5-to-3-s-period ground motion is influenced; (3) Substituting sediments for sea water, which is usual in ground motion simulation, can have bad influence particularly on vertical components and we would sooner replace sea water by vacuum than substitute sediments for sea water. The above findings strongly suggest necessity of considering the sea in ground motion simulation.

Although the BEM used above can afford numerical stabilities even for models including fluid, it is unsuitable for realistic and complex models. This study aims at investigating feasibility of ground motion simulation considering the sea by means of the FDM that is suitable for realistic models but with anxiety of numerical instabilities. We so examined accuracy of FDM solutions by checking with BEM solutions.

The FDM used here is formulated by velocity-stress staggered grids (cf. Figure 2) and finite difference approximation with the second and the fourth order accuracy for temporal and spatial derivatives, respectively (Hayashida et al., 1999). Each of the staggered grids is assigned medium properties at the respective grid position and no averaging is made in a set of staggered grids. As a result of comparing 2-D P-SV waveforms calculated by the FDM for the model shown in Figure 1 with those done by the BEM, we found that the FDM can afford stable solutions only by giving S-wave velocities of zero to sea water. Care only has to be given to that the accuracy decreases when discretization of models let the staggered grids for Txx and Tzz locate onto a solid-fluid boundary, as pointed by Okamaoto and Takenaka (1999).

The sea model shown in Figure 1 is very unrealistic, for the sea suddenly gets deep. We also investigated models that are 800 m deep offshore and get shallow linearly near the coastline. As a result of calculations for two models with lengths of inclined seafloor of 4 and 8 km, we found that there are no big differences in 2-D P-SV waveforms between the step-like seafloor model and inclined seafloor model. We therefore consider that the results of Hatayama (2002) are valid even for the case of the sea getting shallow near the coastline.

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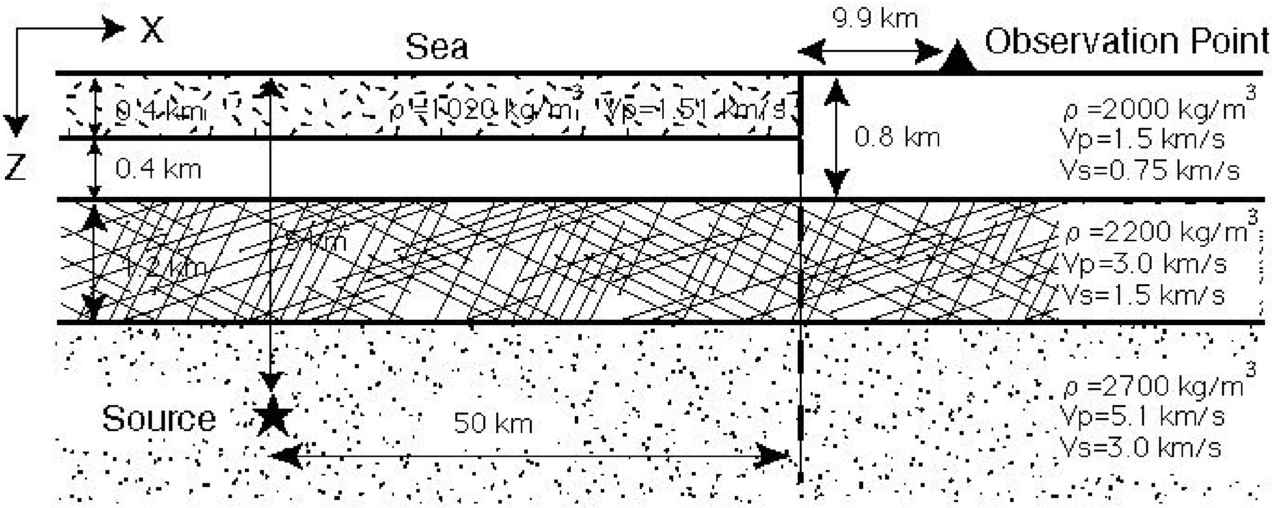

Figure 1 An example of subsurface structure with the sea.

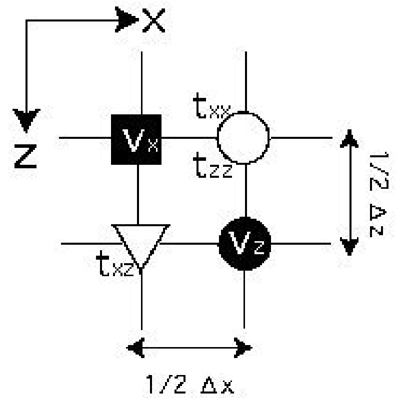

Figure 2 Configuration of staggered grids.