Introduction of rupture directivity effect into the pseudo point-source model

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The pseudo point-source model (Nozu, 2012) is a simple source model for strong ground motion simulation. This simple source model has been applied to some earthquakes and shown good agreement with observations as well as the characterized source model.
In the pseudo point-source model, subevents which generate strong ground motions are assumed on the fault plane and a source spectrum which follows the omega-square model is given to each subevent. This means the spacio-temporal distribution of the slip within the subevent is not explicitly considered in the pseudo point-source model. Thus, parameters concerning rupture propagation such as the size of the subevent are not necessary. However, by giving a corner frequency properly the size of the subevents is implicitly taken into account.
A problem of the pseudo point-source model is that the rupture directivity effect is not considered. This is because we assume a source spectrum for each subevent without considering rupture propagation. As a result, the same source spectrum is used for forward and backward stations and underestimations can happen at stations where forward directivity is observed. In a previous study (Nagasaka et al., 2015) in which this model was applied to the 2005 Central Chiba earthquake (M_w5.9), the results were generally good, however, underestimation was found in the west of the epicenter and this could be attributed to the fact that the current pseudo point-source model does not consider rupture directivity effect. To avoid such underestimation is important when this model is to be used for earthquake-resistant design.
In this study, in order to introduce rupture directivity effect into the pseudo point-source model, we investigated the applicability of a corner frequency model representing rupture directivity effect. The target is the 2005 Central Chiba earthquake (M_w5.9). First, we searched for the optimal corner frequencies at each target station as the error between synthetic and observed Fourier spectra becomes minimum. The result was that the optimal corner frequency was about 1.0Hz in the west of the epicenter where underestimation was found in the previous study, in which the corner frequency of 0.75Hz was used for all the target stations. Therefore, this result indicates that forward directivity could have affected the stations to the west of the epicenter. The optimal corner frequencies were smaller at surrounding stations; this also implies that introducing rupture directivity effect can improve the pseudo point-source model.
Then, we assumed a unilateral rupture along a line source to model the corner frequency. Under this condition, the corner frequency becomes a function of the angle between the direction of rupture propagation and wave propagation to a target station (φ). New source parameters we need are the length of the rupture (L), the rupture velocity (V_r) and the direction of the rupture propagation. Then the corner frequency (f_c) can be represented as $f_c=(V_r/\pi L)(1-V_r/V_s \cdot \cos\varphi)$. This means that the corner frequency varies depending on the apparent duration of the rupture; the corner frequency is higher in the forward region and lower in the backward region with respect to the rupture propagation. We plan to search for the parameters that minimize the error between the observed and synthetic Fourier spectra. Then, this result will be compared with the result of the previous study (f_c=0.75Hz). In addition, the rupture propagation indicated by the optimal parameters will be compared with the rupture process of the earthquake estimated from waveform inversion.

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