A study using waveform simulations on the applicability of seafloor strong motion records to the source process analysis

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Because of the recent development of seafloor strong motion observation networks in the subduction zone of Japan such as DONET and S-net, seafloor strong motion records become available in the source process analysis. The use of seafloor records leads to the improvement in station coverage of the source process analysis for offshore earthquakes, which can improve the resolution and reliability of the analysis (e.g. Iida et al. 1988; Iida 1990). However, because of a limited knowledge on the offshore subsurface velocity structure, it is difficult to obtain Green's functions that can reproduce observed waveforms. Moreover, 1D synthetic waveforms, which are calculated with a 1D velocity structure model and widely used in conventional source-process analyses, are inappropriate to consider the offshore heterogeneous structure including a seawater, a rolling seafloor, thick sediments, and a subducting oceanic plate. One approach for this is to use 3D synthetic waveforms, which are calculated by 3D numerical simulations with a 3D velocity structure model; however the use of them is not easy because of a limited knowledge on the offshore structure and the high calculation cost. In this study, based on waveform simulations, we investigate the applicability of seafloor records to the source process analysis.
We prepare 3D synthetic waveforms for models with/without a seawater and 1D synthetic waveforms at S-net stations off Fukushima for near-coast and near-trench shallow crustal earthquakes in three period bands of 5-10 s, 10-25 s, and 25-50 s. 3D synthetic waveforms for a model with a seawater are calculated with a 3D FDM simulation (Takemura et al. 2015) assuming a 3D velocity structure model, which is based on the 3D subsurface structure model of J-SHIS (Fujiwara et al. 2009, 2012) including topographies and a seawater layer. 3D synthetic waveforms for a model without a seawater are calculated assuming a 3D velocity structure model, which is same as the above model but a seawater layer is replaced with an air. 1D synthetic waveforms are calculated at each station with the discrete wavenumber method (Bouchon 1981) and the reflection/transmission matrix method (Kennett and Kerry 1979) assuming a 1D velocity structure model for each station, which is extracted from the J-SHIS model.
To investigate the effect of a seawater layer, we compare the 3D synthetic waveforms for models with/without a seawater. Although the waveforms at transverse component are almost similar, the difference between their waveforms at radial and vertical components appears at periods lower than 25 s. The distribution of stations with the waveform difference depends on the horizontal event location: the waveform differences in the near-coast event are found at stations with a deep water depth, while these in the near-trench event are shown at almost all stations. Previous studies (e.g. Nakamura et al. 2014; Noguchi et al. 2016) demonstrated that the presence of a seawater and sediments leads to the excitation of oceanic Raleigh waves and that the predominant period of the fundamental mode of the Rayleigh waves depends on the seawater thickness. Our result and previous studies suggest that in the case of the near-trench earthquakes and/or the use of waveforms at stations with a deep seawater depth, appropriate waveform components and period band for the source process analysis are limited as long as Green's functions for a model without a seawater are used.
We also investigate how the 1D synthetic waveforms can reproduce the 3D synthetic waveforms considering the offshore heterogeneous structure. The waveform comparison suggests that although the amplitude difference and the time shift of S-wave and later phases are shown at many stations, there are stations that the phases of S-wave are similar. This suggests the possibility that seafloor records after the corrections of time shifts and amplitude differences can be used in the source process analysis.

Keywords: Seafloor strong motion records, Source process analysis, Waveform simulations

