Prediction of surface ground motion using underground seismic records based on data assimilation (2)

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Introduction

To improve Earthquake early warning (EEW), methods using data assimilation have been proposed for seismic wave field prediction (e.g. Hoshiba et al., 2015) and tsunami prediction (Maeda et al., 2015). Hoshiba et al. (2015) used radiative transfer theory to predict the spatial distribution of seismic intensity. Maeda et al. (2015) used wave equation for tsunami prediction. Recently, Furumura et al. (2018 SSJ) used wave equation for the prediction of long-period seismic ground motion. However, data assimilation based on wave equation has probably not yet used for short-period seismic waves due to restrictions on the density of observation stations, computational costs, and so on. In order to predict short period seismic waves, therefore, we started to apply data assimilation based on wave equation to one-dimensional problems for vertical boreholes such as KiK-net (Ishihara and Nakahara, 2018 SSJ). If we can reproduce surface seismic records quickly and precisely from subsurface seismic records, we will be able to speed up the issuing of alarms more quickly than with surface earthquake records alone. This research is regarded as a basic research towards the advancement of the onsite type EEW for local earthquakes.

Data, Method

In this study, we used NIED KiK-net CHBH10 (Chiba) station. At this observation site, strong motion seismometers are installed on the surface and at a depth of 2000m. We analyzed 60 earthquakes of over M5 occurring around Chiba prefecture. In the simulation, we used the method of Tanaka & Takenaka (2004) which can solve the oblique incidence of plane waves in horizontally stratified structure efficiently by the finite difference method. We calculated the direction of arrival and the incident angle of seismic waves from the particle trajectory of the 1-second-long initial P waves on subsurface records. We simulated the wavefield based on the finite difference method using seismic velocity structure estimated from the logging information. Using the calculated incident angles and subsurface records, we simulated waveforms on the ground surface and compared them with observed waveforms.

Results and discussion

Ishihara and Nakahara (2018 SSJ) found out two problems in this analysis. First, the degree of the fit between observed and calculated waveforms becomes worse with the lapse time. This is caused by artificial upgoing waves which occur when observed waveforms (upgoing wave + downgoing wave) and calculated waveforms (falling wave) do not match at a subsurface station. Another big problem is that the degree of the fit is deteriorated as the angle of incidence becomes larger. This is because artificial SV waves are generated due to the absence of information about stress when inputting observation values (particle velocity) of P waves at the subsurface observation station.
In this study, we calculated the ratio of artificial SV to P waves assuming only P wave input (stress input is zero) to evaluate this effect. The incident angle was varied from 0 °to 45 °with a step of 1 °. As a result, artificial SV waves are generated with an amplitude of about 4% of the P-wave maximum amplitude for an incident angle of 10 °, about 10% for 20 °, about 25% for 30 °and 50% for 45 °. In addition, in order to

reduce this effect, we are repeating simulations by adding virtual stress conditions and subsurface observation stations.
In the future, we will compare our result with the wavefield calculation of Haskell (1962). In order to solve these problems and to improve the prediction accuracy, we will consider optimum arrangements of subsurface observation stations and suitable settings of appropriate stress conditions.

Keywords: earthquake early warning, data assimilation