A hybrid method of simulating broadband ground motion : A case study of the 2006 Pingtung earthquake, Taiwan

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ABSTRACT

For the demand of engineering, the time-history of ground motions which consider the reliability and earthquake physical characters have been provided for earthquake resistant design of important building structures. However, the high frequency portion (> 1 Hz) of near-fault ground motions was restricted by the insufficient resolution of velocity structure. Considering the relative small events which contain path and site effect in waveforms as Green's functions (i.e. empirical Green's function (EGF) method) can resolve the problem of lack of precise velocity structure to replace the path effect evaluation. Alternatively, a stochastic Green's function (SGF) method can be employed when the EGF is unavailable. Further, the low frequency (< 1 Hz) can be obtained numerically by the Frequency-Wavenumber (FK) method. Thus, broadband frequency strong ground motion can be calculation by a hybrid method that combining a deterministic FK method for the low frequency simulation and the EGF or SGF method for high frequency simulation. The slip models had been investigated from Taiwan dense strong motion and global teleseismic data. Characterizing the slip models derived from the waveform inversion can directly extract the source parameters needed for the ground motion prediction in the EGF method or the SGF method. The nuclear power plant in southern tip of Taiwan was experienced a strong shaking by the 26 December 2006 Pingtung, Taiwan offshore earthquake. The closest strong motion station of the Central Weather Bureau, KAU082, recorded the peak acceleration value (PGA) of 0.24 g. We considered the adjacent stations to be the case study for possibility evaluation of predicting ground motion utilizing the EGF method or SGF method. The possible damage impact toward nuclear power plant for specific sites can be estimated and verified according to the simulation results

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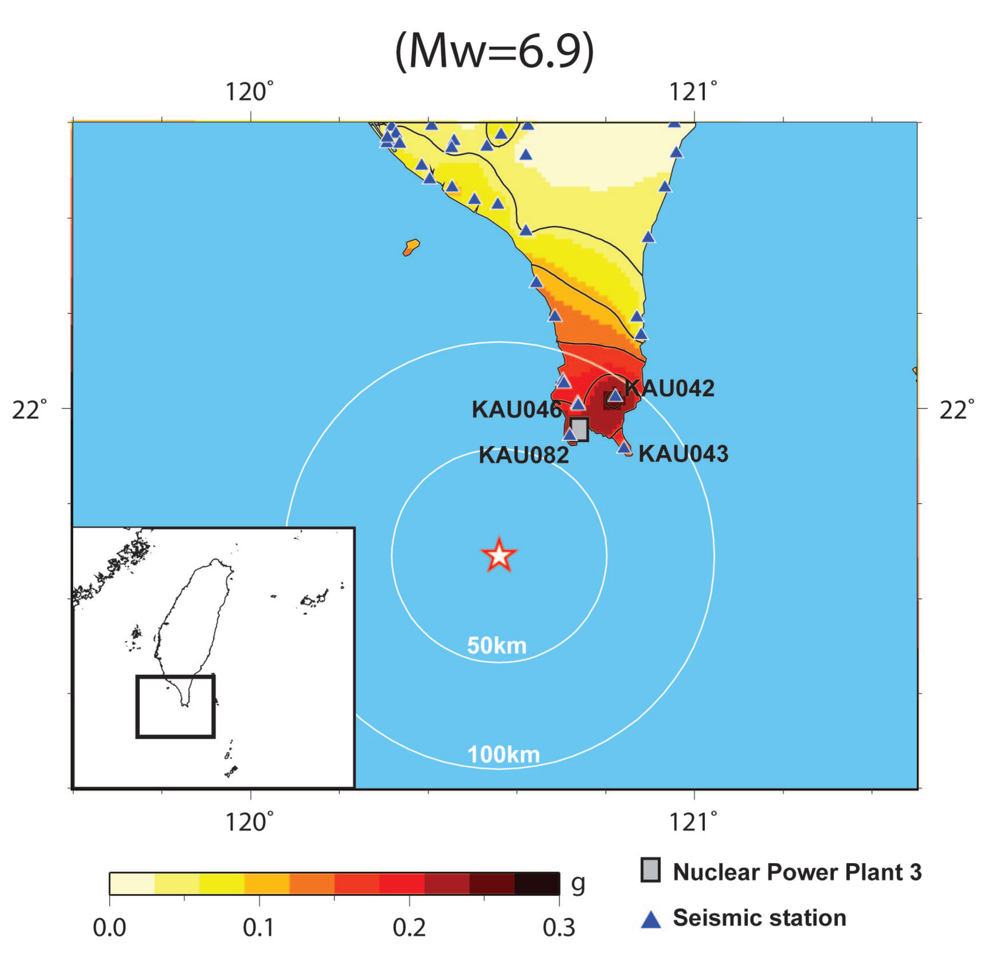
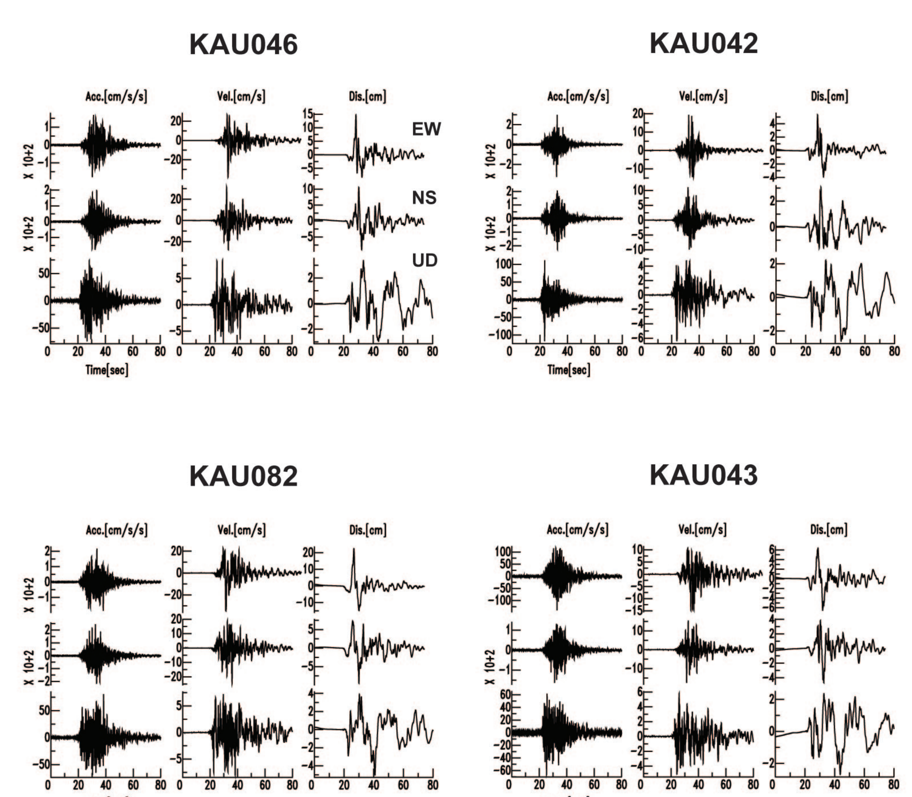
Abstract

For the demand of engineering, the time-history of ground motions which consider the reliability and earthquake physical characters have been provided for earthquake resistant design of important building structures. However, the high frequency portion (> 1 Hz) of near-fault ground motions was restricted by the insufficient resolution of velocity structure. Considering the relative small events which contain path and site effect in waveforms as Green's functions (i.e. empirical Green's function (EGF) method) can resolve the problem of lack of precise velocity structure to replace the path effect evaluation. Alternatively, a stochastic Green's function (SGF) method can be employed when the EGF is unavailable. Further, the low frequency (< 1 Hz) can be obtained numerically by the Discrete-Wavenumber (DWN) method. Thus, broadband frequency strong ground motion can be calculation by a hybrid method that combining a deterministic DWN method for the low frequency simulation and the EGF or SGF method for high frequency simulation. The slip models had been investigated from Taiwan dense strong motion and global teleseismic data. Characterizing the slip models derived from the waveform inversion can directly extract the source parameters needed for the ground motion prediction in the EGF method or the SGF method. The nuclear power plant in southern tip of Taiwan was experienced a strong shaking by the 26 December 2006 Pingtung, Taiwan offshore earthquake. The closest strong motion station of the Central Weather Bureau, KAU082, recorded the peak acceleration value (PGA) of 0.24 g. We considered the adjacent stations to be the case study for possibility evaluation of predicting ground motion utilizing the Hybrid method. The possible damage impact toward nuclear power plant for specific sites can be estimated and verified according to the simulation results.

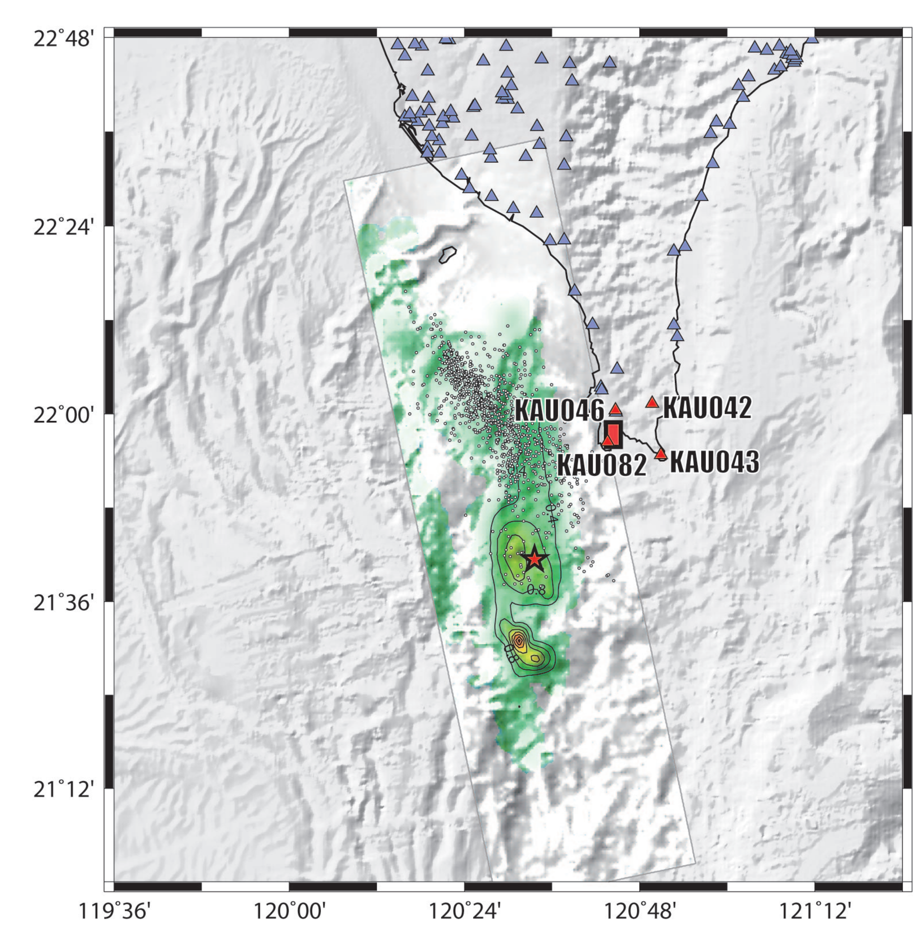
Observed Data



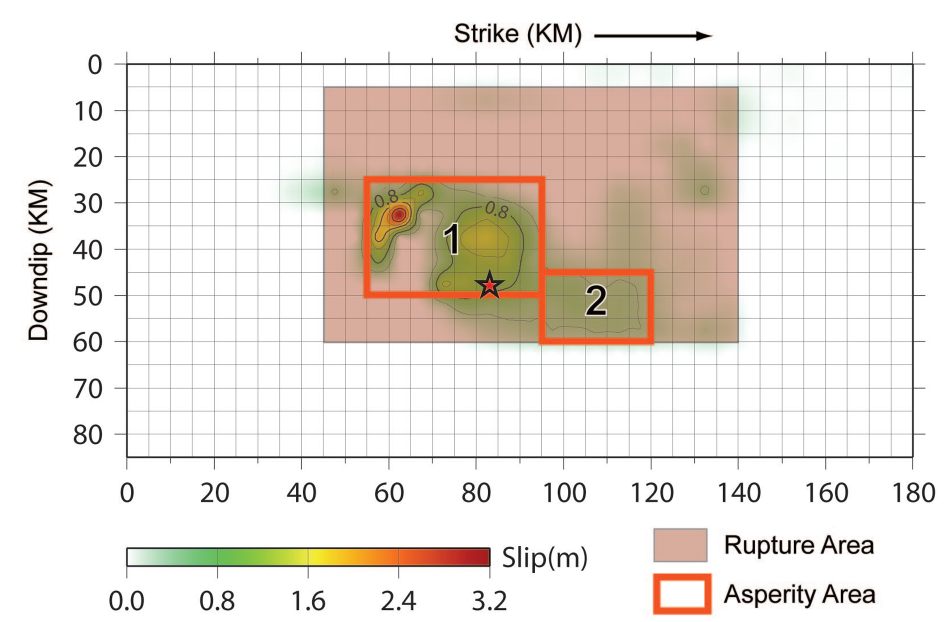


The strong motion waveforms of four stations were chosen to be verified. The figure shows the location of four stations as well the acceleration, velocity and displacement waveforms of three components.

Characterized Slip Model

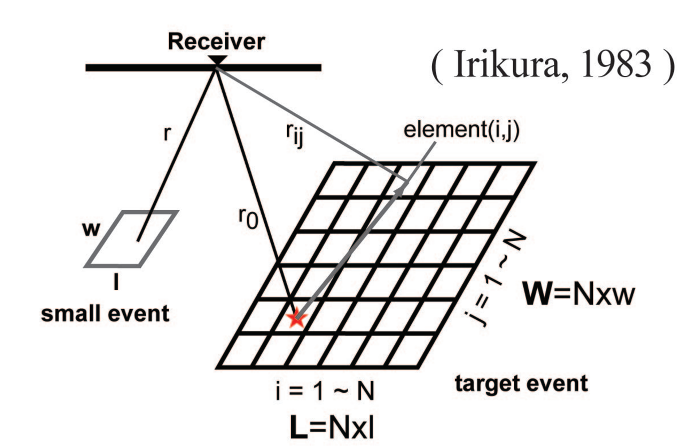


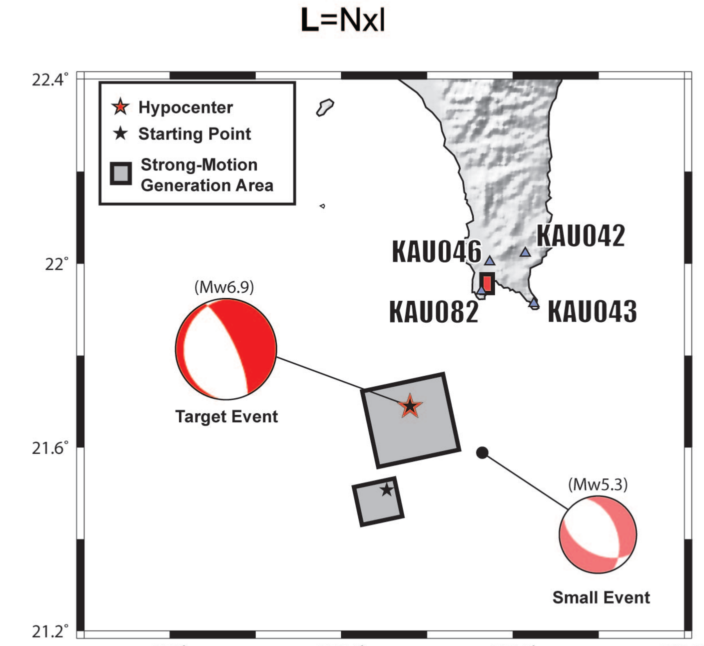
From the slip model of Lee et al. (2008) inverted from strong-motion data, most of the rupture occur along north-south direction and slip toward down-dip direction. Two main asperities can be found over the fault plane. One asperity is close to the hypocenter with larger slip, and another to the south of hypocenter with large slip of about 3 m. The depth range of two asperity is between 25 to 35 km. Red rectangular shape in the figure is the location of nuclear power plant (NPP). The seismic station KAU082 is very close to the NPP.

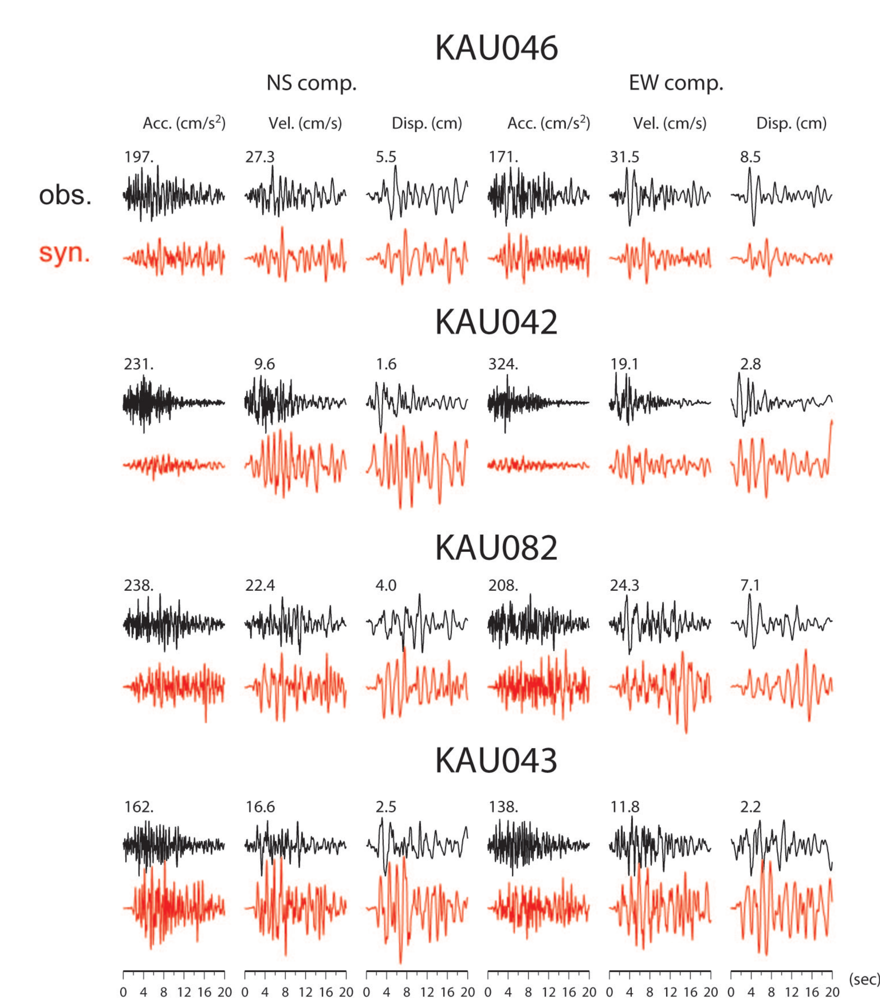


Somerville et al. (1999) has provided a method to extract the rupture area and the asperities with quantitative criterions. We characterized the slip model to dig out the main asperities according to the slip model of Lee et al. (2008). Two main asperities were defined. Their areas are 40 $\times$ 25 km^2 and 25 $\times$ 15 km^2, respectively. Characterized slip model with two asperities is used to calculate the low frequency waveforms.

High Frequency simulaiton with EGF method

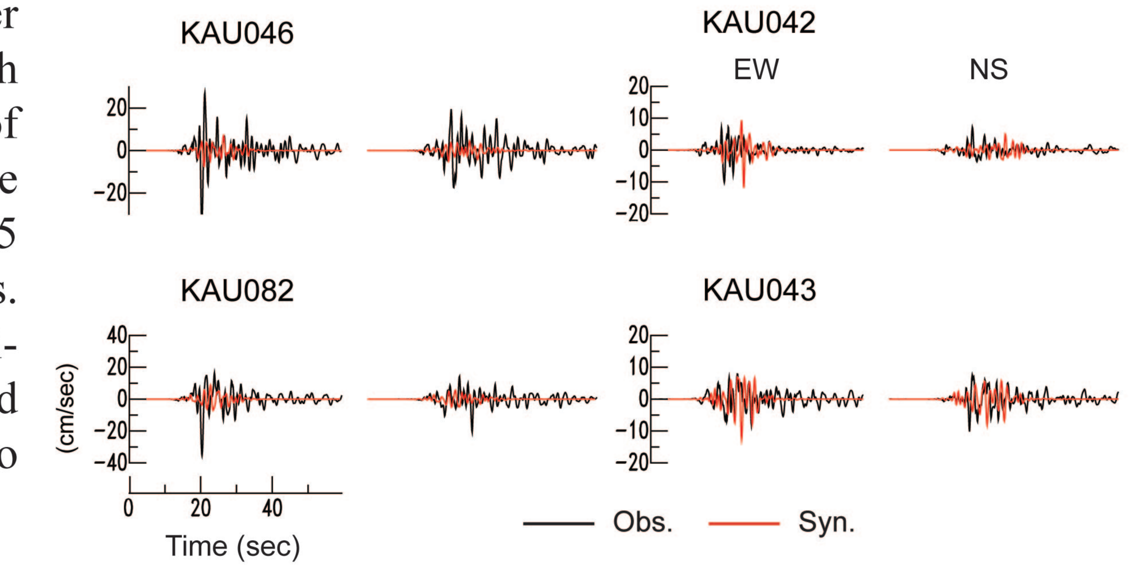




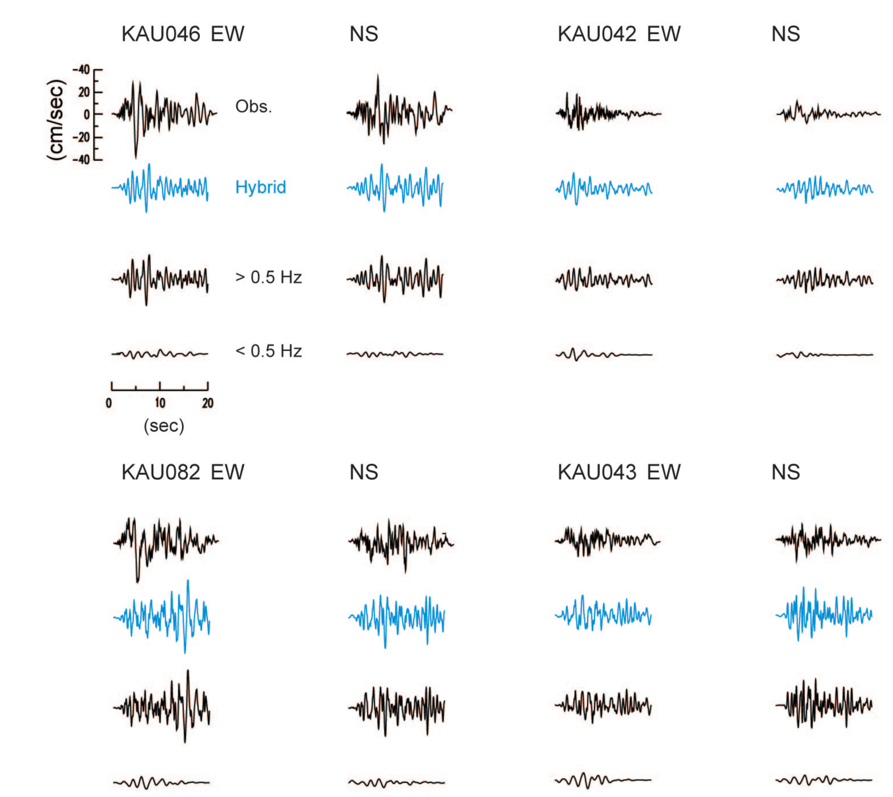


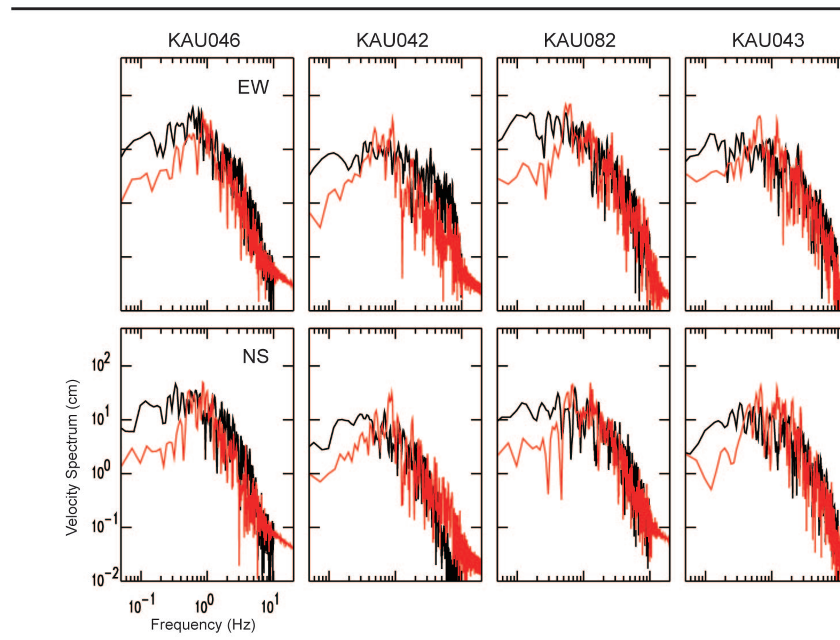
Low Frequency simulation with DWN method

Low frequency waveform (lower than 1 Hz) were simulated with the characterized slip model of two main asperities defined. The areas of 40 $\times$ 25 km^2 and 25 $\times$ 15 km^2 consist of several subevents. The Green's functions of individual subevents are calculated based on the DWN method (Yao and Harkrider, 1983).



Hybrid result & Discussion





The time length of horizontal components about 20 sec after the arrival of S wave was taken to be performed. We found that the lower frequency waveforms can not be explained up to 1 Hz. The reason might be the lack of shallow layer information in the velocity structure when carrying the low frequency simulation . Thus, We combined the low- and high frequency synthetic waveforms accomplished by matched filtering (Hartzell et al., 1999) with a crossover at 0.5 Hz because the site information was included in the high frequency portion of waveform simulation for the EGF method that the observed small event is considered as the empirical green's function.

For futher progress, characterized slip model for the simulation of low frequency potion have to be corrected according to the result of comparison between observed and simulated velocity spectra.

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