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Wavelet domain inversion for estimating the broadband source process

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Estimating source process from the broadband strong motion records is recent challenging issue. One problem to be solved for this is how to evaluate the fittings of broadband seismic records. Miyake et al. (2003) estimated the slip-velocity intensity distribution for several frequency ranges using the complex spectral inversion. They succeeded by imposing the smaller weight on phase spectra for the higher-frequency range. Asano and Iwata (2007) derived the distribution of the slip, maximum slip-velocity and rupture time from the joint inversion of low-frequency velocity waveforms and high-frequency acceleration envelopes. In this study, we will use the wavelet coefficients of broadband waveforms as a target of the source inversion. Square of wavelet coefficient more or less presents power of the signal in time (shift) and frequency (scale) domains. The introduction of the wavelet transform enables us to evaluate the fittings between the observed and synthetic records according to its frequency-dependent characteristics.

Ji et al. (2002) estimated the source process of the 1999 Hector Mine earthquake by wavelet domain inversion. They calculated the Green's function by a theoretical approach, and therefore, its frequency range is limited below 1 Hz. In this study, we employ the empirical Green's function (EGF) method in order to simulate the broadband strong motions including high-frequency range. Following Ji et al. (2002), Meyer-Yamada wavelet proposed by Yamada and Ohkitani (1991) is used as a wavelet basis. This wavelet has compact support or zero value outside of certain range in the frequency domain. It, therefore, works efficient band-pass filter to the strong motion records. A series of the wavelet coefficients itself can be used as a target for scales corresponding to the low-frequency range. However, it is difficult for scales of the high-frequency range to match coefficient itself, since the phase change is fast and looks random. For these scales, absolute value of the wavelet coefficients is used to evaluate the fitness in the form like an envelope. Dealing the wavelet coefficients suitably according to their frequency-dependent characteristics explained above, we try to estimate the source process from the broadband strong motions. Model parameters are the distributions of the slip-velocity intensity and rupture time. The slip-velocity intensity estimated here is relative value to that of the small earthquake whose records are used for EGF. This inversion problem is nonlinear and solved iteratively using the least-squares algorithm.

We confirm the validity and resolution of the inversion method by a numerical test using the source model imitated for the 2000 Western Tottori earthquake. Wavelet coefficients in use are those whose scales corresponding to four frequency ranges 0.2-0.39, 0.39-0.8, 0.8-1.6, and 1.6-3.2 Hz, respectively. The different evaluation of fittings described above is employed taking 1.6 Hz as a boundary frequency between low- and high-frequency ranges. It is found that since the rupture time is less sensitive in the inversion than slip-velocity intensity, the reproducibility for the slip-velocity intensity and rupture time distribution depends on the rupture velocity assumed in the initial model. When the rupture velocity of the initial model is appropriate, the inversion successfully recovers the assumed source model even if the noises are put to the data. Inversions using only low-frequency scales and high-frequency scale can reproduce the assumed distribution each other. Source process obtained from broad and several (high or low) frequency bands will reveal its frequency-dependent characteristics. We will apply this new inversion method to the real data of the 2000 Western Tottori earthquake.