Evaluation of source parameters in the Bayesian framework by Markov Chain Monte Carlo method

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Stress drop is an important factor to express earthquake source characteristics, and it is utilized for the hazard assessment. To estimate the stress drop, we usually compare the theoretical source spectrum representation with the spectrum of the observed waveforms. In this process, we estimate seismic parameters (corner frequency and seismic moment) that are necessary to calculate the stress drop. Previously, the estimation error of these parameters decreased the reliability of the stress drop estimates. For evaluating the estimation accuracy and trade-off among parameters, we used Markov Chain Monte Carlo (MCMC) method in the Bayesian framework for stress drop analysis (Yoshimitsu et al., SSJ, 2018) instead of grid search.

In this study, we introduce F-distribution into MCMC as a probability density function instead of normal distribution. To estimate the stress drop, we use the spectral ratio of co-located two earthquakes to cancel the path effect. The ratio of power spectrum between observed and theoretical spectrum is represented by chi-square, and the ratio of two chi-squares is represented by F-distribution. Thus, the ratio of the observed power spectrum of two earthquakes divided by the ratio of the theoretical power spectrum of two earthquakes is represented by F-distribution.

We focused on a cluster consisted of 36 earthquakes that occurred from 2015 May to 2016 November in Oklahoma. The spectral ratios between the large event ($M_L = 4.1$) and co-located small events ($2.2 < M_L < 3.7$; < 2 km from the large event) were formed to remove path effects. We analyzed 5.12 seconds after twice the S-arrival time with the band-pass filter of 0.5 to 30 Hz. To examine the probability of corner frequencies and moment ratio of each event pair, we applied the Metropolis-Hastings algorithm of the Markov Chain Monte Carlo method that is a random walk adaptation. Each event observed a different number of stations, and we used as many stations as possible. To calculate the likelihood, we use all spectral ratios simultaneously. We update the value of moment ratio and two corner frequencies with 200,000 iterations.

Sampling distribution showed strong trade-off among all three parameters. Moment ratio has a negative correlation with f_{c1} and f_{c2}. f_{c1} has a positive correlation with f_{c2}. The histogram of the sampling showed a single peak in most cases, but some events showed multimodal histogram.

We compared the results obtained from MCMC with F-distribution and normal distribution. Both calculations showed almost similar estimates, but the sampling distribution was different. In this analysis, F-distribution is suitable for probability density function than normal distribution because sampling distribution is reasonable.

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