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Seismic energy estimation of repeating earthquake sequences offshore northeastern Japan

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Repeating earthquakes are thought to occur on locked patches, which represent almost time-independent irregularity on the plate interface, to catch up with stable slip on the surrounding interface. Thus, they produce spatial and temporal stress heterogeneity around the source area, which may control the spatial and temporal patterns of seismic energy of repeating earthquakes. We estimate seismic energy for many small to moderate repeating earthquakes that occurred offshore northeastern Japan, to understand the nature of stress heterogeneity and hidden structural irregularity.

Seismic energy reflects dynamic fault motion during an earthquake, while seismic moment is determined by the difference between the initial and final states of the fault. Seismic moment is determined relatively precisely using the low frequency limit of seismic spectra. In contrast, seismic energy has large errors because it is determined from the entire frequency range of seismic spectra, after correcting path and site effects which can be significant especially at high frequencies. Another problem is the size dependence of seismic energy, which has been a matter of debate for two decades in seismological community. A typical question is whether scaled energy (the ratio of seismic energy to moment) is dependent on seismic moment. These problems have to be alleviated to discuss the spatial and temporal variation of radiated seismic energy. Seismic energy must be estimated as precise as possible.

As mentioned, the most serious problem in estimating seismic energy is removing path and site effects. To avoid this problem, the present study adopts an empirical Green's function (EGF) method. We regard the ratio of seismic spectra as the ratio of source spectra, since the seismic spectra of co-located events observed at one station share the same path and site effects. We modify an EGF method with coda waves developed by Baltay et al. (2010), to rigorously evaluate the uncertainty in corner frequencies and the effects of noise.

This method is applied to several repeating earthquakes of magnitude ˜2 to 6 that occurred offshore northeastern Japan. We estimate seismic energy for a group of events by calculating the ratios of source spectra using S-coda waves in two horizontal components of Hi-net, National Research Institute for Earth Science and Disaster Prevention. The scaled energy is almost constant or slightly increasing with seismic moment. Nevertheless, the results are still tentative because the estimation of seismic energy is dependent on the assumption of source spectral model, such as the omega-square model, which have not been constrained well.