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Estimation of Radiated Seismic Energy of Repeating Earthquakes in Northeastern Japan and its Spatio-Temporal Variation

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Seismic activity on the plate interface is spatially heterogeneous. In addition to ordinary earthquakes of different sizes, tsunami earthquakes and slow earthquakes occur with much longer duration expected from the scaling relation of ordinary earthquakes. However, for example, the source areas of tsunami earthquakes are known to be located at shallower part of plate interface. Additionally, in the source area of the Tohoku-Oki earthquake, more high frequency seismic wave was radiated at deeper region of the plate interface [Ide et al., 2011]. Therefore, the fault property of the plate interface in the Tohoku-Oki region can be spatially heterogeneous. The spatial heterogeneity on the plate interface may result in the variation of radiated seismic energy, which conveys the information of dynamic rupture process. Among various earthquakes occurring near the plate interface, repeating earthquakes are relatively easy to understand because of its simple mechanism, as repeated slips of a small locked region of the plate interface to catch up with aseismic slip in surrounding region. Since, repeating earthquakes are considered to occur on the plate interface certainly, they are ideal targets to constrain the physical mechanism of brittle rupture on the plate interface. Many repeating earthquakes have been detected in the Tohoku-Oki region. The size and inter-event time of some repeating earthquake groups changed after the Tohoku-Oki earthquake. To examine the possible change of source process after the Tohoku-Oki earthquake can also contribute to the understanding of physical process of earthquakes. In this study, we estimated the radiated seismic energy of repeating earthquakes in the Tohoku-Oki region and examined its spatio-temporal variation.

The target earthquakes of this study are 160 repeating earthquakes detected by Uchida and Matsuzawa [2013]. These earthquakes are divided into 52 repeating earthquake groups. Seismic activity of these events extends before and after the Tohoku-Oki earthquake and includes groups that showed enlarged magnitude and shortened inter-event time after the earthquake as represented by Kamaishi sequence. To estimate radiated seismic energy, we use the method for measuring amplitude developed by Mayeda et al. [2003] and the method for estimating source spectra and radiated seismic energy developed by Baltay et al. [2010] with slight modifications. In this modification, we linearized the calculation to quantitatively estimate the error of the radiated seismic energy that has not been discussed precisely.

We obtained a positive depth dependency of scaled energy, the ratio between radiated seismic energy and seismic moment, as a main characteristic of spatial variation. This is consistent with the results in previous studies. We also observe some temporal changes in scaled energy. For Kamaishi-sequence, the scaled energy decreased suddenly after the Tohoku-Oki earthquake and gradually recovered, coinciding with a sudden increase and gradual decay of seismic moment. This temporal change of seismic moment has been interpreted as the expansion of rupture into conditionally stable region around the unstable region [Uchida et al., 2015]. The temporal change of scaled energy suggests that the ratio of fracture energy is larger in this conditionally stable region.

Radiated seismic energy is related to the strength of the fault, which increases after an earthquake. Therefore, we expect some correlation between the inter-event time and scaling energy for repeating earthquakes. In our result, there are several groups and regions that have positive dependency of scaled energy on the inter-event time, but this relation cannot be confirmed generally.