

Estimating source parameters of tectonic tremors using particle motions of continuous seismic records

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Slow earthquakes are now observed in subduction zones worldwide and are keys to understand subduction processes and earthquake source physics. Among various types of slow earthquakes, tectonic tremors are identified in seismic records at high frequency bands and highly relevant to background slow slip events (SSEs). The waveforms of tremors are composed of the superposition of seismic signals derived from tiny seismic sources, such as low frequency earthquakes, hence inevitably difficult to obtain their source characteristics.

Even in the case, polarization characteristics of continuous seismic records are useful for detection and deducing source information of tremors. Wech and Creager (2007) has shown that the ground motion derived from tremors show stable linear particle motion. Such polarization characteristics are extensively used in many studies to constrain the focal mechanisms of tremors (e.g. Wech and Creager, 2007; Imanishi et al., 2015). However, the previous studies are only based on the polarization direction. In this study, we propose a new robust method to estimate source parameters of tremors using both polarization directions and amplitudes.

We first calculate the average particle motion polarization direction for a given time window of displacement records on the basis of the three-component covariance matrix. The dominant polarization direction is represented by the first eigenvector. For the polarization amplitude, we integrate the displacement amplitude in the dominant direction. We define the observed “polarization vectors” by multiplying the first eigenvectors by the polarization amplitudes at all network stations. Assuming the source location, focal mechanism and seismic moment, we theoretically calculate the synthetic S polarization vectors at each station. By minimizing the error between the observed and theoretical polarization vectors in the least squares sense, we estimate the optimum source location and the focal mechanism.

We apply the method to the OBS network data in the off-Miyagi region to approximate the source locations the shallow tremors before the 2011 Tohoku-Oki earthquake (Ito et al., 2015). We assume the focal mechanisms as the same low angle thrust fault on the plate interface a priori due to the limited number of available stations and estimate just their source locations and seismic moments. The tremor timings are also estimated by the clustering technique. The method works well to constrain the tremor timings and locations. The estimated tremor sources are roughly separated to two regions (deeper and shallower) across the SSE region (Ito et al., 2013). The result also shows the migration of tremor sources from deeper to shallower part toward the timing of the largest foreshock of the 2011 Tohoku-Oki earthquake, which suggests the rupture propagation of coincidental slow slip event. We also show the application result of the method to synthetic data and deep tremors in the western Japan.

Keywords: tremor, polarization, source parameter