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Determination of focal mechanisms of non-volcanic tremors using S-wave polarization: Correction for shear wave splitting

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Non-volcanic tremors (NVTs) have been found at various plate boundaries during the last decade. Focal mechanisms of NVTs are important for better understanding physical mechanisms of tremor generation. Stacking of many similar event waveforms greatly enhances the signal to noise ratio of tremor signals, which enables us to use conventional focal mechanism determination methods based on P-wave first motion polarities and/or waveforms (Ide et al., 2007; Bostok et al., 2013). However, the stacking approach cannot resolve spatio-temporal variations of focal mechanisms, so a new method is needed.

Imanishi and Takeda (2010) conducted a polarization analysis to continuous seismic data and showed that the scatter in the particle motion directions becomes small in accordance with a period of NVT activity. The same conclusion was reported for Cascadia tremors by Bostock and Christensen (2012). Because NVTs are primarily composed of shear waves (e.g., Obara, 2002), our observed particle motions contain information regarding focal mechanisms. However, the shear wave particle motion should be treated in caution, since shear-wave splitting may distort the particle motion excited by a seismic source (e.g., Zhang and Schwartz, 1994).

In this study, we first explored the existence of seismic anisotropy using tremor signals. A standard shear-wave splitting analysis (Silver and Chan, 1991) was used to determine the fast polarization direction (LSPD) and the lag time between fast and slow shear waves (DT). The analysis detected clear split arrivals separated by about 0.1 s, indicating the need of the correction for splitting effects to recover radiation pattern of S-wave. The LSPD shows two major directions which are normal or subparallel to the strike of the plate margin. These results are consistent with previous studies using regular earthquakes (e.g., Saiga et al., 2011), demonstrating that tremor signals are also available to investigate seismic anisotropy.

We then determined focal mechanisms of NVTs by correcting for splitting effects on particle motions. The actual procedure is as follows:

(1) We rotate two horizontal seismograms to the fast and slow directions, advance the slow wave by the lag time, and rotate back to NS and EW directions.

(2) A polarization analysis is subject to 1 minute windows to determine S-wave polarization angles.

(3) Average and standard deviation of polarization angles are calculated at each hour.

(4) A grid search approach is performed at each hour to determine the best double-couple solution using polarization angles of multiple stations. Here the epicenter is determined by an average of locations using our ECM catalogue. The depth is assumed to be 35 km.

(5)Uncertainty is estimated based on a bootstrap approach.

We applied the above method to a tremor sequence at northern Mie prefecture that occurred at the beginning of April 2013. Most solutions show NW-dipping low-angle planes or SE-dipping high-angle planes. Because of 180 degrees ambiguity in polarization angles, the present study alone cannot distinguish compressional quadrant from dilatational one. Together with the observation of very long frequency earthquakes near the present study area (Ito et al., 2007), however, it is reasonable to consider that they represent shear slip on low-angle thrust faults. It is also noted that some of focal mechanism solutions contain large strike-slip component. We will present the spatial and temporal characteristics of focal mechanism solutions based on the analysis of more tremor sequences.

Keywords: Non-volcanic tremors, Focal mechanism, Polarization analysis, Shear wave splitting