Detection of shallow very low frequency earthquakes and estimation of energy rate of low frequency tremors in the Costa Rica subduction zone

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Slow earthquakes, such as low frequency tremors (LFTs), very low frequency earthquakes (VLFEs), and slow slip events (SSEs), are fault slip events with slower slip speed than regular earthquakes and occur mainly in subduction zones. In the Costa Rica subduction zone, thrust type large earthquakes with Mw of 7–8 occur repeatedly. Jiang et al. (2012; 2017) pointed out that large slip areas of SSEs were distributed in both downdip and updip areas of the coseismic slip of large earthquakes. Outerbridge et al. (2010) located LFTs in downdip of the coseismic slip area of large earthquakes, whereas Walter et al. (2011; 2013) found LFTs and VLFEs that occur in the updip.

To clarify the relationship between the distributions of slow earthquakes and large regular earthquakes, we detected VLFEs in the Costa Rica subduction zone by the matched-filter technique. We used waveforms of a temporary seismic network, Tomography Under Costa Rica and Nicaragua (TUCAN; Abers and Fischer, 2003), recorded from August 2004 to January 2006. We computed synthetic waveforms at stations from each virtual source grid using OpenSWPC (Maeda et al., 2017) and a 3D velocity model. The grids were widely distributed on the plate boundary beneath both onshore and offshore areas. The focal mechanisms were assumed to be consistent with the geometry of the plate boundary and with plate motion. After applying a band-pass filter of 0.02–0.05 Hz, we calculated cross-correlation coefficients between the synthetic and observed seismograms every 1 s, and selected events whose cross-correlation coefficients exceeded the threshold defined as 9.5 times the median absolute deviation of the distributions. After removing false detections, we also estimated seismic moments and durations of detected VLFEs based on the synthetic waveforms.

As a result, we detected 76 VLFEs mostly in September 2004 and August 2005. Most of VLFEs are located near the trench axis, in the depth range of 5–10 km, updip of the coseismic slip areas of large earthquakes. Furthermore, we found LFT signals in a frequency range of 2–8 Hz within the same time windows of VLFEs. We estimated energy rate functions of such LFTs assuming that an LFT occurs in the same location as the accompanying VLFE. Energy rate functions of LFTs were evaluated based on envelope waveforms in a frequency range of 2–8 Hz. The range of energy rates of LFTs is $10^{3.5}$–$10^{5.5}$ J/s. We estimated the scaled energy from the ratio between the seismic energy rate of an LFT and the seismic moment rate of the corresponding VLFE. The range of scaled energy of slow earthquakes in the Costa Rica subduction zone is 10^{-9}–10^{-8}, which is similar to that of shallow slow earthquakes in the Nankai subduction zone (Yabe et al., 2019).