Comprehensive detection of very low frequency earthquakes off the Pacific coasts of Hokkaido and Tohoku, northeastern Japan

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Very low frequency earthquakes (VLFEs), classified as one type of slow earthquakes, occur near seismogenic zones. VLFEs off the Pacific coasts of Hokkaido and Tohoku in northeastern Japan occur around subducting plate interfaces near trenches. Asano et al. (2008) found VLFEs in the off-Tokachi region, the southern part of the Pacific coast of Hokkaido along the Kuril Trench, by array signal processing using high-sensitivity accelerometers of Hi-net operated by National Research Institute for Earth Science and Disaster Resilience (NIED). In recent years, VLFEs off the Pacific coast of Tohoku were found by visually checking broadband seismograms of F-net operated by NIED and other events were detected by the matched-filter technique using waveforms of detected events as templates (Matsuzawa et al., 2015). However, the number of detected VLFEs may have been limited because of the small number of the VLFE templates in previous studies. Baba et al. (2018, SSJ) set four virtual epicenters off the Pacific coasts of Hokkaido and Tohoku and detected VLFEs by the matched-filter technique using numerically simulated waveforms as templates. We extended virtual epicentral gridsto make more comprehensive detection of VLFEs.

We used continuous seismograms of F-net seismometers from January 2003 to July 2018 after applying a band-pass filter of 0.02–0.05 Hz. We set 123 virtual epicentral grids off the Pacific coasts of Hokkaido and Tohoku, and computed the synthetic waveform from the source at each virtual epicenter by the finite difference method with a three-dimensional velocity structure model, namely, Japan Integrated Velocity Structure Model (Koketsu et al., 2012). The fault mechanisms were assumed to be consistent with the geometry of the plate boundary and a plate motion model, NUVEL-1A. We then calculated station- and component-averaged cross-correlation coefficients (averaged CC) between synthetic waveforms and the data of F-net seismograms every 1 s, and selected the events which have averaged CC above nine times of the median absolute deviation of the distribution. This method is, however, sensitive to regular earthquakes and teleseismic events as well. We then excluded the signal of regular earthquakes by discarding events with the amplitudes of more than 160 nm/s at 1-2 Hz in vertical components at the nearest stations. Moreover, to remove teleseismic events, we used the USGS earthquake catalog and discarded events with high amplitudes and low averaged cross-correlation coefficients.

VLFE activities in the off-Tokachi and off-Aomori regions show synchronized episodic bursts in the interval of several months. VLFEs in the off-Tokachi region was rapidly increased by the afterslip of the 2003 Tokachi-Oki earthquake. Those in the off-Iwate and off-Ibaraki regions, located out of the coseismic slip area of the 2011 off the Pacific coast of Tohoku Earthquake (hereinafter, the Tohoku earthquake), were also rapidly increased by the afterslip of the Tohoku earthquake. VLFE activity in the off-Miyagi region is characterized by episodic bursts in the interval of several months to one year before the Tohoku earthquake, but it became low since then. VLFE activity in the off-Fukushima region show dramatic increase after an Mw 6.9 earthquake at off-Fukushima on July 19, 2008. In the off-Miyagi and

off-Fukushima regions, located within or at the edge of the coseismic slip area of the Tohoku earthquake, VLFE activity has been low since the Tohoku earthquake probably because the earthquake released the stress almost completely. These results suggest that VLFEs are sensitive to the stress perturbation and can be a slip meter that reflect spatiotemporal change of the interplate slip, as has been indicated by previous studies. Consequently, one possible cause of these episodic VLFE bursts in the off-Tokachi, off-Aomori and off-Miyagi regions may be the intermittent release of small portion of stress accumulated by interplate locking between plates in the interval of several months to one year. The interval of episodic bursts is shorter than a periodicity of slow slips ranging from 1 to 6 years off the Pacific coasts of Tohoku indicated by Uchida et al. (2016).

