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Very low frequency earthquakes off the Pacific coast of Tohoku located by Hi-net high-sensitivity accelerometers

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Various types of slow earthquakes have been reported in several subduction zones, after the discovery of deep low frequency tremor in the Nankai subduction zone (Obara, 2002). These slow earthquakes have lower dominant frequency than those of regular earthquakes. Very low frequency earthquakes (VLFEs) are the slow earthquakes which are dominant around the frequency of 0.05 Hz. Active VLFEs have been reported in the off-Tokachi and Nankai region (e.g., Obara and Ito, 2005; Asano et al., 2008). Recently, Ando et al. (2012) have reported VLFEs in the Ryukyu arc region. Very recent study using ocean bottom seismometers shows that shallow VLFEs in the Nankai region occur around the decollement (Sugioka et al., 2012). These VLFEs close to trench axes are considered as a key to understand the stress accumulation process in the shallow part of the subduction zone. Using F-net broadband seismometers, Matsuzawa et al. (2012) have reported VLFEs off the Pacific coast of Tohoku, where rare VLFEs were reported. In this study, to reveal the details of the VLFE activity in this region, we locate VLFEs using Hi-net high-sensitivity accelerometers which are more densely distributed than F-net seismometers.

In this analysis, we adopt a two-step cross correlation technique using a template event to locate VLFEs. An inter-plate regular earthquake is chosen as a template event. At first, we pick candidate events of VLFEs from F-net continuous broadband seismograms which are bandpass-filtered between 0.02 and 0.05 Hz. In the time window of 90 s, an epicenter is located to maximize averaged value of correlation coefficients (CC) within the range of 1 degrees from the template event in the latitudinal and longitudinal direction. If the maximum CC exceeds 0.5, this event is selected as a candidate event. At the next step, using Hi-net high-sensitivity accelerometers, we applied the similar correlation analysis in the finer spatial mesh (intervals of 0.02 degrees) to the candidate events. As regular earthquakes are included in the result, such earthquakes are removed from the list using the catalog of regular earthquakes and amplitude ratio of envelopes in the frequency band from 2 to 6 Hz. CC tends to be high without VLFEs, when surface waves of far-field large earthquakes arrive. Therefore, we excluded the events located in such noisy period, based on the result of the multi array analysis of high-sensitivity accelerometers (Asano et al., 2008). Finally, VLFEs are located, after the manual check of waveforms to remove apparent events caused by microseisms or the coda part of far-field events.

The VLFE activity off Fukushima-Ibaraki is most active in the region off the Pacific coast of Tohoku. In the previous study with F-net data, distribution of epicenters is elongated in the east-west direction. However, this analysis shows that such elongated distribution is apparent and VLFEs occur in the narrower region. Our result shows that, at least, three clusters exist along the trench direction off Fukushima-Ibaraki. VLFE activity in the northern cluster becomes quiescent after the 2011 Tohoku earthquake. On the other hand, VLFEs are activated in the central and southern cluster. This suggests that the northern cluster is located in the slip region of the Tohoku earthquake, and the central and southern clusters are located in the stress accumulation region of the earthquake or afterslip area. This suggests that the monitoring of VLFEs may be useful as an indicator of the slip at the plate boundary. In this correlation analysis, regular earthquakes are also located. Many regular earthquakes occur at the surrounding region of these VLFE clusters. Especially around the central VLFE cluster, the distribution of VLFEs and regular earthquakes seems to be complementary. This may reflect the distribution of inhomogeneous frictional property at the plate boundary.

Keywords: very low frequency earthquake, off the Pacific coast of Tohoku, 2011 Tohoku Earthquake, slow earthquake