Spatio-temporal distribution of very low frequency earthquakes in the eastern Nankai accretionary prism revealed by hierarchical clustering analysis of ocean bottom seismometer records

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Many low frequency tremors (LFTs) occurred in the eastern Nankai accretionary prism in October 2016 through a period of about one week and were recorded by the 20 broadband ocean bottom seismometers of the DONET1 ocean floor network. We detected more than 900 tremors at the frequency range of 2–8 Hz. Among these, 144 events were accompanied by signals at lower frequency range (> 0.1 Hz). In this study, the events with the low frequency signal are referred to as very low frequency earthquakes (VLFEs).

The observed waveforms of the entire network suggest that many of the events are spatially clustered. However, due to the large errors introduced during the travel time measurement processes, the estimated location of each event is spatially scattered, which makes it difficult to evaluate the distribution of the clustered events.

Here, we introduce a hierarchical clustering algorithm to group some of the closely located events. The degree of similarity between any two events is defined by comparing the arrival times of the peak amplitude obtained by a set of stations at which the signals of both events were observed. The peak amplitude at each station is measured from the root-mean-square envelope of two horizontal components filtered at 2–8 Hz, and then smoothed by a low-pass filter with a cutoff frequency of 0.059 Hz.

Thus far, the algorithm has been applied to only the VLFEs, although we intend to eventually cluster all of the events, including the LFTs. Among the 144 VLFEs, 121 events grouped with at least one other event, and a total of 27 groups appeared.

Finally, the horizontal location of each cluster was determined by using the median of the measured differential travel times between stations obtained for individual events within the cluster. The differential travel times were calculated from the previously described peak amplitude arrival times. This procedure also allowed us to detect and remove outliers of measured times, which are caused mostly by noise. The locations were estimated by assuming a constant shear velocity structure.

The results showed that the cluster locations are largely divided into two groups. The clusters in the first group (Group 1) are distributed around a major reverse fault in the northern part of DONET1. They occurred within the first 3 days of the total activity. The cluster locations of the second group (Group 2) are distributed form around the major reverse fault of the southern part of DONET1 and slightly toward the trench axis side. Many of the events in the trench axis side seems to have occurred in the latter part of the total period of activity.

The waveforms of events in Group 1 tended to show somewhat discernable S wave onsets compared to events in Group 2. Furthermore, we were able to identify systematic P arrivals for many events in Group 1 by aligning the waveforms within the individual clusters. By using manually picked P and S

arrival times, we relocated some clusters by a grid search through a 3-D velocity model. The results showed that the depth of the clusters varies from ~8 km to ~2 km beneath the seafloor. Whereas many events are located near the major reverse fault, some are located ~5 km landward of the fault. Our result suggests that the stress state that promotes the occurrence of VLFEs is not limited to the narrow range along the major fault, but exists through a broader range in the shallow accretionary prism.

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