Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SCG085-P06 Room: Convention Hall Time: May 23 17:15-18:45

Detection of very-low frequency earthquakes based on a waveform correlation technique

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We have tried to detect very-low frequency (VLF) earthquakes based on a waveform correlation technique. Continuously recorded seismograms observed at 15 stations of the NIED F-net, which is a broad-band seismograph network in Japan, were analyzed in this study. A band-pass filter with a pass-band of 0.02 to 0.05 Hz was applied to the original seismograms; the filtered seismograms were re-sampled with a sampling frequency of 1 Hz. Cross-correlation coefficients (CCs) were evaluated between two re-sampled seismograms with 150-s length. One is a seismogram of a known event. Another is a seismogram observed at the same station in a time window, in which we attempted to detect unknown events, set in a continuous record. Cross-correlation function, which is time series of CCs, can be obtained by this calculation for a moving window. We also evaluated averaged cross-correlation function over all stations in order to detect repeating VLF earthquakes. If the present detected event occurred in the same asperity as the known event, peak times with maximum CCs in the cross-correlation functions will be the same for all stations; it is expected that the averaged CC will be also large. On the contrary, the averaged CCs will be small for events far from the known event due to travel-time difference of seismic waves between two events.
Two test data, which are an hour length seismograms from 15:00 on August 1, 2004 and 10:00 on November 18, 2003 (UT), were analyzed; a VLF earthquake in Tokachi-oki which occurred at 7:2 8 on February 23, 2009 (UT) was selected to be a known event. Obtained results from both data show large maximum CCs of 0.6 to 0.9 for all stations located in northeastern Japan; however maximum averaged CCs are 0.75 for the first data (August 1, 2004) and 0.17 for the second data (November 18, 2003). In this result for the second data, peak times at stations in eastern Hokkaido are approximately 14 s later than those in Tohoku. These suggest that one event in the first data occurred in almost the same asperity as the known event; another event in the second data occurred in approximately 25 to 30 km southwest from the known event. Consequently, these results show that we can detect adjacent events to a known event and estimate their relative locations from travel-time differences corresponding to peak time variation.

Keywords: very-low frequency earthquake, waveform correlation technique, Tokachi-oki