Deep low-frequency earthquakes beneath Zao volcano: Analysis with Matched Filter method

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The 2011 Tohoku Earthquake (Mw: 9.0) caused large crustal deformation in and around the Tohoku region, and strongly affected the condition of volcanic fluids in the deep crust. As an example suggesting such influence, change in activities of deep low-frequency (DLF) earthquakes occurring in the lower crust have been observed and reported at several volcanoes in the Tohoku region after the earthquake. The analysis of DLF earthquakes is thus considered to be one of the important keys to infer the activity of deep magma and to assess the potential risks of mid- to long-term volcanic activity after a huge earthquake. In addition, the analysis of the correlation between deep and shallow volcanic earthquakes may provide us important information on the fluid transportation through the crust. In this presentation, we report the preliminary results of our analysis of the DLF earthquakes beneath Zao volcano using the Matched Filter method, and discuss the temporal variation of DLF activities after the 2011 Tohoku Earthquake.
Zao volcano is located on the border between Yamagata and Miyagi prefectures, and many eruptive activities including the occurrence of phreatic eruptions have been documented. After the 2011 Tohoku Earthquake, the number of DLF earthquakes beneath Zao volcano started increasing, and volcanic earthquakes and long-period earthquakes which occurred in the shallow depth (up to depth of about 2 km) have been observed since 2013. To investigate the spatio-temporal change of such seismic activities, the number of earthquakes, the hypocenter and the magnitude are the most fundamental information. On the other hand, in the JMA unified earthquake catalog, the completeness of the listing is not guaranteed in the magnitude range of small DLF earthquakes. Therefore, to detect small DLF earthquakes and improve the completeness of the event listing, we applied Matched Filter method (MF method) to the seismic record observed around Zao volcano.
In the analysis using MF method, we used the continuous three-components waveform data recorded at three permanent stations: Shichigashuku (TU.SHC), Kamafusa (TU.KMF) operated by Tohoku University, and Hi-net Kaminoyama (N.KMYH) by NIED. 146 DLF earthquakes beneath Zao volcano which are listed in the JMA catalog between January 2012 and September 2016 were selected as template earthquakes. In the MF analysis, we used a frequency band of 1-8 Hz covering the dominant frequency of DLF earthquakes, and used a 30 sec-long window for the template waveforms. In order to extract the characteristics of DLF seismic activity and to examine the detection threshold in the MF method, we first examined the cross correlation of all template earthquake pairs and the distribution of the maximum correlation value. As a result, it became clear that even those earthquake pairs whose time separation are several years yield high correlation values. Moreover, from the correlation of the template earthquakes, we found that, it is needed to set the threshold to about 0.2 in the MF method to detect all of the listed DLF earthquakes. Based on these considerations, we applied the MF method to continuous record using all templates, and detected DLF earthquakes which are not listed in the JMA catalog. The magnitudes of these DLF events estimated from the amplitude ratio with the template earthquakes are within a range of -0.3 to 0.1. This means that we succeeded in detecting small DLF earthquakes which are missed in the JMA catalog. On the other hand, there are a few cases that the known DLF earthquakes could not be detected possibly due to the absence of appropriate template earthquakes.
Our further analysis including the analysis over longer time period may reveal the activity of DLF earthquakes in more detail, and contribute to the better understanding of deep magmatic process beneath Zao volcano.

Keywords: Zao volcano, deep low-frequency earthquakes, Matched Filter method

