# Hypocenter determination of B-type earthquakes using the envelope correlation method: an application to Miyakejima volcano, Japan

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B-type earthquakes with emergent onsets of P and S phases are frequently observed in active volcanoes, and it is difficult to locate them by traditional phase picking. Recently, we analyzed 1,049 B-type earthquakes occurring at Miyakejima volcano, Japan from August 2010 to April 2011, and succeeded in locating 18 % of the observed 1,049 B-type earthquakes by stacking the waveforms of earthquake families to read the P- and S-wave onset times (Uchida et al., 2012). However, the hypocenters of the rest of B-type earthquakes still remain unknown.

In this study, aiming to locate all of the B-type earthquakes at Miyakejima, we apply the method of Obara (2002), which was used for non-volcanic deep tremors on the subducting plate, to the seismograms observed at nine stations located within 4 km of the summit. At each station, we compute a RMS envelope from 4 - 8 Hz band-pass-filtered three-component seismograms, and measure the differential travel times between stations by taking cross-correlations of the envelopes. We assume that the envelope is composed of S-wave traveling with the velocity of 1250 m/s, as in Uchida et al. (2012).

To assess the applicability of the method to B-type earthquakes, we determine the hypocenters of individual events in each of the four earthquake families (L1, L2, H1, and H2) by applying the envelope correlation method, and compare the resultant hypocenters with those obtained from phase picking of the stacked waveforms (hereinafter referred to as "stack-and-pick hypocenters"). As a result, we found that the epicenters located by the envelope correlation almost coincide with the stack-and-pick epicenters, and the differences are about 0.5 km. On the other hand, the method sometimes yields large error in depth. For example, the hypocenters of family L1 and L2 cluster in the depth range of 1 km, respectively. While the cluster of L1 includes the stack-and-pick hypocenter, that of L2 shifts 1 km shallower than the stack-and-pick hypocenter. In the case of H1 and H2, their hypocenters spread over the depth range of 2 km. The inconsistency in the depths is probably due to the difficulties in measuring the S-wave travel times from the envelopes. To improve the accuracy of the depths, we need to consider the envelope broadening by scattered waves, surface waves and/or reflection phases.

We then apply the envelope correlation method to all of the observed 1,049 B-type earthquakes, of which about 80 % had never been located, and successfully locate them in an automated way. As a result, we found that 97 % of them are located within a 1.5 km diameter centered on the southern part of the summit caldera, where continuous fumarolic gas emission occurs. Those hypocenters are distributed at the depths shallower than 3 km. Our study shows the usefulness of the method as a tool to monitor volcanic earthquakes which are difficult to locate by phase picking.