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# Source amplitudes of volcano-seismic signals determined by the amplitude source location method

Hiroyuki Kumagai[1*], Rudy Lacson[2], Yuta Maeda[1], Melquiades Figueroa[2], Tadashi Yamashina[3], Mario Ruiz[4], Pablo Palacios[4], Hugo Ortiz[4], Hugo Yepes[4]

[1]NIED/Nagoya Univ., [2]PHIVOLCS, [3]Kochi Univ., [4]IG-EPN

The amplitude source location (ASL) method, which uses high-frequency amplitudes under the assumption of isotropic S-wave radiation, has been shown to be useful for locating the sources of various types of volcano-seismic signals. We tested the ASL method by using synthetic seismograms and examined the source amplitudes determined by this method for various types of volcano-seismic signals observed at different volcanoes. Our synthetic tests indicated that, although ASL results are not strongly influenced by velocity structure and noise, they do depend on site amplification factors at individual stations. We first applied the ASL method to volcano-tectonic (VT) earthquakes at Taal volcano, Philippines, where the seismic network consists of eight seismometers (five broadband and three short-period seismometers). Our ASL results for the largest VT earthquake showed that a frequency range of 7-12 Hz and a Q value of 50 were appropriate for the source location determination. We proposed a two-step approach to minimize site effects on the source amplitude estimation as follows: The source location is first determined by using a frequency band of 7-12 Hz and Q = 50 with site amplification corrections, and then the source amplitude is estimated by using waveform data at broadband seismic stations only without site amplification corrections and a reference frequency band of 5-10 Hz and Q = 50. Using this two-step approach, we systematically applied the ASL method to VT earthquakes at Taal, and estimated their source locations and amplitudes as well as seismic magnitudes. We similarly analyzed LP events at Cotopaxi and explosion events at Tungurahua. At all three volcanoes, we found a proportional relation between the magnitude and the logarithm of the source amplitude without any strong dependence on event type. At these three volcanoes, all of broadband seismometers had been installed in a similar way, which may have minimized site effects. The ASL method can be used to determine source locations of small events for which onset measurements are difficult, and thus can estimate the sizes of events over a wider range of sizes compared with conventional hypocenter determination approaches. Previously, there has been no parameter widely used to quantify the sources of volcano-seismic signals. This study showed that the source amplitude determined by the ASL method may be such a useful quantitative measure of volcano-seismic event size.