Amplitude source location method with depth-dependent scattering and attenuation structures for volcano-seismic signals

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The amplitude source location (ASL) method has been used to locate seismic events and tremor at various volcanoes. It has been indicated that the far-field and isotropic radiation equation for *S* waves used in the ASL method is valid in highly scattering wavefields. A constant *Q* value in the far-field and isotropic radiation equation has been commonly used in previous studies. This implicitly assumes homogenous distributions of scattering characteristics represented by the mean free path (l_0) and intrinsic attenuation (Q_i) beneath volcanoes. Wegler (JGR, 2004) and Kumagai et al. (JGR, 2018) showed that highly heterogeneous structures at volcanoes only exist in a surface thin layer with a thickness of about 1 km, below which less heterogeneous layers comparable to those in the normal crust exist. To evaluate the effects of such layered structures for ASL determinations, we performed synthetic tests using envelope waveforms simulated with the Monte Carlo method of Yoshimoto (JGR, 2000) for a two layer model based on the l_0 and Q_i structures at Nevado del Ruiz volcano (NRV) estimated by Kumagai et al. (2018). Our results indicated that the input source locations were estimated by the ASL method when appropriate values of *Q* values for the two layered model were used in the far-field and isotropic radiation equation. When a constant *Q* value was used, the estimated locations were largely deviated from the input locations especially in the depth direction. We then determined ASLs of volcano-tectonic (VT) earthquakes at NRV, which were compared with their hypocenters determined by the onset arrival times. Our results indicated that the differences between the ASLs and hypocenters of VT earthquakes became smaller when using a two layer *Q* model than those using a constant *Q* model. Our estimated ASLs of long-period (LP) events and tremor at NRV using the two layer *Q* model were more sharply clustered beneath the SW flank compared to those using the constant *Q* model. These locations corresponded to high *P*-wave to *S*-wave velocity ratio regions (Londono and Kumagai, JVGR, 2018), suggesting that the LP events and tremor were generated by fragmentation processes in a shallow magma storage region. These results indicate that use of appropriate *Q* values in the ASL method accommodating a thin surface heterogeneous layer is important to estimate precise source locations.

