Development of an eruption plume height estimation system using the high-frequency seismic source amplitude

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Estimation of eruption volume and plume height is fundamentally important to resident and aviation safety. However, it is difficult to estimate plume height especially in night and bad weather conditions. Seismic observations are widely used to monitor active volcanoes. Eruption tremor exhibits sustained oscillatory signatures observed during plinian-type explosive and steady eruptions. Previous studies reported that these signals are correlated to eruption size or eruption volume flux in individual eruption episodes. However, the universality of these correlations is yet to be confirmed.

We studied the high-frequency seismic signals of eruption tremors during recent eruptions at Ontake and Kirishima in Japan and Tungurahua in Ecuador and quantified their seismic source amplitudes (A_s) in the 5–10 Hz based on the assumption of isotropic *S*-wave radiation. We found plume height (H) of plinian eruptions is scaled by A_s, and H is described by the relations depending on the value of A_s (Mori and Kumagai, JpGU, 2017). These relations were divided by $H = 6$ km, and the relation for $H < 6$ km was estimated by data only from the 2011 Kirishima sub-plinian eruptions. In this study, we further analyzed seismic and plume height data of recent eruptions at Nevado del Ruiz in Colombia. These eruptions were characterized by sustained ash emissions with plume height less than 3 km. Our estimates of A_s against H for these eruptions were consistent with the above relation for $H < 6$ km. This result supports that the relations proposed by Mori and Kumagai (2017) can be used to estimate plume height from seismic data.

We have developed the system to estimate plume height using our seismic source quantification approach. In this system, we continuously perform the estimation of A_s and H in every 1 min. If the estimated A_s exceeds a threshold value, an image file containing the following information is automatically created: the estimated values of A_s, H, and seismic magnitude, the maximum seismic amplitude time, observed seismic waveforms, and the locations of seismic stations. First, we get seismic data in 1 min at each station, apply the 5-10 Hz band pass filter, and calculate the envelope seismogram. We use a 10-s sliding time window overlapped with 5 s to estimate the average amplitudes in the individual windows at each station. The average amplitude in the *k*-th window is corrected for medium attenuation and geometrical spreading, and the corresponding corrected amplitudes at different stations are averaged to estimate the source amplitude in the *k*-th window (A_s^k). We identify the maximum A_s^k during 1 min as A_s. Next, we estimate plume height in both km and ft from the relations using the estimated value of A_s. Our system is working with the Linux operating system, and the image files drawn by GMT (Wessel and Smith, EOS, 1998) can be viewed by a Web browser through the Internet. This system may be useful to provide eruption information in real-time and to create an eruption information database.

