Relationship between infrasound-derived and buoyancy-derived eruption cloud volume estimates

Taishi Yamada[1], Hiroshi Aoyama[2], and Hideki Ueda[1]

[1]*National Institute for Earth Science and Disaster Resilience (NIED), Tsukuba, Ibaraki, Japan*

[2]*Institute of Seismology and Volcanology, Hokkaido University, Sapporo, Hokkaido, Japan*

Infrasound observation at active volcanoes has played an important role to monitor volcanic activity and understanding the eruption dynamics. Volcanic infrasound signals show variety in amplitude, duration, and peak frequency, that reflects the diversity of the eruption style and the dynamics at the source. A short-lived eruption, usually represented by a Strombolian or Vulcanian eruption, excites an infrasound pulse signal. Such a pressure pulse has been explained by volume change of a monopole source assumed at the vent. Here, the inferred volume V_{inf} is considered to be equivalent to that of mixtures of hot volcanic particles and gases emerging from the vent, that displaces the atmosphere above the vent. Previous works focusing on small scale gas rich eruptions have demonstrated that analysis with the monopole assumption estimates gas volume comparable with that obtained by other observation method. However, for the events having an eruption cloud with the height of order of several km, V_{inf} estimated by previous studies is considerably smaller than that of video-derived volume. It is still challenging to understand the nature of V_{inf} quantitatively based on the dynamics of eruption cloud. An eruption cloud accompanying the short-lived eruption has been modeled as a thermal (e.g., Woods and Kienle, 1994). Terada and Ida (2007) proposed a simple method to estimate initial buoyancy F_0 of a spherical thermal can be estimated from the maximum eruption cloud height and a vertical profile of ambient air density. The thermal is expected to obtain F_0 when it has entrained enough amount of the surrounding air to ascend with buoyant force only. We focus on that the volume of the thermal V_{b} at the moment that can be obtained with the value of F_0. Investigating relationship between V_{inf} and V_{b} can be valuable to understand the nature of V_{inf}, and examine how V_{inf} can be linked to the dynamics of eruption cloud. The present study examines the relationship between V_{inf} and V_{b} for 53 events at 5 volcanoes. We analyze infrasound data accompanying eruptions at Aso, Shinmoedake, and Lokon-Empung volcanoes to estimate $V_{\mathrm{inf.}}$ The data of V_{inf} examined by previous works at other volcanoes (Sakurajima and Kuchinoerabujima) is also referred. Following the method proposed by Terada and Ida (2007), we estimate F_0 with the maximum height of eruption cloud and vertical profile of ambient air density. V_{b} is then obtained from the value of F_0, the gravity acceleration, and density difference between the thermal and ambient air. Referring previous studies focusing on the thermal near the ground, we assume possible density difference as 0.3±0.2 kg/m3.

Our result shows that the ratio of V_{b} / is almost always larger than 1 (51 events), and most commonly within a range of 3–3.0×101 (33 events). Since the thermal has the self-similarity, we hypothesize that the relation of $V_{\mathrm{b}}/V_{\mathrm{inf}}$ also follows a linear function. A linear regression function of $V_{\mathrm{b}}/V_{\mathrm{inf}} = 1.6\times10^1$ is obtained throughout all events. Since examined infrasound waveforms share a prominent pressure pulse at the onset, V_{inf} likely to ink starting process of the eruption cloud where it is driven by gas thrust, i.e., jets. On the other hand, V_{b} can be regarded that the volume at the moment when the thermal has entrained enough amount of the surrounding air to ascend with the buoyant force only. Referring the previous works, difference of the bulk density of both eruption cloud regimes yields the volume change rate of the 1.8–3.2×10^1, that explains our result of V_{b} /V_{inf} ratio. Although our result may include errors derived from some factors (the maximum eruption cloud height, the entrainment constant, etc), we believe the result provides an effective index to constrain the eruption cloud volume with infrasound data.

References

Terada A, Ida Y (2007) Kinematic features of isolated volcanic clouds revealed by video records. Geophys Res Lett 34:L01305. doi: 10.1029/2006gl026827

Woods A, Kienle J (1994) The dynamics and thermodynamics of volcanic clouds: Theory and observations from the April 15 and April 21, 1990 eruptions of redoubt volcano, Alaska. J Volcanol Geoth Res 62:273–299. doi: 10.1016/0377-0273(94)90037-X