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Numerical simulations of short-term eruption clouds

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The height of volcanic eruption clouds is one of the most informative indicators of eruption conditions at the volcanic vent. A longer-term (e.g., Plinian) eruption ejects a mixture of volcanic gas and solid pyroclasts in a volcanic plume, whereas a shorter-term (e.g., Vulcanian) eruption is characterized by a sudden explosive ejection of a gas/pyroclast mixture in a “volcanic thermal”. The relationship between cloud height and eruption conditions has been investigated theoretically (e.g., Morton et al., 1956) and by one-dimensional modeling (e.g., Woods, 1988; Woods and Kienle, 1994). More sophisticated three-dimensional (3D) models have recently revealed that the earlier models either over- or under-estimated plume heights for long-term eruptions (Costa et al., 2016). Here we aimed to perform 3D numerical simulations of short-term eruptions to clarify the relationship between the thermal height and eruption conditions at the vent in such cases.

A 3D fluid-dynamics model, based on the pseudo-gas model of Suzuki et al. (2005), was employed. This model is designed to simulate the injection of a mixture of pyroclasts and volcanic gases from a circular vent into the stratified atmosphere. With the total mass of the ejected material fixed at 10^8 kg, simulations were conducted with eruption durations of 1, 2, 5, and 10 seconds (i.e., with different mass eruption rates). Non-uniform grid sizes were applied, with grid size increasing at a constant rate with increasing distance from the volcanic center. To reproduce turbulent mixing at locations near the vent, the minimum grid size was set to $< D_0/40$, where D_0 is the vent diameter.

The simulations reproduced the development of volcanic thermals and the horizontal spreading of eruption clouds at the neutral buoyancy level, with thermal height depending on eruption duration. This dependency is different to that indicated by the previously applied scaling law, through which thermal height depends only on the total mass ejected (Morton et al., 1956). This result indicates that either a different scaling law is applicable to short-term eruptions, or that such eruptions (with a duration on the order of several seconds) have different dynamics from Vulcanian eruptions.