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# On the relationship between eruption intensity and volcanic plume height: insights from three-dimensional numerical simulations

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Height of plumes generated during explosive volcanic eruptions are commonly used to estimate the associated eruption intensity (i.e., mass eruption rate; MER). In order to quantify the relationship between plume height and MER, we performed a parametric study using a three-dimensional (3D) numerical model of volcanic plumes for different MERs. We estimated the maximum height of plume, the neutral buoyancy level where the cloud density is equal to the atmospheric density, and the height with the maximum radial injection of the erupted material from the simulation results. We also analyzed the simulation results by comparing with the plume heights predicted by a one-dimensional model based on the Buoyant Plume Theory (Morton et al., 1956).

The simulation results indicate that the flow pattern in the lower region of the plume systematically changes with MER. For MERs < $4\times10^7$ kg s$^{-1}$, the flow in the lower region has a jet-like structure (the jet-like regime). For MERs > $10^8$ kg s$^{-1}$, the flow shows a fountain-like structure (the fountain-like regime). The flow pattern of plumes with $4\times10^7$ kg s$^{-1}$ < MERs < $10^8$ kg s$^{-1}$ shows transitional features between the two flow regimes. Within each of the two flow regimes, the plume height increases as the MER increases, whereas plume heights remain almost constant or even decrease as MER increases in the transitional regime; as a results, the jet-like and fountain-like regimes show distinct relationships of plume height and MER.

Our analyses of the simulation results indicate that the different relationships of plume height and MER between the two regimes reflect the change in the efficiency of air entrainment; the entrainment efficiency in the jet-like regime is substantially lower than that in the fountain-like regime. It is suggested that, the different flow regimes depending on MER should be taken into account for a correct estimation of eruption intensity from the observed plume heights.