COMBINED EFFECTS OF TOTAL GRAIN-SIZE DISTRIBUTION AND CROSSWIND ON THE RISE OF ERUPTIVE VOLCANIC COLUMNS

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The maximum height of an explosive volcanic column, H, depends on the 1/4th power of the eruptive mass flux, Q, and on the 3/4th power of the stratification of the atmosphere, N. Expressed as scaling laws, this relationship has made H a widely used proxy to estimate Q. Two additional effects are usually included to produce more accurate and robust estimates of Q based on H: particle sedimentation from the volcanic column [1], which depends on the total grain-size distribution (TGSD) and the atmospheric crosswind [2]. Both coarse TGSD and strong crosswind have been shown to decrease strongly the maximum column height, and TGSD, which also controls the effective gas content in the column, influences the stability of the column. However, the impact of TGSD and of crosswind on the dynamics of the volcanic column are commonly considered independently. We propose here a steady-state 1D model of an explosive volcanic column rising in a windy atmosphere that explicitly accounts for particle sedimentation and wind together. We consider three typical wind profiles: uniform, linear, and complex, with the same maximum wind velocity of 15 $\mathrm{m\,s^{-1}}$. Subject to a uniform wind profile, the calculations show that the maximum height of the plume strongly decreases for any TGSD. The effect of TGSD on maximum height is smaller for uniform and complex wind profiles than for a linear profile or without wind. The largest differences of maximum heights arising from different wind profiles are observed for the largest source mass fluxes ($> 10^7\ \mathrm{kg\,s^{-1}}$) for a given TGSD. Compared to no wind conditions, the field of column collapse is reduced for any wind profile and TGSD at the vent, an effect that is the strongest for small mass fluxes and coarse TGSD. Provided that the maximum plume height and the wind profile are known from real-time observations, the model predicts the mass discharge rate feeding the eruption for a given TGSD. We apply our model to a set of eight historical volcanic eruptions for which all the required information is known. Taking into account the measured wind profile and the actual TGSD at the vent substantially improves (by $\approx 30\%$) the agreement between the mass discharge rate calculated from the model based on plume height and the field observation of deposit mass divided by eruption duration, relative to a model taking into account TGSD only. This study contributes to the improvement of the characterization of volcanic source term required as input to larger scale models of ash and aerosol dispersion.

References

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