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Results of the IAVCEI inter-comparison study of eruptive plume models

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Volcanic plume heights are key observable data for estimating crucial parameters such as mass flow rate, and they are commonly used as input for dispersal models of tephra particles. Therefore, quantitative relationships between plume heights and eruption conditions are required. During the last decades, many 1D, 2D, and 3D models of volcanic plume have been proposed. In order to investigate the dependence of plume dynamics on the models and their assumptions, we carried out an inter-comparison study of the recent plume models (nine 1D models based on the buoyant plume theory and four 3D models). The study was designed as a test in which a set of common input parameters was given for two reference eruptions, representing a strong and a weak eruption column under different meteorological conditions. Comparing the results of the different models has allowed us to evaluate their capabilities and target areas for improvement. Despite their different formulations, the 1D and 3D models provide reasonably consistent predictions of some of the key global descriptors of the volcanic plumes. Variability in modeled plume height, estimated as standard deviation, is within $\sim$20% for the weak plume and $\sim$10% for the strong plume. Predictions of neutral buoyancy level are also in reasonably good agreement among the different models, with a standard deviation ranging from 9 to 19% (the latter for the weak plume in a windy atmosphere). Overall, these discrepancies are in the range of observational uncertainty of column height. However, there are important differences amongst models in terms of local properties along the plume axis, particularly for the strong plume. The analysis suggests that the simplified treatment of entrainment in 1D models is adequate to resolve the general behavior of the weak plume. However, it appears clearly inadequate to capture complex features of the strong plume, such as large vortices, partial column collapse, or gravitational fountaining that strongly enhanced entrainment in the lower atmosphere. For these reasons, there is a need to more accurately quantify entrainment rates, improve the representation of plume radius, and incorporate the effects of column instability in future versions of 1D volcanic plume models.