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A new strategy for the estimation of plume height from clast dispersal and application to proximal hazard assessment

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Even though the increasing availability of models and real-time measurements has improved the description of volcanic phenomena and their impact, in many circumstances (e.g. ancient eruptions) field data represent the only means to reconstruct key eruptive parameters (ESPs), such as erupted volume and plume height. In particular, plume height is a critical ESP required to characterize explosive eruptions and assess associated hazards and risk. Here we present a revised strategy for the determination of plume height following the approach of Carey and Sparks (1986) that accounts for key aspects of plume dynamics and particle sedimentation. Implementations include the effect of wind advection on the clast support envelope of weak and transitional plumes, a modified equation of gravitational spreading in the umbrella cloud for distances within the plume radius (where the clast support envelope is defined), the effect of particle shape on sedimentation, the effect of different atmospheric structure at different latitudes, three-dimensional meteorological fields from the Era-interim database and topography. A script is provided that can invert field data to determine plume height and has been validated with small, intermediate and high intensity eruptions (i.e. Shinmoedake 2011, Japan; Mount St Helens 1980, USA; Pinatubo 1991, Philippines). A new set of nomograms is also presented and associated uncertainties are quantified and discussed. Intensity scenarios had to be introduced as a non-univocal relation between plume height and particle sedimentation is present. The proposed new model can be also used for the compilation of isopleth contours and probabilistic maps describing the hazard associated with proximal sedimentation of large clasts. As an example, this model has been applied to the hazard assessment and risk management associated with the sedimentation of large clasts at Mt Etna (Italy). The hazard zone and the infrastructure at risk were quantified. The time taken for people to evacuate on foot to a safe area was investigated. A One Eruption Scenario approach was applied to investigate both the event with the largest mass eruption rate (MER) so far experienced from a lava fountain at Mount Etna, and the event with the smallest MER for which large clast sedimentation occurs beyond the immediate area of the vent. In addition, an Eruption Range Scenario was considered, where values of MER and particle parameters were stochastically sampled from a given statistical distribution to better quantify the uncertainty associated with the selected hazard scenarios.