Numerical modelling of the dynamics and hazards of phreatic explosions, with application to the 2014 Mt. Ontake eruption

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Phreatic or hydrothermal eruptions are relatively frequent phenomena on active volcanoes hosting shallow hydrothermal systems, where heat and fluids are transferred from a deeper magmatic source to the surface through a porous and fractured rock. Fluid and heat flow promotes the increase of interstitial pore pressure as well as the chemical alteration and weakening of the host rock, potentially leading to conditions of mechanical failure. The resultant eruptions are generally of relatively small size (volume of the erupted material 10^4-10^6 m^3) and do not involve fresh magma at high temperature (700-1200°C). They are nonetheless capable of fragmenting the shallow host rock, generating vertical or lateral jets of gases and fine ash (< 1 mm), at temperatures of 100-400°C, often accompanied by turbulent gravity currents of gas and solid particles, and intense fallout of large (up to 30 cm) lithic blocks.
The phreatic eruption at Mt. Ontake volcano in 2014 has shown that volcanic ballistic produced during hydrothermal and phreatic explosions pose a significant hazard in areas proximal to the eruption vents. We here present a computational fluid dynamic model that allows simulation of the explosion dynamics from a vent or fissure on a 3D topography. The model describes the gas and finest particles mixture with a two-phase non-equilibrium Eulerian-Eulerian formulation, and the ballistic particles, coupled one-way with the mixture, with a Lagrangian approach. At the initial simulation time, a pressurized, high-temperature mixture (initially confined within the shallow vent) is allowed to decompress and expand in the atmosphere forming an eruptive cloud, while ballistic particles are rapidly accelerated by the coupling effect of drag and pressure forces. The application of the model to the phreatic eruption of Mt. Ontake volcano in 2014 is discussed and model results are compared with the distribution of ballistics derived from geological observations.

Keywords: Phreatic eruptions, Ballistic ejecta, volcanic hazards