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# Three-dimensional, multiphase flow numerical models of phreatic volcanic eruptions.

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Explosive volcanic eruptions are characterized by the ejection in the atmosphere of volcanic gases and fragments of magma and/or lithics at high temperature, pressure and velocity. They encompass a broad range of magnitudes, with volumes of ejecta spanning from less than $10^6$ $m^3$, to $10^9$-$10^{11}$ $m^3$ of Plinian eruptions, up to the largest known volcanic events, able to erupt up to thousands of $km^3$ of magma. Phreatic eruptions are among the smallest in this range; they do not involve the eruption of fresh magma, but are instead triggered by a sudden rise of pressure and temperature in a shallow magmatic-hydrothermal system. Despite their relatively small size, phreatic eruptions are frequent on Earth and difficult to anticipate, and represent therefore a significant hazard, testified by the recent eruptions in Tongariro's Te-Maari crater (NZ, 2012), and during the tragic development of events in Ontake (JP, 2014) and Whakaari/White Island (NZ, 2019).

The main challenges of the numerical simulation of explosive volcanic phenomena have traditionally been identified in the complex fluid dynamics of polydisperse multiphase mixtures (with particle grains ranging from a few microns to metres) and in the extremely broad range of relevant dynamical scales characterizing compressible turbulent flows of gas and particles in the atmosphere. Three-dimensional, high-performance computer models based on different approximations of the multiphase flow theory have been designed to simulate the fluid dynamics of explosive eruptions, and to define hazard and impact scenarios. However, until now, it was difficult to quantify the uncertainty associated with numerical predictions.

We here discuss the present bottlenecks and challenges of the 3D modelling of phreatic volcanic eruptions in the quest for urgent definition of impact scenarios and probabilistic hazard assessment at Vulcano island (Aeolian archipelago, Italy). Exascale computing in these applications offers the opportunity to increase the complexity of the physical model (including new key processes as the flashing of liquid water), to describe the wide range of lithic fragments ejected during the eruption, to achieve unprecedently high spatial resolution at the source and close to the terrain, and to perform large ensembles of numerical simulations to quantify the epistemic uncertainty associated with the model initial and boundary conditions.

Challenges associated with the development, maintenance and porting on new HPC architectures of numerical models are finally discussed.