Geophysical Research Abstracts
Vol. 16, EGU2014-13975, 2014
EGU General Assembly 2014

A fast Eulerian multiphase flow model for volcanic ash plumes: turbulence, heat transfer and particle non-equilibrium dynamics.

Matteo Cerminara (1,2), Tomaso Esposti Ongaro (2), and Luigi Carlo Berselli (3)

(1) Scuola Normale Superiore, Pisa, Italy, (2) Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy, (3) Università di Pisa, Italy

We have developed a compressible multiphase flow model to simulate the three-dimensional dynamics of turbulent volcanic ash plumes. The model describes the eruptive mixture as a polydisperse fluid, composed of different types of gases and particles, treated as interpenetrating Eulerian phases. Solid phases represent the discrete ash classes into which the total granulometric spectrum is discretized, and can differ by size and density.

The model is designed to quickly and accurately resolve important physical phenomena in the dynamics of volcanic ash plumes. In particular, it can simulate turbulent mixing (driving atmospheric entrainment and controlling the heat transfer), thermal expansion (controlling the plume buoyancy), the interaction between solid particles and volcanic gas (including kinetic non-equilibrium effects) and the effects of compressibility (over-pressured eruptions and infrasonic measurements). The model is based on the turbulent dispersed multiphase flow theory for dilute flows (volume concentration <0.001, implying that averaged inter-particle distance is larger than 10 diameters) where particle collisions are neglected. Moreover, in order to speed up the code without losing accuracy, we make the hypothesis of fine particles (Stokes number <0.2 , i.e. volcanic ash particles finer then a millimeter), so that we are able to consider non-equilibrium effects only at the first order. We adopt LES formalism (which is preferable in transient regimes) for compressible flows to model the non-linear coupling between turbulent scales and the effect of sub-grid turbulence on the large-scale dynamics.

A three-dimensional numerical code has been developed basing on the OpenFOAM computational framework, a CFD open source parallel software package.

Numerical benchmarks demonstrate that the model is able to capture important non-equilibrium phenomena in gas-particle mixtures, such as particle clustering and ejection from large-eddy turbulent structures, as well as compressibility and thermal effects. A quantitative assessment of the reliability of Direct Numerical Simulation (DNS) and LES results with respect to modeling approximations and numerical errors has been carried out by comparing numerical results to experimental and computational studies of homogeneous, isotropic turbulence. In such a simplified geometry, the numerical solver is able to accurately reproduce the turbulent spectrum and the so-called energy cascade. The parallel efficiency on high-performance computing platforms exceeds 80% on 1024 processors, demonstrating the code suitability for large-scale 3D numerical simulations.

Several numerical benchmarks have been performed, such as the 2D lid-driven cavity, the natural convection in a square enclosure, the stratified mixing for a dam-break problem and the forced plume in an experimental setting. All these tests have given excellent results, in agreement with the data commonly found in the literature.

Finally, the model is applied to simulate the three-dimensional dynamics of volcanic plume dynamics and demonstrate that gas-particle non-equilibrium phenomena have a significant impact on turbulent structures and can affect the entrainment rate and the subsequent atmospheric dispersal of volcanic ash.