Assessing pyroclastic density currents hazard by means of complex multiphase flow models

Tomaso Esposti Ongaro[1], Augusto Neri[1], Simone Orsucci[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia - Sezione di Pisa, Italy, [2]Università degli Studi di Pisa - Dipartimento di Fisica, Italy

E-mail: ongaro@pi.ingv.it

Pyroclastic density currents (PDC) hazard assessment at active volcanoes represents a complicated problem and a scientific challenge, since the fundamental mechanisms of PDC propagation and interaction with topography are not fully understood and initial conditions cannot be predicted on a deterministic basis. On the other hand, probabilistic approaches integrating different sources of uncertainty (including those associated to the target eruptive scenario) need rapid execution of numerical models with variable input parameter distributions and control on errors and uncertainty. Such conditions are seldom simultaneously fulfilled by multidimensional multiphase flow models, which are needed to describe the complex fluid dynamics of high-temperature particulate currents.

To provide a useful tool for probabilistic hazard assessment, while retaining parts of the information supplied by complex multiphase flow models, we have undertaken a systematic study on the propagation of gravity-driven PDCs aimed at deriving a parameterization of the radial trend of hazard variables (dynamic pressure and temperature) and their associated uncertainty. In particular, we here focus on the propagation of PDCs in the absence of a significant topographic mean slope (as significant for caldera settings). To evaluate PDC hazards in a caldera, we need to understand the mechanism and the controlling factors of current sedimentation and deposition during its propagation, since these control PDCs stratification and their capability of overcoming topographic obstacles and eventually inundate the region outside the caldera margins.

To this aim, we have analyzed the dynamics of finite-volume pyroclastic currents on a flat surface by means of two- and three-dimensional numerical simulations. Initial conditions have been simplified in order to reduce the input parameter space to a few variables (initial mass and buoyancy and mixture temperature), in respect to which scaling properties and uncertainty have been evaluated. By adopting a multiphase flow model for a polydisperse gas-pyroclast mixture and new constitutive equations based on kinetic theory of particulate flows and laboratory experiments, we have simulated the mechanism of flow stratification and the influence of the flow rheology on the large-scale dynamics. In particular, the front propagation velocity, the momentum dissipation rate and the kinetic energy decay have been quantified. A semi-empirical law expressing the decay of dynamic pressure and temperature defined on this basis will be tested in the framework of probabilistic PDC hazard mapping at the Campi Flegrei caldera.