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3D numerical simulations of the multiphase flow dynamics and hazard of laterally directed blasts on Montserrat (December 1997)

T. Esposti Ongaro (1), A. Neri (1), A. Clarke (2), B. Voight (3), C. Widiwijayanti (3)

(1) Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Via della Faggiola 32, Pisa, I-56126 Italy (2) Department of Geological Sciences, Arizona State University, Box 871404, Tempe, AZ 85287-1404 United States (3) Geosciences, Penn State University, 334 Deike Bldg., University Park, PA 16802 United States (ongaro@pi.ingv.it / Phone: +39-0508311937 / Fax: +39-0508311942)

Laterally directed volcanic blasts have had violent consequences at Bezymianny, Russia in 1956, Mt. St. Helens, US in 1980 and Montagne Pelee on Martinique in 1902 where the complete destruction of the city of St. Pierre resulted in $>$30,000 fatalities. More recently, a laterally directed blast from Soufrière Hills volcano (SHV), Montserrat, eradicated the village of St. Patricks on 26 December (Boxing Day) 1997. No lives were lost because a pre-emptive evacuation was enforced, based on flank instability and the anticipation of a blast. The resulting deposits and destructive effects have been thoroughly studied and the unexcelled database provides a unique occasion for comparing field and modelling studies. The initiation and evolution of such explosive events are in fact still not well understood. Here we present the results of recent transient, multiphase flow simulations of the generation and propagation of directed blasts. The numerical model has been validated against a number of experimental and theoretical fluid-dynamics tests, involving the explosive release of mass and energy from a confined source. Two-dimensional, axisymmetric numerical experiments have been preliminarly carried out to calibrate the input source with observational data and to asses the influence of some key parameters of the eruption (such as the total mass and energy released, the dome internal pressure distribution and porosity) on the blast dynamics and on pyroclastic density current propagation. Initial conditions were represented by a compact volume of pressurized gas and pyroclasts, with clasts of different sizes and densities at high temperature. A topographic profile appropriated for the 1997 Boxing Day blast on Montserrat has been included as a bottom boundary condition. Three-dimensional numerical simulations of the explosive event have been then carried-out by imposing the same initial conditions on the actual volcano topography and by exploiting high-performance parallel supercomputers to solve the system of the model equations in a domain with millions of computational elements. The results have highlighted the strong topographic control on the propagation of the dense pyroclastic flows, the triggering of thermal instabilities, and the elutriation of finest particles, and have demonstrated the formation of dense pyroclastic flows by drainage of clasts sedimented from dilute flows, well comparing to the observed distribution of the eruptive products. The computed dynamic pressure and temperature of the flow have shown a good consistency with field observation of damages either in the region of total destruction or in the peripheral areas. We finally demonstrate the advantages of 3D advanced visualization techniques for hazards assessments and for illuminating the risks to public officials and affected populations.