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Computational modelling of pyroclastic density currents using the TITAN2D simulation code: examples from Merapi Volcano, Indonesia

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Pyroclastic density currents are multi-phase flows that range from dense granular flows, where gas plays a negligible role and transport is dominated by particle interactions (block-and-ash flows), to highly diluted, turbulent systems where transport of particles occurs in turbulent suspension. Block-and-ash flows typically comprise two components, a high-density ground-hugging basal avalanche, in which the bulk of material is transported, and an over-riding, dilute ash cloud. Both components commonly extend up to 10 km from source and travel at velocities that can exceed 100 km/h. Block-and-ash flows are gravity-controlled and preferentially follow topographic pathways such as valleys. The basal avalanche deposits are typically confined to the valley floors, whereas the accompanying ash cloud can undergo detachment and reach a wider distribution. The application of geophysical mass flow models to simulate block-and-ash flows at Merapi is fundamental in guiding future hazard assessment at this high-risk volcano. The TITAN2D computer program [1] is based on a depth-averaged model for an incompressible Coulomb continuum, a "shallow water" granular flow [2], and combines numerical simulations of a flow with digital elevation data of natural terrain supported by a Geographical Information System (GIS) interface. The direct outputs are flow depth and momentum, which can then be used to compute field observable variables at different points like run-up height, inundation area, velocity and time of flow. Moreover, the latest release of the TITAN2D code (2.0.0) allows the simulation of material that actively extrudes from the ground at a specific rate over a specific period of time by using a combination of different piles

and flux sources. The May-June 2006 eruption of Merapi Volcano consisted of three eruption phases that produced a complex sequence of block-and-ash flows directed mainly toward the south-western and southern flanks of the volcano. On 14 June, the largest of these flows reached distances of about 7 km from the summit in the Gendol River valley on Merapi's southern flank, causing two fatalities and the partial burial of the village of Kaliadem. The block-and-ash flows generated during the peak of activity on 14 June are interpreted as unsteady, rapidly agitated, inertial granular flows with flow regimes where the collisional and inertial forces are higher than the frictional forces. They were generated by sustained, multiple-pulse dome-collapse events over a period of a few hours. The block-and-ash flows generated after 14 June are short- to medium-runout, quasi-steady granular pyroclastic density currents with flow regimes where gravitational and frictional forces are balanced. They correspond to flows generated by short, single collapses of parts of the 2006 lava dome [3]. TITAN2D modelling allows the reconstruction of the different paths, velocities and extents of these two types of flows and a better characterization of the key parameters (e.g., friction angles, volumes, discharge rate, velocity and duration) that control their flow behaviour. The model results provide the basis for estimating the areas and levels of hazards associated with both types of pyroclastic flows and guidance for improving disaster mitigation plans at Merapi.

References: [1] Patra et al. (2005). J. Volcanol. Geotherm. Res., 139, 1-21; [2] Iverson and Denlinger (2001). J. Geophys. Res., 106, 537- 552; [3] Charbonnier and Gertisser (submitted). J. Volcanol. Geotherm. Res.