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The drag and terminal velocity of volcanic ash and lapilli with 3D shape obtained by X-ray microtomography

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New experiments of falling volcanic particles were performed in order to define drag and terminal velocity models applicable in a wide range of Reynolds number Re. Experiments were carried out with fluids of various viscosities and with particles that cover a wide range of size, density and shape. Particle shape, which strongly influences fluid drag, was measured in 3D by High-resolution X-ray microtomography, by which sphericity and fractal dimension were obtained, the latter used for quantifying the aerodynamic drag of irregular particles for the first time. With this method, the measure of particle shape descriptors proved to be easier and less operator dependent than previously used 2D image particle analyses. Drag laws that make use of the new 3D parameters were obtained by fitting particle data to the experiments, and single-equation terminal velocity models were derived. They work well both at high and low Re (3x10-2 < Re < 104), while earlier formulations made use of different equations at different ranges of Re. The new drag laws are well suited for the modelling of particle transportation both in the eruptive column and pyroclastic density currents, where coarse and fine particles are present, and also in the distal part of the umbrella region, where fine ash is involved in the large-scale domains of atmospheric circulation. A table of the typical values of 3D sphericity and fractal dimension of particles from known plinian, subplinian and ash plume eruptions is presented. Graphs of terminal velocity as a function of grain size are proposed as tools to help volcanologists and atmosphere scientists to model particle transportation of explosive eruptions. Some volcanological application examples are finally presented.