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Experimental constraints on volcanic ash generation and clast morphometrics in pyroclastic density currents and granular flows

Adrian Hornby[1,2], Ulrich Kueppers[2], Benedikt Maurer[2], Carina Poetsch[2,3], and Donald Dingwell[2]
[1]Cornell University, Earth and Atmospheric Sciences, Ithaca, United States of America (ahornby@cornell.edu)
[2]Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Theresienstr. 41/III, 80333 Munich, Germany
[3]Institute of Earth and Environmental Sciences—Geology, Albert-Ludwigs-Universität Freiburg, Albertstrasse 23-B, 79104 Freiburg im Breisgau, Germany

Pyroclastic density currents (PDCs) present perhaps the greatest proximal primary hazard of volcanic activity and produce abundant fine ash that can present a range of health, environment and infrastructure hazards. However, direct, fully quantitative observation of ash production in PDCs is lacking, and little direct evidence exists to constrain the parameters controlling ash generation in PDCs. Here, we use an experimental approach to investigate the effects of starting mass, material density and ash removal on the efficiency of ash generation and concurrent clast rounding in the dense basal flow of PDCs. We employ a rotary drum to tumble pumice and scoria lapilli clasts over multiple transport "distance" steps (from 0.2 to 6 km). We observe increased ash generation rates with the periodic removal of ash during the experiments and with increasing starting mass. By scaling to the bed height and clast diameter we obtain a general description for ash production in all experiments as a function of flow distance, bed height and average clast diameter. We confirm that changes in lapilli shape factors correlate with the ash fraction generated and that the grain size of ash produced decreases with distance. Finally, we estimate shear rate in our experiments and calculate the inertial number, which describes the ratio between clast-scale and flow-scale rearrangement during flow. We show that, under certain conditions, fractional ash production can be calculated accurately for any starting mass solely as a function of the inertial number and the flow distance. This work sheds light on some of the first systematic and generalizable experimental parameterizations of ash production and associated clast evolution in PDCs and should advance our ability to understand flow mobility and associated hazards.