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Gravitational instabilities in volcanic ash deposition: their role and their dynamics

I. Manzella[1], C. Bonadonna[1], S. Scollo[2], J. C. Phillips[3] & H. Monnard[1]

[1]Department of Earth Sciences, University of Geneva, Switzerland.

[2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Italy.

[3]School of Earth Sciences, University of Bristol, United Kingdom.

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Gravitational instabilities forming at the bottom of spreading volcanic clouds have been observed in many explosive eruptions. These instabilities initially take the form of downward-propagating fingers and they act to increase the sedimentation rate of fine particles with settling velocity lower than the fingers. For the first time, we characterize the dynamics of gravitational instabilities from analysis of video imagery from the 4th May 2010 eruption of Eyjafjallajökull (Iceland) and field observations of the associated tephra accumulation. Fingers started to reach ground level and thus deposit ash about 10 km from the vent where also aggregates have been observed. Fine particles found as individual particles in the deposit here could have been either transported as aggregates, which may have formed within convective instabilities or within the ash cloud itself, or they could have been transported passively as individual particles within the instabilities at a greater downward velocity than their settling speed. With dedicated laboratory analogue experiments we also investigated the evolution of particle concentration that results from the propagation of gravitational instabilities and the effect of particle size, composition and concentration on finger dynamics and generation by means of Particle Image Velocimetry. Results show that finger downward propagation significantly exceeds the settling speed of individual particles, that the number and the speed of fingers increase with particle concentration and that the speed increases with particles size while it is independent on particle composition. Experiment and field observations also indicate that a threshold of fine ash concentration and mass eruption rate exists below which fingers are not likely to form. Our observations challenge the view that aggregation is the primary explanation of proximal fine-ash sedimentation, and provide direct support for the role of gravitational instabilities in increasing sedimentation rate of fine ash and in promoting aggregation.