Premature fallout of fine ash: the role of convective instabilities

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Tephra fallout is one of the most widespread natural hazards and can significantly affect several economical sectors. In addition, volcanic fine ash suspended in the atmosphere can represent a significant threat to aviation as shown by the 2010 Eyafjallajökull eruption (Iceland). A good understanding and description of tephra dispersal is crucial to the mitigation of the associated risk. Processes that might significantly affect sedimentation of volcanic ash and that have not been yet well parameterized include particle aggregation and convective instabilities (gravitational instabilities which occur at the base of volcanic clouds where a denser fluid, the ash cloud, is emplaced above a lighter one, the atmosphere). Convective instabilities develop in series of discrete particle-rich protrusions (i.e. fingers), which seem to generate preferential paths for fine ash to settle. Both aggregation and convective instabilities make fine particles fall closer to the vent than expected, and due to the associated high concentration of fine ash in the fingers, aggregation processes could also be enhanced by convective instabilities.

Fingering is observed at the base of many volcanic clouds but we have been able to quantify their motion for the plume generated during the 2010 Eyafjallajökull eruption. Considering the measured finger speed and the volcano topography we found that fingers started sedimenting at about 10 km from vent, and this distance corresponds to the first observations of particle aggregation (Bonadonna et al. 2011).

We have conducted a series of laboratory experiments in a tank of 50x 30.3x 7.5 cm. A removable barrier was placed at a height of 25.1 cm to separate two different layers of fluid and ensure an impermeable separation and an initially sharp interface before the beginning of the experiments. The upper part was filled with a suspension of water and particles; the lower part was completely filled with a denser sugar solution. Experiments consisted of removing the separation and analysing the formation of fingers. Various initial conditions were investigated (including mixed and unmixed layers) resulting in different variation of concentration with time. However, in all cases, after removing the separation, particles started to sediment at the bottom of the upper particle-rich layer and the gravitational instabilities started developing. In all cases, results show that convective instabilities do not affect the sedimentation rate in the upper layer but strongly affect sedimentation in the lower layer. In presence of convective instabilities, particles reach the bottom of the tank faster than predicted by individual settling velocities. Particle sedimentation rates in the experiments can be described using a model of dilute particle suspensions which takes into account the role of the interface layer between the two fluids with different density and the behaviour of fingers.