Ash aggregation and disaggregation in volcanic plumes

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Keywords:

Volcanic ash aggregation is a crucial factor in mediating the dispersal of ash plumes. The 1980 Mount St. Helens and the 2010 Eyjafjallajökull volcanic eruptions are prominent examples that proofed the discrepancy between observed and predicted plume dispersal. This was likely due to the fact that ash aggregation was not incorporated in the ash plume dispersal models. Recently, aggregation processes have been included with certain assumptions but without the possibility of subsequent aggregate break-up during airborne transport. This limits the accuracy of plume forecasts and therefore presents shortcomings for the volcanic ash risk and hazard mitigation sector.

We experimentally produced aggregates from natural volcanic ash and synthetic glass beads via industrial granulation techniques. We investigated the aggregates through leaching and SEM, showing that natural and experimental aggregates of volcanic ash and glass beads have been cemented by salts, as e.g. NaCl. We find NaCl crystallized at the contact points of particles. In contrast, NaCl crystals are smaller and more evenly distributed on non-aggregated particles. We explain this apparent redistribution of NaCl by invoking the capillary-driven flow of water films towards the particle-particle contact points. These liquids can re-dissolve NaCl to form a brine. Brine movement and renewed NaCl crystallization results in thick (10s of µm) solid bridges that cement the aggregates.

We performed fall experiments to test the mechanical stability of our experimental aggregates. We find that aggregates consisting of coarse particles (starting grain size distribution: 40-90µm for volcanic ash, 50-70 µm for glass beads) are significantly more resistant to breakup processes than aggregates consisting of fine particles (starting grain size distribution: < 40µm and <50µm, respectively). We show that the larger surface area of coarse particles represents a larger "catchment area" to allow for thicker NaCl bonds at contact points. Although aggregates made from the finer starting grain size distribution are expected to be more densely packed and accordingly exhibit more contact points, our fall experiments revealed that they were more prone to disaggregation upon collision. Aggregation potential is correlated with particle concentration, as is the probability for collision. As a consequence, ash bound in aggregates is not necessarily doomed for premature settling. It may be liberated again and be dispersed as a single ash clast, potentially re-entrained into the ash plume. This finding should be considered for incorporation into ash plume dispersal modeling.