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Ash aggregation in volcanic plumes: when, where, how. A new theoretical perspective.

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Particle aggregation is a general aspect common to several scientific disciplines (e.g. planetary formation, air pollution, food industry). The impact of particle aggregation on the dispersal and sedimentation of volcanic ash has been identified during the last few decades and was further demonstrated during the 2010 Eyjafjallajökull eruption in Iceland when most of the European airspace was closed for several days and field observations revealed evidences of ash aggregation at various distances from source. Ash aggregation generally leads to an increase in the terminal velocity and in a resulting variation of the residence time of particles in the atmosphere. Therefore, neglecting ash aggregation could potentially lead to an overestimation of ash concentration in the far field and an underestimation of ash load in proximal area.
So far, the common approach to describe ash aggregation has been based on the application of empirical or semi-empirical relationships to redistribute part of the initial mass fraction into predetermined classes of particle size. In our work we propose an alternative approach, where the mathematical limitations of previous models (e.g. a unique size for aggregates or their a priori geometry) have been addressed and the physics of the processes better quantified. Our theoretical framework is based on a multidimensional solution of discrete Population Balance Equations (PBE). The final numerical scheme is capable to describe the evolution of aggregates tracking their changes in two or more internal variables. A complete set of collisional frequencies in a turbulent plume is proposed for the first time in volcanology. Particular attention has been posed in describing the mechanisms of sticking among volcanic particles. Two main mechanisms of dissipation of relative kinetic energies are considered: wet aggregation in saturated and undersaturated environments, where the water plays a major role; dry aggregation in the undersaturated parts of the plume, where the adhesive and viscoelastic forces are considered as one of the controlling phenomena. The role of ash hygroscopy is taken into account. Several examples and applications of the various aspects mentioned above (e.g. the role of water or relative kinetic energies associated with the collisions) are discussed and proposed, together with an application to real eruptions.