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Towards a better description of tephra dispersal and sedimentation

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Tephra dispersal and sedimentation has been shown to cause widespread damage to different systems (e.g. built environment, critical infrastructures, ecosystems) and sectors (e.g. transport, tourism, agriculture) at various spatial and temporal scales. In addition, tephra deposits retain important clues on the associated eruptions that sometimes cannot be inferred in any other way (e.g., plume height, erupted mass, grainsize of erupted material). As a result, the study and modeling of tephra dispersal is crucial both to our understanding of volcanic eruptions and to the hazard assessment of active volcanoes that have the potential of disrupting communities and economic systems at local, regional and global scale. Even though Volcanic Ash Transport and Dispersal Models (VATDMs) have now reached a high level of sophistication, an accurate and comprehensive parameterization of size-selective sedimentation processes (i.e. particle aggregation and gravitational instabilities) does not exist. Nonetheless, all size-selective sedimentation processes lead to a reduction in the atmospheric lifetime of fine ash. As most operational forecasting models do not account for these processes, proximal ash deposition may be underestimated, and distal airborne ash fraction overestimated, which is particularly relevant for forecasting aviation hazards (e.g., the pan-European airspace closures in 2010 were largely guided by model-based predictions). Various examples of empirical parameterization of particle aggregation have recently improved specific hazard assessments, while gravitational instabilities from volcanic clouds are far from being understood and quantitatively described. Besides, given that both size-selective processes affect the same size population (i.e. fine ash) in a similar manner (i.e. increasing the settling velocity), the associated effects might be often misinterpreted and wrongly described. These misconceptions have important implications for long-term hazard assessment of tephra sedimentation, real-time forecasting of ash-rich plumes and health-hazard assessments. A new versatile and comprehensive theoretical framework for the description of particle aggregation is here discussed that is based on new experimental investigations, addresses various mathematical limitations of previous models and better quantifies the physics of the process. In addition, key features of gravitational instabilities are presented and the interaction with particle aggregation is explored. We show how gravitational instabilities promote both high concentration of fine ash and turbulence and, therefore, particle aggregation could more easily occur both at the base of the clouds where instabilities form and inside the resulting fingers. Certainly, a better description of size-selective sedimentation processes is required to reduce the uncertainty associated with both long-term hazard assessments and real-time ash dispersal forecasting.