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Experiments on the influence of temperature and water content on volcanic plume electrification

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Volcanic lightning is the result of ash electrification within volcanic plumes. It is increasingly being detected at erupting volcanoes (Bogoslof, 2017; Ambae, 2018; Fuego, 2018 among the most recent) emphasising its great value for the detection of volcanic plumes and analysis of plume dynamics. However, lack of knowledge on the quantitative relationships between the jet conditions and the electrical activity within the plume hinders efficient analysis of the data. To fill this gap, an increasing number of experimental studies has been recently carried out to constrain these relations (e.g. Cimarelli et al., 2014; Mendez-Harper et al., 2018).

In this study, we investigate the influence of water content and temperature on electrification. Decompression experiments were carried out using loose volcanic ash samples (grain size 90 to 300 micrometers). Samples with similar mass (13 g) were pressurised to identical initial pressures (9 MPa). With all parameters kept constant, only temperature (between 25 and 320 °C) and water content (between 0 and 27.0 wt.%) were varied systematically. The samples were ejected into a 3 m high, fully electrically insulated collector tank. The tank itself served as Faraday cage to detect both the built-up and neutralised charge within the jet at a rate of 1/μs. A high speed camera (30000 frames/s) was used to record the experiments.

Temperature has a major influence on the charge generation processes. Hotter plumes rise quicker in our experiments, producing more air entrainment into the jet. This causes the creation of small eddies, in which more collisions can take place, producing more charge. With increasing temperature, the rate of air entrainment increases and jet density decreases such that particle collisions are diminished. As a consequence, the amount of charge neutralised by the discharges decreases towards the highest experimental temperatures.

We observe that an increased amount of water hinders effective charging of the material. Already few weight percent are sufficient to reduce the amount of charge and discharge by orders of magnitude. This is caused by a reduced number of particle-particle collisions, as the jet expands much quicker in presence of water vapour. Additionally, the highly increased conductivity of wet ash compared with dry ash decreases the charge density on the ash particles.

Water can therefore have a two-fold effect on plume electrification. On the one hand, water within the plume (like in our experiments) reduces the amount of charge. On the other hand, water present during fragmentation (like in phreatomagmatic eruptions) would increase the fragmentation rate and thus the amount of fines, which has a positive influence on the electrification.

Future experimental work will cover further parameters, e.g. ash chemistry, crystal content or the presence of ice to develop a model predicting discharge generation for known conditions.