Geophysical Research Abstracts
Vol. 16, EGU2014-9004, 2014
EGU General Assembly 2014

Experimental generation of volcanic lightning

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Ash-rich volcanic plumes that are responsible for injecting large quantities of aerosols into the atmosphere are often associated with intense electrical activity. Direct measurement of the electric potential at the crater, where the electric activity in the volcanic plume is first observed, is severely impeded, limiting progress in its investigation.
We have achieved volcanic lightning in the laboratory during rapid decompression experiments of gas-particle mixtures under controlled conditions. Upon decompression (from $\sim$100 bar argon pressure to atmospheric pressure), loose particles are vertically accelerated and ejected through a nozzle of 2.8 cm diameter into a large tank filled with air at atmospheric conditions. Because of their impulsive character, our experiments most closely represent the conditions encountered in the gas-thrust region of the plume, when ash is first ejected from the crater. We used sieved natural ash with different grain sizes from Popocatépetl (Mexico), Eyjafjallajökull (Iceland), and Soufrière Hills (Montserrat) volcanoes, as well as micrometric glass beads to constrain the influence of material properties on lightning. We monitored the dynamics of the particle-laden jets with a high-speed camera and the pressure and electric potential at the nozzle using a pressure transducer and two copper ring antennas connected to a high-impedance data acquisition system, respectively.
We find that lightning is controlled by the dynamics of the particle-laden jet and by the abundance of fine particles. Two main conditions are required to generate lightning: 1) self-electrification of the particles and 2) clustering of the particles driven by the jet fluid dynamics. The relative movement of clusters of charged particles within the plume generates the gradient in electrical potential, which is necessary for lightning. In this manner it is the gas-particle dynamics together with the evolving particle-density distribution within different regions of the plume that emerge as the key variables in volcanic lightning generation. A proportionality between fine ash content of the jet and number of lightning strikes is also evident in our experiments. This first recorded experimental generation of volcanic lightning means that rapid progress can now be expected (under controlled laboratory conditions) in understanding electrical phenomena produced during explosive volcanic eruptions. This in turn may aid the development of lightning monitoring systems for the forecasting of volcanic ash emissions into the atmosphere. Furthermore, our experiments are significant for the investigation of self-charging mechanism of particles that are relevant for atmospheric phenomena (such as dust storms) on Earth and other planetary bodies.