Introduction

Volcanic eruptions in Iceland in 2010 and 2011 were associated with significant lightning activity in the ash plume, as measured by the UK Met Office’s lightning detection network, ATDnet [Bennett et al. 2010]. A number of mechanisms have been put forward to explain the electrification of volcanic plumes, including triboelectric or fractoemission processes at the vent, the ‘dirty thunderstorm’ mechanism [e.g. Arason et al. 2011], internal radioactivity of the plume [Mather and Harrison 2006, James et al. 2008] in addition to triboelectric charging within the plume. Sustained electrical charging of the Eyjafjallajökull plume was observed 1200km from the volcano [Harrison et al. 2010] which indicates that some charging of the plume is independent of the eruption process. The lightning activity associated with the eruption from Grímsvötn in 2011 was up to 100 times as intense as that associated with the Eyjafjallajökull eruption in 2010. These observations have motivated a series of experiments in which we investigate the triboelectric charging of samples of volcanic ash from the 2010 Eyjafjallajökull and 2011 Grímsvötn eruption.

Experiment

Volcanic ash samples were provided by the Iceland Meteorological Office. Ash from the 2010 Eyjafjallajökull eruption was collected at Sólheimahæði, 22 km from the crater, and ash from the 2011 Grímsvötn eruption was collected 70 km from the crater.

A series of experiments were carried out whereby samples of volcanic ash were released to fall vertically through a cylinder onto a screened metal plate, located close to the bottom of the cylinder. The charge associated with the ash fall was measured by connecting the metal plate to an electrometer which recorded the voltage on the plate. The apparatus consisted of a 1m long cylindrical Perspex tube, 0.25m in diameter, the top of which was sealed with an inverted funnel connected to a loading trap and shutter (made of cardboard to minimise charge generation within the ash). The voltage on the bottom plate was measured with a Keithley 6512 electrometer and logged to a PC via an IEEE-488 interface. Approximately 50g of ash (baked to remove adsorbed water) was loaded into the trap and the shutter released to enable ash to fall under gravity to the bottom of the tube. The tube was mounted on a support frame so that after each ash drop it was rotated to reload the ash [Krauss et al. 2003, Aplin et al. 2011].

To provide vertical resolution in the measurement of ash charge, a displacement current sensor [Nicoll and Harrison 2009] was mounted on the inside of the Perspex cylinder, halfway between the conducting plate and the shutter of the loading plate. This sensor consists of a spherical electrode connected to an electrometer circuit, which measures the voltage on the electrode. Changes in electrode voltage result from charge transfer from either induction or impaction of ash particles.
Results

Eleven ash drops were obtained with the Eyjafjallajökull ash, and six for the Grímsvötn ash, with typical results shown in Figure 2. The difference in polarity and magnitude of the voltage generated on the bottom plate between the two ash samples is clear.

The capacitance of the system has been estimated to be 100pF using a technique described in Aplin and Harrison (2001). The total charge transferred per unit mass can therefore be estimated to be between +4 to 5.2pC/g for the Eyjafjallajökull ash and -36 to -60pC/g for the Grímsvötn ash. The volumetric distribution of particle diameters in the two samples was measured with a Malvern Mastersizer, and is shown in Figure 3. Although the bulk statistics of each sample were similar, with a median size of 106 and 103 µm for Eyjafjallajökull and Grímsvötn respectively, the Grímsvötn ash shows a monomodal distribution of particle sizes, and Eyjafjallajökull shows a bimodal particle size distribution with peaks at 45µm and 350µm. Grímsvötn had proportionately more small particles by volume, whereas Eyjafjallajökull had more large particles.
Figure 3: The volumetric particle size distribution for the sample of ash from Eyjafjallajökull is bimodal, whereas the distribution for ash from Grimsvötn is monomodal.

As the median particle sizes were so similar, the enhanced, negative, charge transfer per unit mass for the Grimsvötn sample compared to Eyjafjallajökull is thought to be related to the different sample size distributions.

Conclusions

Experiments dropping ash onto a collector plate have indicated that ash from the Grimsvötn eruption is more triboelectrically negative than ash from the Eyjafjallajökull eruption. It is known empirically that in single-material particle systems, the smaller particles charge negatively and the larger ones positively. Lacks and Levandovksy (2007) have explained this phenomenon in terms of transfer of electrons in trapped high-energy states. Smaller particles become depleted of these electrons more quickly than larger particles, which leads to net charge transfer of electrons to the smaller particles from the larger ones. The two peaks in the Eyjafjallajökull sample were relatively similar in size, therefore substantial net charging is not expected. Since charge is carried by individual particles, the charging is likely to be dominated by the number size distribution, rather than the volumetric distribution shown in Figure 3. The number size distribution would show enhanced numbers of small particles for Grimsvötn ash, which would be expected to charge negatively as a consequence.

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