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Charge mechanism of volcanic lightning revealed during the Eyjafjallajökull 2010 eruption

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The second phase of the subglacial Eyjafjallajökull volcanic eruption in Iceland, 14 April - 23 May 2010, may have revealed its charge mechanism of volcanic lightning. During these almost 40 days, the eruption went through a few phases while the conditions of the surrounding atmosphere also changed, but at different times. We have collected various measurements related to volcanic lightning in Iceland during the last volcanic eruptions: Grímsvötn 1998, Hekla 2000, Grímsvötn 2004, and Eyjafjallajökull 2010. The previous three eruptions lasted only a few days each and the main lightning activity only for 1-2 days. Several processes have been proposed to explain the electrification of volcanic plumes, such as a) Magma-water interactions. Submarine and subglacial eruptions lead to magma-water interactions and explosive volcanism. Laboratory experiments show that such processes lead to charge generation with water droplets positively charged and the ash negatively. b) Magma pulveration. The break up or internal friction and collisions of fine grained dry material may lead to charge generation. c) Dirty thunderstorm. Conditions, especially vertical temperature profiles of the atmosphere control at what height the water droplets in the volcanic plume will freeze. Processes related to the freezing of cloud droplets are thought to be responsible for charge generation in meteorological thunderclouds. Such conditions in a volcanic plume may lead to charge generation, and ash in the plume may facilitate such meteorological processes. The most surprising change in the lightning activity during the Eyjafjallajökull eruption occurred on 11 May when there was no obvious change in the physical eruption character or strength. Before 11 May there was no lightning recorded by long range networks, but 11-20 May the lightning activity in the plume was intense, with the highest activity of the entire eruption on 16 May. The change in lightning activity on 11 May coincides with a change in the conditions of the surrounding atmosphere. At this time the isotherms for droplet freezing (about -20°C) dropped drastically and the plume top reached the lowest temperatures on 16 May. Therefore, the atmospheric conditions around the plume are influencing or even controlling the lightning activity. Photographs of lightning during the Eyjafjallajökull eruption reveal two types: many show numerous small sparks at the base of the plume and a few photographs show large thunderbolts through the entire plume. The small sparks must be due to charge generation within the volcanic crater, such as magma-water interaction or ash friction/break up processes. However, the syncroneity of the main lightning activity with the atmospheric freezing conditions supports that the charge generation of the large volcanic lightning is analogous to meteorological lightning.