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VOLCANOGENIC LIGHTNINGS DURING A SUB-GLACIAL ERUPTION IN ICELAND

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Abstract: The Icelandic lightning location system detected several lightnings during the Grímsvötn volcanic eruption in December 1998. However, many were not registered due to the fact that the direction finders (DF) are expected to register only ground flashes. We expect that many of the flashes may have been too weak or seemed strange to the DF's. Furthermore, it is possible that our old DF-equipment is poorly tuned. From the lightning data that we gathered, it appears that the lightning current of these volcanogenic lightnings is considerably lower than in weather lightnings.

Keywords: Volcanogenic lightnings, Volcanic eruption, Grimsvotn caldera, Iceland

1. INTRODUCTION

The Grímsvötn caldera lies beneath the Vatnajökull-glacier in SE-Iceland (see Figure 1). The diameter of the caldera is about 10 km. The caldera is filled with geothermally melted ice, covered by a thick ice cap. The last volcanic eruption in Grímsvötn before 1998 was in 1983, although a near-by sub-glacial eruption occurred in 1996.

The eruption started on 18 December 1998 at 09:20 AM, on the southern caldera-rim (64°24'N, 17°20'W) where the ice was thought to be 50-100 m thick. The first days of the volcanic eruption were the most fierce and during that time the weather was calm with relatively clear skies. This allowed us to view the eruption and the frequent lightning flashes in its 10 km high column of ash and water vapor. These lightning flashes were visible even from Reykjavík (220 km), but in this time of year the time between sunrise and sunset is only about 4 hours. After a few days the eruption diminished, followed by single explosions between quiet periods. The eruption ended on 28 December 1998.

Measurements of the volcanic cloud during the Surtsey-island eruption in Iceland 1963-1967 indicated that the volcanic ash was negatively charged while the water vapor was positively charged [1, 2].

The interaction between water and magma is responsible for the charge separation. Some of the earliest experiments and demonstrations of electricity included splashing water on very hot surfaces or coals, which lead to a charge separation and positively charged steam [3, 4]. Experiments in connection with the Surtsey eruption, on charge separation due to interaction between water and hot lava indicated that saline water was more powerful in charge separation than pure water [1, 2]. These experiments also showed that water from the Grímsvötn caldera, splashed onto hot lava produced positively charged steam.

In this paper we report measurements of lightnings during the Grímsvötn 1998 eruption by the Icelandic lightning location system.

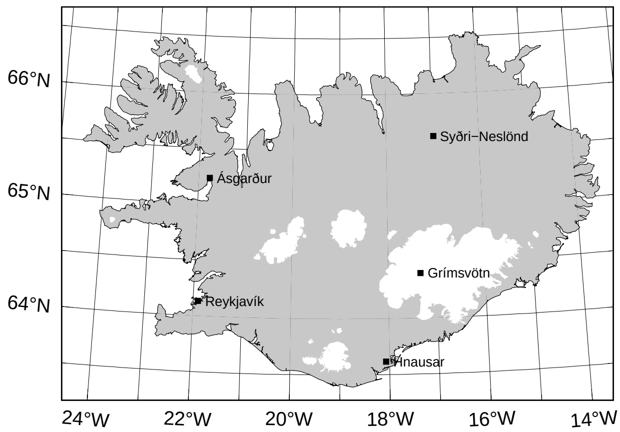

Figure 1. Location map of Iceland and the Grímsvötn caldera in the central part of Vatnajökull-glacier (glaciers are indicated by white). The locations of the four DF-stations are also shown.

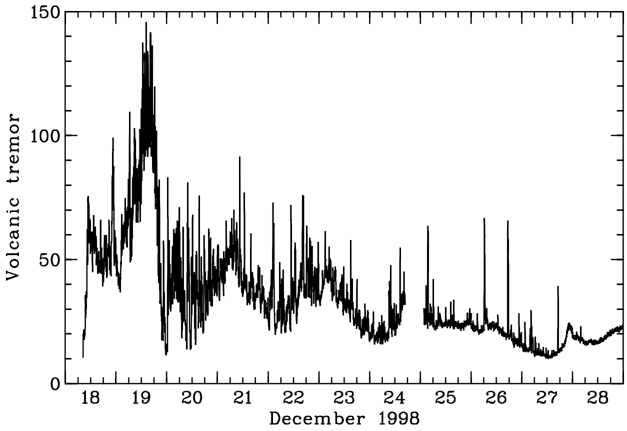

Figure 2. Volcanic tremor as measured at a seismological station 53 km from Grímsvötn.

2. THE LIGHTNING LOCATION SYSTEM

The Icelandic lightning location system consists of four LLP-type DF 80-02 at Reykjavík (RE), Ásgarður (ÁS), Syðri-Neslönd (SN), and Hnausar (HN), (see Figure 1). The data acquisition is controlled by PC's. The lightning data is processed at the Icelandic Meteorological Office in Reykjavík. The location system was described at ICLP in Birmingham [5], and in a recent paper and a report [6, 7].

Additionally, we now have a Danish vertical E-field waveform recording system in Reykjavík [8, 9]. It enables us to study the waveforms accepted or rejected by our LLP system. Unfortunately, we did not have the E-field system installed until three weeks after the Grímsvötn 1998 eruption.

3. REGISTERED EVENTS

In Figure 2 we show intensity of the 0.5-1.0 Hz volcanic tremor measured at Kálfafell (63°57'N, 17°41'W) about 53 km from Grímsvötn. This graph shows how the intensity of the eruption was greatest during the first two days and decreased after that.

Eyewitness accounts described periods of intense lightning activity. During some of these periods the LLP-system registered no events. During the eruption the LLP-system registered 35 lightning events. The number of registered events per day are shown in Figure 3. The lightning activity decreases after the first day of the eruption and is very low after the third day.

Of the 35 events, 26 were only registered by a single DF-station, four events by two stations, three events by three stations and two events were registered simultaneously by all four DF-stations. This totals to 51 registrations. It is not clear whether the DF-stations are poorly tuned, most of the lightnings were of low intensity, or that these volcanogenic lightnings over a thick glacier did give the impression of cloud flashes and were rejected.

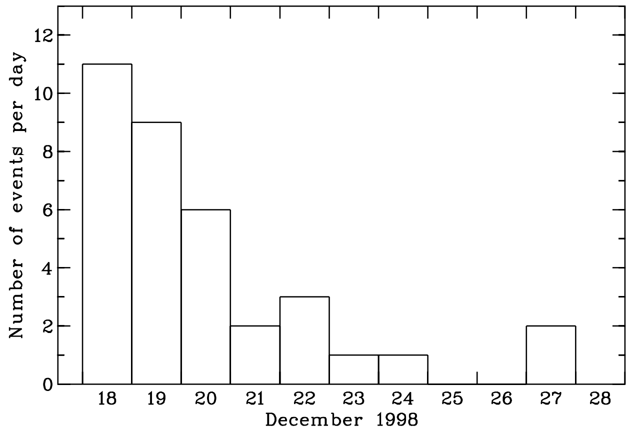

Figure 3. Number of registered lightning events per day by the LLP-system.

In Figure 4 we show the directions to lightnings as reported by the DF's. The true directions from the DF-stations to Grímsvötn are shown by dashed lines. There seems to be a good overall correspondence between observed and expected directions.

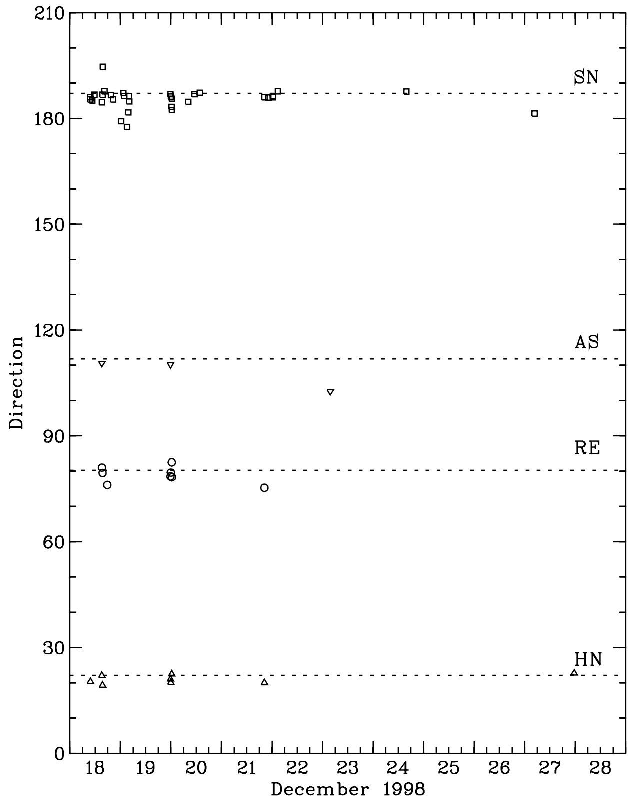

Figure 4. Observed directions at the four DF-stations during the eruption. Dashed lines indicate directions to Grímsvötn.

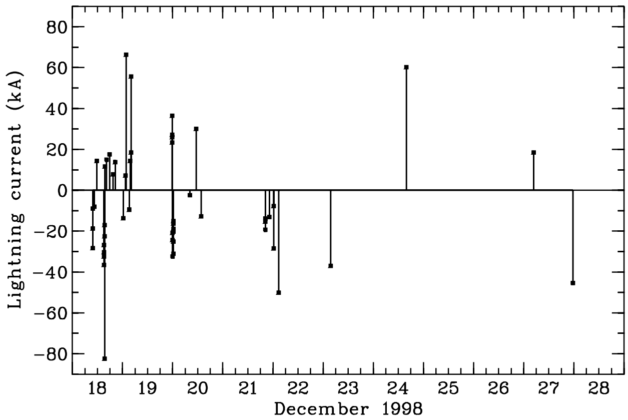

Figure 5. Estimated lightning current (kA) of the observed lightnings over Grímsvötn.

For the 51 registration at our DF-stations we calculated the lightning current assuming that locations of the lightnings were at Grímsvötn. The estimated current of the volcanic lightnings vs. time is shown in Figure 5. The geometric mean of the 33 negative and 18 positive polarity events are -20 and +21 kA, respectively. These numbers can be compared to the lightning current of located weather lightnings in Iceland in the area 60°-70°N and 0°-40°W for the whole year 1998. The geometric means of weather lightning currents are -47 and +71 kA for 64 negative and 173 positive lightnings, respectively. These means are lower than those for the first year of operation [5].

It is interesting to note the similarity in strength of the two polarities for the volcanogenic lightnings, as opposed to the significant difference between the polarities of weather lightnings. Furthermore, it appears that the volcanogenic lightnings have on average only about a third to a half of the strength of weather lightnings. It is not clear why these volcanogenic lightnings should have lower current. We can only speculate that the volcanic cloud with its high temperature high buoyancy steam mixed with fine grained ash has a higher conductivity than a normal colder pure ice and water cloud. Increased conductivity of the cloud column probably leads to lowering of the charges needed to initiate the lightning process.

4. CONCLUSIONS

The Icelandic lightning location system registered a few of the lightnings associated with the Grímsvötn 1998 volcanic eruption. However, many lightnings were not registered.

It appears that the registered volcanogenic lightnings have lower current than regular weather lightnings.

While finishing this paper, another volcanic eruption started in Mount Hekla (64°00'N, 19°41'W) on 26 February 2000. The LLP lightning location system and also the E-field waveform system have recorded some lightnings in this Hekla 2000 eruption.

Acknowledgements

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