Volcanogenic Lightning

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1 Abstract

Lightning activity is common in volcanic ash plumes, especially in subglacial or submarine eruptions. The interaction between magma and water is considered responsible for electric charge separation, leading to positively charged vapor and negatively charged ash.

Lightning data was collected during the last three volcanic eruptions in Iceland; Grímsvötn 1998, Hekla 2000 and Grímsvötn 2004. The lightning in the Grímsvötn 1998 subglacial eruption were measured by both the LLP Icelandic lightning location system and the ATD sferics system of the UK Met Office. During the eruption of Hekla 2000 we collected data from both these lightning location systems as well as from our EFMS wave recording station, located in Reykjavík.

Our best data comes from the Grímsvötn 2004 eruption; lightning were recorded by three systems, the Icelandic LLP lightning location system, the UK Met Office's ATD sferics location system, and by the EFMS waveform recording system.

We note a good correlation between the lightning activity and the intensity of the eruptions as indicated by the height of the ash plume observed by weather radar. The lightning data collected during these three brief volcanic eruptions gives valuable insight into the character of volcanogenic lightning and how they differ from weather lightning.

2 Located Lightning during Grímsvötn 2004

On 1 November 2004 a volcanic eruption began in the Grímsvötn caldera beneath the Vatnajökull ice cap in Iceland. The eruption was most vigorous during the first 36 hours.

The eruption was preceeded by both a long term increase in seismicity and a short term earthquake swarm, which enabled successful prediction of the eruption by the staff of the Icelandic Meteorological Office.

Fortunately for our data collection, no "weather" thunderstorm activity was occurring close to Iceland during the eruption.

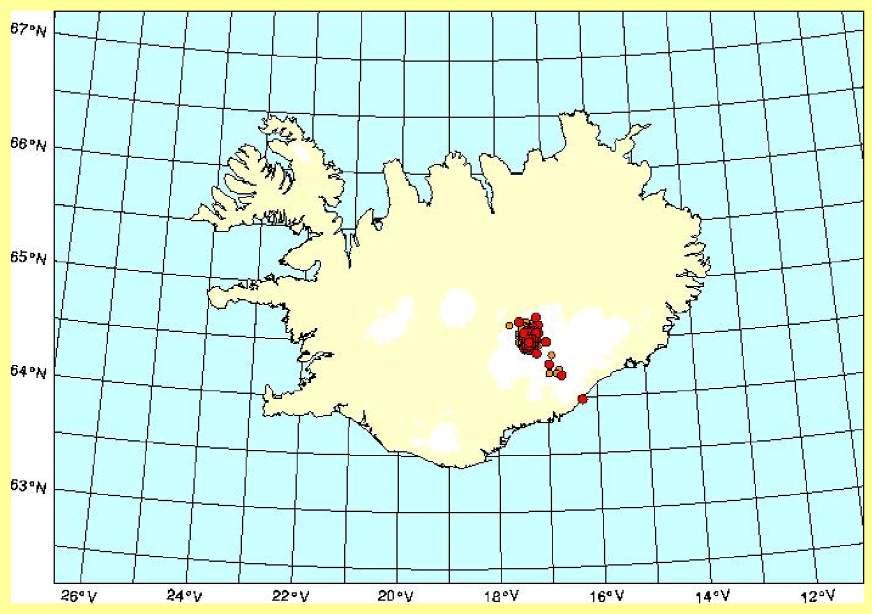


Fig. 1. Over 250 lightning strikes were located by the ATD sferics lightning location system of the UK Met Office. The SE-trend of the locations is an artifact of poor locations.

Fig. 3. Lightning in the volcanic column recorded on film by Ómar Ragnarsson (RÚV) in the afternoon of 2 Nov. The film shows 5-6 strokes in the flash. The time interval between the major strokes fits well with three negative polarity cloud-to-ground events recorded by the EFMS system at 16:57:39 on 2 Nov. The LLP system recorded this lightning as four negative polarity cloud-to-ground strokes, the first of which had a peak current of -23 kA.

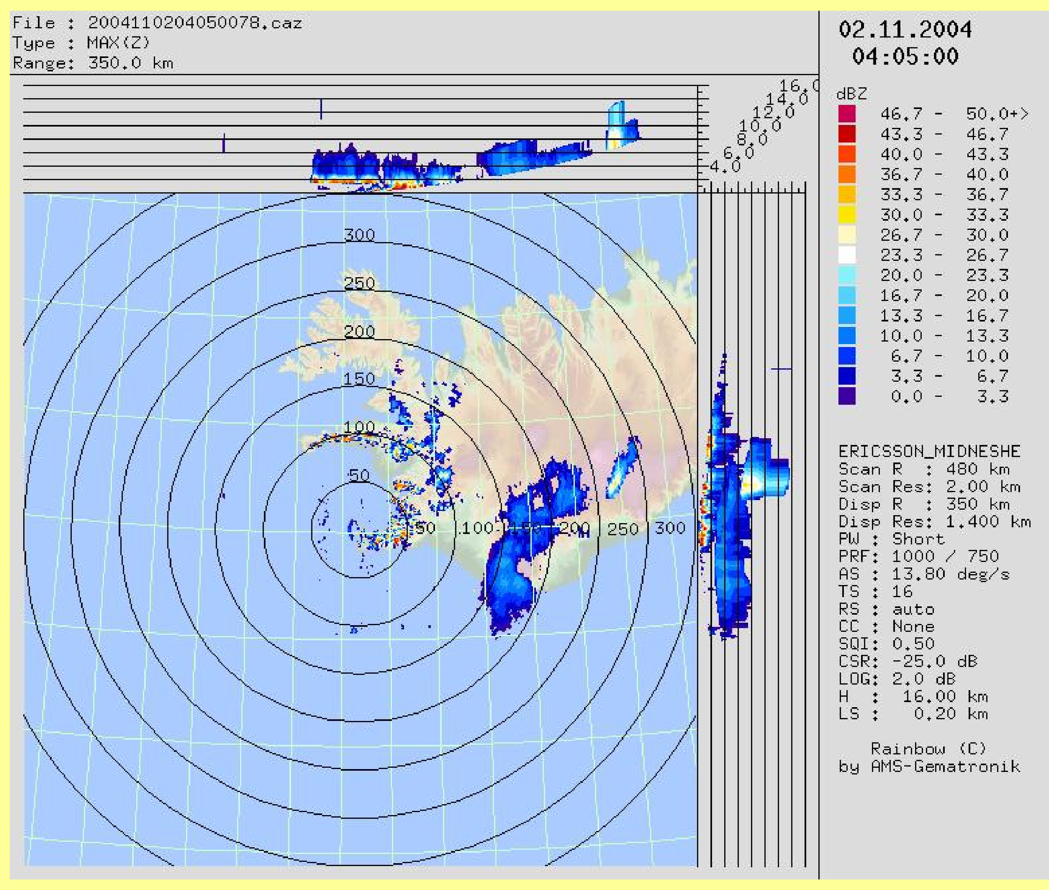


Fig. 2. Weather radar image at 04:05 AM on 2 Nov showing the tephra plume at its maximum.

3 Systems Recording the Grímsvötn 2004

Real-time access to the ATD sferics lightning location system of the UK Met Office enabled the location of 252 lightning strikes over the eruption site in the first 36 hours of the eruption (see Fig. 1). The ATD system does not distinguish between cloud-to-cloud (CC) and cloud-to-ground (CG) lightning.

The LLP Icelandic lightning location system was not successful in locating the lightning, but was able to give useful polarity and intensity measurements, from which we were able to calculate peak electric current estimates of 149 CG lightning. The first lightning was at 01:37 UTC on 2 Nov and the last one at 08:40 UTC on 3 Nov.

Our EFMS wave recording station is located in Reykjavík, 220 km from the volcano. This station records variations in the vertical electric field with a sampling interval of 0.2 µs. We were able to record the waveforms of 152 lightning with the EFMS system from 23:23 UTC on 1 Nov to 08:37 UTC on 3 Nov. Of these waveforms 70 indicate CC lightning and 82 of the waveforms show negative polarity CG lightning.

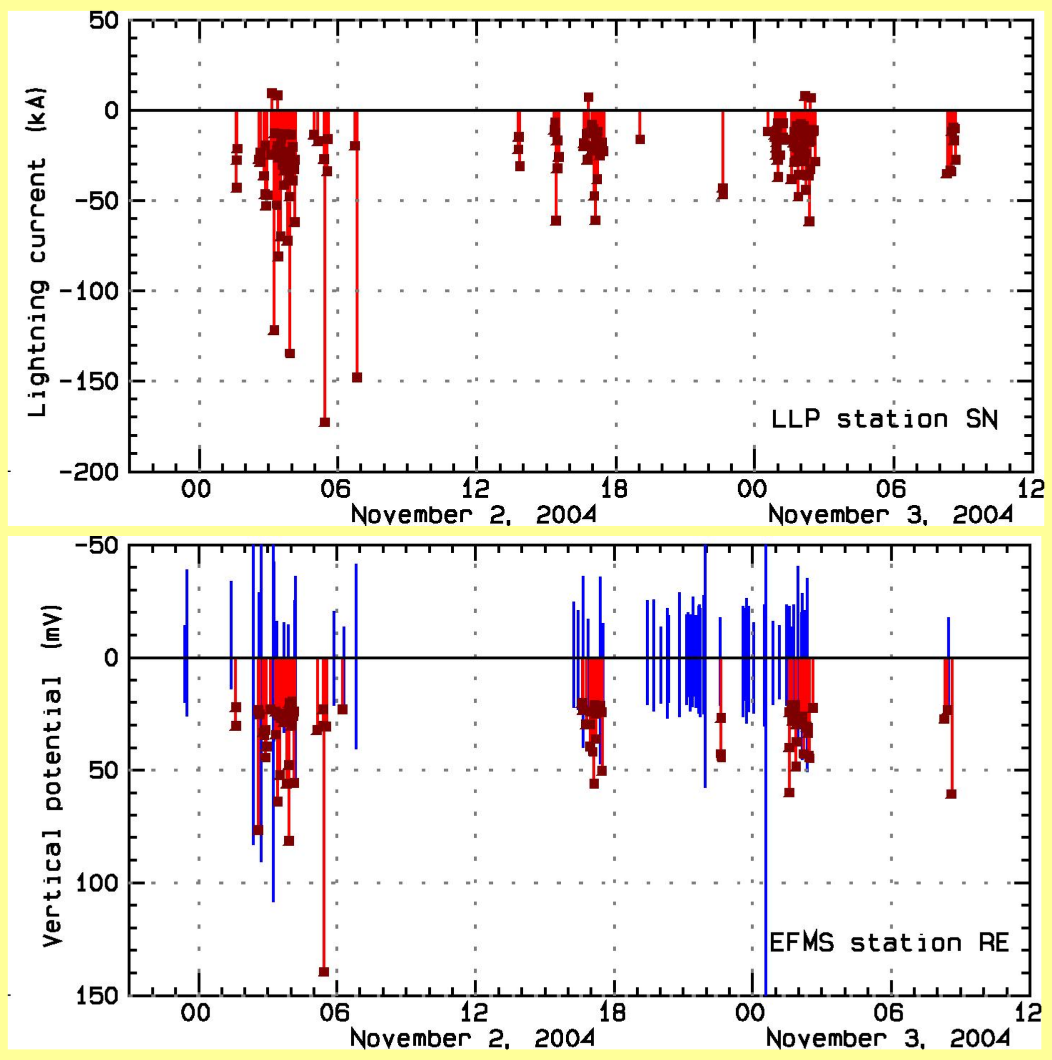


Fig. 4. Signal strength of the LLP and EFMS measured lightning. Blue spikes show CC lightning. There is a very good correlation but the LLP system has a lower threshold value.

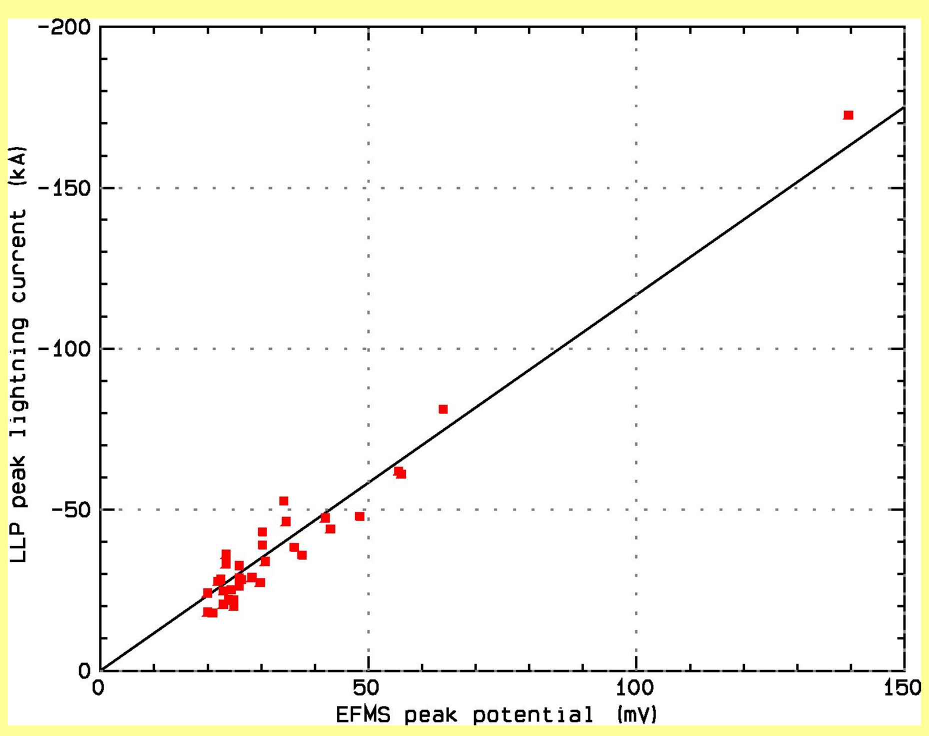


Fig. 6. Comparison of signal strength from single stroke negative polarity CG lightning recorded by the LLP and EFMS systems.

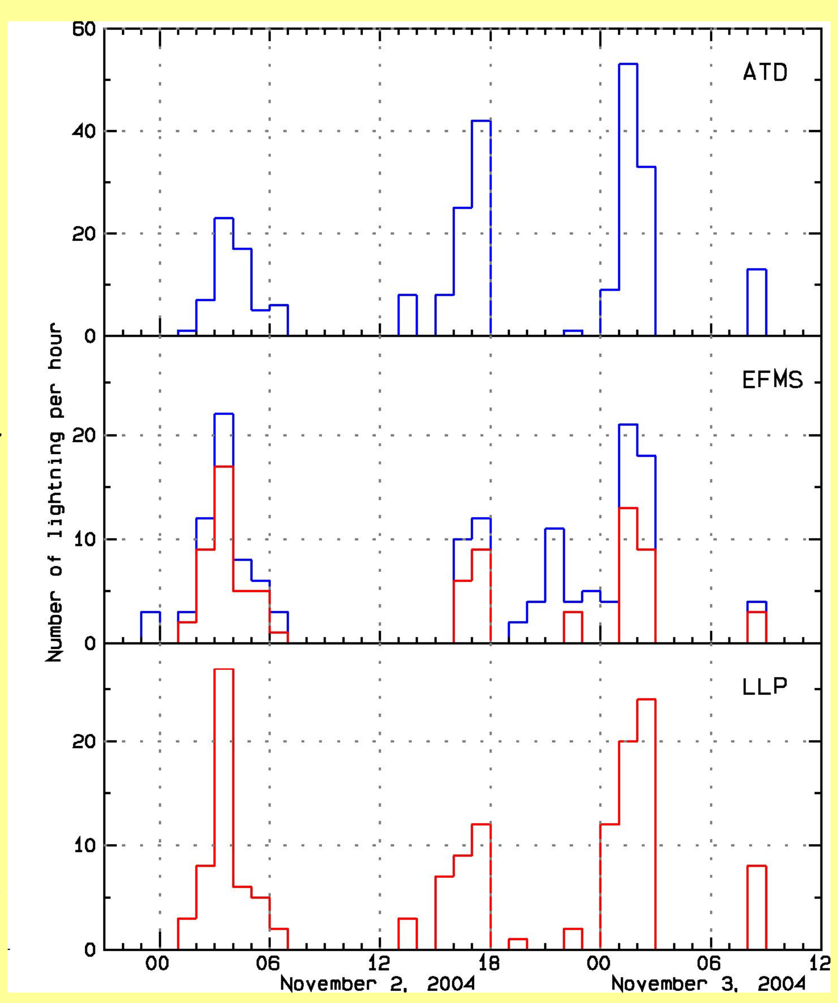


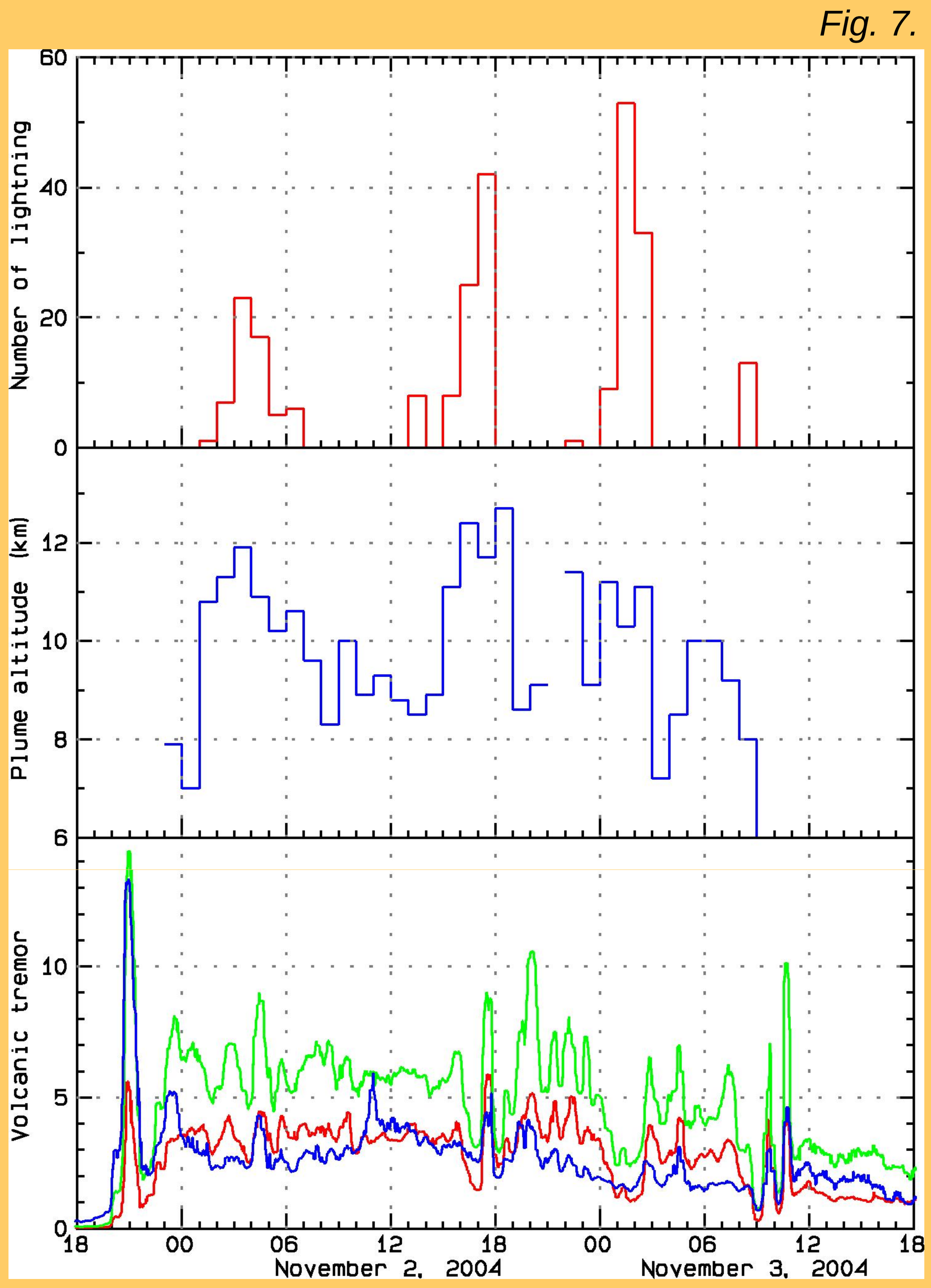
Fig. 5. Number of lightning per hour measured by the three systems. The ATD system does not distinguish between CC and CG lightning. The EFMS system measures both and the LLP system only records CG lightning.

4 Conclusions

The developement of the volcanic eruption in Grímsvötn 2004 during its first two days shows good correlation between lightning activity and the intensity of the eruption as indicated by height of the ash plume and the volcanic tremor.

Fig. 7 shows the number of lightning per hour located in Grímsvötn by the ATD system, hourly averages of the height of the volcanic ash plume as measured by weather radar, and the volcanic tremor, from a seismic station located on the caldera rim, in three frequency bands (— 0.5-1 Hz, — 1-2 Hz, — 2-4 Hz).

Fig. 7.



Poster presented at the International Association of Volcanology and Chemistry of the Earth's Interior - IAVCEI 2008, General Assembly, 18-22 August 2008, Reykjavík, Iceland