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INITIAL RESULTS OF THE ICELANDIC LIGHTNING LOCATION SYSTEM

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A lightning location system has been operational in Iceland since the summer of 1997. In this paper we describe the system and our initial results of winter-lightnings between 60°N and 67°N. Although the high latitude winter thunderstorms that we have observed give only a few lightnings per storm, we are observing more thunderstorms than previous estimates from human observations have indicated. Usually we observe only one stroke per lightning. Furthermore, the data indicate that positive-lightnings are more abundant than the negative ones. Our lightning current estimates are extremely high, or on the average close to 100 kA.

1 INTRODUCTION

In 1996 eight institutions in Iceland, in the fields of electricity, telephone, aviation, insurance, and meteorology, made an agreement to buy and operate, experimentally for a limited time, a lightning location system. Previously, Jóhannsdóttir [1] made a comparison study between some of the available systems. We acquired an used LLP system from Norway and set up a network of four direction finder (DF) stations. Unfortunately, we were not able to get any lightning locations the first winter because of malfunctions in these old DF's, and we had to repair most of them. After those repairs, we have had two stations operational since May 1997 and all four since October 1997. During this first year of data acquisition we have been able to locate lightnings from several thunderstorms. Furthermore, we have now been able to make our initial site-error corrections and relocate the lightnings.

2 THE DF STATIONS

The location of the four DF stations is shown in Figure 1. On each station we have a set of LLP's DF 80-02 and a set of 70 cm sized E and B-sensors. The DF's are connected through direct telephone lines to an APA-281 central unit in Reykjavík. Due to problems with the APA we have also collected the raw data at the stations in a PC-computer. The PC's are connected to the Meteorological Office through regular phone lines. The clock of the PC's is monitored regularly, so that relative time information between stations is accurate to within 10 ms.

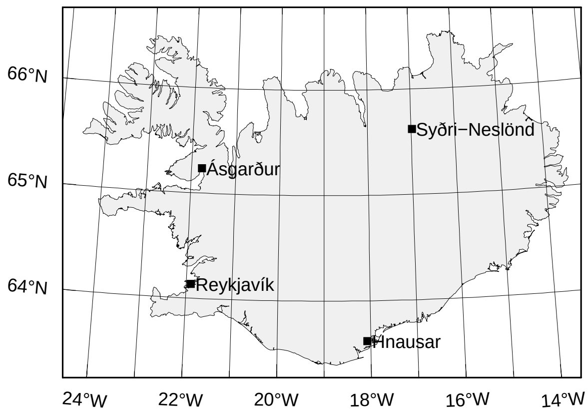

Figure 1: Location map of the DF stations in Iceland.

The station at *Syðri-Neslönd (SN)* is located in a farm by Lake Mývatn at 65.619°N, 16.981°W, 280 m a.s.l. The station is surrounded by the lake and a flat area for the closest 5-10 km. SN has been collecting data since 30 September 1997. The station at *Hnausar (HN)* at 63.616°N, 18.073°W, 20 m a.s.l. is located in an area of flat sands and lava for the closest 20 km. HN has been collecting data since 30 September 1997. The station at *Ásgarður (ÁS)* at 65.235°N, 21.767°W, 40 m a.s.l., is located in a 2 km wide valley oriented N-S. ÁS has been collecting since 26 February 1997. The fourth station is in central *Reykjavík (RE)* at 64.133°N, 21.900°W, 70 m a.s.l. at the Icelandic Meteorological Office, where we operate the system. The RE station has been collecting data since 30 May 1997. A summary (in Icelandic) of the installation of the stations was published in October 1996 [2].

3 DATA FROM THE FIRST WINTER

From the end of May to October 1997 we had two stations working, and since October 1997 all four stations collected data. During this time we have recorded 470 simultaneous events from at least two stations. On closer inspection we eliminated locations very far away, where the directions were almost parallel, or even diverging. Furthermore, we eliminated the very close events where only one station was non-saturated. By constraining us to locations North of 60°N we end up with 221 lightnings, and by omitting lightnings where stations are reporting opposite polarity we are left with 216 fairly reliable lightning locations.

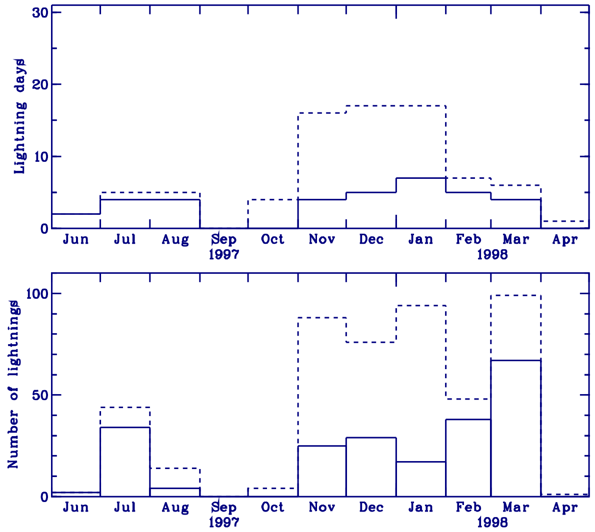

Figure 2: Number of lightnings and lightning days per month located by the Icelandic system in its first year of operation. The dashed line shows all the 470 events and the solid line shows the selected 216 reliable lightnings.

Figure 2 shows the lightnings located by the Icelandic system from June 1997 to April 1998. This figure shows well how winter-thunderstorms are more frequent at these high latitudes, than the summer-thunderstorms. We are now fairly convinced that the previous estimate of 1 thunderstorm per year [3] is not correct.

4 SITE-ERROR CORRECTIONS

From these rather few lightning locations we have selected all the data where three or four stations have participated in locating a lightning. A total of 19 lightnings were observed by all four stations, whereas 71 lightnings were located by three stations. These 90 lightnings were used to constrain our estimates of site-errors. Unfortunately, the locations are not ideally distributed, as most of them are South of Iceland, outside the system. Therefore, our site-error values can only be viewed as crude first estimates, subject to change as we gather more data.

For a located lightning we calculated the difference between the measured and observed direction for each DF. For stations *SN* and *HN* we only fitted a constant shift to the directional anomalies. For stations *ÁS* and *RE* we fitted a constant shift and a two-cycle sinusoid to the anomalies versus observed direction. The least-squares fit was our choice for a site-error correction.

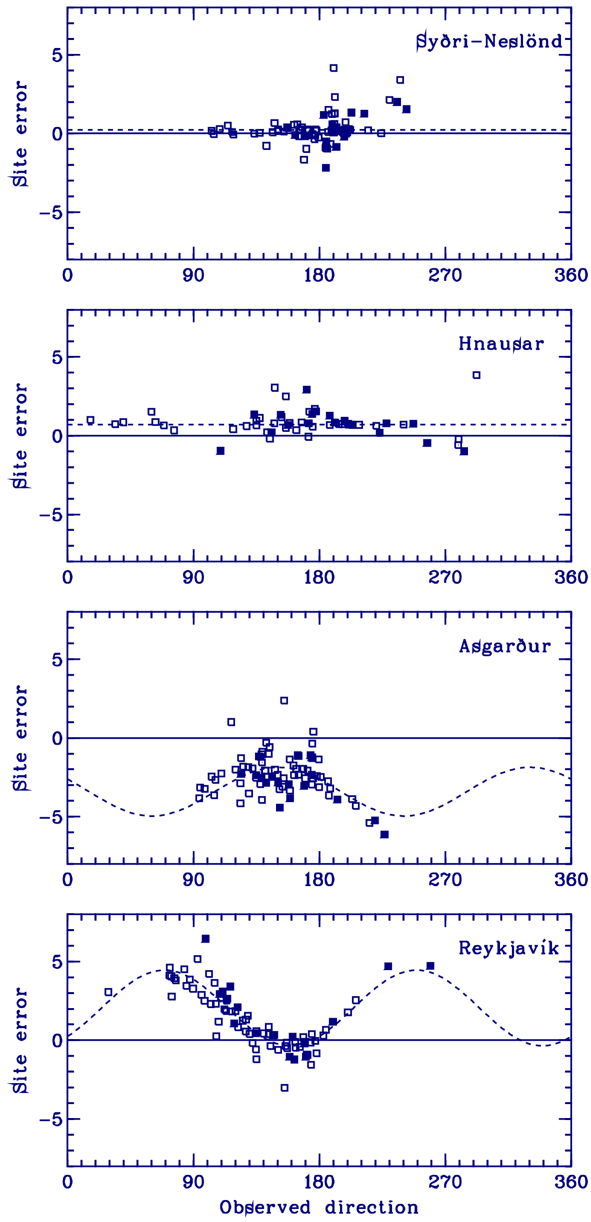

Figure 3: Site-error corrections (in degrees) of this study for individual stations, shown by the dashed curves. Filled/open squares represent site-error estimates for individual stations from lightnings observed by four/three stations.

The choice of a particular site-error function will slightly affect the lightning locations. Therefore, we used our selected site-error correction to get better locations for the selected 90 lightnings. By an iterative process we adjusted the site-error functions and the locations until a stable solution was found. We used 10 iterations to find our chosen solution. The correction is made by

$$\alpha_{corr} = \alpha_{obs} + \beta \quad (1)$$

where α is the direction at a station to the lightning and β is the site-error correction. The resulting site-error functions of this study are:

$$\beta_{SN} = 0.22° \quad (2)$$

$$\beta_{HN} = 0.70° \quad (3)$$

$$\beta_{ÁS} = -3.41° - 1.33° \sin 2\alpha + 0.79° \cos 2\alpha \quad (4)$$

$$\beta_{RE} = 2.05° + 1.59° \sin 2\alpha - 1.80° \cos 2\alpha \quad (5)$$

The selected site-error functions and the observed anomalies are shown in Figure 3. This figure shows that the differences are quite small. In fact, after the correction, the standard deviation is 1.0°, and the chosen site-error functions decrease the variance in the observed anomalies by 70%. However, it is evident that further data collection is needed to better constrain these functions.

5 LIGHTNING LOCATIONS

To locate the lightnings we use a non-linear least squares inversion technique [4,5] to minimise the angular differences between observed and calculated directions for all the stations. To calculate the directions to a lightning we assume a spherical Earth and use spherical trigonometry. A lightning observed only by two stations has of course no difference between calculated and observed directions.

In Figure 4 we show the locations and polarity of the lightnings North of 60°N. Historically, the SE-coast of Iceland has the highest frequency of thunderstorms.

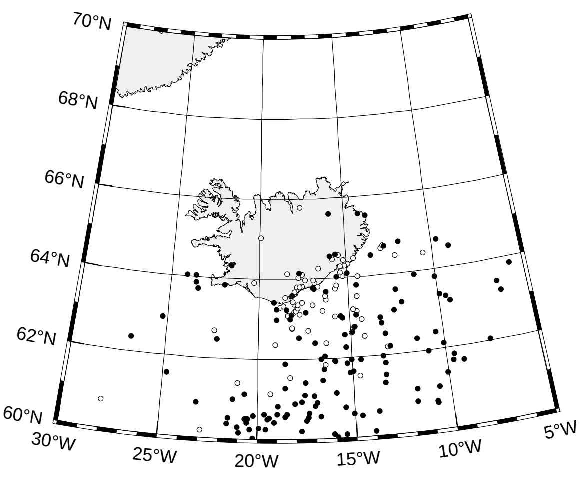

Figure 4: Lightnings North of 60°N as located by the Icelandic system for the period from June 1997 to April 1998. Filled/open circles show positive/negative polarity lightnings.

6 LIGHTNING CURRENT

Of the 216 lightnings, 75 (35%) are negative-polarity and 141 (65%) positive. This ratio may change significantly with further data collection, since a single thunderstorm in March 1998 gave 60 positive and no negative lightnings. However, it is very interesting to see this high proportion of positive-polarity lightnings.

In Figure 5 we show a histogram of the current in the lightnings. The average current in positive lightnings is 111 kA (geometric mean is 96 kA), and the average for negative lightnings is 101 kA (geometric mean 76 kA). These values are uncomfortably high.

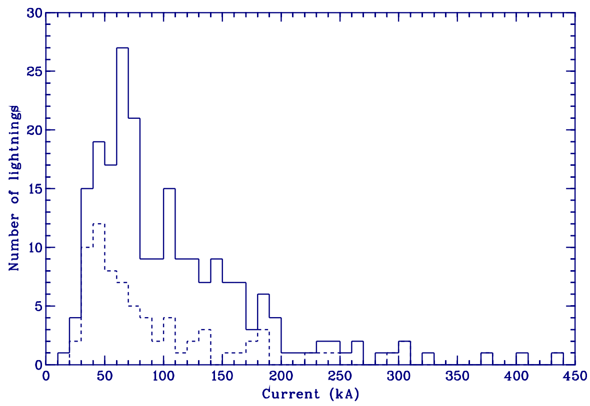

Figure 5: Histogram of the currents in the lightnings. The dashed line shows only negative-polarity lightnings and the solid line shows the total.

7 CONCLUSIONS

Although, we had several problems during installation of the system, we were able to repair the equipment and the system seems now to be giving reliable results. A recent report (in Icelandic) of the results during the first winter was published in April 1998 by the Working Group on Lightning Research in Iceland [6].

The lightning data of the Icelandic system is now available on-line on the Web, both in numerical form and as graphs and maps. The path to our website is `http://www.vedur.is/ta/elding` and access is open to all.

In our view the initial results of the Icelandic lightning location system are very interesting and further data collection is needed to verify and clarify some of the initial findings.

7.1 Acknowledgements

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7.2 References

[1] Jóhannsdóttir, H. : "Comparison of Lightning Location Systems", *Report*, Electric Power Engineering Department, Technical University of Denmark, 208 p., 1993.

[2] Arason, P. : "Uppsetning eldinganema á Íslandi", *Report VÍ-G96029-TA02*, Icelandic Meteorological Office, Reykjavik, Iceland, 3 p., 1996, (in Icelandic).

[3] Uman, M. A. : "*The Lightning Discharge*", Academic Press, 1987.

[4] Menke, W. : "*Geophysical Data Analysis: Discrete Inverse Theory*", Academic Press, Florida, 260 p., 1984.

[5] Passi, R. M., and R. E. López : "A Parametric Estimation of Systematic Errors in Networks of Magnetic Direction Finders", *J. Geophys. Res.*, 94, pp. 13 319-13 328, 1989.

[6] The Working Group on Lightning Research in Iceland : "Uppsetning á búnaði til mælinga og skráningar á niðurslætti eldinga til jarðar á Íslandi", *Report*, Samstarfsnefnd um rannsóknir á eldingum, Reykjavik, Iceland, 55 p., 1998, (in Icelandic).

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