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THE RATIO BETWEEN FIRST AND SUBSEQUENT LIGHTNING RETURN STROKE ELECTRIC FIELD PEAKS IN SWEDEN

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Abstract - Electric field measurements of first and subsequent lightning return strokes by the Austrian Lightning Detection and Information System (ALDIS) and by electric-field antennas in Florida, United States, show no agreement about the relationship between first-stroke peak field and subsequent stroke peak field in negative cloud-to-ground lightning [1]. While in Florida the results are in agreement with what is usually accepted in the literature, that is, the median negative first-stroke peak field (or current) is approximately two times larger than subsequent stroke peak field in the same channel, in Austria the ALDIS network has observed no significant difference between the median values of the electric field (or current) peak for first and subsequent strokes. To investigate this puzzle in more detail several field measurement campaigns were performed during the last years, e.g. in Austria [2] and in Brazil [3]. During summer 2006 field measurement data was collected in Sweden also with the same field measurement system which was used in Austria and Brazil. In this paper we will show a comparison of the peak field ratio between first and subsequent strokes given by the field measurement data and the Swedish lightning location system. We will further compare the result from Sweden with results from Austria and Brazil.

1 INTRODUCTION

In 2004 a field measurement system (FM-system) was developed in Austria to continuously measure electric fields during thunderstorms. Details about the FM system can be found in [3]. The main goal for developing this FM-system was to have a tool for checking the data of the Austrian Lightning Location System (LLS). The data of the FM-system together with data from the LLS can be also used to verify the relationship between first and subsequent stroke electric field peaks. During the last years this relationship was often a subject of discussion because electric field measurements in Florida and results from the LLS in Austria showed no agreement.

2 MEASUREMENT SETUP AND DATA

The measurement setup in Sweden (see Fig. 2.1) was slightly different to the setup in Austria. Contrary to Austria in Sweden no fiber optic link was used between the Integrator output and the Data Acquisition Box (DAQ). In Sweden a double shielded coaxial cable RG223 was used. Further the E-Field antenna was setup on top of a Uppsala University building approximately 20m tall.

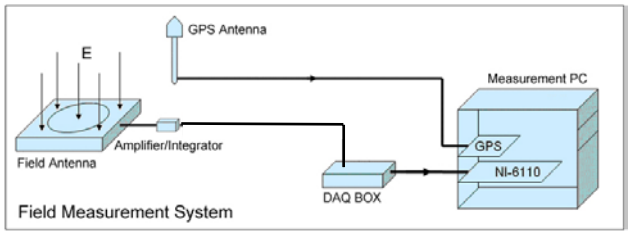

Fig.2.1: Field measurement setup

The background noise level at the selected measurement site was approximately +/- 0.1 V/m, which is quite low. It has to be noted that the field enhancement due to the building was not compensated.

For our analysis we used data recorded on the 24.7.2006 between 14:35:45 and 16:57:20. We used data only within

60 km from the measuring site because more distant strokes may not show all the field signatures to classify the stroke. The geographical overview of the lightning activity in Fig. 2.1 shows all positive, negative and cloud discharges detected by the Swedish LLS during this time.

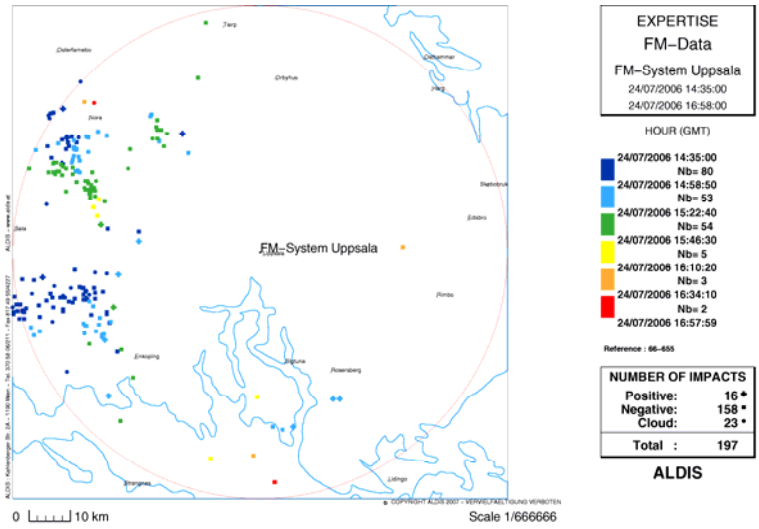

Fig. 2.2: Geographical overview of the lightning activity during the measurement time. The field measurement equipment was located in the center of the circle with 60km radius.

We analyze in this paper negative flashes only. Of the 158 negative flashes identified by the LLS, we have analyzed 134 negative flashes only because the remaining 24 flashes detected by the LLS (21 single stroke flashes and 3 multiple stroke flashes) were actually misclassified cloud discharges.

3 RESULTS

As already pointed out by Schulz and Diendorfer [2] there exist several possibilities to compare the relationship between first and subsequent stroke electric field peaks. In this paper we will still use the same nomenclature as in the previous papers namely:

- Method A1) By the first method the mean peak values of strokes are calculated for each stroke order. Afterwards the mean values can be compared to each other and a statement can be made on the ratio of the first stroke mean value to the overall mean values of subsequent strokes (single stroke flashes included).
- Method A2) Additionally this can be done for all flashes or for multiple stroke flashes only (single stroke flashes are excluded in the sample of first strokes).
- Method B) Another method is to calculate the ratio of the first stroke peak fields and the mean value of peak fields of all the subsequent strokes in each individual multiple stroke flash and than calculate the mean of the individual ratios .

In our evaluation of the FM-data we used the data from the LLS to get the distance to the stroke and to group the strokes into flashes. We rated first strokes as first strokes if one of several typical field signatures of a first stroke was visible, e.g.

- Initial breakdown before the return stroke waveform or
- Leader fields visible before the return stroke waveform or
- Field variation in the back of the return stroke waveform.

In our analysis 88% of the first strokes had an initial breakdown field waveform before the return stroke waveform. The LLS reported 305 negative cloud to ground strokes in multi stroke flashes. 27 (9%) of those strokes were misclassified cloud discharges. Fig. 3.1 shows the number of strokes for each stroke order according to the data from the FM-system.

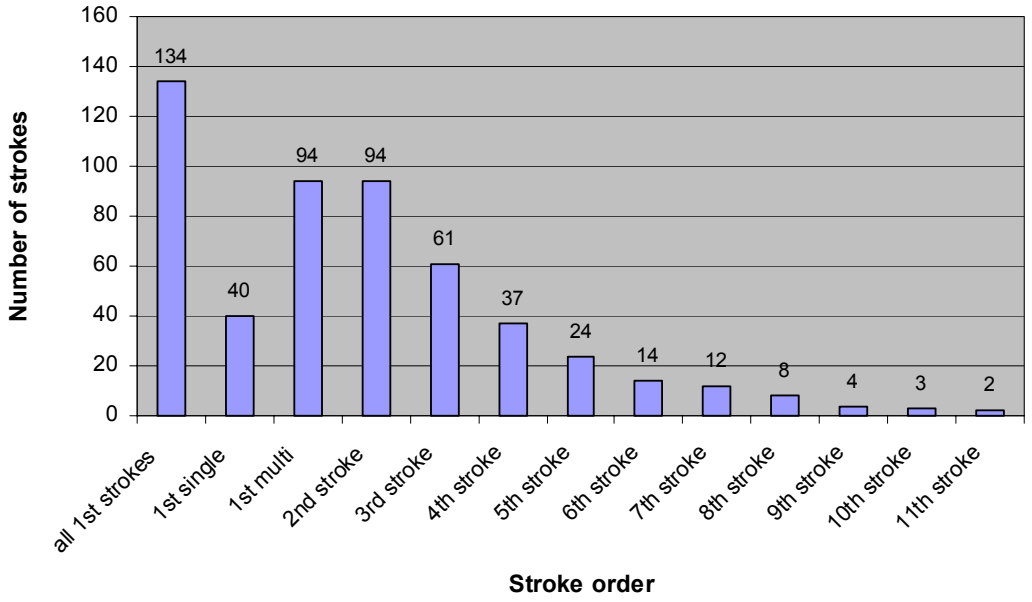

Fig. 3.1: Number of stroke for each stroke order of the FM data

The resulting mean peak values normalized to 100 km for the individual stroke orders are shown in Fig. 3.2. It is necessary to take into account that those values are overestimates because of the uncorrected field enhancement at the FM antenna site.

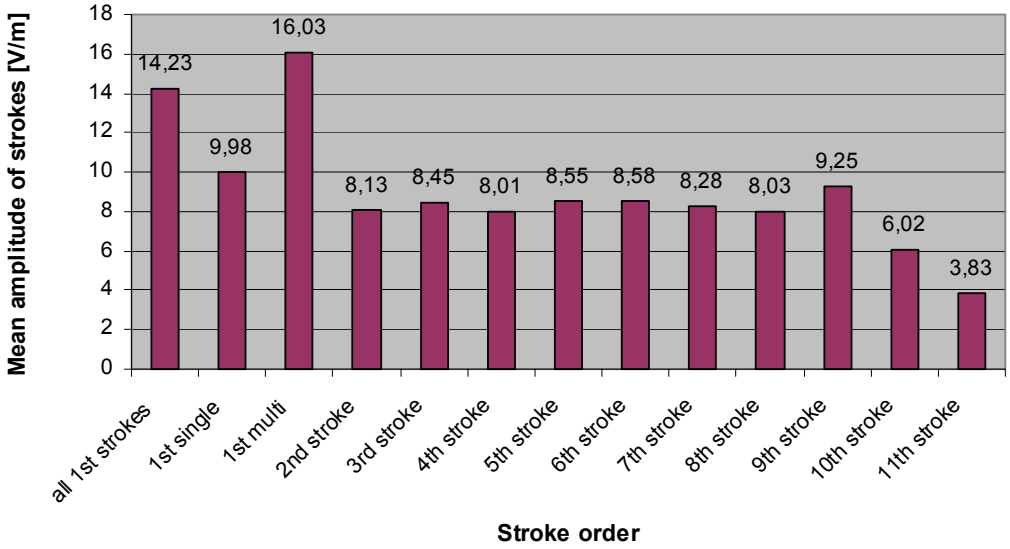

Fig. 3.2: Mean peak values normalized to 100km in V/m versus stroke order of CG strokes of the FM data (uncorrected for field enhancement)

The amplitude ratio of all first strokes (including single strokes) to all subsequent strokes is 1.7 (Method A1 – Mean). If only multiple stroke flashes are considered (no single stroke flashes included) the ratio becomes 2.0 (Method A2 – Mean). The mean peak ratio of first to subsequent strokes within each individual multiple stroke flash is 2.1 (Method B). All ratios are calculated for amplitudes up to the 11th stroke order.

Table 1 shows the resulting values of the peak field ratios for Sweden together with the values for Austria, Brazil and Florida. It is interesting to note from Table 1 that the ratios for Sweden are more or less similar to the values in Brazil and that the ratios in Austria are significantly smaller compared to the other studies. Table 1 further shows that all the studies based on field measurements in conjunction with LLS data exhibits smaller ratios compared to what was measured in Florida based on field measurements and video observations.

Table 1: Ratios between first and subsequent stroke peak fields

	Method A1		Method A2		Method B	
	GM	Mean	GM	Mean	GM	Mean
Sweden [this study]	1.6	1.7	1.8	2.0	1.8	2.1
Brazil [2]	1.7	1.6	1.8	1.7	1.5	1.8
Austria [3]	-	1.0	-	1.4	-	1.6
Florida [4]	2.03	-	2.14	-	-	-

For all four studies the results from method A1 are smaller compared to method A2 or method B. The reason for this is that single stroke flashes, which are included in Method A1, normally exhibit smaller amplitudes compared to first strokes in multiple stroke flashes [5]. From Table 1 it is clear that the results regarding the peak field ratios in Austria are different to the other regions. Up to now it is not clear why there are such small peak field ratios in Austria.

4 SUMMARY AND DISCUSSION

In this paper we compared the ratio between first stroke electric field peaks to subsequent stroke electric field peaks in Sweden with two similar studies in Austria [2] and Brazil [3] and data from field measurements in Florida [4]. The reason why we looked at the amplitude ratios between first and subsequent strokes was that in literature an overall ratio between first and subsequent strokes of two is mentioned [4] and that LLS data in Austria shows a ratio of about one (depending on how you look at the data). Due to the reason that the same field measurement system was used for the measurements in Austria, Brazil and Sweden and that almost the same methodology was used to analyze the data we can attribute differences almost exclusively to differences in the different climatic zones.

We have shown in this paper that all peak field ratios based on field measurements and LLS data show smaller peak field ratios compared to a study in Florida with electric field and video measurements. However, ratios for Sweden are more or less similar to the values in Brazil and the ratios in Austria are significantly smaller compared to the other studies. The reason for this is currently unclear.

It should be noted that the Swedish LLS missclassified during the recording time of the FM-System 24 negative flashes (21 single stroke flashes and 3 multiple stroke flashes) out of the 158 negative flashes.

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5 REFERENCES

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