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LLS DATA AND CORRELATED CONTINUOUS E-FIELD MEASUREMENTS

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Abstract - In 2003 we developed a PC based and GPS synchronized field measurement system which is able to measure and record electric field data continuously. This field measurement system is based on a 12 bit digitizing board operating with a sampling rate of 5 MS/s. The board allows to record a maximum of two channels at the same time. Once every second the field data are stored on the hard disc of the PC. Depending on the number of recorded channels (one or two) the size of the "one-second" file is 10MB or 20MB, respectively. Such a continuous and GPS synchronized field measurement system has some important advantages compared to a triggered system. There is no trigger threshold and no dead time and therefore we basically do not miss any events. In this paper we show some preliminary results of a first measurement campaign in summer 2004. We show results from the amplitude ratios between first and subsequent strokes [Diendorfer et al., 1998] and we give some examples of erroneously classified bipolar flashes [Schulz and Diendorfer, 2003].

1 INTRODUCTION

During the last years data from lightning location systems (LLS) gained increasing interest by the lightning research community. Lightning parameters determined with LLS are compared to lightning parameters determined with other methods, e.g. tower measurements, trigger experiments and even with single station field measurements. Often those comparisons revealed significant differences and therefore discussion started about the origin of those differences. There are several attempts to explain those differences – one of them is the limited performance of the used LLS and therefore increasing attention is paid to the evaluation of the performance of LLS. Further it is often argued that the data from the LLS has limited value because all the sensors have a threshold and therefore they fail to report strokes radiating fields that arrive at the sensor site with amplitudes smaller than the threshold value of the sensor. It is the goal of this field measurement project to shed some light on this discussion.
To be able to analyze available LLS data properly different strategies are possible. Two of them are:

- Analysis of distinct flashes in a nearby thunderstorm with GPS synchronized continuous E-field measurements combined with a high speed camera records (see Saba et al. [2004a, 2004b]).
- Analysis of thunderstorms with GPS synchronized continuous E-field measurements only

The main disadvantage of the second method is that there will remain some uncertainty and discussion regarding CG versus CC categorization of the field signal. Due to the lack of a high speed camera we have chosen to use in this project continuous E-field measurements only. The big advantage of this type of analysis is the number of data. One close thunderstorm is enough to get sufficient data for the analysis.

As already mentioned we think that ideally a thunderstorm should be located within 50 km to 100 km of the E-field measurement site to assure that the second method gives enough information to analyze the LLS data correctly. During late summer 2004 the closest thunderstorm we could record occurred at a distance ranging from 250 km - 300 km to the E-field measurement site and therefore the presented results are only preliminary.

2 EXPERIMENTAL SETUP

The measurement hardware consists of a PC with two PCI-cards (the GPS card Meinberg GPS168PCI and the data acquisition card NI PCI-6111), a data acquisition box (DAQ BOX NI BNC-2110), a flat plate E field antenna, an integrator/amplifier, a GPS antenna and a fiber optic link (Tektronix A6905 S – technically identical to ISOBE 3000). For outdoor measurements a small gas power generator (Kawasaki GD 700A) is used for the power supply. The principal setup of the measurement system is given in Fig. 2.1.

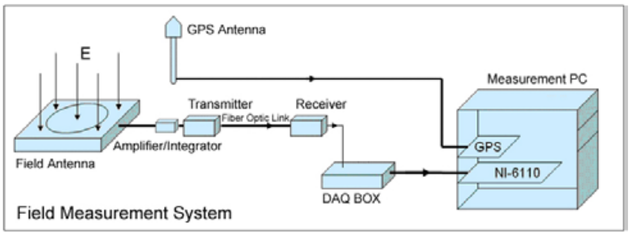

Fig. 2.1: Field measurement (FM) system

The measurement system can be used to record the electric field during lightning activity continuously. Information about the construction and the dimensions of the used flat plate antenna is given in Mair [2000]. The measurement system has two channels and is configured to operate with a sampling rate of 5 MS/s for each channel. Although synchronous recording of two channels is possible with a sampling rate of 5 MS/s and the existing hard- and software, only one channel was used for the field measurement in this project. The vertical resolution of the digitizer is 12 bits and is therefore providing sufficient dynamic range. The total recording duration is limited only by the size of the storage media, the hard disc. For the used 80 GB hard disc, data from one channel can be continuously recorded for a duration of about 2.4 hours. Every second a file (size of the file is 10 MB) is created containing the digitized field data of the last second. Moreover the recorded data are GPS synchronized in a way that each file starts and ends exactly at the full second and starting time is assigned as filename.

The bandwidth of the FM system is limited by the bandwidth of the integrator/amplifier. During these measurements the FM system (integrator/amplifier + flat plate antenna) had an overall bandwidth from 10 Hz to about 1.5 MHz. With this bandwidth the local noise level of approximately ±0.25 V/m at the selected measurement site in Bad Vöslau allowed to analyze fields from strokes with amplitudes greater than approximately 5 kA at a distance of 300 km.

3 DATA

On 30.08.2004 electric field data were recorded with the FM system at the site Bad Vöslau for a time period of about two hours. Bad Vöslau was selected because one of the ALDIS sensors is located at that site and the FM next to a sensor allows direct comparison of measured data and sensor reports. The recording was started at 12:59:41 and continued until 15:08:30 with a short break between 14:08:04 to 14:13:45. The lightning activity for this time period is illustrated in Figure 3.1.

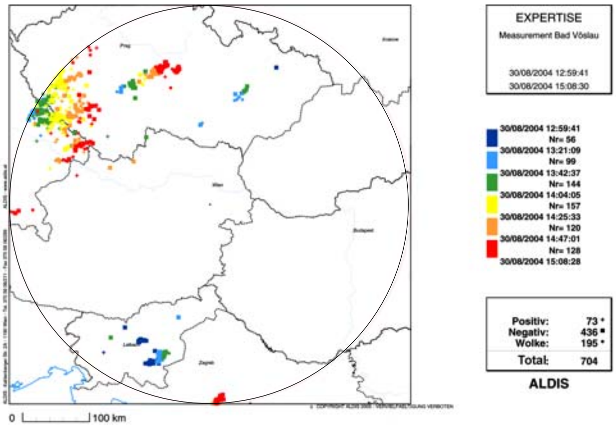

Fig. 3.1: Geographical overview of the lightning activity during the measurement time (Bad Vöslau is located at the centre of the circle with 300 km radius).

The geographical overview of the lightning activity in Figure 3.1 shows all positive, negative and cloud discharges, detected by the LLS during the measurement period. The red circle, with its centre in Bad Vöslau, has a radius of 300 km. 436 negative CG strokes are located within the circle. This number is slightly greater than the number of strokes available from the FM data, because there is a break in the recording for about 5 minutes, as mentioned above. Due to this, no FM files exist for this period and some negative cloud-to-ground strokes that were detected by the LLS during this time are not considered for the following analyses. Further, the data available for the analyses include some strokes that occurred more than 300 km away from the measurement site, assuming they were a part of a multistroke flash with at least one stroke within the given radius. Besides the negative strokes, 73 positive CG strokes and 195 cloud discharges were detected by the LLS during the measurement period.

We analyze in this paper negative flashes only. One example of the field records, a correctly detected typical negative flash is given in Fig. 3.2. The initial breakdown process is not detected by the LLS but the three strokes are correctly detected and categorized as CG strokes.

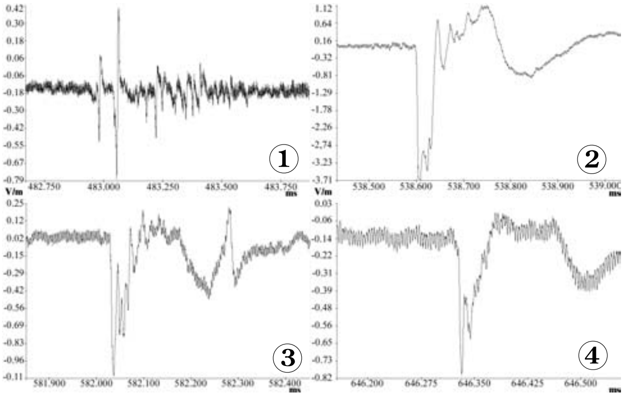

Fig. 3.2: The electric field of a typical negative CG flash (30.08.2004 13:11:53).
① … initial breakdown; ②, ③, ④ … CG-strokes

4 FIRST RESULTS

A) Peak field ratios

One goal of this field measurement campaign was to shed some light on the discussion about the ratio of peak fields of first stroke to subsequent strokes.

There are basically two possibilities to calculate this parameter:

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 multistroke 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 multistroke flash.

For the calculation of the following ratios all electric field waveforms are used, which are visible in the FM files and have the typical characteristics of negative CG strokes. If a field pulse shows the characteristics of a negative CG stroke and is time correlated to other strokes of a flash (within 1 second) and no correlated data is found in the ALDIS database at a distance greater than 300 km, this stroke is assigned to this multistroke flash of the FM data which is analyzed. For the calculation of the normalized E-field the location of the previous stroke is used. Negative strokes from bipolar flashes are not taken into account. As a result, 365 CG strokes are found, 120 (33 %) of them are single strokes and 245 (67 %) resulted from 92 multistroke flashes.

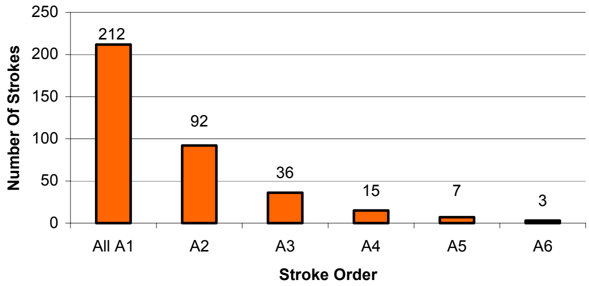

Fig. 4.1: Number of negative CG strokes for each stroke order of the FM data.

Due to the relatively small number of strokes for stroke orders greater than 4, the mean values for these stroke orders may not be statistically significant. In Figure 4.2 also the mean amplitude for first strokes of multistroke flashes (A1 Mu) is given.

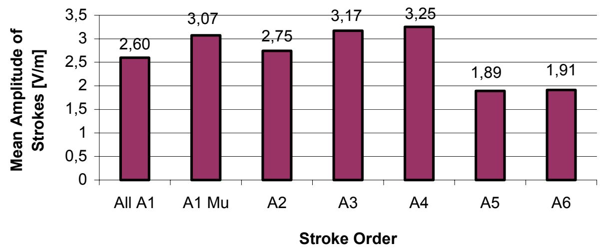

Fig. 4.2: Mean peak value normalized to 100 km in V/m versus stroke order of CG strokes of FM data

The amplitude ratio of all first strokes (including single strokes) to all subsequent strokes is 1.00 (Method a1). If only first strokes of multistroke flashes are used (no single strokes included) the ratio is 1.18 (Method a2). Both values include mean amplitudes of stroke orders greater than 4.

The mean peak ratio of first to subsequent strokes of each individual multistroke flash is 1.32 (Method b). The minimum and maximum ratios calculated for these data are 0.29 versus 7.58, as shown in Figure 4.3..

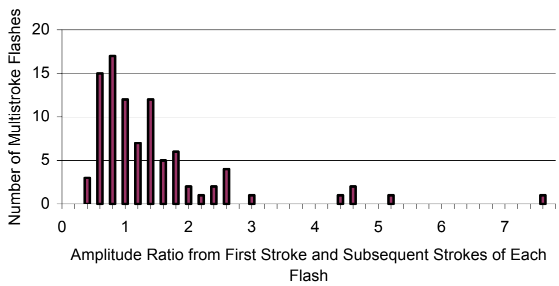

Fig. 4.3: Frequency distribution of the amplitude ratios from all first and their subsequent strokes of multistroke flashes of FM data.

B) Bipolar flashes

Rakov [2000] divided bipolar flashes into three categories. (1) Bipolar flashes having polarity reversal during the slowly-varying (millisecond-scale) current component. (2) Bipolar flashes having different polarities of the initial stage current and the following return strokes. (3) Bipolar flashes having return strokes of opposite polarity. Only bipolar flashes from the third category are detectable by a LLS. Additionally to the categories by Rakov [2000] we separate in positive and negative bipolar flashes according to the polarity of the first stroke [Schulz and Diendorfer, 2003]. In total 19 (17%) of all 111 (92 unipolar + 19 bipolar flashes) detected multistroke flashes are bipolar. The LLS detected 7 positive bipolar and 12 negative bipolar flashes. Altogether, the bipolar flashes consist of 20 positive and 34 negative CG strokes.

Only 2 (11 %) out of 19 bipolar flashes were detected correctly. Those 2 bipolar flashes were positive bipolar flashes. All 7 negative bipolar flashes were erroneously assigned to bipolar flashes. According to our analysis the main reason for erroneously detected bipolar flashes are falsely assigned positive strokes. All those positive strokes have a small amplitude and the corresponding field waveform is either bipolar or part of an initial breakdown. This supports the hypothesis that a significant fraction of the field waveforms assigned as positive strokes are actually associated with cloud discharges.

5. SUMMARY AND DISCUSSION

It is typically assumed that most of the time the first stroke of a multistroke flash is a factor 2 to 3 larger (in terms of peak current or a peak field) than the subsequent strokes in the same flash [Rakov and Uman, 2003]. Diendorfer et al. [1998] showed that this ratio between first stroke peak current and subsequent stroke peak current is not present in the data from the Austrian LLS and speculated about the reason for this result (influence of misidentified CC strokes and missed first strokes).

We have shown in this paper that there are basically two possibilities to calculate this ratio. If mean values of the individual stroke orders are used for the calculation of this ratio a value of 1.00 was calculated for all flashes and a value of 1.18 is received if only data from multistroke flashes are taken into account. It is clear that the ratio for multistroke flashes is larger because first stroke peak fields for multistroke flashes are normally larger than peak fields for single stroke flashes [Rakov and Uman, 1990; Schulz et al., 2005]. If the ratio for each multistroke flash is calculated we get a value of 1.32.

These preliminary ratio results in this paper based on data from quite distant strokes are not biased by misclassified CC strokes and/or by missed first strokes but are still comparable to the results from the LLS.

The LLS reported 7 (37 %) positive bipolar and 12 (63 %) negative bipolar flashes. Both together made up about 17 % of all 111 detected multistroke flashes. Only for 2 (11 %) out of the 19 detected bipolar flashes the detection of was totally correct. Those 2 are positive bipolar flashes. All 7 negative bipolar flashes were erroneously assigned to bipolar flashes. The main reason that the majority of bipolar flashes were not detected are falsely assigned positive strokes. Those strokes had a small amplitude and the waveforms were bipolar.

6 REFERENCES

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