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Flash Multiplicity and Interstroke Intervals in Austria

W. Schulz and G. Diendorfer
OVE-ALDIS, Austria, Kahlenberger Str. 2A, A-1190 Vienna

Abstract: In 2003 we have developed a PC based and GPS synchronized field measurement system which is able to measure and store electric field data continuously. This field measurement system is based on a 12 bit digitizing board operated 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 is stored on the hard disc of the PC. Depending on the number of recorded channels (one or two) the size of the file is 10MB or 20MB, respectively [Schulz et al., 2005a]. The main advantage of such a continuous and GPS synchronized field measurement system compared to a triggered system is that it is not suffering from any trigger threshold and dead time and therefore we basically do not miss any events. Consequently this system is ideal for critical analyzes of data from lightning location systems (LLS). In this paper we will show a comparison of the flash multiplicity and the interstroke interval derived from data from the Austrian LLS ALDIS (Austrian Lightning Detection and Information System) and the data from the new field measurement system. We will further compare the result with parameters previously published in the literature.

I. Introduction

Flash multiplicity is a lightning parameter which is very sensitive to the performance of a LLS. Since 1998 the performance of ALDIS increased as a result of the interconnection with neighboring systems. During the same period also the measured average flash multiplicity in Austria decreased significantly [Schulz et al., 2005b]. In 2001 the average multiplicity for negative flashes measured by ALDIS was about 2.0 what is significantly lower than values reported in literature for so called accurate stroke count studies. In these studies, which were summarized by Rakov and Huffines [2003] the multiplicity values were in the range from 4.6 to 6.4. There are several possible reasons for this difference:

- Analyzed data are collected by different observation techniques: Normally in literature so called accurate-stroke-count studies by video and/or field measurements are used as a reference.
- Different amount of data: LLS data are averaged over thousands of flashes and different types of storms.
- Due to the increase of detection efficiency (DE), an additional population of small amplitude single stroke flashes is detected.
- Analyzed LLS data are corrupted by a significant amount of cloud-to-cloud flashes that are misclassified as single stroke CG flashes.

As shown by Schulz et al. [2005b] also the number of single stroke flashes in the ALDIS data increased during the last years which of course significantly influences the multiplicity statistics. In this paper we compare the ALDIS data to data from a continuous field measurement system (FM-System) to shed some light on the questions mentioned above.

II. 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.

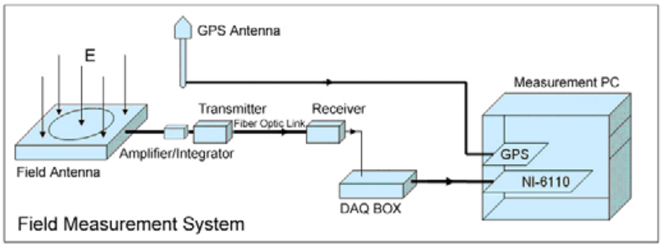

Figure 2.1: Field measurement (FM) system

The measurement system can be used to record the electric field during lightning activity continuously. Technical information about 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 data 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 the measurements in 2005 the FM-System (integrator/amplifier + flat plate antenna) had an overall bandwidth from 350 Hz to about 1.5 MHz and the local noise level at the selected antenna site Bad Voeslau was approximately ±0.15 V/m. Assuming that a return stroke field needs to be about 3 times greater than the noise level to be correctly analyzed we were able to analyze fields from strokes with amplitudes greater than approximately 3 kA at a distance of 100 km.

III. DATA

Lightning data was recorded at the site of one of the ALDIS sensors in Bad Voeslau on July 11th, 2005. We have chosen the location Bad Voeslau for two reasons:

- It is easy to compare the calibration of the FM-System with the data of the nearby lightning location sensor.
- The site exhibits a very low noise level.

Data recording was started at 12:00:36 UTC and continued until about 15:00 h. For the following analyses we only use data from 12:00:36 till 12:52:38 because after this time heavy rain disturbed the electric field measurements. The data set was further limited to flashes within a distance of 50 to 100km from the FM-System because closer flashes may saturate the FM-System and more distant strokes may not show all the field signatures to classify the stroke. The lightning activity for this time period is illustrated in Figure 3.1.

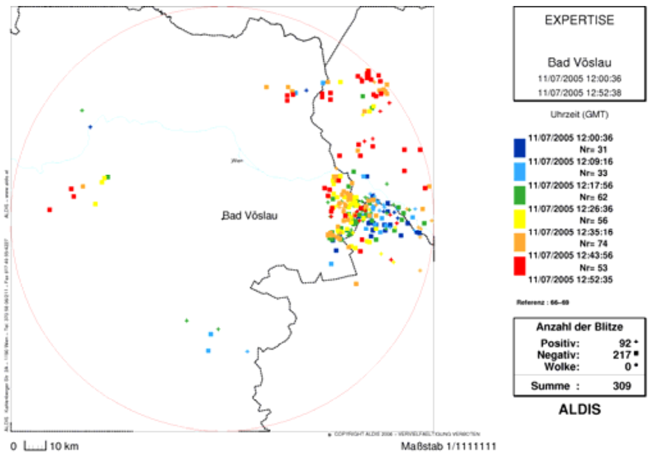

Figure 3.1: CG Lightning activity during the measurement period detected by the LLS. Bad Vöslau is located at the centre of the circle with a radius of 100 km. Flashes within a distance of 50km were not analyzed and therefore not shown in the figure.

During this time the LLS detected 309 flashes. 92 of them were positive and 217 negative. In this paper we analyze 220 negative flashes (128 single-strokes and 92 multistroke flashes) because we included 3 multistroke flashes which had at least one stroke outside the 50-100 km range limits.

IV. RESULTS

From the 92 analyzed negative multistroke flashes 52 (57%) were detected correctly by the LLS, which means that all strokes of the flash were correctly detected and classified by the LLS. The different reasons why the remaining 40 multistroke flashes were not detected correctly are given in Table 1.

Table 1: Reasons for multistroke flashes not being correctly detected

	Nb.
Initial breakdown was assigned as first stroke	7
First stroke missed by LLS	2
LLS first stroke corresponds to bipolar field impulse (probably a CC discharge)	6
Subsequent stroke not detected by the LLS	7
LLS assigned bipolar field impulse as subsequent stroke (probably a CC discharge)	12
Double detection	7
LLS assigned strokes of one flash to two separate flashes	2
LLS combined strokes of 2 separate flashes to one flash	1

Some of the reasons listed in Table 1 appeared in the same flash. Therefore the sum of all the events is not identical to the difference of 40 between the analyzed and the correctly detected multistroke flashes. Double detection in Table 1 means a stroke is detected two times by the LLS due to limitations of the location algorithm. It is interesting to note that almost all field records of multistroke flashes (89%) show a so called initial breakdown before the first stroke. The average time interval between the initial breakdown and the first stroke in these data is 58 ms (median 23 ms). Seven of the initial breakdown signals exhibit at least one impulse with an amplitude greater than the field pulse of the first stroke. 80% of the first strokes of the multistroke flashes show also a significant field variation (fine structure) after the initial field peak. For strokes at this distance range (50-100km) we could only see stepped leader fields for the strokes with high peak current.

During the period of investigation ALDIS detected 128 negative CG single-stroke flashes. According to our field measurements 73% of the located single-stroke flashes were correctly and 27% were incorrectly assigned to a single-stroke flash. Table 2 gives the reasons for the misclassification of these single-stroke flashes.

Table 2: Reasons for misclassified single-stroke flashes

	Number (Percent)
Initial breakdown assigned as stroke	9 (7.0%)
Stroke was actually part of a multistroke flash	9 (7.0%)
Stroke corresponds to bipolar field pulse (probably from a CC discharge)	16 (12.5%)

71% of the correctly identified single-stroke flashes show an initial breakdown before the stroke pulse and 8% of these initial breakdowns have at least one impulse greater than the first stroke peak. 81% of the single strokes exhibit a field variation after the peak of the field which is typical for first stroke fields.

The multiplicity distribution for the original ALDIS data and the multiplicity distribution derived from the FM-System data is given in Fig. 4.1.

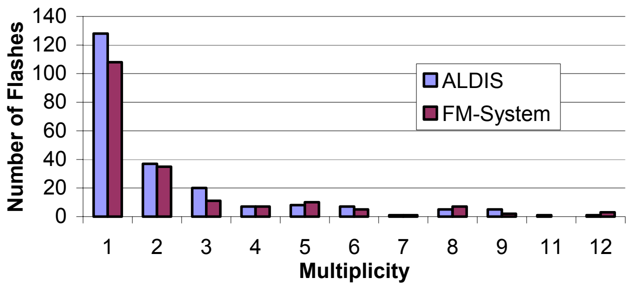

Figure 4.1: Comparison of ALDIS and FM multiplicity statistics

The mean multiplicity for the ALDIS system is 2.21 and for the FM-System 2.29. The main difference is the number of single-stroke flashes (ALDIS 128, FM-System 104). Although there is some difference between the ALDIS and the FM-System counts for the individual multiplicities the mean multiplicity values for multistroke flashes (m≥2) of ALDIS and the FM-System are almost identical (4.1 strokes per flash).

Multistroke flashes in this analysis exhibit a ratio of first stroke peak field to subsequent stroke peak field of 1.86 (ALDIS) and 1.60 (FM-System) by averaging the first/subsequent peak ratios of the individual flashes. The ratio of average range normalized fields of all first to all subsequent strokes is 1.46 (ALDIS) and 1.41 (FM-System), respectively. It is interesting to note that the LLS slightly over estimates the ratio. If also the single stroke flashes are included in the statistics the numbers decrease to 1.01 (ALDIS) and 1.04 (FM-System).

The interstroke interval statistics from the ALDIS data and the FM-System data is shown in Fig. 4.2. Only data for stroke orders up to 6 are shown because for higher stroke orders not enough data are available.

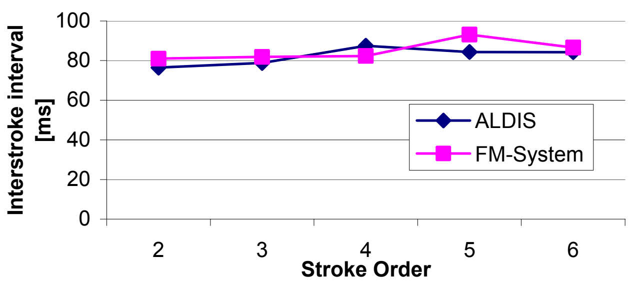

Figure 4.2: Mean interstroke interval versus stroke order for ALDIS and the FM-System

Mean values of interstroke intervals for all stroke orders inferred from the ALDIS data (87ms) and the FM data (84ms) do not differ significantly.

V. SUMMARY AND DISCUSSION

In this paper we analyzed data provided by the ALDIS LLS to evaluate how good the LLS detects and classifies the lightning data. With the FM-System used for this analysis we do not have any limitations with trigger thresholds because the system digitizes the electric field continuously. This means that we do not miss any stroke of a multistroke flash assuming that all field pulses are above noise level and at least one of the strokes was located by the LLS. Because we analyze basically the LLS data with the help of the FM data we may miss some single stroke flashes in our analysis, e.g. a single stroke flash not detected by the LLS would not be included in this analysis.

After detailed analyses of the entire field waveforms of the flashes/strokes detected from the LLS we found that the LLS detected 57% of all negative multistroke flashes correctly. Although this number appears to be small it is necessary to keep in mind that we used very strict criteria to classify whether the flash is detected correctly or not. The stroke statistic shows that from 351 strokes of the negative multistroke flashes 328 (91%) were detected/classified correctly. According to our analysis 24% of 128 detected negative single-stroke CG flashes were not correctly classified.

The average multiplicity value of about 2 and the mean interstroke interval of about 85 ms reported by Schulz et al. [2005b] for Austria for a period of the highest performance of the ALDIS network are similar to the values reported in this analysis. Furthermore the differences of the mean of peak field ratios of first to subsequent strokes between the ALDIS data and the FM data are quite small.

Although there are some limitations of the current analysis with the FM-System we can conclude that negative flashes are detected very well with LLS and therefore also the lightning parameters multiplicity, ratio of first stroke peak field to subsequent stroke peak field and interstroke interval derived from LLS data for negative flashes should be of sufficient accuracy.

VI. REFERENCES

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Contact address:

Dr. Wolfgang Schulz
Austrian Electrotechnical Association (OVE)
Dept. ALDIS
Kahlenberger Str. 2A
A-1190 Vienna, Austria
E-mail: w.schulz@ove.at
Tel.: +43-1-3705806-212