Bipolar flashes detected with lightning location systems and measured on an instrumented tower

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Abstract - Flashes with subsequent strokes of polarity opposite to the polarity of the first stroke are called bipolar flashes. In 1998 a new central processor (LP2000) for the Austrian lightning location system ALDIS (Austrian Lightning Detection & Information System) was installed. This LP2000 also includes a new algorithm for the grouping of strokes to flashes. This algorithm allows to group strokes to a flash even when the strokes do not have the same polarity, resulting in a bipolar flash. Therefore in our database five years of data is available which contains bipolar flashes.

To provide a ground truth reference for a comparison of natural lightning current parameters and the data of ALDIS, a radio tower on the mountain Gaisberg near the city of Salzburg (Austria) was set up for direct lightning current measurements. Also at this tower some bipolar flashes were measured during the last years.

In this paper details about bipolar flashes measured at the Gaisberg tower and detected with the Austrian lightning location system are presented and analyzed.

1 INTRODUCTION

Occurrence of bipolar flashes has been reported before in literature. Berger [1978] reported that 6% of all the measured flashes (upward and downward flashes) between 1963 and 1973 showed polarity reversals.

Rakov [2000] gave a review about bipolar flashes and separated them in three different groups:

(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

A lightning location system can only detect bipolar flashes of the third group because the slowly varying current components of (1) and (2) do not radiate sufficient electromagnetic fields to be detected by the sensors of a lightning location system (LLS).

2 DATA

If no additional restrictions are given we extracted and analyzed data for a rectangular area around Austria with longitudes between 9.50°E and 17.5°E and latitudes between 46.00°N and 49.25°N. We used for all the investigations data from 1998 till 2002 because during this time period the LP2000 was the operational central processing unit. The APA 280T, the central processing unit used before this time, did not allow to group strokes of different polarity to the same flash.

The data from Gaisberg measurements [Diendorfer et al., 2000] were used from the years 2000, 2001 and 2002.

3 BIPOLAR FLASHES DETECTED BY THE LLS

In our lightning database we found about 55.000 bipolar flashes in the region of investigation out of a total number of about 1.6 million flashes. We separated the bipolar flashes into positive and negative bipolar flashes according to the polarity of the first stroke in the flash. Although the total number of negative flashes is much higher than the total number of positive flashes the numbers of negative and positive bipolar flashes are about the same (see Table 3.1).

The percentage of bipolar flashes of 2.9% of the total number of flashes is about 1/2 of the 6% reported by Berger [1978]. The percentages of negative and positive bipolar flashes are 1.8% and 7.7% of the total number of negative and positive flashes. Taking into account only flashes with a multiplicity greater one 4.0% of the negative flashes and 54.1% of the positive flashes are detected as bipolar flashes.

Table 3.1: Number of positive and negative flashes versus multiplicity

Multiplicity	negative flashes	neg. bipolar flashes	Positive flashes	pos. bipolar flashes
1	827754	0	297624	0
2	286504	9936	35764	15472
3	155799	5862	8252	6129
4	92354	3866	2729	2442
5	57008	2582	1218	1170
6	36781	1821	638	630
7	24502	1202	365	362
8	16051	875	247	246
9	10422	673	129	129
10	6845	424	66	66
11	4551	315	56	56
12	2752	212	36	36
13	1803	141	20	20
14	1148	94	11	11
15	1466	74	15	15
total	1525740	28077	347170	26784

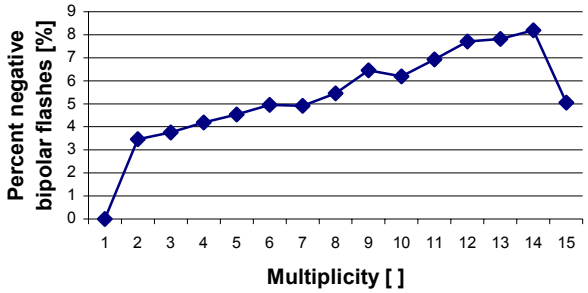

Fig. 3.1 - Percentage of bipolar flashes for negative discharges

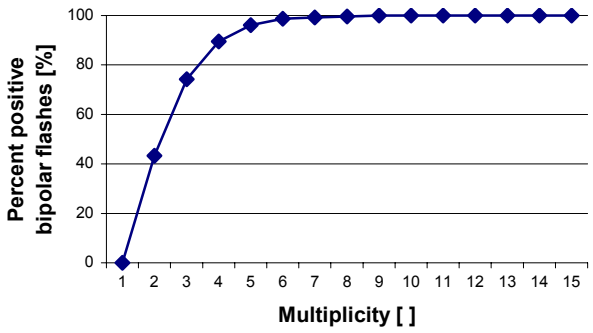

Fig. 3.2 - Percentage of bipolar flashes for positive discharges

Fig. 3.1 and Fig. 3.2 show for both polarities an increasing percentage of bipolar flashes with increasing multiplicity.

It is interesting to note that for positive flashes with a multiplicity greater than eight only bipolar flashes exist in our database. A similar relation between the percentage of positive bipolar flashes and multiplicity is found in the data of the North American network NLDN (K. Cummins, 2003, personal communication).

Fig. 3.3 shows the probability of bipolar flashes to change polarity after the first stroke versus multiplicity. The percentage of negative bipolar flashes having the polarity change between the first stroke and the second stroke decreases with increasing flash multiplicity (see Fig. 3.3). The probability of a change of polarity is almost 1/multiplicity distributed over all stroke numbers, this means for a 3 stroke flash there is about the same probability to change polarity before the second stroke or to change polarity before the third stroke.

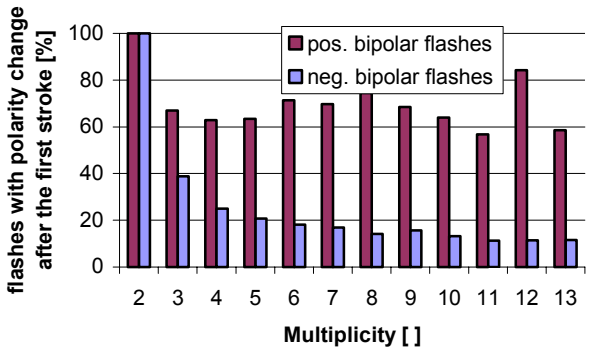

Fig. 3.3 - Probability of positive bipolar flashes to change polarity after the first stroke

Positive bipolar flashes show a different behavior. Fig. 3.3 shows that almost independent of multiplicity the polarity change occurs right after the first stroke for more than 60% of the flashes. Also in the NLDN data almost all of the positive bipolar events had a second stroke that was negative (K. Cummins, 2003, personal communication). Therefore we think that the positive first stroke of these positive bipolar flashes may be a detected predischarge in the cloud and the polarity of those flashes may be misclassified.

The median amplitude of the positive bipolar flashes (15kA) is greater than the median amplitude of non bipolar positive flashes (11kA).

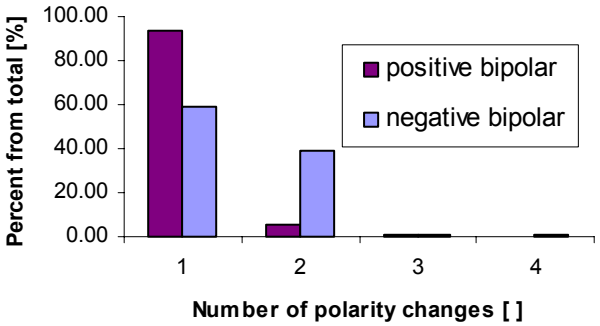

Fig. 3.4 - Number of polarity changes for positive and negative bipolar flashes

Fig. 3.4 shows that more than 90 % of the positive bipolar flashes change the polarity only once whereas almost 40% of the negative bipolar flashes change the polarity twice. The result for positive bipolar flashes is not only related to multiplicity because this statistics includes positive bipolar flashes with up to 20 strokes.

4 BIPOLAR FLASHES MEASURED AT THE GAISBERG

In the period from 2000 to 2002 we measured at the Gaisberg tower six bipolar flashes. According to the classification of Rakov [2000] five of these bipolar flashes were of type (1) or (2) which are not fully detectable as bipolar flashes for LLS. The remaining Gaisberg flash (#312) was of type (3) and was detected as a bipolar flash from the LLS.

Tab. 4.1: Bipolar flashes measured at the Gaisberg

Date/Time	Internal Flash-number	Type Rakov [2000]	Multiplicity (Gaisberg)	ALDIS
06.08.2000 14:48:50.4054	180	2	5	Detected 1 stroke
08.11.2000 02:48:25.1754	209	1	4	no
17.08.2001 16:53:42.9155	246	2	39	Detected 12 strokes
08.11.2001 19:34:45.9002	255	2	22	Detected 4 strokes
06.07.2002 13:56:42.9409	312	3	4	Detected 2 strokes
06.07.2002 14:07:40.3698	316	1	0	no

The column multiplicity in Tab. 4.1 includes all slowly varying current components measured at the Gaisberg tower. Due to the reason that those slowly varying current components do not radiate enough field not all the strokes are detected by ALDIS.

The three bipolar flashes of type (2) (#180, #246, #255) were detected by the LLS as negative flashes. Flash #209 exhibits two positive strokes with a slow varying current component of negative polarity afterwards and flash #316 did not show any return stroke at all but only slowly varying current components of reversing polarity.

Flash #312 (see Fig. 4.1) was detected by the LLS as a negative flash with a peak current of -19.8 kA whereas at the Gaisberg tower a peak current of -15.7 kA was measured. For the second stroke the LLS reported a peak current of +8.4 kA (Gaisberg direct measurement +8.3 kA). The time difference between the strokes was 17.2 ms in both data sets, LLS and Gaisberg. This flash exhibits also two slowly varying current components which are not detectable by the LLS.

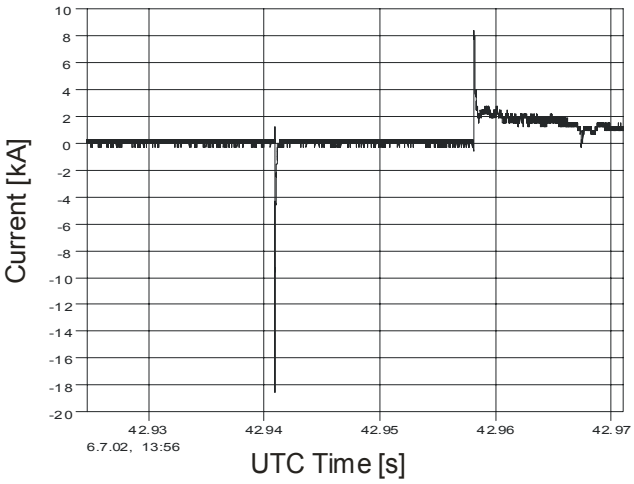

Fig. 4.1 - Waveform of the flash #312 (waveform is cut before the negative and after the positive stroke)

5 DISCUSSION

Many bipolar flashes are available in the data of the Austrian LLS. The percentage of bipolar flashes detected by the Austrian LLS (2.9%) is smaller compared to the percentage of bipolar flashes reported by Berger [1978] (6%). We have shown that 50% of positive multistroke flashes detected by the LLS are bipolar positive flashes. Contrary to negative bipolar flashes the positive bipolar flashes tend to change the polarity after the first stroke. This suggests that these positive bipolar flashes are the result of a positive predischarge followed by a negative flash. More investigations are necessary to understand whether these positive bipolar flashes are real or related to the behavior of the LLS.

We have further shown that a lightning location system is able to detect lightning flashes with strokes of different polarity (type 3 of the Rakov classification). The LLS did

not only detect both polarities correctly but also provided a good estimate of the amplitudes for the positive and the negative stroke.

6 REFERENCES

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