Performance Improvement of the German Lightning Location System during the 11 Years of Operation

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Abstract: The German lightning location system (LLS) BLIDS (**BLi**tz **I**nformations **D**ienst von **S**iemens) is now in service for more than 11 years. During this time the system was improved several times. In this paper we are showing the effect of the performance improvements of the system by evaluating some lightning parameters given by the system during the individual years.

1. Introduction

Since the beginning of 1992 the German LLS is in operation. In 1992 the lightning location network consisted of two sub networks. Each sub network employed six LPATS III receivers and a **C**entral **A**nalyzer **P**rocessor (CAP) [Bownes K.F. and Koolman M., 1992]. The border between those two sub-networks was 51° latitude. Due to the reason that one sensor (Leipzig) had noise problems starting from 1994 one sensor was used in both networks.

The first major change in the network was the installation of a LP2000 [Diendorfer et al., 1998] as a central processing workstation in 1998. With this upgrade the separation in two subnets was not necessary anymore. During 1998 the system was also extended by integrating sensors in Switzerland (LPATS III) and Austria (IMPACT). Further the communication link between the sensors and the LP2000 was changed from X.25 (1200 Bit/s) to the Siemens Intranet (minimum 2400 Bit/s) providing a much higher reliability as the German X.25 network. Due to the integration of the Austrian IMPACT sensors into the BLIDS network it was possible to perform an amplitude calibration of the LPATS III sensors. All the changes mentioned above resulted in improved detection efficiency (DE) and had a significant influence on the peak current estimates.

The upgrade of 10 LPATS III sensors to a newer sensor technology (LPATS IV) followed during 1999. For all LPATS IV sensors the communication rate was increased to 9600 Bit/s and an extra sensor location in Germany was added and therefore 13 sensors are in operation since that time. The sensor upgrade was finished after the lightning season 1999 and the resulting performance improvement can be seen in the data since the year 2000. Three additional sensors in the Benelux countries (LPATS III), two sensors in Poland were added in 1999. Because of problems with the location algorithm when a larger area is covered by LPATS type sensors only, four LPATS IV sensors were exchanged to IMPACT ESP sensors in 2001. As a result of this change the location algorithm was reconfigured to require at least one IMPACT sensor in a solution. This change in the configuration reduced the number of so called fake strokes significantly. A further reduction of the number of fake strokes was achieved in 2002 by the installation of an improved location algorithm with an implemented outlier filter. The network configuration at the end of 2002 is shown in Fig. 1.1.

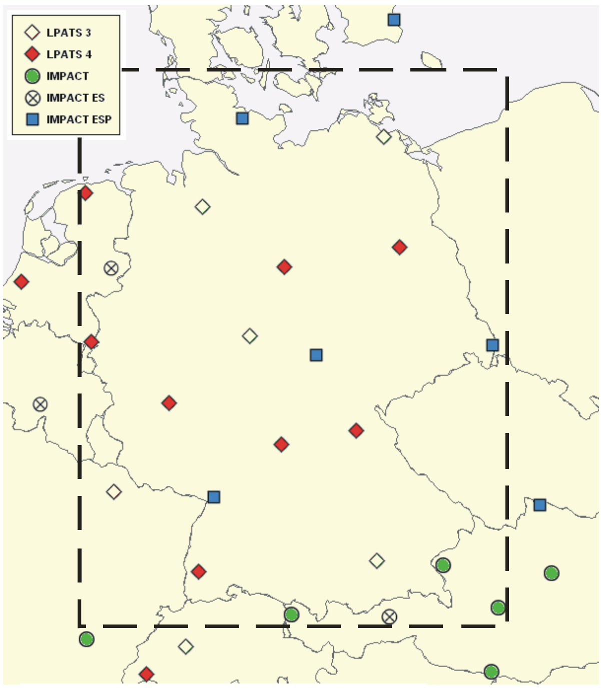

Figure 1.1: BLIDS Network configuration (2002) and region of investigation (rectangle)

2. Data

Although the network started operation in summer 1991 we will use for all the following investigations data from year 1992 to 2002. If no additional restrictions are given we extracted and analyzed data for a rectangular area around Germany with longitudes between 5.5°E and 15.3°E and latitudes between 47.4°N and 55.0°N (see Fig. 1.1).

Before 1998 the central analyzer of the German LLS was not able to group strokes to flashes in real-time. Therefore the flash grouping was performed offline. The applied algorithm groups strokes to flashes according to a time (strokes of a flash have to be within 1s of the first stroke) and a distance (stroke locations have to be within 10km of the first stroke location) criterion independent of the polarity of the strokes. Therefore also so called bipolar flashes [Rakov, 2002] should be reported. Since 1998 the LP2000 flash grouping algorithm is used [Cummins et al., 1998] which is also able to report bipolar flashes.

As typical for former LPATS systems before 1998 the peak currents were tuned in order to get a median peak current of 30 kA according to Berger et al. [1975]. Starting in 1998 current peaks are inferred from fields according to Eq. (1) by using a signal normalization factor of 0.23 [Diendorfer et al., 1998]. Additionally the LPATS sensors were calibrated relative to the IMPACT sensors signals reported by the Austrian sensors.

$$I[\mathrm{kA}] = 0.23 * \overline{\mathrm{RNSS}} \qquad (1)$$

The range normalized signal strengths (RNSS) of the individual sensors are calculated using a simple 1/Distance relation. No attenuation constant of 1.13 as proposed by Orville [1991] or 1.09 as proposed by Idone et al. [1993] is used.

3. Results

3.1 Flash and stroke counts

Fig. 3.1 shows the number of flash and stroke counts during the 11 year period from 1992 to 2002. The differences in the cloud-to-ground (CG) flash/stroke counts in the area of investigation are not all attributable to variation in the lightning activity during those years. Some of them are related to the better coverage of the network in the border area. After the upgrade to LPATS IV sensors in 1999 the number of cloud-to-cloud (CC) strokes increased significantly. This increase is mainly attributable to the new sensor technology and the better coverage at the border area due to an increased number of sensors around Germany (sensors in Poland and the Benelux countries).

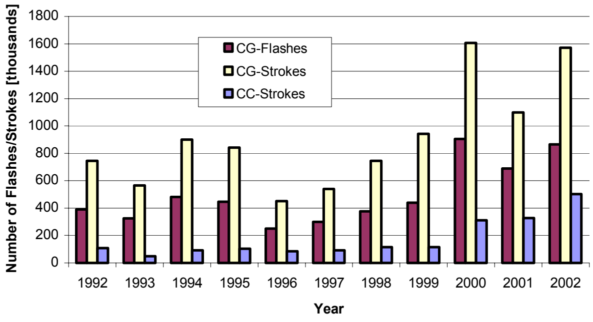

Figure 3.1: Annual flash/stroke counts

Table 3.1 summarizes the average flash/stroke counts before and after the upgrade to the LPATS IV sensor technology and the installation of additional sensors around Germany.

Table 3.1: Mean CG-flash/stroke and CC-stroke counts before and after upgrade

	CG Flashes	CG Strokes	CC-Strokes
Mean 1992-1999	376111	716723	94557
Mean 2000-2002	819434	1424823	380355
Ratio	2.2	2.0	4.0

The mean CG flash/stroke count increased by 2.2/2.0 whereas the average CC stroke count increased by a factor of 4.

3.2 Flash polarity

It is interesting to note that the percentage of positive strokes increased after the upgrade to the LP2000 in 1998 and it also increased when more and more sensors around Germany were integrated in the BLIDS network as a result of the EUCLID cooperation. This increase of sensitivity and therefore increase of detection efficiency (DE) of the LLS results in an increasing number of cloud to cloud strokes classified as positive cloud to ground strokes [Cummins et al., 1998]. Often attempts are made to limit the influence of those misidentified cloud to cloud strokes by neglecting positive strokes below 10 kA. Although this approach seems too simple because the misclassification of cloud to cloud strokes occurs over the full amplitude range we use the same approach in Fig. 3.2. It can be seen that the percentage of positive flashes greater than 10kA remained basically the same over the 11 year period.

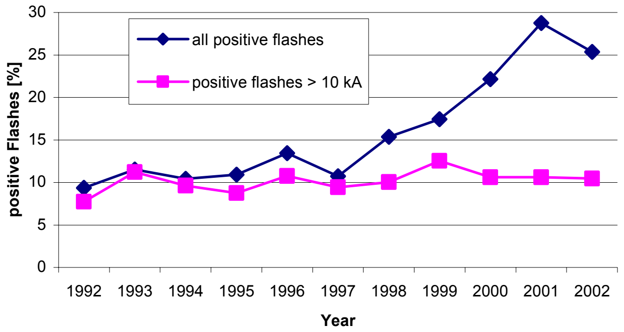

Figure 3.2: Percent positive flashes from total flashes

Recently it was reported that the Austrian LLS with smaller baselines and LPATS/IMPACT technology showed an unrealistic high number of positive bipolar flashes [Schulz and Diendorfer, 2003]. We separated also in this paper the bipolar flashes into positive and negative bipolar flashes according to the polarity of the first stroke in the flash.

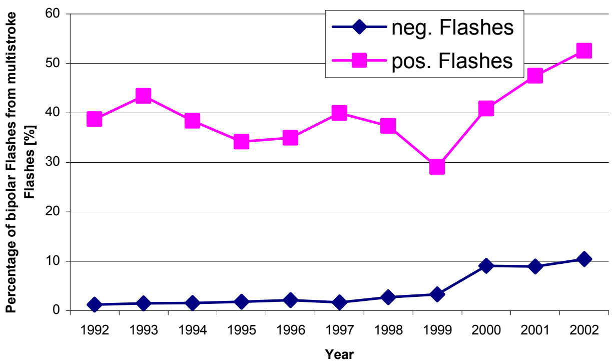

Figure 3.3: Percent of bipolar flashes from multistroke flashes

It is interesting to note that also from 1992 to 1998 a large number of positive bipolar flashes are reported because during this time only LPATS III sensors were used in the network. Further the percentage of positive bipolar flashes from 1992 to 1998 is comparable to the percentage from 1999-2002 where mainly IMPACT and LPATS IV sensors were used. It also seems that the percentage of positive bipolar flashes is not very sensitive to the sensor baseline because also the Austria network reported a value of about 50% positive bipolar multistroke flashes [Schulz and Diendorfer, 2003].

The upgrade to LPATS IV sensors in 1999 increased the number of negative bipolar flashes, because of the increase in DE.

3.3 Peak currents

Annual median peak currents, especially for positive flashes, have been very variable between 1992 and 1997 (see Fig. 3.4). We want to emphasize that during this time there was no real absolute calibration of the network regarding the peak current measurement. After 1997 LPATS III and also LPATS IV sensors were calibrated relative to the IMPACT sensors installed around Germany. The calibration of the LPATS III sensors in Germany and the additional information of the Austrian and Swiss sensors reduced the measured peak currents significantly in 1998. A further reduction was observed after the upgrade of the network to LPATS IV and IMPACT ESP sensors.

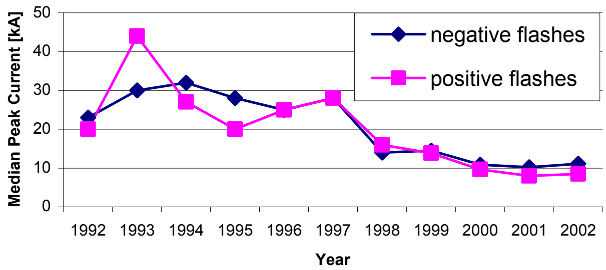

Figure 3.4: Median peak currents for negative and positive flashes versus year

It is well known from literature that positive flashes exhibit average peak currents greater than negative flashes [Berger et al., 1975]. Contrary to this peak currents of positive flashes detected with BLIDS are smaller than the peak currents of negative flashes since 1999 because they are contaminated with CC-flashes. Looking at positive nonbipolar flashes does not change the result in Fig. 3.4 significantly.

4. Discussion

Obviously the changes in the network configuration given in chapter 1 influenced the overall network performance of the system. All three parameter discussed in this paper, the percentage of positive flashes, the percentage of bipolar flashes and the peak currents show a significant change in the year 2000, after the upgrade to the new sensor technology and the installation of more sensors around Germany in 1999.

From the decrease of the median peak current for negative flashes we infer an increase of detection efficiency (DE) of the network. It shows a significant improvement of the LLS after the major network changes in 1999. Normally a small increase in DE is not visible in the annual flash/stroke counts because of the variability of the lightning activity from year to year. Contrary to that the improvement of DE over the entire area of investigation (rectangle around Germany) is that significant that it is even obvious in the flash and stroke counts in Fig. 3.1.

This improvement is related to the sensor upgrade in Germany and the increased number of sensors around Germany which enhanced the DE especially at the border area.

The annual median peak current was significantly influenced by the first calibration of the LPATS sensors in 1998. Due to the calibration it was possible for the first time to estimate the peak current in a reliable way.

5. References

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