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VALIDATION OF THE AUSTRIAN LIGHTNING LOCATION SYSTEM ALDIS FOR NEGATIVE FLASHES

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SUMMARY

In this paper we present a detailed performance evaluation of the Austrian Lightning Location System ALDIS in terms of detection efficiency and location accuracy based on ground truth measurements. The ground truth measurements used in this evaluation are video and E-field measurements.

151 out of the 154 negative cloud to ground flashes and 449 out of 540 strokes were detected by the lightning location system (LLS). This results in a flash detection efficiency of 98% and a stroke detection efficiency of 83%. Only two additional cloud to ground strokes (0.4%) were detected but misclassified as cloud discharges. The analysis of 37 flashes which exhibit at least two strokes within one lightning channel results in a median location accuracy of 368 m (STD = 650 m).

The results of those measurements are in good agreement to performance evaluation done with data from current measurements at the Gaisberg Tower in Austria.

KEYWORDS

Lightning, Lightning Location Systems, Performance Evaluation, Detection Efficiency, Location Accuracy

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1. INTRODUCTION

Lightning location data are used by power utilities for more than 20 years. The data are important to support the network operator in order to increase the power system security and to provide advanced warning information for maintenance crews in case of approaching thunderstorms. For all applications it is important to know the performance of the lightning location system (LLS) in terms of location accuracy and detection efficiency (DE). Often it is tried to determine the performance of a LLS by cross comparison with data from another LLS covering a common area. Such comparisons typically do not provide any clear results, e.g. [1]. Therefore the comparison of lightning location data with ground truth data is the preferential way to determine the performance of a LLS. Different approaches to collect lightning ground truth data are known:

(1) Lightning to instrumented towers
(2) Triggered lightning
(3) Video and E-Field studies of natural downward lightning

In the study presented we use video and E-Field studies of natural downward lightning by employing a GPS synchronized measurement system consisting of a flat plate antenna, an integrator, a fiber optic link and a camera, which is described in detail in [2, 3]. The measured data are compared to the results from ground truth measurements at the Gaisberg Tower (GBT) in Austria.

2. DATA

During summer periods of 2009 and 2010 a total of 154 negative flashes were recorded by the video- and E-Field measurement system in 15 different storms (see Table 1) at 13 different locations shown in Fig.1.

Table 1. Number of recorded negative flashes

Year	# storms	# flashes
2009	2	45
2010	13	109
Total	15	154

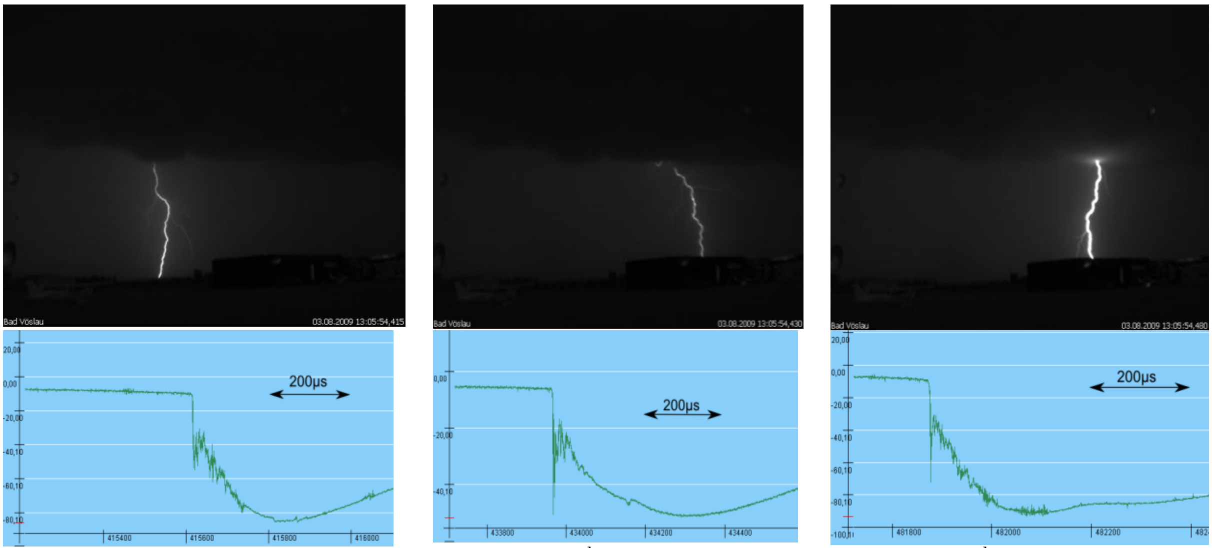
The measurements were taken at different locations in the east and south of Austria. The mean multiplicity of all recorded negative flashes is 3.51 and the mean number of ground contacts is 1.82.

Fig. 1. Measurement locations in the east and south of Austria in 2009 and 2010

The peak current for the measured strokes was determined from the Austrian lightning location system ALDIS. The median peak current of all the negative cloud-to-ground strokes was -11.5 kA, with a smallest peak current of -2.3 kA and a largest peak current of -171.0 kA. It has to be noted that there exists no peak field to peak current calibration of lightning location data for negative first strokes [5]. Therefore the values given above are inferred from peak fields using the same field-to-current conversion as applied for subsequent strokes which was validated by triggered lightning [6] and tower measurements [5] for peak currents up to about 40kA.

3. METHODOLOGY

The recorded video and E-Field data sets are complementing each other because sometimes it happens that strokes can be identified only either on the video or in the E-field data and sometimes the strokes can be clearly identified in both data sets. As an example flash #57 recorded in Austria 2009 is shown in Fig. 2. This flash contained three strokes and each stroke exhibits a separate ground strike point. According to the LLS data the distance of the individual ground strike points from the measurement system were in the range from 5 to 7 km.



1st Stroke 2nd Stroke 3rd Stroke

Fig.2. Video images and correlated electric field data for flash #57 (03.08.2009 13:05:54 UTC)

Such a dataset allows a straight forward correlation of each individual stroke detected from the LLS to a field signature and a video frame. After the correlation of the data it is possible to determine the Flash-DE and the Stroke-DE. It is further possible to evaluate if the LLS categorized the field signals detected by the LLS sensors correctly as cloud-to-ground stroke or cloud discharge.

The accuracy of the LLS can be estimated by searching for multiple strokes in a flash following the same channel. Fig. 3 gives an example of a flash with nine strokes exhibiting four different ground strike points. By analyzing the individual video frames it can be seen that stroke 3, 5, 6, 7, 8 and 9 are following the same channel to ground. Assuming that the strokes which are following the same visible channel to ground attach to the same ground strike point the LLS should locate those strokes at the same place.

In reality there are differences of the individual stroke coordinates which reflect the location accuracy of the LLS. By calculating the distances of those strokes to the location of the first stroke it is possible to estimate the accuracy of the LLS. As stated in [7] there is a possibility that the channel geometry and/or the actual ground contact location varied slightly from stroke to stroke and were not resolved by the video camera. Therefore the differences determined by this method should be regarded as upper bounds of the actual position differences.

1^{st} stroke

2^{nd} stroke

3^{rd} stroke

4^{th} stroke

5^{th} stroke

6^{th} stroke

7^{th} stroke

8^{th} stroke

9^{th} stroke

Fig.3. Different ground strike points of a flash with 9 strokes, Flash #222 (18.07.2010 00:22:55 UTC)

4. RESULTS

As a result 151out of the 154 negative cloud to ground flashes (flash detection efficiency 98%) and 449 out of 540 strokes (stroke detection efficiency 83%) were detected by the LLS. Only two additional cloud-to-ground strokes (0.4%) were detected but misclassified as cloud discharges.

Analysis of the 103 first to subsequent stroke distances in the same channel within 37 flashes results in a median location accuracy of 368m (STD=650m). In this distribution the scaling factor of $\sqrt{2}$, whose theoretical background is explained in [8], is already considered. The histogram of those 103 distances is shown in Fig. 4. For four strokes the distance to the first stroke in the same channel is greater than 2 km and these data are not shown in Fig.4.

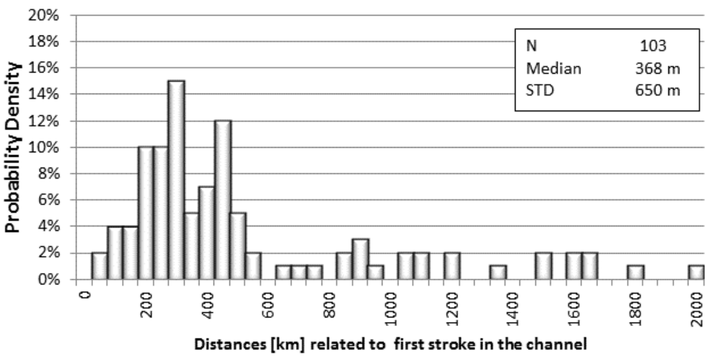


Fig. 4. Histogram of location error derived from the video and E-field records 2009-2010

Comparing the results from the video measurements to results from ground truth measurements at the instrumented GBT in Austria [5] reveals a good agreement. At the GBT a flash DE of 96% is obtained for 221 flashes containing a subsequent stroke greater than 2 kA and occurring during the period 1.1.2000 - 31.12.2011. The stroke DE for 958 subsequent return strokes during the same period with peak currents greater than 2 kA is 78%. At the GBT the median location accuracy for those 958 subsequent strokes is 308 m (STD 687 m).

No first strokes, which are supposed to be stronger than subsequent strokes, are measured at the GBT. Therefore the stroke DE determined at the GBT is to a certain extend an underestimation of the actual stroke DE of the LLS. Consequently the agreement between the measurements regarding the DE is very good. Also the location accuracies video/E-field and tower data are in a good agreement seeing that the results from the video data are only slightly larger. This small difference is explainable by the fact that with video measurements often the real ground strike point is not seen and the results of those measurements are therefore an upper limit of location accuracy [7]. This good agreement between the video and tower measurements further suggest that the performance of the network is quite homogenous over the eastern and southern part of Austria – shown in Fig. 1.

It is important to mention that the location accuracy was significantly improved in 2011 by enabling the so called onset time correction [9] at the newest sensor type (LS7000). With this new method to determine the onset time the median location accuracy at the GBT is in the range of ~120 m. Fig. 5 shows the histogram of the location errors for strokes located after the installation of the improved onset time correction.

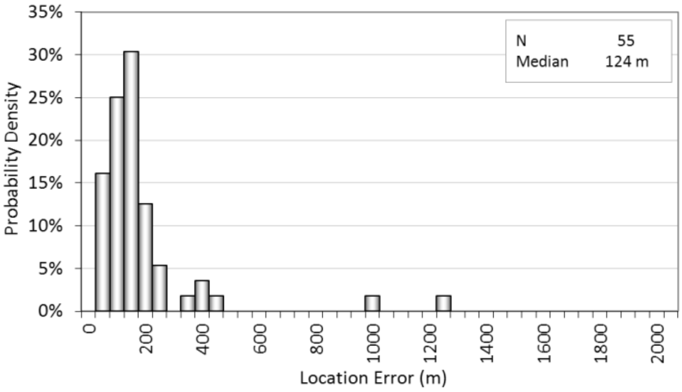


Fig.5. Histogram of location errors for strokes to the Gaisberg Tower in the period 1.7.2011 - 24.01.2012.

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