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A NEW PERFORMANCE EVALUATION OF THE BRAZILIAN LIGHTNING LOCATION SYSTEM (RINDAT) BASED ON HIGH-SPEED CAMERA OBSERVATIONS OF NATURAL NEGATIVE GROUND FLASHES

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1. INTRODUCTION

The lightning detection network data is very useful in many activities of the society. Power utilities in general, weather nowcast, and agriculture can be cited as some examples. For this reason, it is important to know the performance of the network for an appropriate use of these data. The network performance is usually described by two parameters: (a) the Detection Efficiency (DE) and the (b) Location Accuracy (LA). The DE means the percentage of strokes (or flashes) that are detected by the network and LA means the error level on the location given by the network. Schulz (1997) discussed about the performance evaluation of lightning location systems in general presenting also some modeling.

Preliminary results on the performance evaluation of RINDAT (Brazilian Integrated Lightning Detection Network) were already presented by Saba et al. (2004) for a small dataset. This paper presents an evaluation based in a larger dataset and in a more detailed analysis for the same region in the Sao Paulo State (Paraíba Valley). Both studies were based on data obtained by a high-speed camera in which negative return-stroke could be identified with a high confidence level.

2. INTRUMENTATION AND METHODOLOGY

The high-speed video recordings were made by a *Red Lake 8000S MotionScope* high-speed camera with 1.0 ms of time resolution and exposition. This equipment is GPS synchronized and time stamps each frame (*Figure 1*). It is capable to record sequences of images from 60 to 8000 frames per second, depending on the setting. Images from the camera or from the image memory are displayed on the computer monitor. Each sequence of images can be stored in a computer file, retrieved and replayed at various speeds to analyze a motion sequence in detail.

The *MotionScope* system is triggered manually, depressing a hand-held switch when of the occurrence of the flash. All high-speed video recordings had one second of pre-trigger time and one second of pos-trigger, resulting in a total recording time of two seconds. The frame rate used in this study was 1,000 frames per second and the image resolution at this rate is 240x210 pixels.

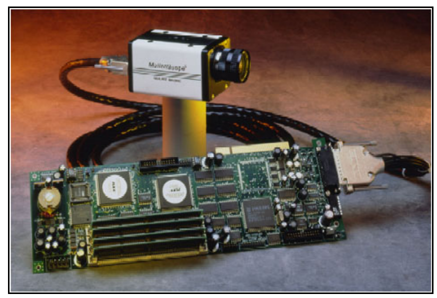

Figure 1. The high-speed camera Redlake Motion Scope 8000S used in this study.

A high-speed video example of a negative ground flash obtained with the high-speed camera is shown in *Figure 2*. It is possible to observe the final stage of the stepped-leader and the return-stroke.

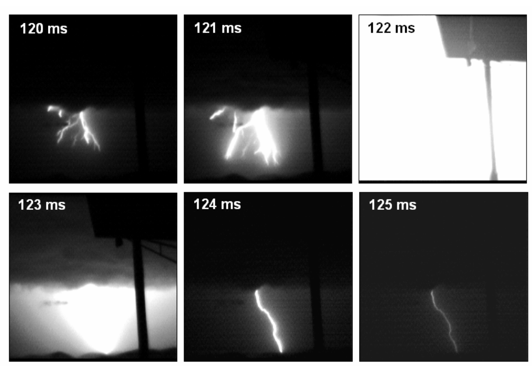

Figure 2. An example of ground lightning record obtained by the high-speed camera at 1,000 frames/sec. Frames 120 and 121 show the final stages of stepped-leader towards the ground connection that occurs in frame 122 (return stroke).

The observing sites are located at the cities of São José dos Campos (23.215º S, 45.864º W) and Cachoeira Paulista (22.686º S, 44.984º W). Each site is located nearby a respective network antenna. *Figure 3* shows the sensor configuration of the Brazilian Integrated Lightning Detection Network (RINDAT) in the period of study (Nov/2003 to Apr/2004) – for more details about RINDAT see Pinto et al. (2006). 18 days of thunderstorms have been selected to this analysis (both convective and frontal systems) between November 7th of 2003 and April 16th of 2004.

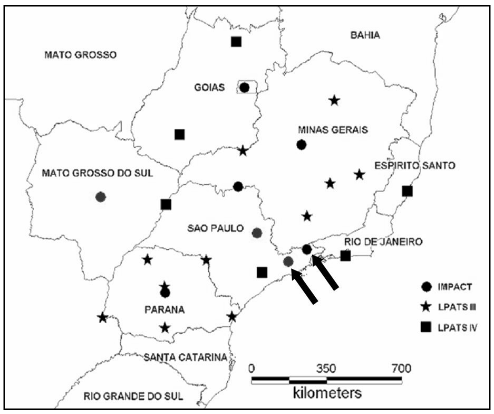

Figure 3. The Brazilian Integrated Lightning Detection Network – RINDAT in the period of study (Nov/2003 to Apr/2004). The two arrows indicate the observation sites.

Figure 4 shows the Paraíba Valley region analyzed in this study, and the six antennas closer to the region of the observations. In most lightning events observed by the camera, these sensors are the more important ones in the solution given by RINDAT. All stroke solutions took into account in this performance evaluation were generated when all these six antennas were operating normally.

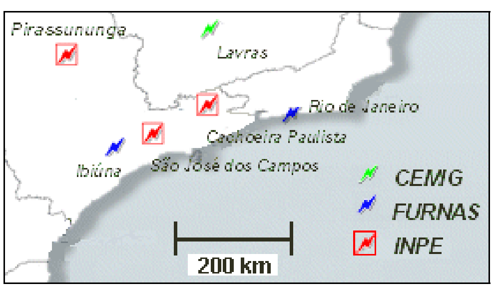

Figure 4. The six RINDAT antennas considered in the analysis around Paraíba Valley and its respective owners (CEMIG, FURNAS and INPE).

We used only reprocessed data in this study. In the reprocessing process, we adopted at least four time-of-arrival information as a minimum criterion. *Table 1* lists the type of the sensors shown in *Figure 3*.

TABLE 1. Type of sensors around Paraíba Valley region.

Cachoeira Paulista	IMPACT
Ibiúna	LPATS IV
Lavras	LPATS III
Pirassununga	IMPACT
Rio de Janeiro	LPATS IV
São José dos Campos	IMPACT

3. RESULTS AND DISCUSSION

3.1 Detection Efficiency (DE)

We calculated the detection efficiency for both strokes and flashes. A flash is detected when at least one of the lightning strokes had being detected. For this period of observation, we selected 413 negative strokes with clearly visible channel connected to ground in the video records. Among these events, 226 strokes were detected by the network. It resulted in a DE of 54.7% for strokes. We could identify the polarity of the non-detected strokes based on antennas *raw data*. We selected a group of 206 negative cloud-to-ground lightning flashes. Among these events, 180 negative ground flashes were detected. It resulted in a DE of 87.4% for flashes. *Table 2* summarizes these results comparing with corresponding estimated values by the manufacturer VAISALA. The results show that the network in Paraíba Valley region is operating properly in terms of DE.

TABLE 2. Detection Efficiency (DE) values measured in Paraíba Valley (2003-2004).

DE	For Strokes	For Flashes
Measured	54.7% (226 of 413)	87.4% (180 of 206)
Expected	~ 50%	80-90%

Figure 5 displays the geographical solutions location of all 226 strokes detected and with clear connection to ground on video records. The median distance between camera and stroke location for these events was 21.5 km (average of 24.6 km). Consequently, we believe that near 50% of them could cause signal saturation on either

São José dos Campos or Cachoeira Paulista antennas, excluding one of them from the solutions.

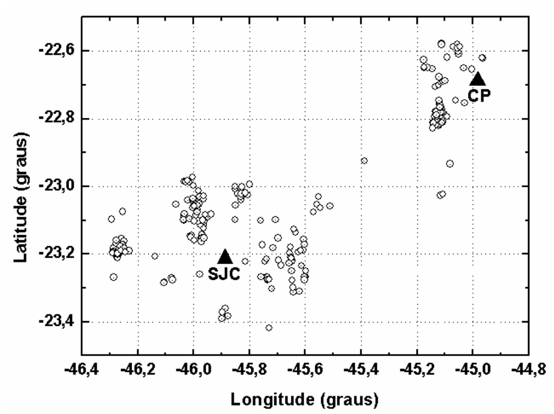

Figure 5. Distribution of strokes detected by RINDAT and observed from on of the two sites by the high-speed camera.

Idone et al. (1998) evaluated the performance of the National Lightning Detection Network (NLDN) in U.S.A. based on several hundreds records of multiple VHS camera stations and electric field antenna and found significant variation on the DE between different thunderstorms. According to them, the DE may vary from storm to storm due to the inherent variability in the characteristics of the return-stroke. We consider that such variations would not be expressive in our results since this study is based in 18 different thunderstorms. Another interesting result is the average peak current of -13.6 kA, calculated by the network for 105 events of our dataset. The climatologic average for the same region between 1999 and 2003 was – 18.0 kA. The last value was calculated based on hundreds of thousands of strokes related to four years but before the Pirassununga antenna installation. We suggest that this difference is due to the installation of the Pirassununga antenna; this network has increased the DE of the network allowing the detection of lower current peak values.

<u>3.2 Location Accuracy (LA)</u>

Based on these dataset of natural ground flashes, we could not evaluate exactly the Location Accuracy (LA) of the network because we used just one single camera. Nevertheless, we calculated the maximum distance between stroke locations given by the network for strokes that occurred in the same channel. This measurement will be consequently an overestimation of the LA but can be considered as an estimated maximum error for the LA.

For this LA estimation, we selected 26 negative cloud-to-ground lightning flashes with three or more strokes in same ground contact point. We selected only 26 events because in these cases we could clearly identify the contact point. *Figure 6* exhibits the histogram of this parameter. The geometric mean found for this estimated maximum error for the LA was 3.6 km and the average was 5.3 km.

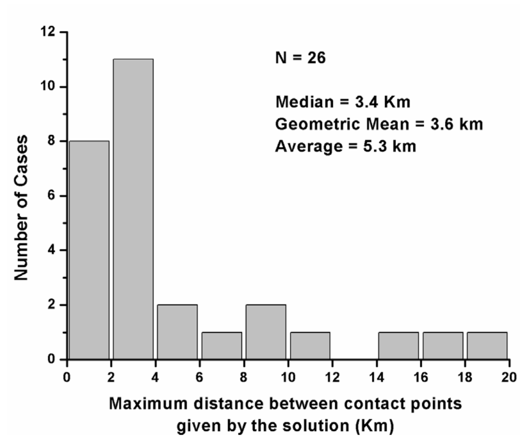

Figure 6. Histogram of the maximum distance between stroke locations of the same single-channel lightning.

4. CONCLUSIONS

In this paper, we presented a new performance evaluation of the Brazilian Lightning Location System (RINDAT) based in a reasonable amount of samples. We should mention that for the first time an evaluation was done carefully in Brazil for a region where all antennas involved were operating normally. We made this analysis based on high-speed imagery records of negative natural cloud-to-ground lightning.

We found that the detection efficiency in Paraíba Valley region is in agreement with it is expected based on the manufacturer: 54.7% for strokes and 87.4% for flashes based on 18 different thunderstorms. We concluded also that the technique used here is appropriate to such evaluation.

It was not possible to measure the Location Accuracy based on our single camera observations, but we calculated an overestimated and maximum error for the LA. The geometric mean found for this estimated maximum error for the LA was 3.6 km and the average was 5.3 km.

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