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CHARACTERISTICS OF PRELIMINARY BREAKDOWN FOR FIRST STROKES AND SUBSQUENT NEW-CHANNEL STROKES

Leandro Z. S. Campos[1] Marcelo M. F. Saba[1] Maurício G. Ballarotti[1] Osmar Pinto Jr.[1] Wolfgang Schulz[2]
[1]National Institute for Space Research, INPE – Brazil, [2]Austria Electrotechnical Association, ALDIS – Austria

Abstract - The aim of this work is to obtain some characteristics of the preliminary breakdown (PB) pulses for negative cloud-to-ground flashes. We present the correlation between the electric field peak of first strokes and subsequent new-channel strokes and the time interval from the beginning of the PB and the stroke event. For this purpose we employed a high-speed observation system (with a time resolution of 1000 frames per second), electric field measurements (flat plate antenna) and data from the Brazilian Lightning Location System – RINDAT. All the measurement systems were synchronized with GPS. All measurements and observations were made in S. José dos Campos (45.864°W; 23.215°S), Brazil. The beginning of the PB pulses could be determined both in the electric field data and in the high-speed video recordings (in which it is possible to observe a low intensity light emission from the cloud). The identification of this instant is a very difficult task in the absence of the images. The electric field peak values of the strokes were all normalized to 100 km, based on the location solution given by RINDAT. An amount of 30 first strokes and 16 subsequent new-channel strokes, all from the same day (March 23rd, 2005), were analyzed, and their data (PB to stroke time interval versus the inverse of the stroke electric field peak) were plotted. The graph obtained for first strokes showed a linear relationship (correlation coefficient: 0.85). No correlation was found for subsequent new-channel strokes.

1 - INTRODUCTION

Previous studies on preliminary breakdown (PB) pulses are based solely on electric field measurements ([1] to [4]), focused on the characteristics of the pulses disregarding any correlation with the strokes parameters and without data from a lightning detection network. Some other previous studies studied characteristics of cloud-to-ground flashes using a high-speed camera [5, 6] which proved to be a very reliable method.

The aim of this work is to combine the instrumentation cited before in order to obtain a relationship between characteristics of PB pulses and return strokes. It is focused on the influence of the time interval from the beginning of the PB pulses to the stroke over its electric field peak value (directly related to its current) for first strokes and subsequent strokes. We present the low intensity luminosity pulse observed through the camera associated to the beginning of the PB pulses and a new criterion based on this feature in order to eliminate dubious cases in the determination of the instant of beginning of the PB pulses based only on electric field measurements.

2 - INSTRUMENTATION

The observation site used during the data acquisition is located at São José dos Campos (23.212ºS; 45.867ºW, altitude 635 m). All data analyzed were obtained on 23 March 2005, when more than 80 CG flashes occurred in the Paraíba Valley region.

2.1 - HIGH-SPEED CAMERA

The studied flashes were recorded by a high-speed digital video camera (Red Lake Motion Scope 8000s). The time resolution (1000 frames per second) and exposure time were 1 ms. The triggering system was operated manually for all the flashes and all images were GPS synchronized and time stamped.

2.2 - DETECTION NETWORK (RINDAT)

The location of each stroke was available via data given by RINDAT – Brazilian Lightning Location System. The stroke data contains information such as event time (also GPS synchronized, which permitted an unequivocally matching between the camera, antenna and RINDAT), latitude and longitude of each stroke (used to determine the distance from the observation site), peak current and polarity.

2.3 - ELECTRIC FIELD ANTENNA

A fast electric field flat-plate antenna was also used in this study to observe some flashes. Its bandwidth was from 306 Hz to 1.5 MHz and the sample rate used was 5 MS/sec. The acquisition module used was a National Instruments PCI-6110, 12-Bit with 4 analog inputs. Similarly to the high-speed camera, the triggering system of the acquisition module was manually operated. To eliminate the distance dependence of the measured field peaks, they were normalized to an arbitrary distance, chosen as 100km, by the inverse distance relationship valid for radiation fields propagating above perfectly conducting ground [7]. Data from the Brazilian Lightning Location System - RINDAT was used to find the distance.

3 - RESULTS AND ANALYSIS

From the 80 flashes observed, we selected 29 first strokes and 91 subsequent strokes (16 initiated a new channel and 75 followed the same channel of the previous stroke). All flashes had at least one stroke detected by RINDAT.

No preliminary breakdown pulses (PB) were observed before subsequent strokes that followed the same channel of the previous stroke (N = 75).

The largest observer-event distance for first strokes was 76 km, and for subsequent new channel strokes was 18 km. This considerable difference between the distances is due to the fact that PB pulses are less intense in subsequent strokes than in first strokes. We had to choose the nearer cases in order to exclude the dubious ones. This matter will be discussed in details in the next section.

3.1 - LOW-INTENSITY LIGHT EMISSIONS IN THE CLOUD ASSOCIATED TO PB PULSES

Many previous works about PB were based solely on electric field observations. ([1] to [4]). During the analysis of our data, we found that the use of the E-field alone makes the identification of the beginning of the PB very difficult in cases of distant lightning (larger than 30-35 km) for PB pulses of subsequent new channels. The use of the high-speed camera helps to identify this moment in both close and distant discharges. One example of usage of both techniques is shown by Figure 1. Figure 1a presents the E-field data and Figure 1b the corresponding sequence of frames.

Frame 2 in Figure 1b, shows the occurrence of a low-intensity light emission in the cloud during the same millisecond of the beginning of the PB pulses. This matching was possible not only for first strokes but also for subsequent strokes which formed a new channel.

In our data we considered only cases in which the beginning of the PB pulses was observed simultaneously by the electric field measurements and by the high-speed video.

3.2 - CORRELATION BETWEEN THE TIME INTERVAL FROM THE BEGINNING OF THE PB PULSES TO THE STROKE AND ITS ELECTRIC FIELD PEAK

We have measured the electric field peak of the return stroke (Ep) and the time interval between the beginning of the PB pulses and the stroke ($T_{PB\text{-}RS}$) as show in Figure 2.

In order to compare different strokes that occurred in different distances from the observer, we have normalized their Ep values through this relationship [7]:

$$Ep_{std} = \frac{Ep.D}{D_{std}} \qquad \text{(Eq.1)}$$

where Ep_{std} is the normalized electric field peak, D_{std} is the normalization distance (100 km), Ep the electric field peak measured at the observation site and D is the observer-event distance (obtained from the RINDAT data).

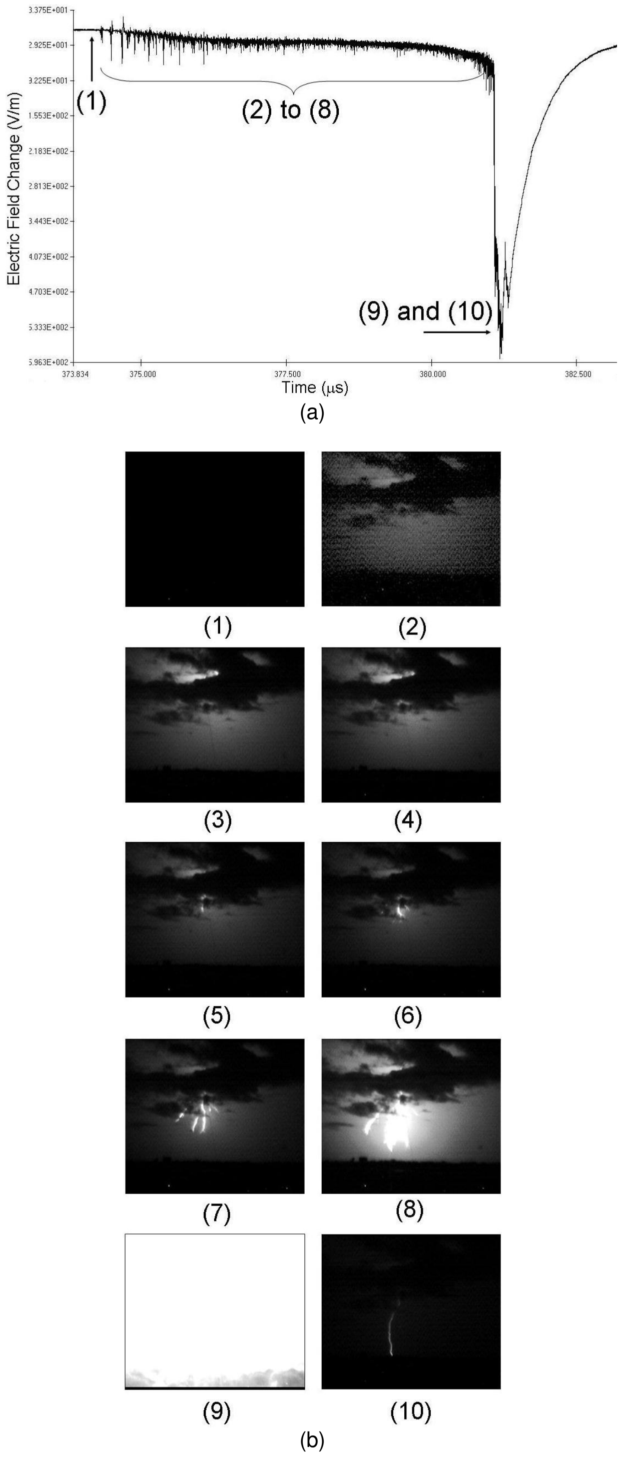

Figure 1 - Relation between (a) electric field measurements and (b) frames recorded by the high-speed camera for the same stroke, at about 10 km from the observer.

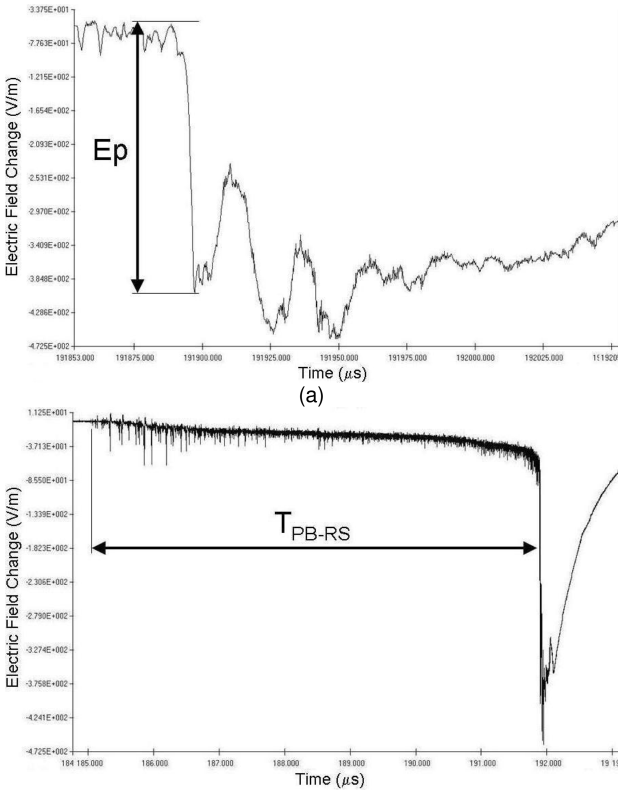

Figure 2 - Example of the measurement of (a) the return stroke electric field peak and (b) the time interval between the beginning of the PB (T_{PB-RS}) and the stroke.

3.2.1 - DATA FOR FIRST STROKES

A scatterplot illustrating the relation between 1/Ep (m/V) and T_{PB-RS} (ms) for first strokes is shown in Figure 3. There is a clear linear relationship between these parameters indicating that the longer the time interval T_{PB-RS}, the lower is the Ep of the return stroke.

3.2.2 - DATA FOR SUBSEQUENT NEW-CHANNEL STROKES

A scatterplot illustrating the relation between 1/Ep (in m/V) and T_{PB-RS} (in ms) for subsequent strokes is shown in Figure 4. Contrary to what was found for first strokes, there is no relationship at all between these parameters for new channel subsequent return strokes.

4 - CONCLUSIONS

The combination of different techniques frequently used in an independent way allowed us to obtain some interesting parameters on PB pulses and its influence on the return strokes.

We found that for first strokes when the time interval T_{PB-RS} is shorter the electric field peak of the return stroke is larger. A possible explanation could be that high peak current (and high Ep) strokes are related to high density charge stepped leaders. As high density charge stepped leaders have higher potential, their propagation speed towards ground is higher and consequently the T_{PB-RS} will be shorter.

It is necessary to extend this work to different days and storms in order to observe whether the relationship between 1/Ep and T_{PB-RS} changes and what factors influence it. Beasley et al. [3] suggests that geographic factors may influence the PB parameters. This is an interesting aspect to be focused in further studies.

In order to obtain conclusive data for subsequent new channel strokes it is necessary to make a survey in a region in which climate is drier than Paraíba Valley's, where the bifurcation point of the channel is obscured by the cloud formation. It is necessary to take into consideration which portion of the channel formerly ionized is reused from the preceding stroke and which parcel was ionized by the succeeding stroke during the study and measurement of the T_{PB-RS}.

Due to the relatively high humidity of the Paraíba Valley climate, forming storm clouds in low altitudes, we could not determine what parcel of the channel was previously ionized by the preceding stroke and what parcel was formed by the studied subsequent stroke. In a region in which the climate is drier we could estimate each parcel and consider this information when analyzing the dataset, so that it could be possible to notice a specific relationship similar to that for first strokes.

The fact that no preliminary breakdown pulses (PB) were observed in 75 subsequent strokes that followed the same channel suggests that PB are always associated with the formation of a new path to the ground and the leader propagation in virgin air.

The analysis of 75 subsequent strokes that occurred in a previously ionized channel (in which no PB was observed in any case) allowed us to conclude that the PB pulses occurrence is directly related to the necessity of ionization of a channel and the start of a stepped-leader process

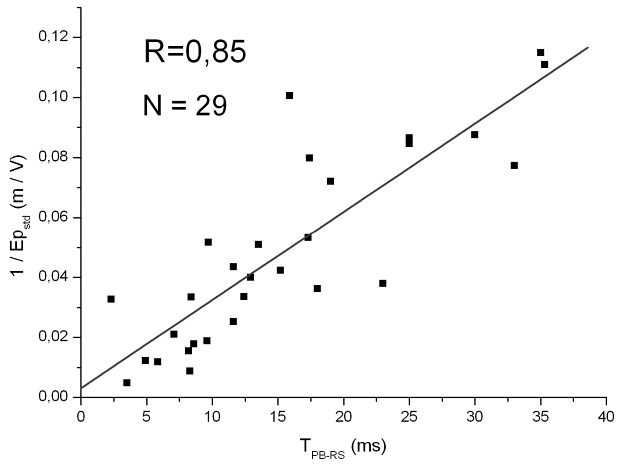

Figure 3 - 1/Ep *versus* T_{PB-RS} graphic for 29 first strokes. A good linear relationship was found (R = 0.85).

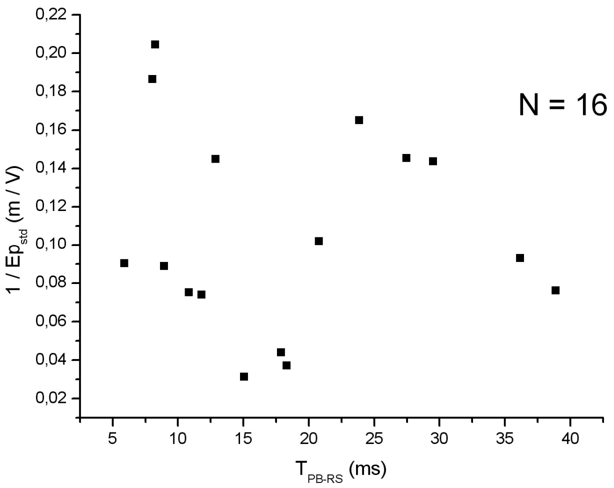

Figure 4 - 1/Ep *versus* T_{PB-RS} graphic for 16 subsequent strokes in which we have observed the formation of a new channel.

5 - REFERENCES

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Main author
Name: Leandro Zanella de Souza Campos
Address: Rua Corinto, 67
CEP: 12233-240 São José dos Campos/SP, Brazil
Fax: (12) 3945-6810; Phone: (12) 3916-4253
E-mail: leandro.zanella@gmail.com