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THE ELECTRICAL AND METEOROLOGICAL CONDITIONS IN THUNDERSTORMS IN THE VICINITY OF SÃO BERNARDO DO CAMPO, SÃO PAULO

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Abstract - An integrated campaign for monitoring of thunderstorms in São Bernardo do Campo region, occurred at FEI from November 2004 to March 2005. The aim of this campaign is study the electrical-meteorological behavior in a high lightning activity region. The local electric field, the lightning activity and the general weather conditions were being monitored. This monitoring identified the convective cells, their life stages and activity of total and CG lightning flashes. Eight events were monitored by local electric field, video cameras and lightning detection simultaneously. These events showed strong wind and high rainfall accumulation and caused several local floods in São Bernado do Campo and São Paulo City. The most of storms presented variation of local electric field exceeding to 16kV/m for about 4 hours. Some transients of IC and CG lightning were recorded been identified visually by video camera. Rate of total flashes, 5 per min. $^{-1}$, suggest occurrence of ordinary thunderstorms. About 29.5 thousands of CG lightning flashes were analyzed. These storms were predominantly negative, about 94%, and presented average peak current of above 25 kA common for this region.

1 INTRODUCTION

Recent studies of lightning flash densities in the south and southeastern Brazil showed that Sao Paulo City and surrounding areas are heavily struck by lightning [1,2] .This region present high level of lightning activity and lightning density. About 6,3 flashes per km^2 per year occur at Sao Bernardo do Campo, São Paulo [3]. Several floods occur in this region due to summer afternoon convection. The heat island effect (urban area) with its strong vertical and horizontal circulation combined with higher moisture content from the local sea breeze in the afternoon hours can explain these much higher rainfall accumulations and thunderstorm occurrences[4] .

The monitoring of local electric field on the ground can show the cycle life of storms. This monitoring can show also the total flashes rate, intra-cloud and cloud-to ground lightning flashes, to these storms. In the cycle of life of storms is showed the initial, active and dissipating stages. According to Kriehbiel (1986) [5] negative value of the electric field measured at the ground of about 100V/m was found on New Mexico in the absence of storms

(fair weather). The initial stage is identified by electric field reverse sign form fair weather (FW) increasing rapidly in magnitude caused by electrification of negative charge in its storms. The active stage begins with the occurrence of the first lightning discharges and can last from a few minutes to an hour or more depending on the size and convective vigor of storm. During the dissipating stage of the storm the lightning activity closed and the electric field exhibited a large oscillation on swing to negative values called an end of storm oscillation (EOSO). EOSOs are observed directly beneath a dissipating storm and are associated with the storm's physical collapse. This is supposed to be a favored time for occurrence of positive CG lightning. The flash rate can be used to show the vigours of these storms.

The aim of this paper is to investigate the behavior of storm by the monitoring of local electric field. These storms occurred in São Bernardo do Campo, São Paulo for the period of November 2004 to March 2005. This electric behavior is associated with meteorological conditional.

2 THUNDERSTORM MONITORING SYSTEM

An integrated campaign occurred from November 2004 to March 2005, the summer period, at The University of FEI, São Bernardo do Campo, São Paulo. The local thunderstorm monitoring system (TMS) consists of 2 electric field mill (EFM), 1 Flat Plate (FP), 3 Videos cameras (VC) and sensor of temperature synchronized by global position system (GPS). The EFM detect the ambient electric field at ground level and estimated the total flash occurred cover area with radius around of 20km [6] . The ambient electric field detected is presented as positive value where the transient of field shows the occurrence of storms. In this paper the records of electric field are obtained with a time resolution of about 4 msec. Some lightning were observed by EFM and VC, simultaneously. The image by video camera are recording continuously on 30 frames per second. Some events are ignited by motion detection. These pieces of information are complemented by CG lightning strokes obtained by Lightning Detection System (LDS) of RINDAT. The LDS identifies and locates the stroke of cloud-to-ground lightning flash occurred and estimates the peak currents of such strokes. This system covers the state of Sao Paulo and the efficiency of lightning detection is around 80% in this region [7] . The meteorological conditions were obtained by Weather Radar and Satellite meteorological. Figure 1 shows the location of the FEI, sensors of LDS and the weather radar covering area illustrated by the circle with radius 240 km.

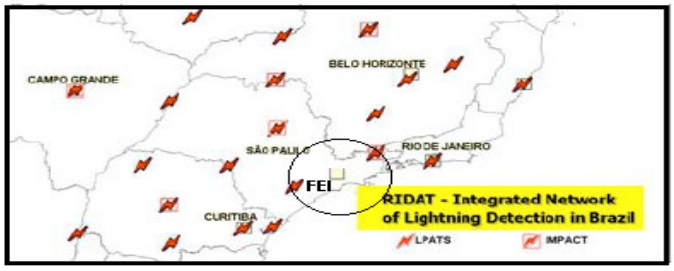


Figure 1. Map of RINDAT sensor locations and the weather radar covering (circle) are shown.

A total of eight cases were selected for this study. These events presented high local electric field and high activity of CG lightning flashes. Positive flashes with peak current less than 10kA were not considered for the analysis. According to *Cummins et al.* [1998] and *Wicker and Orville* [1999a, b] [8-10] , weak positive flashes (less than 10kA) are mostly cloud flashes.

The CG lightning activity maps is showned on Figures 2. In this paper the activity was study having a total of 1125 points (45 along the east-west direction and 25 along the north-south direction), with a spatial resolution of 400km². Variations of flash parameters occurring on a smaller scale will not be taken into consideration in the present maps.

3 RESULTS

Eight cases are presented on this paper. These storms presented variation of local electric field exceeding to 16 kV/m for about 4 hours. These recordings show transients of convective storms and transients of total lightning. Some Transients of lightning were recorded simultaneously by VC suggesting waveforms of IC and CG.

Table 1 presents these cases and summarizes the results of CG lightning flash incidence in São Bernardo region. About 29.5 thousands of CG lightning flashes were analyzed. These storms were predominantly negative (about 94%) and presented average peak current of above 25 kA. The same characteristics were found on others studies for this region [1,2] .

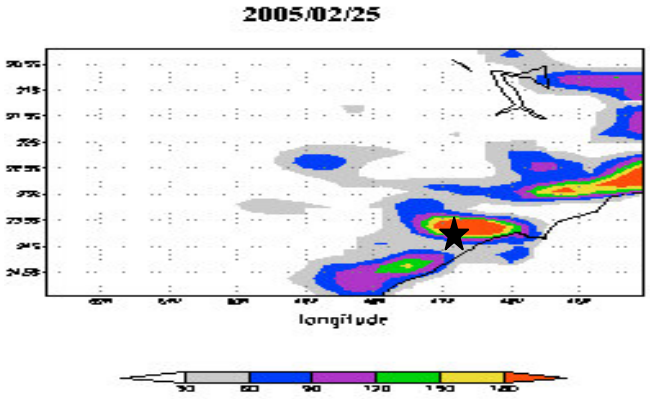
Table 1. Storm Cases at São Bernardo region

Date of cases	Period (UT)	Lightning Stroke s (by LDS)			meteorological conditional
		Neg.	Pos.	Max. Activity of Neg. CG per min (period)	
04/12/06	15-20	2980	17	30 (16:30-17:00) cell above FEI	LC Flood at SBernardo
04/12/07	15-20	2081	43	20 (17:30-18:00)	LC
05/02/12	16-24	2488	104	8 (19:00-19:30)	LC
05/02/25	17-21	4278	53	30 (18:10-18:40) cell above FEI	LC Flood at SBernardo
05/03/14	17-24	3839	150	15 (18:50-19:20)	PF
05/03/15	1-4 17-24	3089 4270	432 508	15 (01:00-01:40) 15 (19:40-20:00) (22:50-24:00)	CF
05/03/16	1-7	3789	546	15 (01:00-02:10 (02:40-03:20)	CF
05/03/17	20-24	882	17	8 (20:50-21:50)	LC

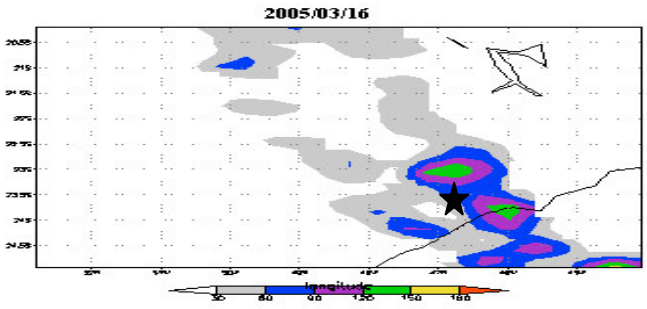
LC: Local convection/ PF: pre- cold front/ CF: cold fronts

Total	27696	1870		29.566

Mesoscale meteorological influences often provide thunderstorm production. Besides, the synoptic-scale cold fronts electrically active often occur in these regions in summer. Figure 2 a and b show the cloud-to-ground lightning activity map to the thunderstorms LC and CF, respectively. The lightning activity is identify by color intervals of 30 flashes for all life cycle of these storms. The black star at this map locate the FEI campus. The thunderstorms LC are produced by local convection and the CF are associated to cold front. Both events presented heavy rainfall being registered strong floods in São Bernardo and surrounding areas of São Paulo City. In the most events presented active cells of negative CG lightning strokes of about 100 x 100km. These cells presented activity superior to 60 CG lightning remaining active for about 4 hours. Some cases present maximum lightning activity occurring exactly above FEI Campus (25th February). The figure 2a shows one of these cases occurred on 25th February of 2005. In this case the peak of maximum activity occurred around 18:20 UT (03:20 PM local time) presenting a rate of about of 30 negative CG lightning per minute and density of 0,007CG per km^2. This density is similar than observed at Florida [11] . This period shows the storm active stage.



(a) Local convection_LC



(b) Cold front_CF

Figure 2. Activity of negative cloud-to-ground lightning flashes to local convection (a) and cold front (b) at São Bernardo do Campo, São Paulo. The black star locate the FEI Campus.

The electric field recorded at ground level can identify the life cycle of the thunderstorms. Figure 3 shows a recording on the time of the local electric field (blue line) and the CG lightning activity (red line) occurred on 17th March of 2005. The measurement of electric field (left scale) is showed in kV/m (unit arbitrary). The CG lightning activity (right scale) is showed in number of

flashes within of 20km around FEI campus in a ten-minute interval. This CG flashes is. Were observed electric field from fair weather similar that one observed by Krehbiel(1986) [5].This field is represented by positive polarity caused by the unipolarity of instrument. A ten-minute gap occurred in the measurement around 20:30UT (17:30 LT). The initial stage was identified by the small increasing of the fair weather electric field and by the absence of CG lightning. The active phase can be seen by the high intensity of electric field and by the high lightning transient field rate. Intra-cloud and negative CG lightning transients were identified in this stage. In the dissipating stage there was a large electric field oscillation and the absence of transients due to discharges. These stage are coincidence in time with the total lightning and CG lightning activity . Both showed the period of maximum lightning activity on active stage around 21:30 UT (18:30 LT). No flashes were observed on initial and dissipating stage. It was also compared the rate of IC and CG flashes around the maximum CG lightning activity. The IC transients and CG lightning were observed in ten minute interval. The rate IC to CG flash was of 10 to 1 to before and after of maximum CG lightning activity. However, in the maximum CG activity the rate was of 4 to 10 per minute. The maximum total flash rate is around 5 min-1. It suggest that this thunderstorm seem be ordinary thunderstorm [12] .

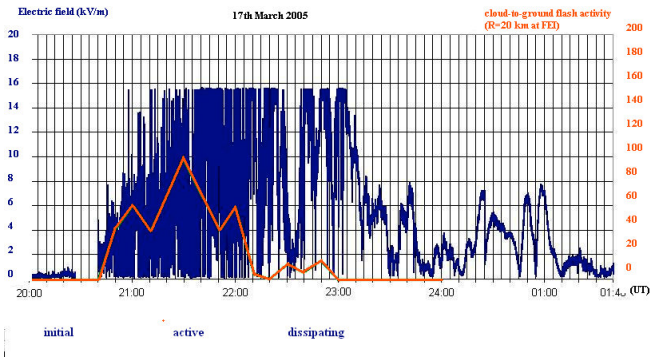


Figure 3. The electric field records by EFM(blue line) and the CG lightning activity obtain by LDS (red line) to the thunderstorm occurred on 17th March of 2005 at FEI.

Five interesting cases were studied in detail (11th February , 25th February, 14th March, 15th March and 17th March). All cases presented cells with 2 or 3 hours of life and 30minutes between the first maximum of electric field and the precipitation phases. The active stage showed fields between 14-16kV/m and some cases presented fields exceeding to 16 kV/m. The figure 4 shows the local field (red line, left scale) and temperature (cyan line, right scale) to 14th March. The precipitation phase coincide with high decreasing of temperature at 05:36 UT (02:36 LT). This behavior is similar than observed by Krehbiel (1986) and Carey (2000) [5,13]. . The dissipating stage is show on decreasing of temperature.

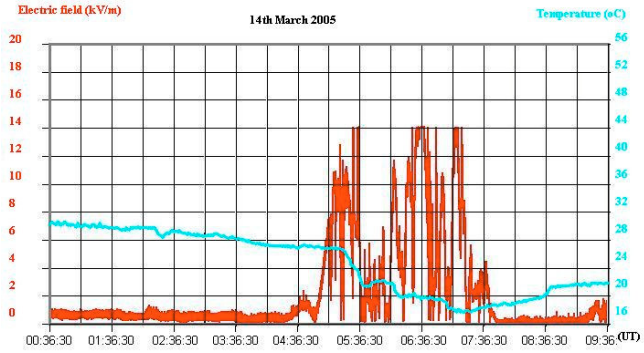


Figure 4. Local electric field (line red) and temperature (cyan line) to 14th March 2005.

Some lightning transients of electric field recorded by EFM were visually observed by VC images. These transients suggest some waveforms to IC and negative CG of lightning. In this paper are show only the transients exceeding to 5 kV/m. The waveforms found on this paper are similar to these identified by various authors [5, 6, 14-18] . Figure 5 shows recordings of transients of IC lightning on 17th March event. The first two arrows identify the transients of IC flashes visually observed by video. This storm was interesting to identify waveforms to IC because it presented a low CG lightning activity when compare with the others storms observed (see table 1). No recording of CG lightning stroke were found on LDS for this transients fields. In the most events it was also observed that only the lightning containing luminosity lasting more then 100 msec were recorded by EFM. The persistent luminosity detectable visually is produced by continuing current of flashes. This current can last for until few seconds. It suggest that lightning with continuous current can be easily observed by local electric field.

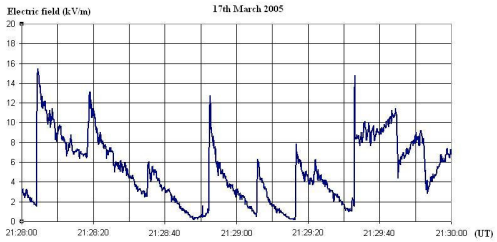


Figure 5. The electric field recorded on 17th March 2005 at FEI campus. The two first arrows indicate transients of IC lightning and the third arrows indicate the IC (by EFM) and CG flash (by LDS) occurring simultaneously.

Some limitations were found on records by VC. Due of the sight vision camera several lightning couldn't be observed. Some VC images seem to be strongly saturated

too. Some images suggest IC and CG occurring simultaneously. The third arrow at figure 5 shows one of

these events. This transient seem be IC and CG flash visually observed by VC. The recording by LDS identify a negative CG lightning occurring about 5 km from FEI campus. In these case IC can introduce the field stress to start the CG flashes. Usually, these events occur on cells dissipating storms as occurred in this case. No positive CG lightning was recorded on LDS in this period. Some horizontal discharges could be seen by VC. They show how long the storms are and that they happen specially on the anvil at the storms final stage. Some of these presented transients IC with amplitude less to 5kV/m. The Spider visually observed by VC recorded transients field around 1 kV/m (figure 6). This discharge occured during dissipating stage of storm the persistent luminosity was of 60 msec. No CG lightning stroke were found on LDS for this period.

Figure 6. Spider visually observed by VC on 17th March 2005 over FEI Campus.

Transients of negative CG lightning recorded by EFM could also be visually identified by VC. Figure 7a shows the recording of electric field identifying the negative waveform of CG lightning. The blue arrow shows the transient visualized by video camera (figure 7b). This lightning presents the channel luminosity during approximately 230 msec. The luminosity due to the continuous current could also be observed. No record of negative CG lightning stroke were found to this event visually identified. It can be due to limitation of VC or limitation of LDS. The detection efficiency is around 80% to this area. Therefore, some flashes can be lost by LDS. The black arrows identify multiple strokes flashes. The peak current of negative CG lightning was about 20KA. The peak current estimated to negative flashes is around 20 kA to this region [1-2].

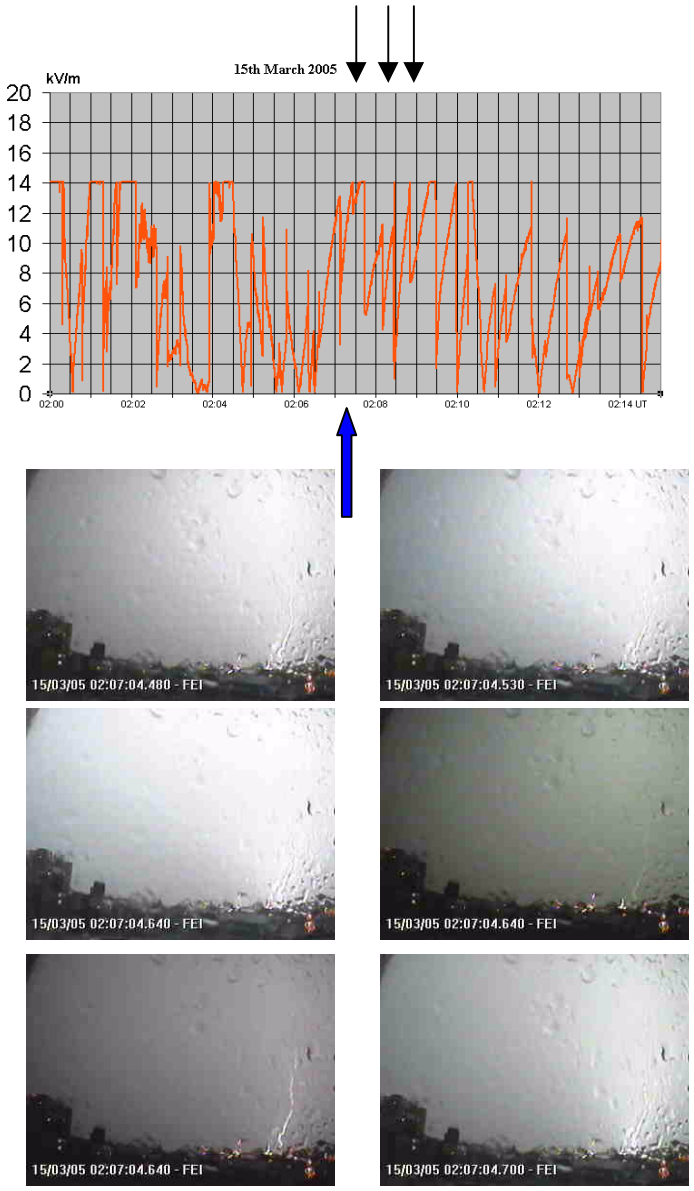


Figure7. The electric field transient of negative CG lightning recorded by EFM (a) and sequence of images obtained by video cameras (b)

Transients of CG lightning recorded by EFM could also be identified by LDS. Figure 8 shows the transient of lightning where five strokes were recorded by LDS occurring above FEI campus. The strokes intervals were around 100ms presenting a peak of current from 15kA to 32kA. The flash saturated the VC images of recorded for this event. No recording of positive CG lightning were found coincide with EFM data.

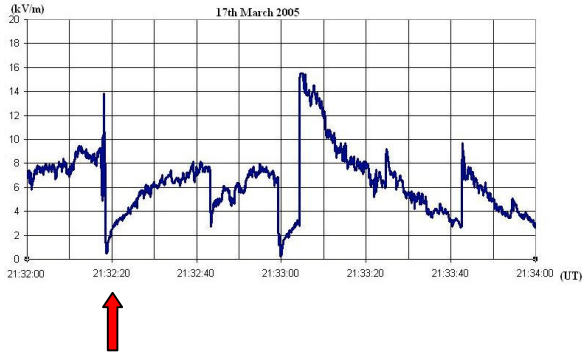


Figure 8. Electric field record by EFM (identify by arrow) identify five negative CG lightning strokes at FEI campus.

4. CONCLUSIONS

This paper could show a study of thunderstorms using local electric field. These thunderstorms occurred at São Bernardo do Campo, São Paulo, in a region of high flash activity. It was identified the life cycle of storms showing initial, active and dissipating stage. These stages were confirmed by flashes activity. Rate of intra-cloud and cloud-to ground also was studied. The higher rate IC to CG was founded of 10 to 1. This rate shows the initial and dissipating stages. Waveforms of IC and CG flashes were suggested been identified visually by video camera. The negative CG flashes presented peak current of around 20kA common for this region. However, no positive CG flash could be identify in this study. Some development are been study to improve the monitoring by local electric field sensors and video camera. The aim is enlarge the region in study, put others sensors in others regions, to understand the behavior of storm in area of high flash activity as São Paulo city and ABC region.

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