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HIGH PEAK CURRENT IN LONG CONTINUING LUMINOSITY OF POSITIVE FLASHES: A CASE STUDY

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1. INTRODUCTION

Measurement of channel luminosity and electric field changes can identify continuing current of lightning flashes. Continuing current can last for few tenths of a second and produce a persistent luminosity that is sometimes detectable visually. Many studies have reported about continuing current flashed recording channel luminosity and electric field [Kitagawa et al., 1962; Brook et al., 1962; Shindo and Uman, 1989; Rakov and Uman, 1990 and Gin et al., 2006]. Continuing current occurs when the cloud charge density along the path of an interstroke junction process exceeds some critical level. The magnitudes is of the order of 100 A and transfer about 10C from cloud charge to ground [Uman, 1987]. Continuing current in negative cloud-to-ground lightning flashes can be classified as: long continuing current (LCC) or short continuing current (SCC). The long continuing current flashes lasting in excess of 40 ms and the short continuing current flashes having a duration less than 40 ms. Although, some flashes can present long and/or short continuing current. These flashes are classified as hybrid flash, a flash who containing at least one LCC, and discrete flash, a flash without LCC [Kitagawa et al., 1962; Brook et al., 1962]. Hybrid flashes transfer more charge to earth than other ones and can indicate lateral extensive structure of thunderstorms [Gin et al., 2006].

Long continuing current in negative cloud-to-ground flashes are of significance in that they transfer to earth about twice the charge that flashes without LCC do. This fact can be serious on objects struck heating damage [Uman, 1987]. Some multiple stroke flashes are following by LCC. Long continuing current is more frequent in multiple flashes than in single flashes. Rakov et al. [1990] observed 6% of single flashes contained long continuing current and 49% of multiple flashes occurring in thunderstorm at Florida and at New Mexico

Multiple flashes seem be associated to long channels [Heckman,1992]. These flashes and horizontal discharges can indicate how extensive are the horizontal structure of thunderstorms. Laboratory experiments that spider lightning is a natural response to extended regions of space charge characteristic of stratiform precipitation [Williams et al., 1989].

2. INSTRUMENTATION

Sao Paulo Weather Radar (SPWR) identified the rainfall systems in this study, a S-band system located in eastern São Paulo State. Maps of radar-derived rainfall rates at 3-km altitude within 240-km radius were obtained for these events.

The behavior of continuing luminosity of cloud-to-ground lightning flashes was obtained by video cameras (VC). Seven video camera recording flashes in time interval from 15 to 31ms, simultaneously. The flashes were identified by discrete video image showing the illuminating of lightning channel to ground. Flashes occurred in least time intervals are lost.

Cloud-to-ground lightning activity was obtained by the Lightning Detection System (LDS) from the Integrated Network of Lightning Detection in Brazil - RINDAT. These data identifies and locates the stroke of a cloud-to-ground lightning flash and estimates the stroke's peak current. Positive flashes with peak current less than 10kA were not considered for the analysis. According to Cummins et al. [1998] and Wacker and Orville [1999[a], 1999b], weak positive flashes (lower than 10kA) are mostly cloud flashes. This system covers Sao Paulo State and exhibits an efficiency of lightning detection of 80% in this region [Beneti et al., 2004].

3. RESULTS AND DISCUSSION

Long continuing luminosity in cloud-to-ground lightning flashes was observed at Metropolitan Area São Paulo (MASP) on February, 2008. These observations suggesting long continuing current of flashes indicating the lateral extensive structure of thunderstorms.

The most of thunderstorms that presented high rate of long continuing luminosity in cloud-to-ground lightning flashes were associated to heavy rain and flood at MASP. An extensive area of maximum rainfall rate was observed at MASP from 12 to 13 February, 2008. The rainfall system presented an extensive area of maximum rainfall rate, higher than 75 mm h^{-1} , and strong wind up to 70km/h. The rainfall system was associated to stationary cold front and moves to the southeast of MASP.

Figure 1 shows the E-field recorded from 12 February at 23:30 UT to 13 February 03:30 UT, 2008 at MASP. Electric field of 10kV/m and transient of flash larger than 5kV/m were observed in this period. Fifty five flashes were recorded presenting 75% of long continuing luminosity. This set of flashes recorded, 64% presented negative polarity, presenting multiplicity of 3 strokes and average peak current of 30 kA. The polarity, the multiplicity and the location of flashes were identified by electric field recording and video camera been confirmed by LDS. Maximum negative flashes activity was around 5 flashes per minute, suggesting thunderstorm ordinary with long horizontal extensive [Williams, 2001]. The set of positive flashes (36%) all presented single-stroke flash and average peak current of 54kA.

Transient of flashes were recorded until 01:30 UT. An EOSO period without sign of lightning was observed at the end of storm. The EOSO period suggesting the dissipating the electrical charge in the cloud associated to cloud decay at the end of storm [Marshall and Lin, 1992]. So the EOSO period recorded confirms the large lateral extensiveness of this storm.

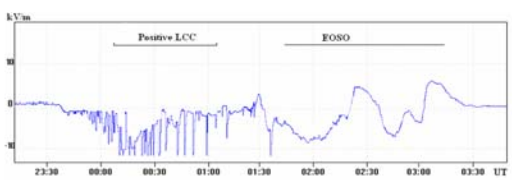


Figure 1: The electric field recorded on 12-13 February, 2008.

High rate of long continuing luminosity of flashes was observed on February 13 from 00:00 to 01:30UT within 30km radius at MASP. Forty one flashes were recorded by video camera, electric fields and LDS, simultaneously, lasting from 100 to 500 ms. About 60% of flashes presented positive polarity, recording average peak current of 73kA. The negative flashes (40%) recorded average peak current of 25kA. Table 1 shows the time of occurrence of flashes, the duration, the average peak current and the location of long continuing luminosity of positive cloud-to-ground flashes recorded in this period. All events presented more than 100ms of duration and peak from 12 kA to 143 kA.

Some flashes presented a long continuing luminosity preceding the luminosity of return stroke channel. This luminosity, identified like stepped leader luminosity, was recorded by video lasting from 30ms to 170ms. Figure 2 shows a sequence of image to a long continuing luminosity of positive flash recorded at 00:47 UT on 13 March, 2008.

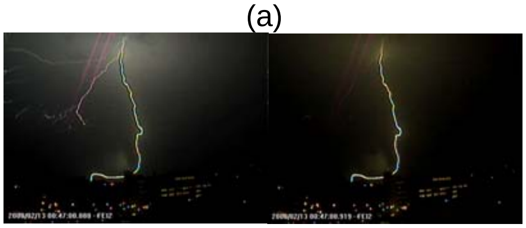
Table 1 Long continuing luminosity of positive cloud-to-ground flashes observed at MASP on 13 February, 2008

CG Flashes	LCL	LDS	
Time (UT)	Duration (ms)	Peak Current (kA)	Distance from SBC (km)
00:07:50	110	+44	24
00:13:48	141	+75	14
00:16:04	500	+84	25
00:18.59	500	+91	20
00:23:13	406	+90	3.5
00:29:35	437	+40	17
00:32:39	422	+80	11
00:36:37	500	+101	25
00:47:00	438	+113	10
00:54:51	312	+32	21
00:59:20	140	+12	26.6
01:04:28	109	+143	13

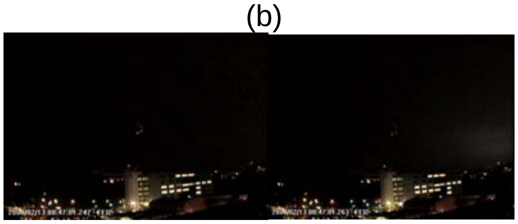
This flash presented average peak current of 113 kA and was located around of 10 km from Sao Bernardo do Campo. The stepped leader luminosity is recorded 32 ms before return stroke luminosity and it last about of 140ms. That's show there is a long breakdown process in cloud before the return stroke. This long breakdown process has seen observed by Zhang et al. [2006]. Discharge of long duration preceding the positive return stroke for about 370 ms and show the long laterality of positive charge region of storms.

Branches on positive cloud-to-ground flashes were observed. Figure2a shows the luminosity of branches lasting for about of 94ms. The total duration of long continuing luminosity of positive flash was 438 ms. The observations are according to observed by at Florida and New Mexico [Rakov and Uman, 1990].

(a)



(b)



(c)

Figure 2: Sequence of image shows the beginning (a,b) and the end (c) of long continuing luminosity flash occurred at 0047UT on 13 February 2008 at MASP. The first frame was recorded at 00.778s and the last frame at 01.263s.

Many spiders and long discharge air occurred on this storm. Figure 3 shows a spider (3a) and the long discharge air (3b) recorded to this period. Spiders are associated to extended regions of space charge characteristic of stratiform precipitation.

(a)

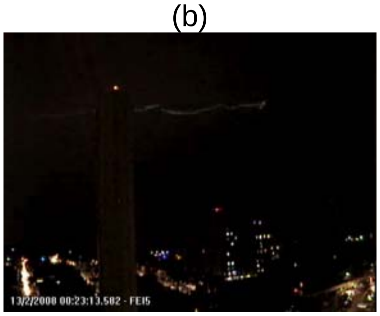
(b)

Figure 3: A spider flash (a) and a long discharge air (b) recorded on February 13, 2008.

Some long discharge occurred simultaneously to long continuing luminosity in positive cloud-to-ground lightning flashes. The long discharge air preceding the positive flashes and maintain the luminosity after the end the luminosity of positive flashes. Figure 4 shows the discharge air and the positive cloud-to-ground flash occurring simultaneously on 0023 UT on 13 March, 2008. The total duration of the air discharge is about 600ms. This discharge was recorded 140ms before the positive flash (figure 4.a) and 60ms after of the end the positive flash (figure 4.c). This indicates that there is a long positive charge region at base of the cloud. The total duration of positive flash is about 406ms (figure 4.b). The positive flash was recorded on 3.5 km from FEI exhibiting average peak current of about 90 kA. These observations are according to observed by at Qinghai-Tibetan Plateau [Qie et al., 2005] where optical images confirmed the occurrence of discharge air before and after the return stroke. These events confirm the long lower positive charge region in the mature stage of thunderstorm.

(a)

(b)



(c)

Figure 4: Sequence of image shows discharge air (a) recorded 140ms before the positive CG flash (b) and 60ms after the end of positive CG flash (c) occurred at 0023 UT on 13 March 2008 at MASP. This image identifies the long laterality of positive charge region of storm.

4.CONCLUSIONS

Long continuing luminosity in cloud-to-ground lightning flashes was observed on February 12, 2008 at Metropolitan Area São Paulo (MASP). Thunderstorm recorded fifty five flashes around 30km of Sao Bernardo do Campo presenting 75% of long continuing luminosity. This thunderstorm presented E-field of 10kV/m and transients of flashes higher than 5kV/m and EOSO oscillation. On flashes period were recorded 64% of negative flashes, presenting multiplicity of 3 strokes and average peak current of 30kA. On this period was observed high rates of long continuing luminosity flashes in mature stage of the storm lasting from 100 to 500 ms. Forty-one flashes were recorded by video camera presenting long continuing luminosity lasting at least 100ms. This set of flashes, 60% presented positive polarity, all single flashes, average peak current of 73 kA and duration of long continuing luminosity of till 500ms. Many LCC positive flashes presented peak current upper than 90kA. High peak current and long duration of continuing current in positive flashes is one order of magnitude longer than that in negative flashes [Uman, 1987]. Some events showed long luminosity of about 170ms before the return stroke. Some stepped leader channels were recorded in this period. Long discharge air occurred simultaneously with positive flashes in LCC positive flashes period. A long discharge air was recorded by video 140ms before the recording of positive flash occurred at 00:23 UT. The discharge air is visually identified during all process of positive CG flash and close about 60ms after the end of positive CG flash. Long discharge air show the long laterally of lower positive charge suggesting thunderstorm with long horizontal extensive.

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