Cloud-to-ground lightning characteristics of severe storms in Southeastern Brazil

F.M. Santana[1], K.P. Naccarato[2], Menezes, W.F[3]

1. Federal University of Rio de Janeiro - Alberto Luiz Coimbra Institute Graduate School and Research in Engineering - UFRJ/COPPE, Rio de Janeiro, Rio de Janeiro, 21044-020, Brazil
2. ELAT / CCST - National Institute for Space Research (**INPE),** S. J. Campos, São Paulo, 12227-010, Brazil
3. Federal University of Rio de Janeiro - UFRJ/CCMN, Rio de Janeiro, Rio de Janeiro, 21044-020, Brazil

ABSTRACT: The objective of this work is to study the atmospheric conditions during cloud-to-ground (CG) lightning activity and the associated meteorological systems. A more comprehensive study of the CG lightning characteristics may lead to a better understanding of the thunderstorm severity. For these developments, it was selected two cases of severe thunderstorms that occur in Southeastern Brazil. The synoptic and mesoscale conditions previous to and during the CG lightning activity was analyzed. Furthermore, the number of CG strokes and its polarity are also evaluated in time in order to verify the electrical behavior of the thunderstorm. As a main result, it was observed that some patterns in CG lightning activity might indicate some level of severity in such thunderstorms. A storm occurred on November 17, 2008 has its genesis around 12:00 Z on the state of Sao Paulo. It's a gradual evolution over time, but since its inception has caused heavy rain over the state, and this accompanied by lightning occurrence. The number of negative flashes during the whole time the storm was higher than the positive flashes, indicating a not so intense severity. But on June 27, 2009 a storm reaches State of the Sao Paulo near 12:00 Z, isn't a gradual evolution over time. The number of negative flashes is much higher than the positive in a few hours. But at other times, the number of positive flashes is closer to the number of negative flashes, particularly from 21:00 Z to 22:00 Z, where both number are almost equal. This behavior indicates a much higher severity in this case compared to the previous case. Among the results, considering storms with similar characteristics, not necessarily they present the same severity. Thus, the study of the lightning occurrence is important for the assessment a storm severity. As a future proposal other cases of severe storms including a more detailed study of lightning will be studied. The idea is to create a severity rating from the set of meteorological data based also in the lightning characteristics.

1. INTRODUCTION

The events of lightning (also called lightning flashes), except to floods, are responsible for several material and human life losses. In Brazil, some non-official statistics reveal that approximately 400-500 persons are hit by lightning per year. Considering the country has more than 190 million inhabitants, the probability of a Brazilian citizen to be hit by lightning is of approximately P = 2x10-6year-1 (Pinto Jr et al 2000 and Naccarato, 2007). The meteorological phenomena that are mainly associated to lightning occurrence are the Mesoscale Convective Systems (MCSs) and cold fronts. Thus, these systems have become subject of several researches in order to

∗ Correspondence to:

Fernanda M. Santana, Alberto Luiz Coimbra Institute Graduate School and Research in Engineering - UFRJ/COPPE, Rio de Janeiro, RJ, 21945-970, Brazil. Email: santana.fernandam@gmail.com

improve their understanding and forecast and minimize the general losses. In the civil construction, petrochemical and mining sectors, where several employees work outdoors, safety has been a matter of several discussions. During storm, followed by lightning (or thunderstorms), the employees are highly exposed, with high probability of being hit by lightning that could lead to death. A specific procedure has been created by the Atmospheric Electricity Group (ELAT) from the Instituto Nacional de Pesquisas Espaciais - INPE, which can predict, with about one hour in advance, the occurance of lightning caused by particular meteorological system over monitored areas (Naccarato, et al 2007 and Naccarato, 2008).

This paper proposes a more detailed study of the behavior of the lightning during the storm, aiming to gather a more information on the severity of the systems. This can help characterizing the atmospheric conditions associated to be lightning occurrence and the meteorological systems that can produce such discharges. This was made through study of cases of events associated to a large volume of lightning.

2. METHODOLOGY

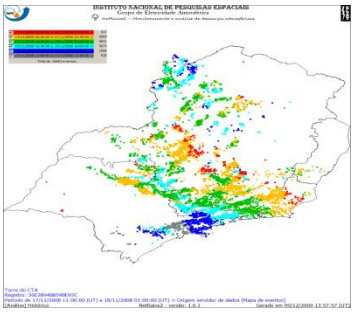
Two severe storms that occurred in the Southeast region were studied. For the follow-up of these cases, outputs of the ETA model (ETA 40x40 km) were used, an operational regional weather forecast model from the Centro de Previsão de Tempo e Estudos Climáticos - CPTEC, together with enhanced satellite images and, radar images and the number and polarity of cloud-to-ground lightning flashes. The two systems chosen had differences between themselves regarding their genesis characteristics, formation place, displacement, duration period and in the lightning activity intensity. The first was on November 17, 2008, where an instability line sweeps the states of São Paulo and Rio de Janeiro. The second was on June 27, 2009, which was a storm with an excessive number of lightning, which leads to intense rain followed by hail in Paraíba Valley and South of Minas Gerais.

3. CASE STUDIES

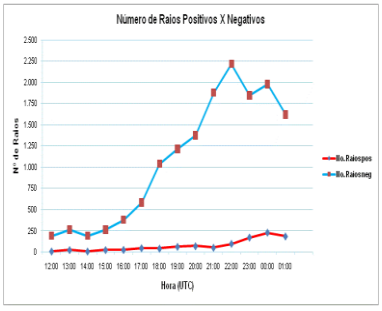
3.1 Case 1

The storm on November 17, 2008 has it genesis close to 12:00Z in the State of São Paulo, its evolution is gradual over the time, however, from its beginning, it caused strong rain over São Paulo's capital and is followed by lightning.

The storm vertex was at the end of the afternoon in the State of Rio de Janeiro, causing strong rain, followed by a high number of lightning (Figure 1 (a)). The evolution of number of lightning is grasual, as well as the strom, after 23:00Z of lightning starts to lessen, the rain is also less intense and there is a total number of 15,682 lightnings. The number of negative lightning (Figure 1 (b)) at the entire duration of the storm was larger than the positive, indicating a not so intense severity. The number of positive lightning has an increase as from 23:00Z, suggesting the end of the thunderstorm.

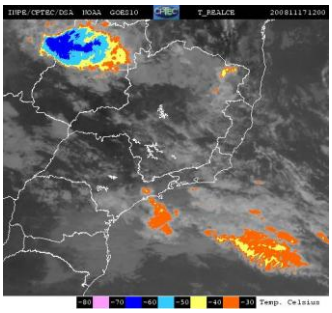


(a)



(b)

Figure 1: (a) Distribution of lightning flashes throughout the Southeast region, color coded in time. (b) Rate per hour of lightning for the same region. (**Source**: ELAT/INPE)



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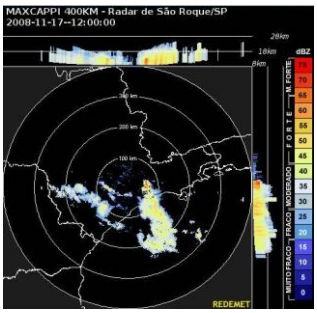

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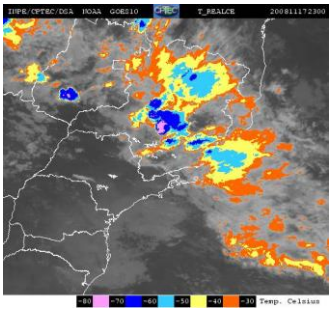

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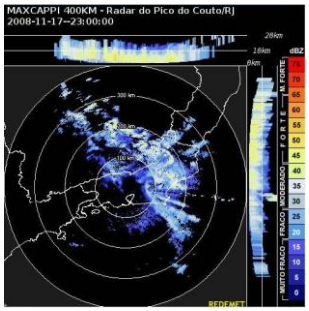


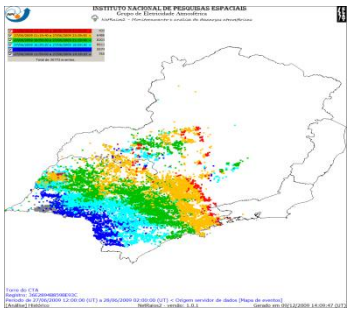
(d)

Figure 2: Images of the GOES-10 satellite with the respective images of radars of São Roque and of Pico do Couto on November 17, 2009, (a) at 12:00Z, enhanced, sectorized and (b) radar of São Roque, (c) at 23:00Z, enhanced, sectorized and (d) radar of Pico do Couto. (**Source**: CPETC and REDEMET)

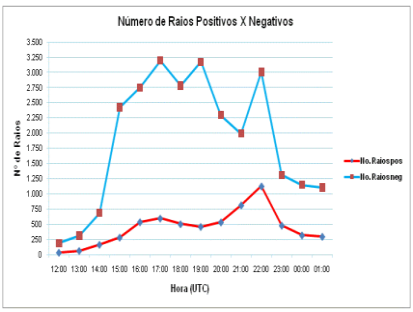
3.2 ***Case 2***

The storm on June 27, 2009 reaches the State of São Paulo close to 12:00Z, and is intensified in two hours, from its beginning it caused strong rain and is followed by a lot of lightning. Figure 4 exposes the behavior of the atmosphere at 18:00Z, that there was dynamic support for the occurrence and sustainability of the storm.

Its vertex is around 15:00Z, with very deep convective cores, followed by a large number of lightning. The storm reaches Vale do Paraíba and to the south of Minas Gerais close to 18:00Z, causing strong rain and in some places, hail. The evolution of the number of lightning is gradual, as well as the storm. After 23:00Z, the number of lightning lessens, however, the rain remains intense, with a total number of 30,772 lightning. The number of negative lightning is really superior to the positive ones in a few hours, from 16:00Z to 19:00Z, in other hours, the number of positive atmopheric discharges is close to the negative ones, with highlight to 21:00Z and to 22:00Z. This behavior indicates a high severity in this case. The number of positive and negative lightning are really close to 23:00Z, suggesting the end of the storm.

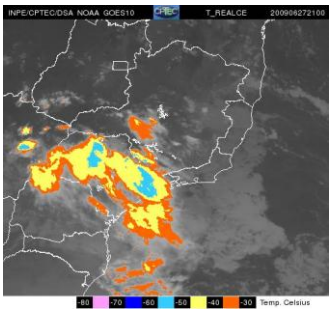


(a)



(b)

Figure 3: (a) Distribution of lightning flashes throughout the Southeast region, color coded in time. (b) Rate per hour of lightning for the same region. (**Source**: ELAT/INPE)



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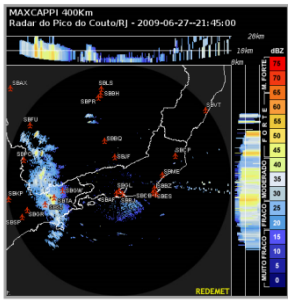

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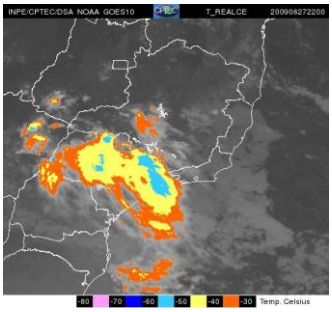

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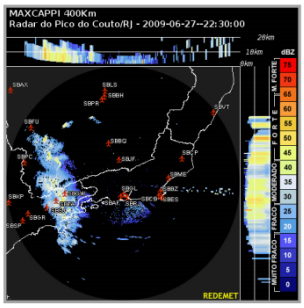

(d)

Figure 4: Enhanced and sectorized images of the GOES-10 satellite and images of the Pico de Couto radar on June 27, 2009, (a) at 21:00Z, (b) at 21:45Z, (c) at 22:00Z and (d) at 22:30Z. (**Source**: CPETC and REDEMET)

4. CONCLUSIONS

Through this, the study of the lightning activity is important and is another variable that should be considered for the severity assessment of severity.

A future proposal is to study other severe storm cases, including a more detailed study of lightning activity, thus creating a severity classification from the set of meteorological information added to the lightning behavior.

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