Cloud to Ground Lightning Properties and Mesoscale Convective System: Characteristics and Evolution During the Life Cycle

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Introduction

The knowledge of the clouds processes associated to the occurrence of cloud to ground (CG) lighting in MCS can be used as a nowcasting tool to support the extreme events mitigation decision. In particular, Brazil has an extensive land area and is near to the equator, it is intensely affected by this phenomenon, causing major damage to the sectors of electricity energy, telephone and telecommunications. Therefore the objective this work is present the relationship between CG lightning occurrence with some MCS physical properties and characterize the lifecycle evolution differences between MCS with (thunderstorm) and without lightning (storm). Moreover are evaluate some microphysical properties associate the electrical activity in mesoscale convective systems. In this way, combined information originating from infrared and microwave channels and occurrences of CG lightning are applied to the São Paulo state region in the period from 2007 to 2009.

Data and Methodology

The region of study is centered at São Paulo State as showed in Figure 1 and the data utilized correspond to period from 2007 to 2009. This Study was realized in three steps:

1-CG lightning occurrence from BrasilDAT network and Infrared images from GOES satellite in the period from 2007 to 2009 was used to characterize MCS physical properties and CG lightning. The brightness temperature (BT) was assimilated by ForTraCC model, which determined MCS physical properties. For each moment in the system life cycle, occurrences of CG lightning were counted from 7.5 minutes before until 7.5 after the image line;

2-BT in 23 GHz and 31 GHz (AMSU-A2) and 89, 157 and 183.31 GHZ (MHS) from NOAA-18 was assimilated by microphysics model presented by Zhao and Weng (2001). The Ice Water Path (IWP) and Ice Particle Effective Diameter (IPED) was coupled with CG lightning occurrence. Therefore for each pixel with value of IWP and IPED were CG lightning counted from 7.5 minutes before until 7.5 after the time of the scanned line.;

3-The BT from the 85 GHZ channel with vertical (TBV) and horizontal (TBH) polarization from the TMI sensor onboard the TRMMM satellite were used to estimate the orientation of ice particles. For each pixel was determined TBV-TBH and combined with the CG lightning information.

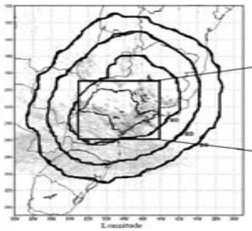


Figure 1. Region of study, location of BrasilDAT sensors inside this region and contour lines of CG lightning detection efficiency within 20, 60 and 90 %.

1- The diurnal cycle of the MCS area expansion and convective fraction and CG lightning

- 16,520 MCS identified over the area and during the analyzed period (2007-2009);
- 951,359 occurrence of CG lightning was associated;

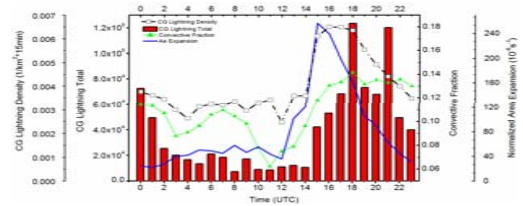


Figure 2. Mean hourly normalized area expansion ($10^{-6}s^{-1}$), MCS convective fraction and CG lightning total and CG lightning density (CG lightning by area of MCS in 15 minutes intervals) for São Paulo State.

2- Relationship of Convective System Area and Temperature With CG Lightning

- Large areas are associated with strong CG lightning occurrence (R = 0.96, pv = 9.63×10^{-11});
- The highest tops (lowest brightness temperature) are strongly correlated (R = 0.84, pv = 1.24×10^{-6}) with the regions with the most electrical activity;

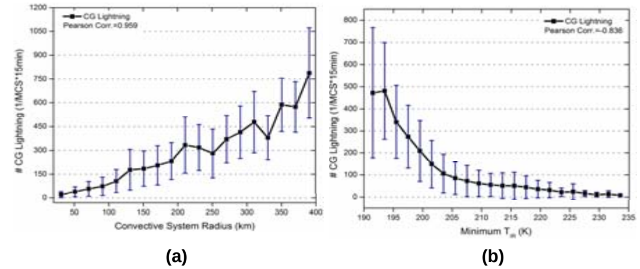


Figure 3. Variation of average and standard deviation of MCS CG lightning occurrence in 15 minute intervals (# CG lightning/15min) as a function of the (a) effective radius (km) and (b) IR Minimum Temperature of the Convective System.

3- Convective System Life Cycle Characteristics

- 420 systems were identified with lightning (henceforth denominated Thunderstorms);
- 300 without lightning (henceforth denominated Storms);

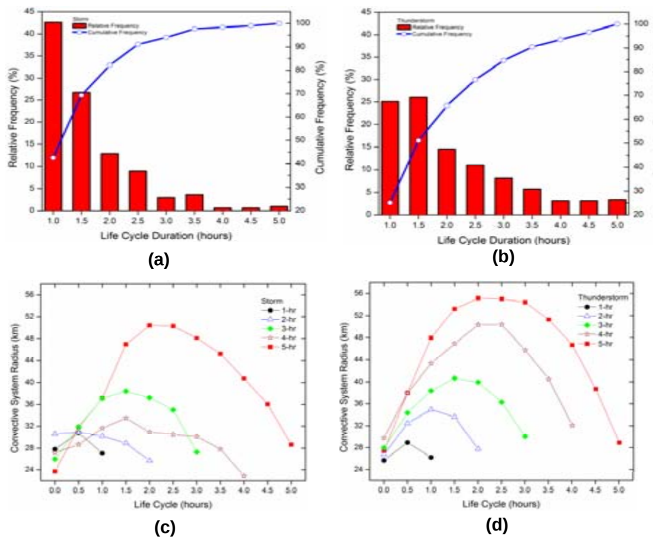


Figure 4. The relative and cumulative frequency distribution of the life cycle duration of (a) Storms and (b) Thunderstorms, and average variation over the life cycle of the convective system effective radius (km) of (c) Storms and (d) Thunderstorms for systems with duration of 1-5 hours.

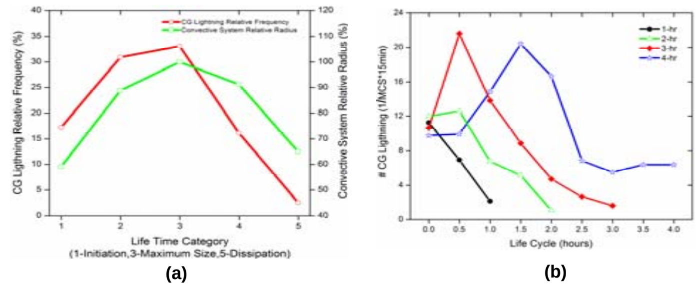
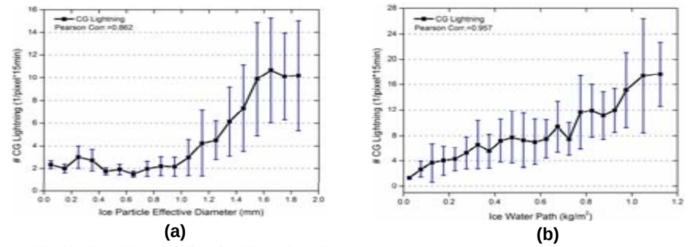


Figure 5. (a) Relative Frequency of the total CG lightning occurrence by MCS and the relative MCS size (to the mature stage) as a function of the five lifetime categories and (b) convective system effective radius for convective systems having a duration of 1-4 hours.

4- Microphysical Properties



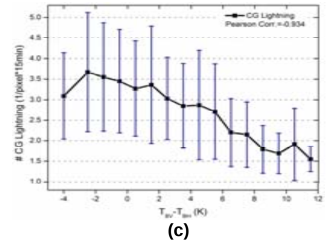


Figure 6. Variation of average and standard deviation of CG lightning occurrence in 15 minute intervals by pixel (# CG lightning/pixel*15min) as a function of (a) Ice Particle Effective Diameter (mm), (b) Ice Water Path (kg/m3) and of the (c) polarized Temperature Difference at 85 GHz (TBV-TBH).

Conclusions

- Electrical activity maximum occurs close to the time of maximum convective fraction and 3 hours after the maximum rate of area expansion;
- Size and IR minimum brightness temperature showed the strongest correlations with the convection intensity and the lightning frequency;
- Initial area expansion is a strong parameter for defining the stage of development, duration and the Thunderstorms showed a well defined life cycle in relation to the Storms, with a longer life time and larger area;
- Intense condensation rate and mass flux during the development leads to the maximum lightning frequency occurs during the growth phase close to maturation;
- High availability of the largest ice particles, ice content and vertically oriented ice particle are important to formation of intense charge centers and the initiation of electrical activity.