Lightning Characteristics of Severe Storms in Southern Brazil

Cesar Beneti[1,*], Augusto J. Pereira Filho[2], Leonardo Calvetti[1], Eloa Damian[1]

1. SIMEPAR – Parana Meteorological System, Curitiba, Parana, Brazil
2. Sao Paulo University – IAG/USP, Sao Paulo, Sao Paulo, Brazil

ABSTRACT: Lightning activity is intense in the continent throughout the year, but mostly active during the warm season (spring and summer), generally associated to the occurrence of Mesoscale Convective Systems (MCS) in the area, with maximum activity in the subtropical region, between Paraguay, northern Argentina and the south of Brazil. This paper presents results of an analysis of 10 years of radar and lightning data, with the study of electrical characteristics of severe storms observed in the radar coverage area in the south of Brazil. A total of 42% of the days were identified with convective activity, 26% with Isolated Convective Systems (ICS) and 16% with MCS (larger then 100km). In general, the convective region is the most active (86%) in terms of lightning, even for the events with larger stratiform areas with predominance of positive lightning. However, peak current in the stratiform region is higher for both negative and positive lightning flashes when compared to the convective region. The MCS play an important role on the hydrological cycle and on the incidence of severe weather events in this region, highlighting the importance of improving the knowledge of those weather systems, with the goal of better forecasts.

INTRODUCTION

In South America, northeastern Argentina, Paraguay, Uruguay and southern Brazil are regions particularly prone to severe weather events, generally associated with intense precipitation, lightning, hail, gust winds and some tornadoes. Lightning activity is intense in the continent throughout the year, but mostly active during the warm season (spring and summer), with maximum in the subtropical region, between Paraguay, northern Argentina and south of Brazil, but there is a limited knowledge in relation to the characteristics of those severe storms including frequency, type, morphology, intensity and location of cloud-to-ground lightning associated to the MCS.

In the South of Brazil, agricultural industry and electrical power generation are the main economic activities. This region is responsible for 35% of all hydro-power energy production in the country, with long transmission lines to the main consumer regions which are severely affected by these extreme weather conditions. Monthly precipitation distribution is very uniform, but with daily variability associated, mostly, with frontal systems and MCSs, which form in this area. The MCSs play an important role on the hydrological cycle and on the incidence of severe weather events, highlighting the importance

* Contact information: C. Beneti, SIMEPAR, Curitiba, Parana, Brazil, Email: beneti@simepar.br

of improving the knowledge of those weather systems, with the goal of better forecasts.

Precipitation is well distributed during the year, but Low Level Jets, east of Andes, bring more moisture and convective instability to the region during spring and summer, favouring the frequency of MCSs occurrence in this period of the year (Durkee et al, 2009; Albrecht et al, 2011) as observed from the lightning and precipitation seasonal variation, as presented in Figure 1.

DATA AND METHODOLOGY

This paper presents results of an analysis of 10 years of radar and lightning data, with the study of electrical characteristics of severe storms observed in the radar coverage area in the south of Brazil.

A hydrometeorological system comprising a network of automatic weather stations, S-Band Doppler weather radar, lightning sensors, satellite information in the south of Brazil was used to characterize and evaluate the weather events in the region. Figure 2 presents (a) the distribution of automatic weather stations and radar coverage area, as well as (b) distribution of lightning detection sensors network.

In order to objectively identify the MCSs while in the radar area (200k range), after a quality control and interpolation of raw data, a convective-stratiform classification algorithm was developed, based on Biggerstaff and Listemaa (2000) and Zhang and Qi (2010), using a threshold of VIL (Vertically Integrated Liquid) to separate the convective and stratiform precipitation areas within the radar coverage. Radar volumetric data were used to identify convective and stratiform precipitation areas associated to MCS, using VIL larger than1kg/m^2 and reflectivity larger than 30dBZ as convective threshold and an ellipsis fitting algorithm to identify MCS larger than 100km (Figure 3).

In the analysis presented here, weather radar and lightning data information from the period of January 2000 to December 2010 was used, with a total of 4018 days of data. In this period, 42% of the days with some convective and lightning activity were observed.

RESULTS

For each MCS identified, radar and cloud-to-ground lightning were analyzed, specially vertical reflectivity profile and isothermal reflectivity, VIL, lightning flash rate and other characteristics.

A total of 42% of the days were identified with convective activity, 26% with Isolated Convective Systems (ICS) and 16% with MCS (larger then 100km). Frequency with Altitude Diagrams (FADs) of reflectivity is presented (Figure 4) with distinct differences between isolated convection and organized MCS, with higher echo tops and different vertical profiles for MCS.

MCS with a leading convective line and trailing stratiform (MCS-LLTS) structure with horizontal extent > 200km is present in 20% of the cases studied. Vertical reflectivity profiles presented in Figure 5, show a mixed phase layer (0 to -10°C) with 30-35dBZ in most cases, and lower Z values above -10° C for those MCS with larger percentage of positive lightning (LLTS-POS) indicating less ice water content in those cases. An analysis of the mean vertical reflectivity profile, for the convective area, indicate the strong electrification processes occuring during the MCS life, specially considering observations of reflectivity around the 30dBZ well above the mixed-phase layer in the storms (around -10ºC and -40ºC) as indicated in Figure 5, for MCS observed with this radar. Another interesting feature, which should be investigated further, is the distribution of 40dBZ reflectivity levels above the -0ºC to be used as indicative for lightning and hail with the storms (Liu et al 2012).

The daily cycle of MCS occurrence in the radar area indicates a strong diurnal cycle with most of the events occurring late in the afternoon, and this is the same for the electrical activity in the region, as presented in Figure 3. The annual cycle , not presented here, indicates more organized MCS during spring and summer, as already observed in other studies.

Using an algorithm for convective and stratiform separation together with lightning flash data, we were able to analyse the electrical activity in those distinct areas within the MCS. In general, the convective region is the most active (86%) in terms of lightning, even for the events with larger stratiform areas with predominance of positive lightning (LLTS- POS). However, peak current in the stratiform region is higher for both negative and positive lightning flashes when compared to the convective region, as presented in Figures 6 and 7.

Lightning distribution within the studied area, presented in Figure 8, indicates concentration of activity in two main areas. In the east, around 'Serra do Mar' mountain range, with most convective isolated storms during summer, and a second active area to the west plateau, with most of the lightning activity related to the MCS and larger CCM originated in the northern Argentina and Uruguay, moving through this region later in the day. Seasonal variations, with more active spring (SON) and summer (DJF) are a result of the effect of MCS in this region, more than other weather systems (e.g. cold fronts).

CONCLUSIONS

The objective of this study is to better understand the evolution of these storms as they occur in this area, in order to improve our abilities of analysis and forecast of severe weather events. The MCS play an important role on the hydrological cycle and on the incidence of severe weather events, highlighting the importance of improving the knowledge of those weather systems, with the goal of better forecasts.

This report indicates that during all the MCSs events necessary conditions for electrification process were observed, with reflectivity factor between 30 and 35dBZ in the mixed phase region of the storms, between 0 and -20^{0}C, with a large amount of lightning occurrence. Echo tops, not presented in this paper, above 7 to 11km were observed in 82% of the events, indicating several overshooting tops in most events.

Lightning characteristics in convective and stratiform regions of the MCSs were quite different. Most of the events, 97%, had 1 to 3 strokes in each lightning flash, and average peak current for the stratiform region were larger, on average, than the peak current observed in convective region, with predominance of positive lightning in stratiform region. These results should be investigated further.

With the pursuit of further improvements new observation systems (S-Band Polarimetric Radar and Total Lightning Network) will be installed in the region in the near future and more interesting cases will be studied in the near future.

REFERENCES

Albrecht R. I., Goodman S. J., Petersen W., Buechler D., Bruning E., Blakeslee R. J., Christian H., 2011: The 13 years of TRMM Lightning Imaging Sensor – from individual flash characteristics to decadal tendencies. *In XIV Int. Conf. Atmos. Electricity*.

Biggerstaff M. I., Listemaa S. A., 2000: An improved scheme for convective/stratiform echo classification using radar reflectivity. *J. App. Meteor.,* **39,** p. 2129.

Durkee J., Mote T. L., Shepherd J. M., 2009: The contribution of mesoscale convective complexes to rainfall across subtropical South America. *J. Climate*, **22**, p.4590.

Liu C., Cecil D. J., Zipser E., Kronfeld K., Robertson R., 2012: Relationships between lightning flash rates and radar reflectivity vertical structures in thunderstorms over the tropics and subtropics. J. Geo. Res..

Zhang J., Qi Y., 2010: A real-time algorithm for the correction of brightband effects in radar-derived QPE. *J. Hydromet*., **11**, p. 1157.

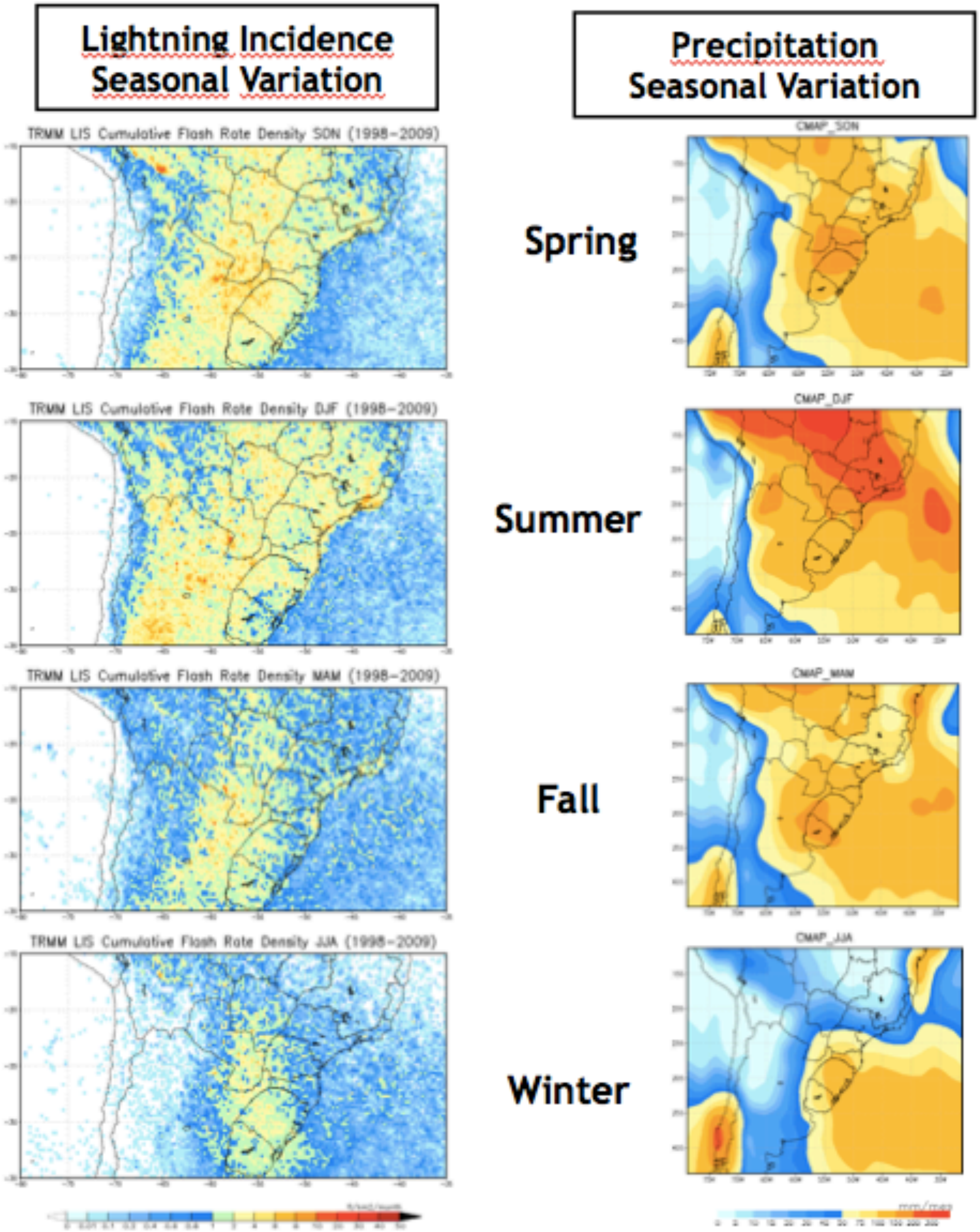

Figure 1: Lightning incidence and precipitation seazonal distribution in the area of study.

(a) (b)

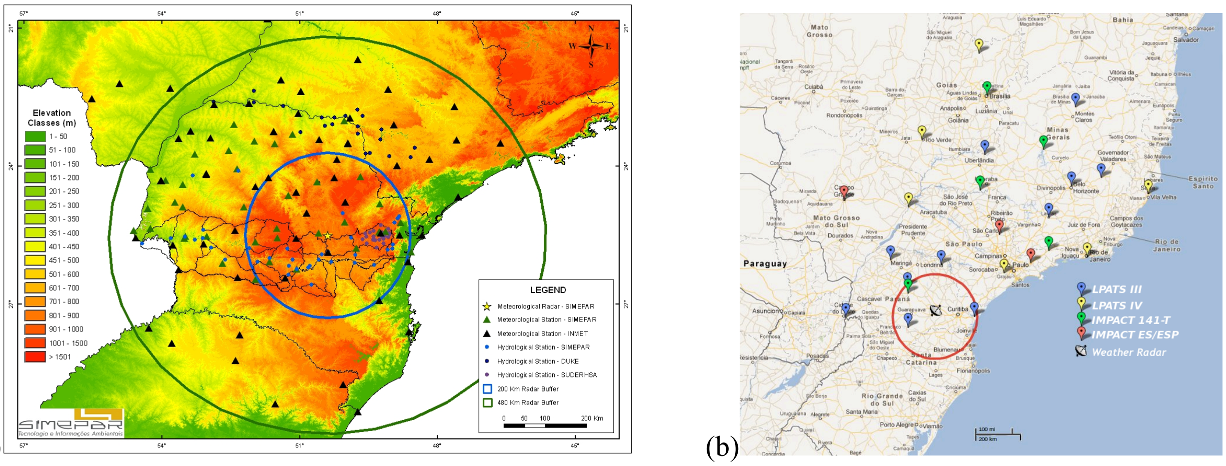

Figure 2: (a) Hidrometeorological monitoring infrastructure and (b) Brazilian Lightning Detection Network

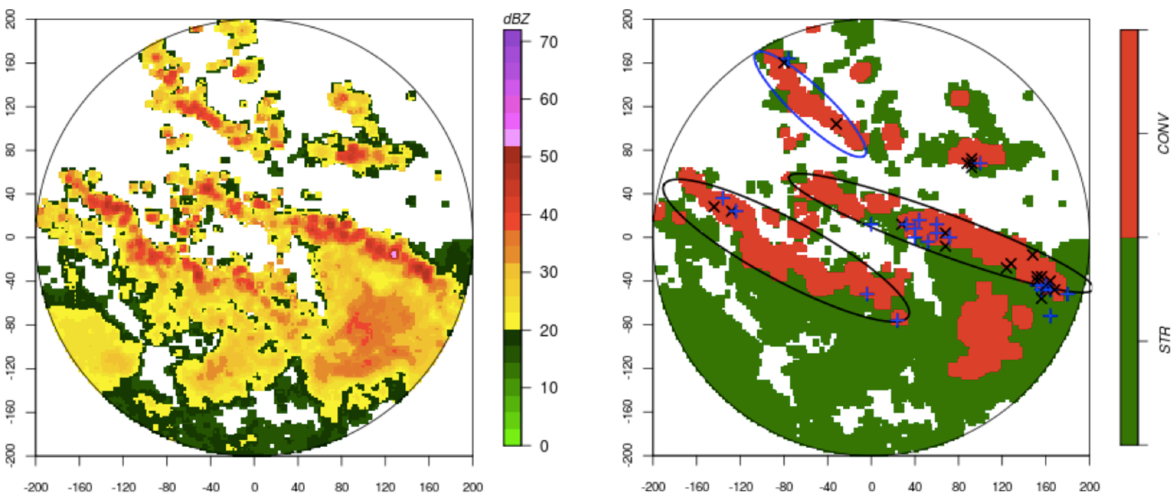

Figure 3: Example of radar reflectivity data and convective-stratiform identification algorithm.

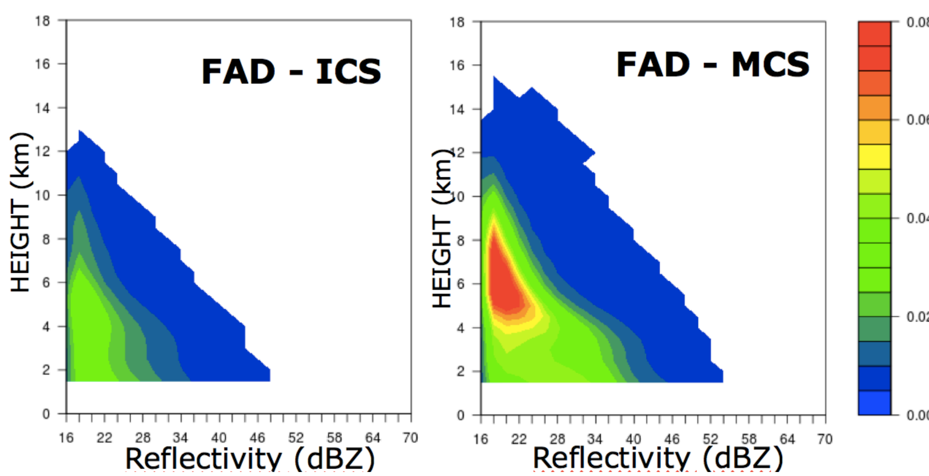

Figure 4: Frequency with Altitude Diagrams (FAD)

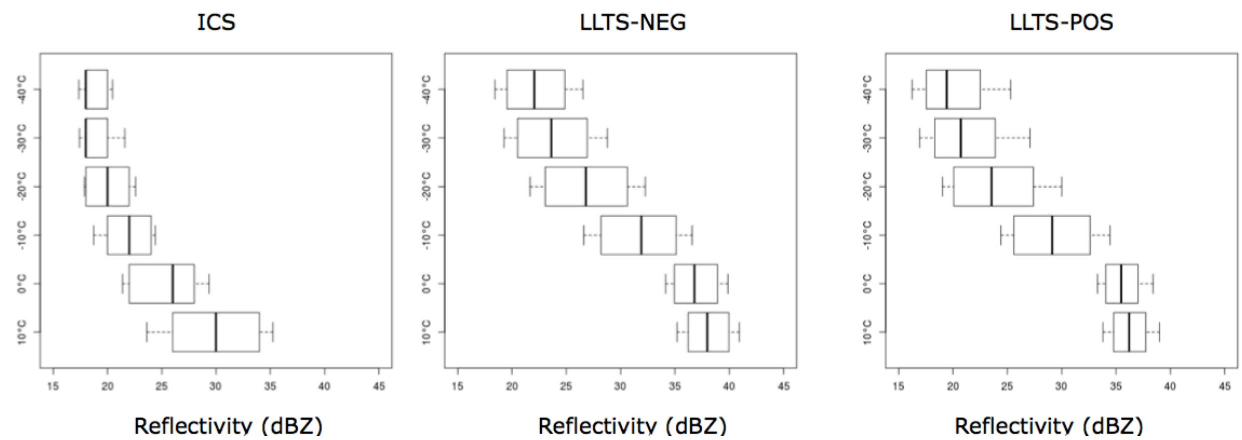

Figure 5: Boxplot vertical reflectivity profiles for isolated convective storms (ICS) and MCSs leading convective line with trailing stratiform region and with negative (LLTS-NEG) and positive (LLTS-POS).

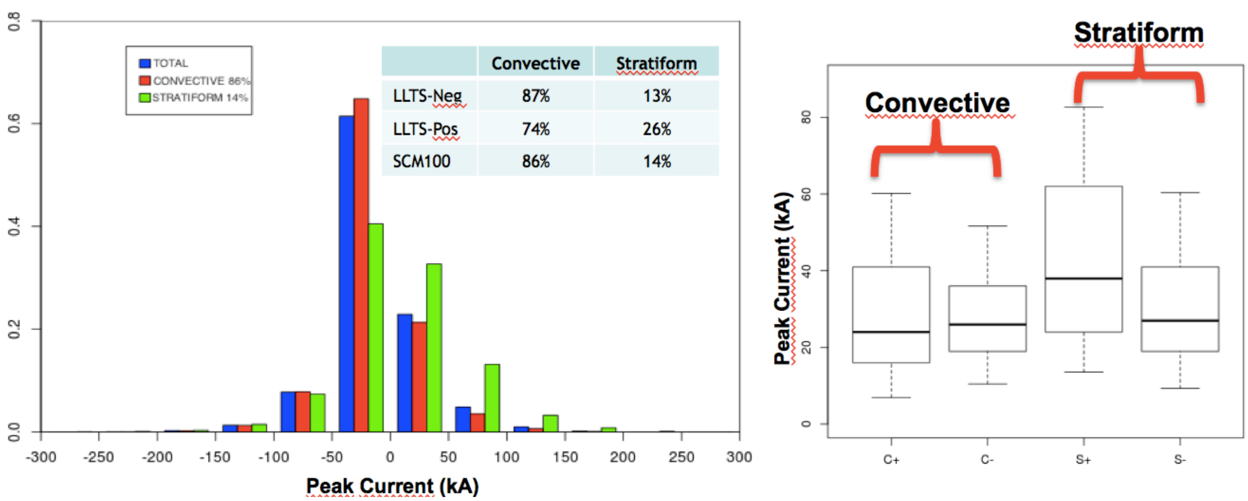

Figure 6: Peak current intensity distribution of lightning occurrence in MCSs analyzed. Data was distributed after convective-stratiform algorithm.

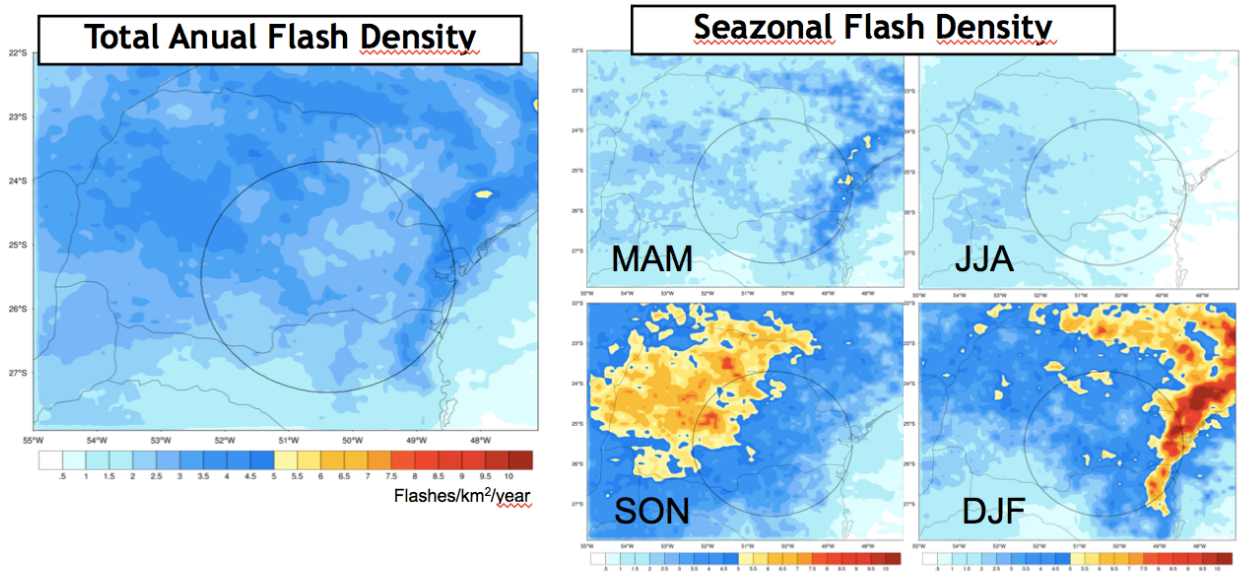

Figure 7: Lighting flash density distribution for annual and seasonal events.