Seasonal and Diurnal Cycle of the thunderstorms observed in South America

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ABSTRACT: This study describes the daily lighting cycle and the annual thunderstorm distribution as observed by the Precipitation Radar (PR), the Visible and Infrared Scanner (VIRS) and the Lightning Imaging Sensor (LIS) on board the Tropical Rainfall Measuring Mission (TRMM) satellite over South America. Based on a TRMM measurements from 1998 through 2011, a database of individual thunderstorms have been created in the area of 10N-40S and 90-30W. To cluster individual thunderstorms, VIRS 10.8 μm channel is used to delineate the clouds and LIS is employed to check if it has lightning (thunderstorm) or not. Clustering the observed thunderstorms on 10 $\times$ 10 degree grid boxes it was possible to observe a season variation between south and north hemisphere.

INTRODUCTION

Nesbitt et al. [2000] introduced a methodology that clustered Precipitation Features (PF) by using TRMM Microwave Imager (TMI) and PR. In this work, they analyzed the PF with and without ice scattering signatures at the 85 GHz channel and found that African thunderstorms have more lightning and ice scattering than the South American ones. On the diurnal cycle analysis, they found that PFs with ice signature have well defined cycle, i.e., a maximum during the afternoon and over the continent. Over the ocean no time dependency was found during the diurnal cycle.

Later, *Cecil et al.* [2005] explores the PF dataset (*Nesbitt et al.* [2000]) and ordered by the flash rate. In this work they have found that only 10% (1%) of PFs over continent (ocean) had lightning. Moreover, higher flash rates were associated with large PFs. Finally, in South America (SA) the systems with more intense convection and more lightning production were located at southern SA,i.e., Argentina, Paraguay, Uruguay and southern Brazil.

Zipser et al. [2006] explored the PF database based on different methods (vertical reflectivity profiles, 85 GHz and 37 GHz ice signatures and flash rates) to search for the severe thunderstorm along the globe in order to make a census. They found that all the methodologies pointed the south of SA is the region where it is found the most intense convection. Furthermore, the time of more frequent intense convection over land was between 15-16h local time.

In this paper, we seek to identify the region of most intense thunderstorms as well as the thunderstorm diurnal cycle over South America. The thunderstorms have been defined as clouds with brightness temperature below 258 K in the VIRS 10.8 μm channel and had at least one LIS flash [*Morales and Anagnostou*, 2003].

To explore the thunderstorm activity in SA, this study uses 14 years of TRMM measurements (1998 up to 2011). Based on the criteria defined priorly, it was possible to observe 154,141 thunderstorms over SA (10N-40S and 90-30W). Based on this thunderstorm database, this study presents an analysis of diurnal and annual cycle and how the thunderstorm activity is related to the flash density over South America.

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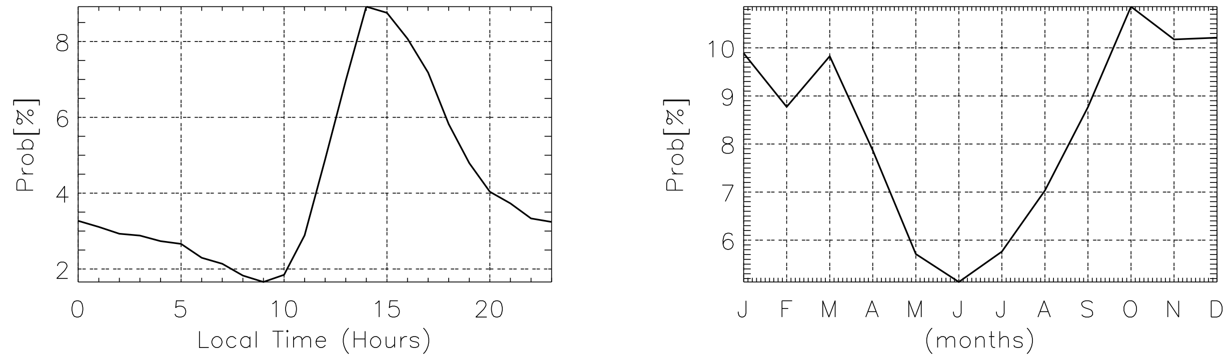

Figure 1: Diurnal and annual cycle for TRMM thunderstorm observed over South America between 1998 and 2010.

DIURNAL AND ANNUAL CYCLE

To evaluate how the thunderstorm activity vary in South America, the occurrence time of the individual thunderstorm extracted are converted to local time according to its longitude location, Figure1. On Figure 1 it is shown the frequency of occurrence of thunderstorms as a function of local time and month.

On Figure 1 it is possible to observe that the highest lightning activity in SA occurs between 14-15 LT, which shows that the diurnal heating and the increase of boundary layer height are key elements for thunderstorm development. Additionaly it reveal that it is 4.6 times more likely to have thunderstorm in this time than other periods of the day.

In terms of annual cycle, it is possible to note that the thunderstorm activity initiates in September and remains until March, Figure 1. The highest probability of occurrence is found in October, where we have a transition between dry and wet season. During this time of the year, it is common to observe Meso-scale Convective Systems (MCS) and Meso-scale Convective Complex [*Durkee and Mote*, 2009] in the Amazon basin, north of Argentina, Paraguay and Bolivia. Between summer time, December-March, the thunderstorm activity is related mainly with solar irradiation and available moisture.

Figure 2 shows the thunderstorm activity diurnal cycle for individual 10° by 10° grid boxes over South America. The frequency of occurrence has been normalized by the total number of thunderstorms observed, i.e, 154,141.

These results show clearly the diurnal heating over continental areas, bi modal distributions over the ocean and Colombia and Venezuela. The region bound by 0-10N and 80-70W, shows at 5 UTC the highest thunderstorm activity of the entire South America (0.4, which means 616 thunderstorms). In this region we find pronounced topography surrounded by lakes that produce a lake/valey (Lake Maracaibo) and valey/mountain circulations and the influence of ITCZ (Colombia) that promote a more efficient nocturnal thunderstorm activity.

In the Atlantic Ocean, 0-10N and 50-30W, the ITCZ triggers the electrical activity that is concentrated during nighttime, but with low probability of occurrence.

Further south, 40-30S and 70-60W, in the extra-tropics, Cordoba mountains together with the low level jet (LLJ) that transports moisture and warm air from the Amazon basin and the frontal systems that brings cold and dry air produces the MCS that are more often to be developed during the night or day but lasting several hours or days [*Durkee and Mote*, 2009].

In terms of annual cycle, Figure 3, we do observe a seasonal dependence, i.e., over the northern hemi-

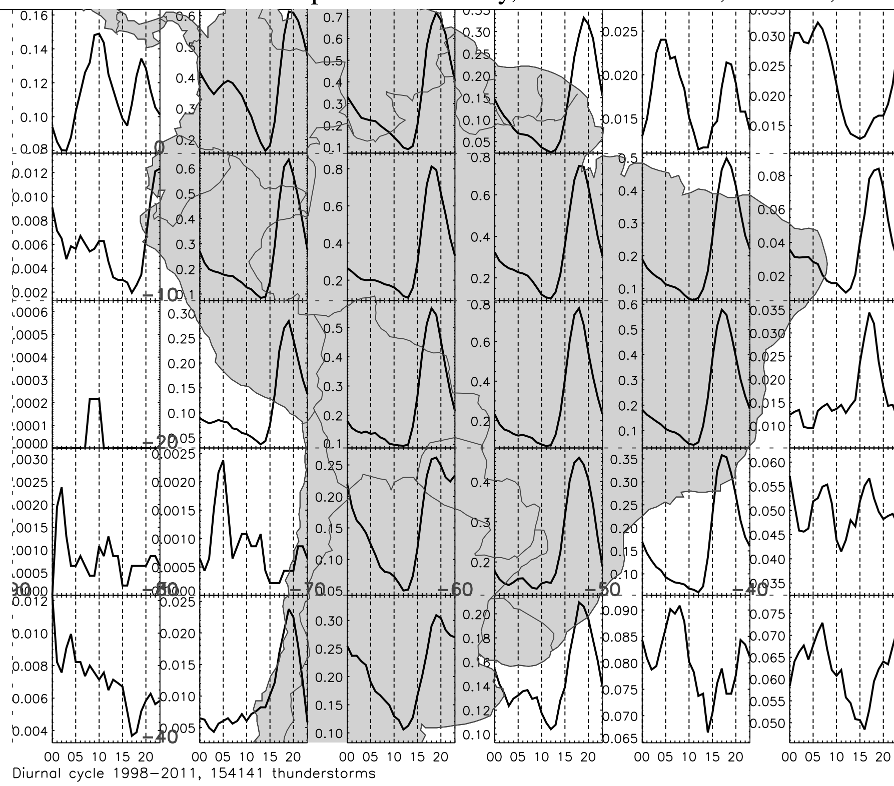

Figure 2: Diurnal cycle of thunderstorm in each 10 x 10 degrees.

sphere more thunderstorms during June-August while in the South Hemisphere more between November-March.

In the region of severe thunderstorms found by *Cecil et al.* [2005]; *Zipser et al.* [2006](70-60W and 40-20S), it is found a short and very well defined season. Between May and August there isn't almost none thunderstorm activity, but as the wet season and summer becomes active the LLJ intensities and triggers the development of deep convection.

SPATIAL DISTRIBUTION E LIGHTNING DENSITY

The distribution of lightning flashes on LIS is strongly dependent on the view time, i.e., the more time TRMM passes over one area the higher is the chance to observe thunderstorms. On Figure 4 it is presented the cumulated LIS view time over the 14 years of measurements used in this study, and it is possible to see that the southern regions samples 10 more days than in the tropics. Therefore, any statistics that does not take into account the number of TRMM visits might be tendentious.

To avoid this artifact the results on Figure 5 have been normalized by the area observed and view time, i.e., so we have the number of thunderstorms per area per time and number of flashes per area per time.

On Figure 5 it is possible to observe that in the northern South America we observe most of the thunderstorms (Colombia and central Amazon basin) but most intense lightning flash rate is found in the southern part of South America. Thus we can say that southern thunderstorm are more lightning efficient than the northern one. For instance, in the Amazon region where have a flash density higher than 36 flash km^{-2} $year^{-}1$ we found more than 150 thunderstorms km^{-2} $year^{-1}$. In northern Argentina and Paraguay the same flash rate is related with no more than 60 thunderstorm km^{-2} $year^{-1}$. These results evidence that

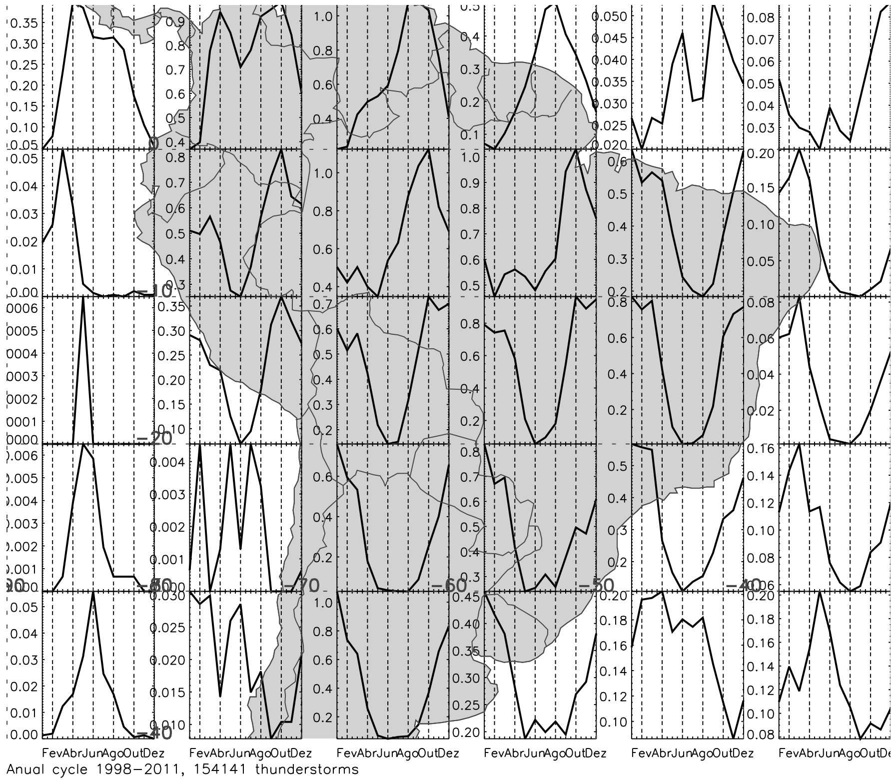

Figure 3: Annual cycle of thunderstorm in each 10 x 10 degrees.

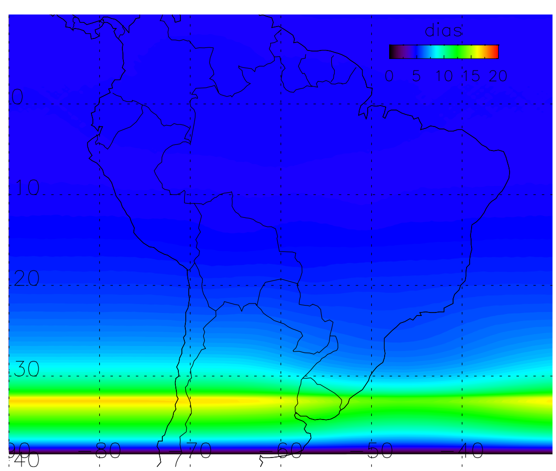

Figure 4: LIS View Time (days) accumulated for 14 years, 1998-2011.

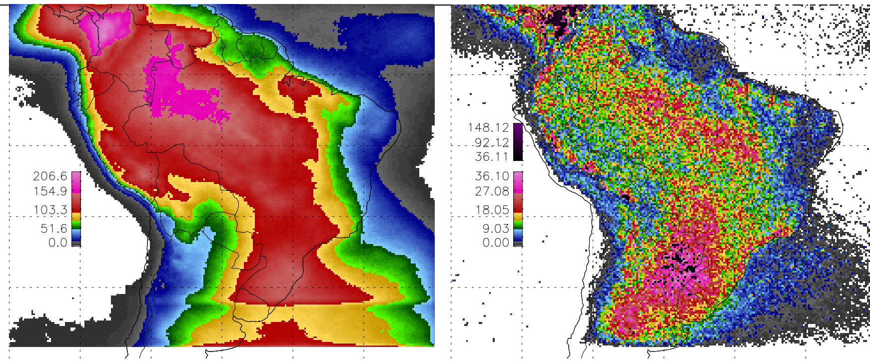

Figure 5: Total spatial density of thunderstorm [km^{-2} $year^{-1}$] and flash [km^{-2} $year^{-1}$].

southern thunderstorms are more electrical efficient than the ones in the northern area.

Finally on Figure 6 we inspect the seasonal variability (DJF, MAM, JJA, SON) of the thunderstorm activity and flash rates. During summertime, we observed a lot of thunderstorm activity in the Amazon until southeast Brazil, but the highest flash rate is observed in Argentina and Paraguay, which is consistent with Figure 5 results. During the transition periods, though, MAM and SON, the regions with highest thunderstorm activity present the highest flash rates, while during the winter time, JJA, it moves to Colombia. These results are indicating that MCS and deep isolate convection are more efficient in producing lightning than other systems.

CONCLUSIONS

This study presented an analysis of the diurnal and annual thunderstorm activity over South America based on TRMM measurements. It was found that thunderstorms are more likely to develop at 2-3 pm local time.

Nighttime thunderstorms are more likely to be found in the Pacific and Atlantic Ocean and near the Andes like Colombia and enhanced topography surrounded by lake/valleys in Venezuela, or Cordoba mountains in Argentina. The remaining areas the daytime heating is the main factor to create unstable atmosphere.

The regions with most of the thunderstorm activity is not the same as the highest lightning flash rates. In the Amazon region, the highest flash rates km^{-2} $year^{-1}$ are associated with higher thunderstorm activity than in Argentina and Paraguay. Southern thunderstorms produce 40% more flashes km^{-2} $year^{-1}$ than the northern ones.

The highest flash rates are located in Argentina and Paraguay where both LLJ and frontal system act to develop MCS and create a transition region.

Finally the transition from dry to wet season (fall) shows the highest production of lightning.

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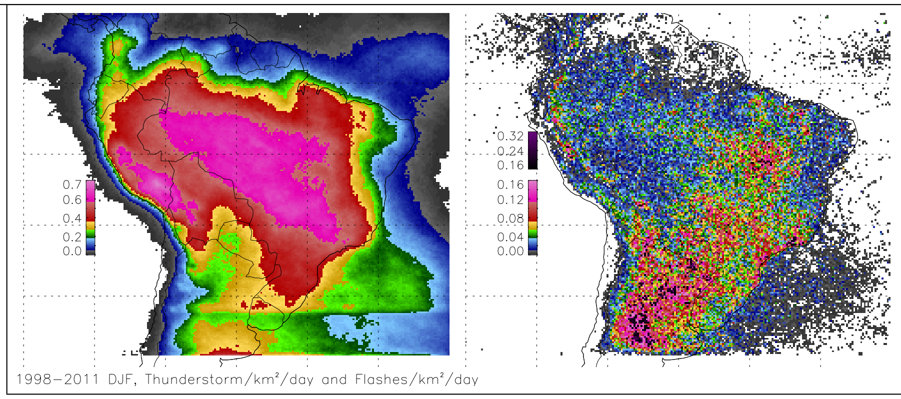
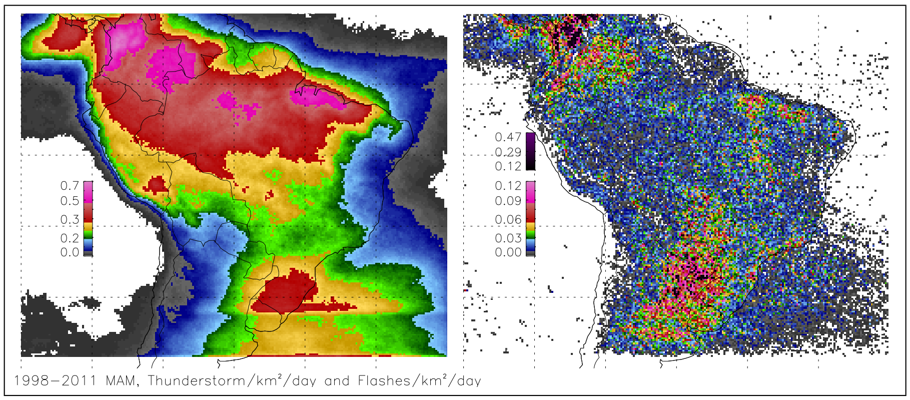
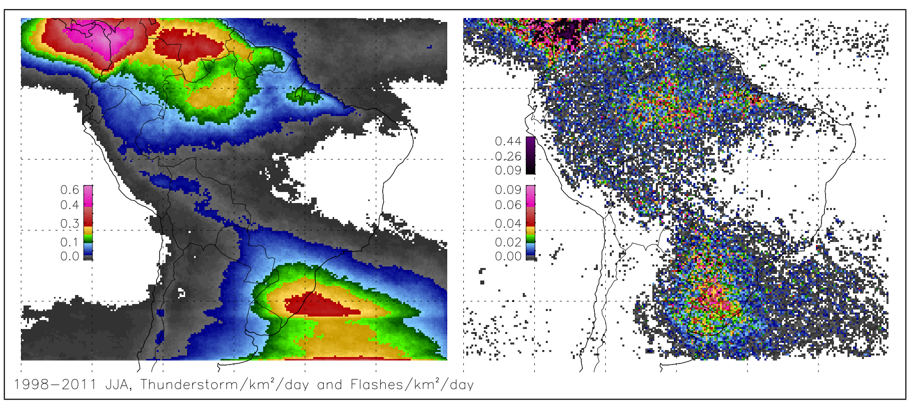


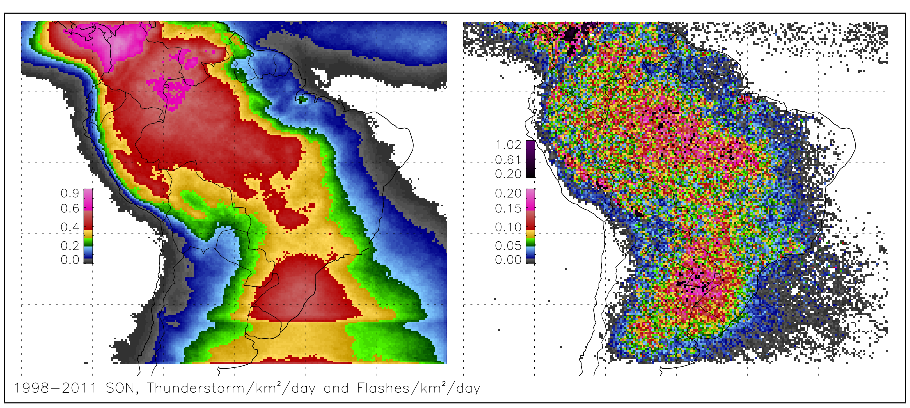
(a) DJF



(b) MAM



(c) JJA



(d) SON

Figure 6: Spatial density of thunderstorm and flash during each season.

References

Cecil, D., S. Goodman, D. Boccippio, E. Zipser, and S. Nesbitt, Three years of trmm precipitation features. part i: Radar, radiometric, and lightning characteristics, *Mon. Wea. Rev.*, *133*, 543–566, 2005.

Durkee, J. D., and T. L. Mote, A climatology of warm-season mesoscale convective complexes in subtropical South America, *International Journal of Climatology*, *30*, 418–431, 2009.

Morales, C. A., and E. N. Anagnostou, Extending the capabilities of high-frequency rainfall estimation from geostationary-based satellite infrared via a network of long-range lightning observations, *J. Hydrometeor*, *4*, 141–159, 2003.

Nesbitt, S. W., E. J. Zipser, and D. J. Cecil, A Census of Precipitation Features in the Tropics Using TRMM: Radar, Ice Scattering, and Lightning Observations, *Journal of Climate*, *13*, 4087–4106, 2000.

Zipser, E., D. Cecil, C. Liu, S. Nesbitt, and D. Yorty, Where are the most intense thunderstorms on earth?, *Bull. Amer. Meteor. Soc.*, *87*, 1057–1071, 2006.