UNDERSTANDING THE ELETRIFICATION PROCESS

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1. INTRODUCTION

According to the lightning distribution observed in South America by STARNET (Sferics Timing And Ranging NETwork, Morales et al., 2011), Brazil shows a diverse thunderstorm activity in its territorial extent. The onset of thunderstorm follows the summer time period in most of the southeast and central region, but in some northern regions it is possible to find two active periods, i.e., during the transition period (dry to wet season) and at the end of the raining season, Figure 1.

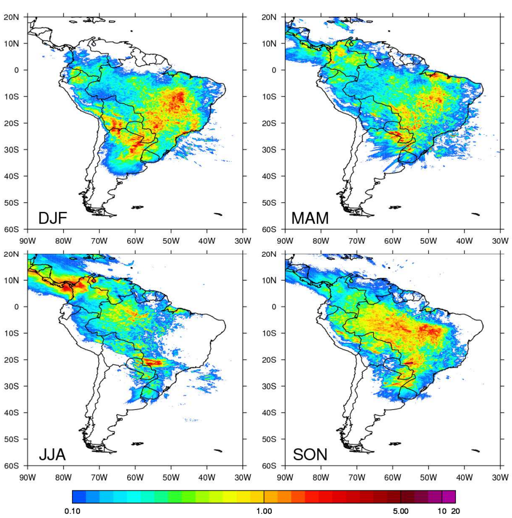

Figure 1. Mean seasonal lightning distribution (sferics/km^2) as observed by STARNET during 2009 through 2011.

These lightning features reveal regions that have more than 30 days per year with thunderstorm activity to more than 300 days and the lightning flash rate varies from 0.1 to more than 50 sferics/ km^2/year. In analyzing these maps, we find regions with higher thunderstorm activity that are not necessarily very electrically activate. For example Belém (northern part of Brazil) area presents than 250 days with thunderstorms but less than 10 sferics/km2/year, Fortaleza (northeast coast) has less than 50 days in a year with thunderstorms and a density less than 1 sferics/km2/year. São Paulo area though has around 100 days with thunderstorms but more than 16 sferics/km2/year. Thus this electrification behavior is most likely associated with the cloud and precipitation physics complexity among the different precipitation systems observed in Brazil.

In order to understand these particular characteristics, this study will focus on the precipitation measurements taken during the CHUVA field campaign in 2011 to explore some features that might aloud a better understanding of charging mechanisms.

2. CHUVA PROJECT and DATA SET

CHUVA (Cloud processes of tHe main precipitation systems in Brazil: A contribUtion to cloud resolVing modeling and to the GPM - GlobAl Precipitation Measurement) is a research project that aims to build a database that can describe the cloud processes of the main precipitating system in Brazil, in order to improve the satellite rainfall estimation. Moreover, this project is seeking to answer the following questions:

• How to estimate rainfall from warm clouds?
• What is the contribution of rain from warm clouds to the total precipitation in different regions of Brazil?
• How to improve both space and time precipitation estimation of rainfall over the continent for the GPM constellation?
• What are the average characteristics (3D - cloud processes) of the main regimes of precipitation in Brazil?
• What is the contribution of the aerosol in the process of formation of precipitation?
• What are the main surface and boundary layer processes in the formation and

maintenance of clouds?

• How cloud microphysics and electrification processes evolve during the cloud life cycle?

• How to improve precipitation estimation and cloud microphysics description by using conventional and polarimetric radar?

To elaborate the precipitation database that can answer these points, CHUVA prepared a series of 7 field campaigns that will be able to depict the main precipitating systems observed in Brazil, i.e., warm raining clouds, local convection, MCS, MCC, instability lines, and frontal systems.

Until the present moment, 3 field experiments have been realized: Fortaleza (April/2011), Belém (June/2011) and VALE-GLM (November-December/2011). Fortaleza is characterized mainly by warm rain process and maritime precipitating systems, Belém, maritime systems that trigger instability lines, while Vale do Paraíba (VALE-GLM) we find frontal systems, local convection, orographic systems and instability lines.

For this study, the thunderstorms are identified by the lightning measurements of STARNET while the electrical properties are done with the use of field mills that are measuring the vertical electrical field. The precipitation features are diagnosed by the Dual Polarimetric X-Band measurements performed during the 3 CHUVA field campaigns.

3. RESULTS

The daily and hourly lightning distributions along the 3 experiments are shown on Figure 2. It is possible to note that most of the thunderstorms were concentrated during 15-22 UTC, except in Fortaleza that had some episodes during night and early evenings. This daily cycle points to the influence of local convection in the thunderstorm triggering.

For the daily accumulations though, each location presented some different frequencies. Fortaleza, had less than 150 sferics per day, except the first lightning burst with almost 300 sferics per day. Belém in contrast was between 200 and 600 sferics per days and in Vale do Paraiba between 300 and 400 sferics/day. These results are intriguing since one would expect more lightning flashes at VALE than Belém due to its oceanic proximity and influence.

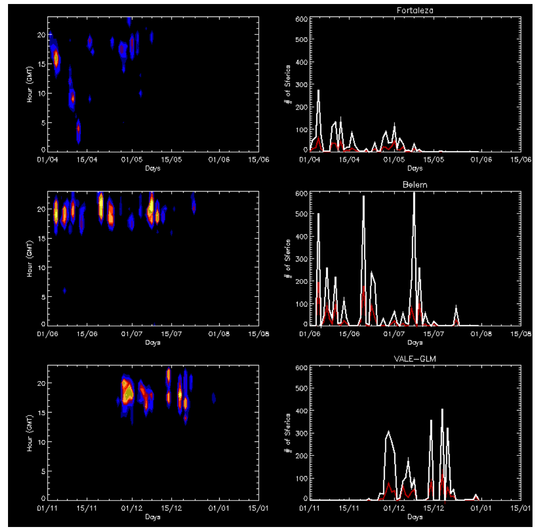

Figure 2. Hourly (left) and daily sferics accumulation during the 3 CHUVA field campaigns: Fortaleza (April/2011), Belém (June/2011) and VALE-GLM (November-December/2011).

In order to understand these differences, we selected some RHIs during the maximum lightning activity during the campaigns. Thus, Figures 3, 4 and 5 show radar reflectivity RHIs over specific azimuths where CHUVA had its super sites for Fortaleza, Belém and VALE-GLM field campaigns respectively. Those cross sections provide detailed information about the vertical structure of the storms sampled and will be used here as examples to understand the differences between the thunderstorms in each field campaign. Detailed analyses require other polarimetric variables and the match between lightning and field mill measurements.

Despite that, these RHIs can be used to seek some features among those thunderstorms. The time of these images correspond to the periods of maximum lightning activity. In all thunderstorms it is possible to see radar reflectivity values above 35 dBZ between the 5 and 7 km height, roughly the isotherm of 0 and -25

°C). These values might indicate the presence of graupel, super cooled water droplets and other ice particles [Petersen et al. 2002] that are the ingredients for the non inductive charging process [Takahashi, 1978 ; Saunders and Brooks, 1992]

Although we find vertical developed towers at Fortaleza and Belém (14-15 km echotops) in comparison to VALE-GLM (< 12 km), the later had around 300 sferics/day against the others with less than 200 sferics/day. In contrast, the vertical electrical at Belém (~3 kV/m) is more intense than VALE (2 kV/m), which is a paradox when we compare to the frequency of lightning strokes. As STARNET measures mainly cloud to ground (CG) lightning, this result might indicate that Belém had more intra-cloud lightning than VALE.

As the electrical field depends on the magnitude of the charges and it is inversely proportional to the distance square, we would expect more charged particle at Belém than VALE. By looking the RHI cross sections (Figure 3-5), Belém and Fortaleza show much more liquid and ice content than VALE due to higher reflectivity values and vertical extend, thus higher electrical field. Due to these characteristics, we would expect several charge centers in the vertical among the maritime storms than the more continental storm that might be better represented by a dipole. The charge centers are highly dependent of hydrometeors development and interactions, and depending on the temperature and the terminal velocity (graupel, ice particles and super cooled water droplets), the hydrometeors might gain positive or negative charges. [Takahashi, 1978; Saunders and Brooks, 1992, Pereyra et al. 200]. So more charge regions would imply in more competition, thus more IC [MacGorman and Nielsen, 1991] opposite to a more defined dipole-tripole that might have more CGs.

In order to understand these mechanisms and the presence of different types of hydrometeors, polarimetric and Doppler measurements are required to evaluate the cloud microphysics and perhaps its temporal evolution.

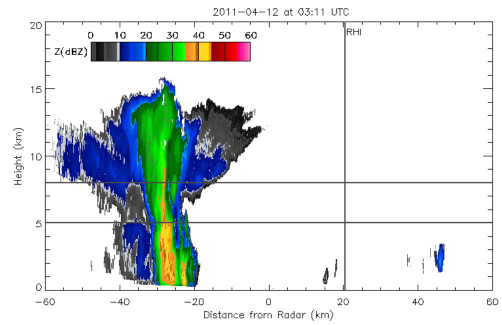

Figure 3. Radar reflectivity RHI for Fortaleza during April 12th at 03:11 UTC

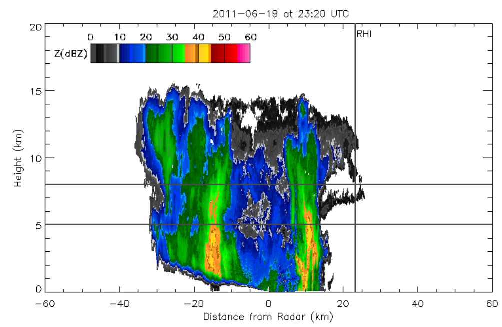

Figure 4. Radar reflectivity RHI for Belém during June 19th at 23:20 UTC

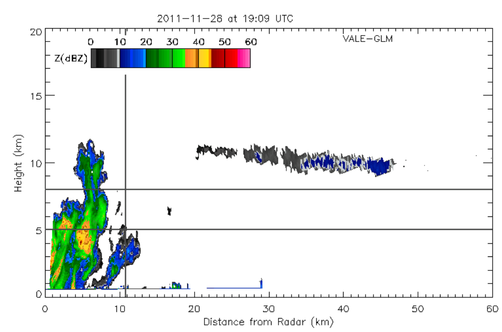

Figure 5. Radar reflectivity RHI for VALE-GLM during November 28th at 19:09 UTC.

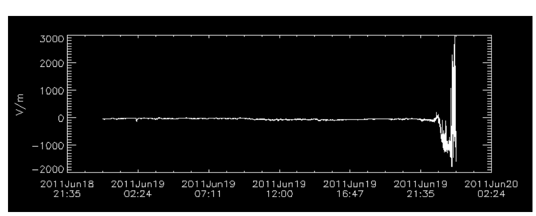

Figure 6. Electrical vertical field at June 19, 2011 in Belém

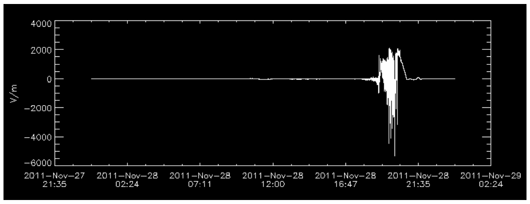

Figure 7. Vertical electrical field at November 28th in Vale do Paraíba.

4. CONCLUSIONS

This study presented a preliminary analysis of some thunderstorms that developed in Brazil and were observed during the CHUVA field campaigns. The main interesting features found were: a) the vertical extent of the maritime (Belém and Fortaleza) thunderstorms that produced high electrical field (> 3 kV/m) but few lightning, the opposite to VALE-GLM storm that was shallower, had more lightning and the vertical electrical field was under 2 kV/m.

Although we only used radar reflectivity values, it seems that a competition between the charge regions might be responsible for the low frequency of CG at Belém and Fortaleza than at VALE.

Later studies will concentrate on the analyses of polarimetric and Doppler measurements to seek the hydrometeor identification and vertical movements, because the collision between graupel and ice particles on the presence of super cooled water droplets is the key mechanism for cloud electrification.

5. REFERENCES

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6. ACKNOWLEGEMENTS

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