Lightning incidence over the southeastern microregion of Para State, Brazil

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***Abstract*—Lightning is a real threat for different activities in the Pará State in Brazil. The southeastern microregion of the State of Pará is a region with high population density, extensive agricultural activity, large mining companies and hydroelectric power plants. This paper presents a study of lightning occurrence in the southeastern microregion of Pará for the period from 2013 to 2017 using STARNET reprocessed data. In addition, in order to study the occurrence of different types of lightning in the region, we used data from the LDWSS to observe compact intracloud discharges (CIDs), regular intracloud, and positive and negative cloud-to-ground lightning. Currently, there is a LDWSS installed in the building of the Federal University of Southern and South of Pará, located in the city of Marabá. The results show which cities have the highest lightning density. In addition, we show the statistics of occurrence of different types of lightning to one day through LDWSS data.**

Keywords—Lightning density; Southeastern micro-region of Pará State; STARNET; LDWSS.

I. INTRODUCTION

The State of Pará has a territorial dimension of 1,245,759, 305 km² approximately, and it is the second largest State of Brazil in territorial extension [1]. In addition, the state has hot and humid climate, providing the occurrence of convective events and so formation of thunderstorm clouds or cumulonimbus (Cb).

The southeast microregion of Pará (Fig.1) has 39 municipalities: Breu Branco, Nova Ipixuna, Abel Figueiredo, Goianésia do Pará, Ulianopólis, Bannach, São Feliz do Xingu, Águla Azul do Norte, Eldorado dos Carajás, Brejo Grande do Araguaia, São Domingos do Araguaia, Pau D'arco, Rio Maria, Xinguara, Conceição do Araguaia, Santana do Araguaia, Itupiranga, Novo Repartimento, Bom Jesus do Tocantins, Paragominas, Cumaru do Norte, Tucumã, Canaã dos Carajás, Parauabepas, Marabá, São Joao do Araguaia, Piçarra, São Gerado do Araguaia, Floresta do Araguaia, Jacundá, Tucuruí, Dom Eliseu, Rondon do Pará, Ourilândia do Norte, Curionopólis, Palestina do Pará, Redenção, Sapucaia e Santa Maria das Barreiras.

The microregion has an area of more than 297,000 km², and had a gross domestic product (GDP) of R$ 37.5 billion in 2012 [2], which is equivalent to 41% of the whole State GDP. According to ELAT [3], in this microregion are some the cities with the highest lightning density in Brazil, such as the city of Santa Maria das Barreiras, Redenção and Conceição do Araguaia.

The high lightning incidence in the southeastern microregion of Pará can affect the main economic activities in the region, such as agriculture and mining. In addition, also can affect transmission lines and distribution energy systems, since in this region there are two of the main hydroelectric power plants of Brazil: UHE Tucurí located in the city of Tucuruí and UHE Belo Monte in the city of Altamira. Recently, transmission lines were installed between the power plant of Tucuruí and cities of Manaus and Macapá. These new transmission towers are certainly more likely to be struck by lightning.

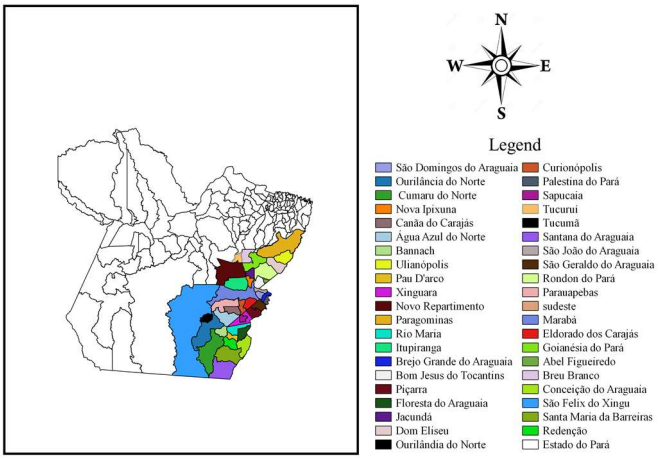

Fig.1 Cities of southeast microregion of Pará.

Lightning density for a given region allow us to evaluate the effects of lightning on buildings, electricity generation and transmission and distribution lines [4]. Lightning Location System (LLS) are used in many countries to obtain the lightning location [5]. These systems are based on measurements of electromagnetic fields produced by lightning [6]. There are numerous of LLSs that use different types of sensors and detection techniques, allowing to detect electrical activity between cloud and ground, between cloud and air, and between clouds and clouds. Such systems allow us to identify geographically the distribution of lightning on a global scale.

There are only a few long range LLSs that cover the southeastern microregion of Pará. In this work we used data provided by the STARNET network (Sferics Timing and Ranging Network) that operates in the VLF frequency band [7], and detect essentially cloud-to-ground lightning. However, for a complete study is necessary to identify other types of lightning. The Lightning Detection and Waveform Storage System (LDWSS) [8], [9] was used with this purpose.

[10] described the current knowledge on cloud-to-ground lightning density in Brazil as a whole and they discussed the future perspectives to improve this information. In the State of Pará, several lightning studies have already been developed during the past decade, such as lightning prediction [11] and [12], LLS as [9], death caused by lightning [13] and lightning characterization [14]. However, there is a lack of information for understanding the lightning occurrence in the southeastern micro-region of Pará. This is important because will allow the adoption of strategies to minimize the risks of lightning-related disasters at this region.

In this work, we estimate an average annual density cloud-to-ground lightning over a five-year period (2013-2017) for all thirty-nine cities, which compose the southeastern micro-region of Pará. In addition, we investigate one day of data from the LDWSS installed at Federal University of Southern and Southeastern of Pará (UNIFESSPA) (Fig.2), which it is located about in the center of southeastern micro-region of Pará state.

II. DATA AND METHODOLOGY

The methodology used in this work is composed of two stages:

1. Processing of STARNET data in order to calculate the average cloud-to-ground lightning density for each city in the southeastern micro-region of Pará state.
2. Identification of CGs, ICs and CIDs recorded by the LDWSS-UNIFESSPA in November, 15 of 2018.

The STARNET (Spherics Timing and Ranging Network) is a long-range lightning detection network operating in the VLF (7-15 kHz) frequency. This LLS employ the ATD (Arrival Time Difference) technique to locate lightning [15]. Currently, STARNET coverage is on a global scale in South America. It has eight receiving antennas in Brazilian territory, including the Amazon region. The LLS has one sensor in Argentina, one in Chile, one in Central America and one in Africa. [15] in 2011, determined STARNET's relative detection efficiency over BrasilDAT, achieving 50-60% with a location accuracy of between 6 and 12 km.

The STARNET provides mostly CG information. Thus, in the second stage, in order to expand the study about the occurrence of other types of lightning in the southeastern micro region of Pará, we will also investigate lightning occurrence using LDWSS data.

The LDWSS is a wideband lighting electric field system. It has a bandwidth from 160 Hz to 500 kHz, the decay time constant of 1 ms, the time resolution (sampling interval) of 1 μs, and the digitizing system has an RTC (Real Time Clock) which is synchronized with a GPS module [8], [9]. LWDSS has no detection efficiency, because it is not a lightning detection network

The LDWSS is in operation at UNIFESSPA since July 23, 2018. The data analyzed in this work through LWDSS, was registered in November 15, 2018. We choose this, because it was a day of very high lightning occurrence in the region. Both analyzed data from STARNET and LWDSS are of type strokes.

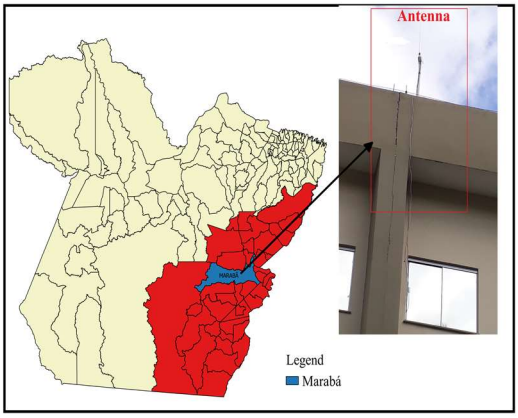

Fig.2 Location of LDWSS-UNIFESSPA.

III. RESULTS

A. *CG lightning density calculated with STARNET data.*

Between 2013 and 2017, about 10 million CG lightning were recorded by STARNET in the southeastern microregion of Pará. The total of Sferics recorded per year are shown in Table 1.

TABLE 1. TOTAL OF LIGHTNING REGISTERED BY STARNET TO THE SOUTHEASTERN MICRO-REGION OF PARÁ.

Year	Lightning Total
2013	3113695
2014	2215665
2015	2352690
2016	1817915
2017	1404246
Total	10904211

The average of annual CG lightning density (km² / year) obtained by STARNET is shown in Fig. 3. According to Fig. 3, the top 3 cities with the highest annual average lightning density are:

- 1º - Cumaru do Norte 14.214 lightning/km²/year;
- 2º -Conceição do Araguaia 12.972 lightning/km²/year;
- 3º - Ourilândia do Norte 12.78 lightning/km²/year;

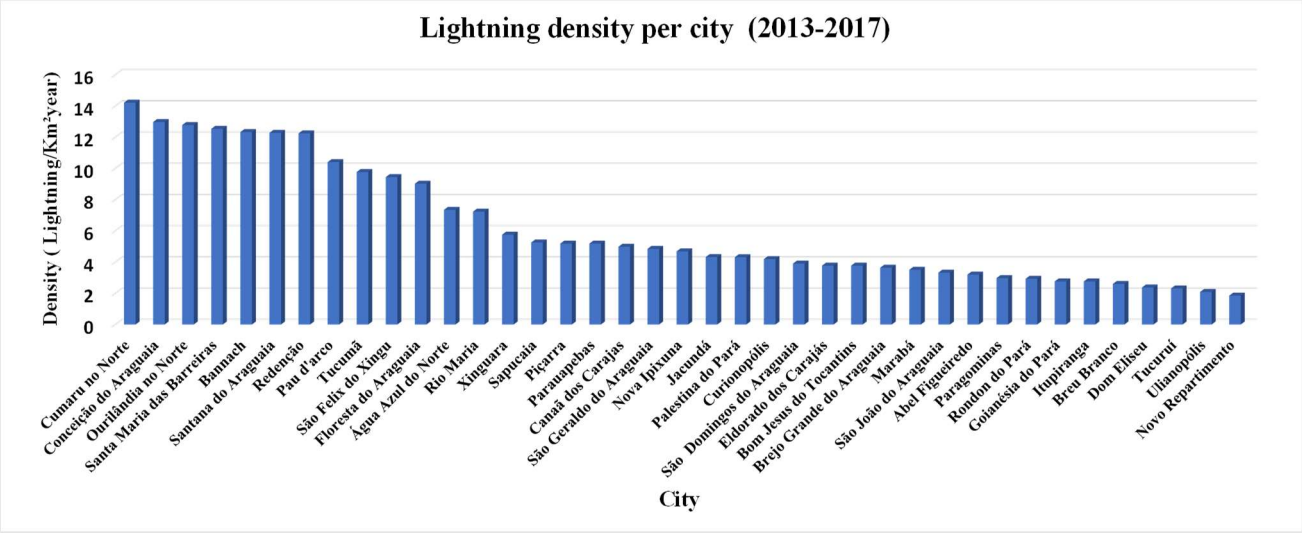

Fig. 3. Lightning density per city. Average (2013 – 2017)

The cities of Ourilândia do Norte, Cumaru do Norte and Conceição do Araguaia are about 371 km, 470 km, and 352 km away from the LDWSS respectively.

The entire region had an average of annual lightning density of 6.1 lightning/km²/year with standard deviation of 3.7 lightning/km²/year. The statistical value of standard deviation shows that same cities have high density and others have low density, as seen in Fig. 3.

B. Case study with LDWSS data on November 15, 2018

On November 15, 2018, the LDWSS installed at UNIFESSPA recorded 3065 lightning waveforms being each event in a 5 ms time window. The recorded events on this day starts at 1:46 UTC and ends at 23:59 UTC.

In order to compare the recorded lightning events with the thunderstorm clouds in the region we use images from the infrared channel of GOES-16 satellite. Fig. 4 shows different images for different times on November 15, 2018.

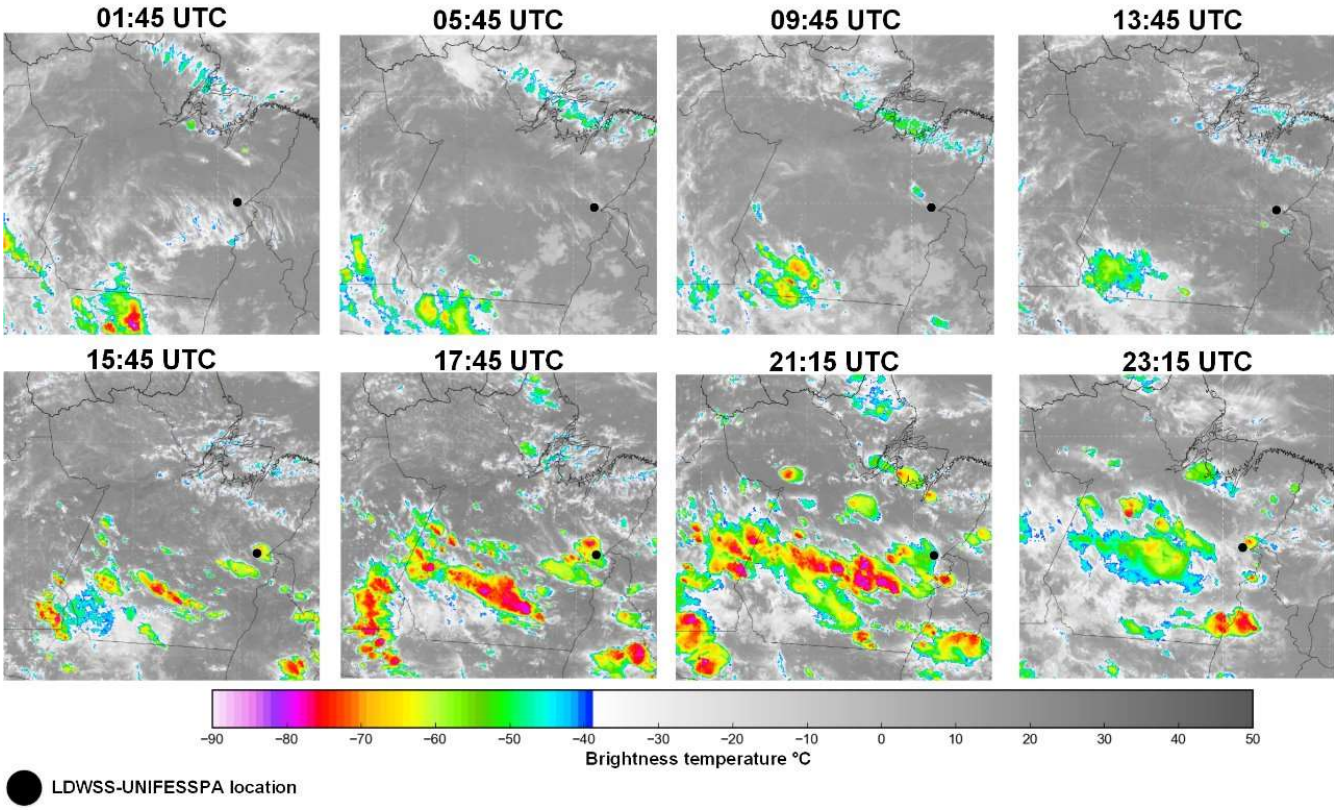

Fig. 4. Images from the infrared channel of GOES-16 satellite on November 15, 2018.

Fig. 5 shows the histogram of lightning events per hour. The peak of the number of events occurred at 15h (UTC). Most of the recorded lightning waveforms occurred between 14h and 23h (UTC), that is in the afternoon and night (local time).

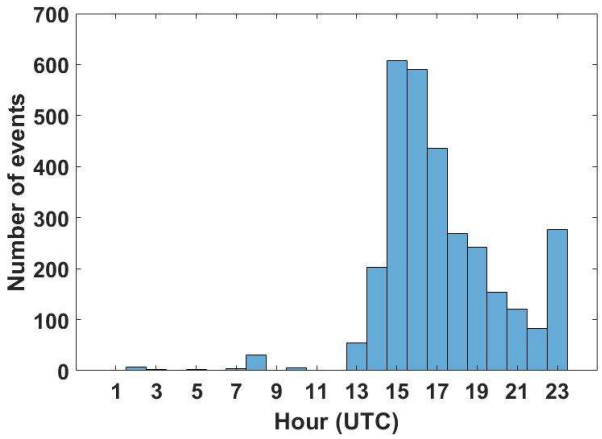

Fig.5 Histogram of lightning events per hour through LWDSS.

We manually classified all the events according to five different types of lightning. The classification was as follows; regular intracloud (IC), negative compact intracloud discharge (-CID), positive compact intracloud discharge (+CID), negative cloud-to-ground (-CG) and positive cloud-to-ground (+CG). The summary of this classification is shown in Fig.6.

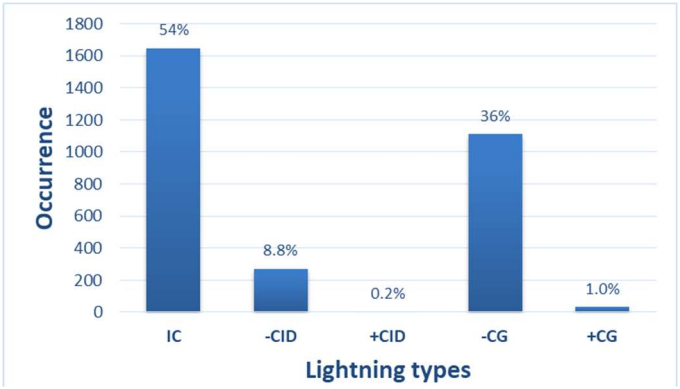

Fig.6 Results of lightning occurrence for 11/15/2018 through LWDSS.

The reference to field polarity of cloud-to-ground lightning in this paper is based on the atmospheric electricity sign convention, according to which a downward-directed electric field (or electric field change) vector is assumed to be positive. Thus, -CG waveforms have positive E-field polarity and +CG have negative polarity.

The negative CIDs in this paper transported negative charge upward, and +CIDs transported positive charge upward.

In Figures 7, 8, 9, 10 and 11 are show examples of field waveforms of IC, -CID, +CID, -CG and + CG respectively.

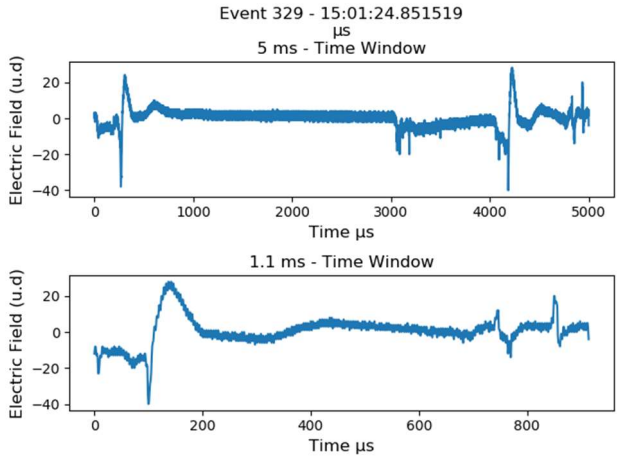

Fig.7 Example of IC electric field waveform recorded on November 15, 2018 in southeast micro region of Para state, Brazil.

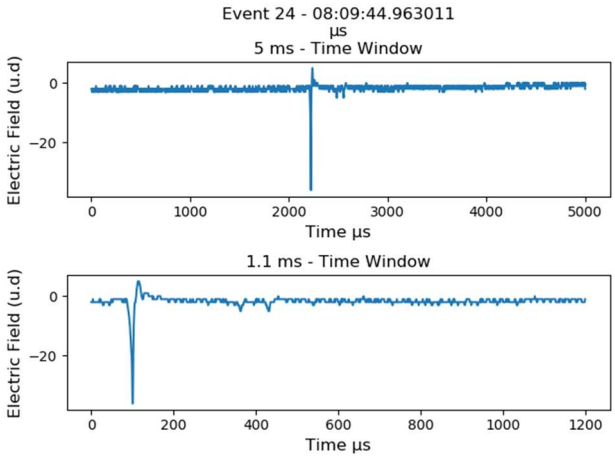

Fig.8 Example of -CID electric field waveform recorded on November 15, 2018 in southeast micro region of Para state, Brazil.

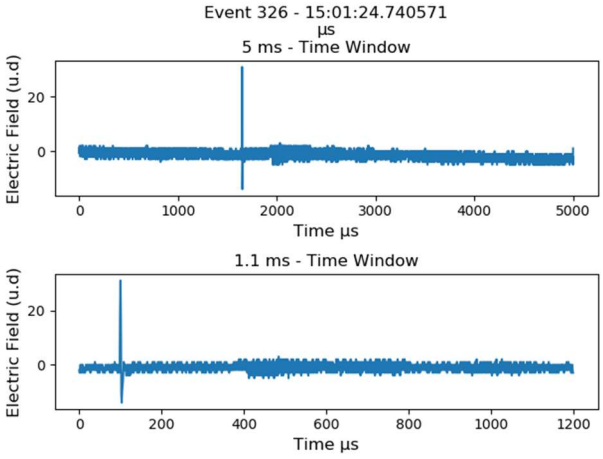

Fig.9 Example of +CID electric field waveform recorded on November 15, 2018 in southeast micro region of Para state, Brazil.

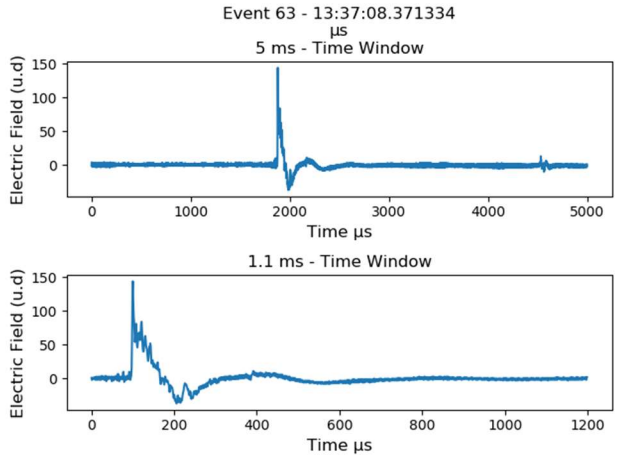

Fig.10 Example of -CG electric field waveform recorded on November 15, 2018 in southeast micro region of Para state, Brazil.

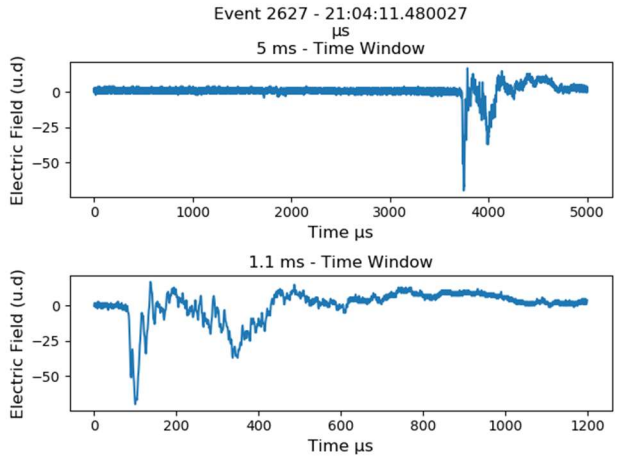

Fig.11 Example of +CG electric field waveform recorded on November 15, 2018 in southeast micro region of Para state, Brazil.

IV. SUMMARY

In this paper, we used STARNET and LDWSS data to study lightning occurrence in the southeastern micro region of the State of Pará. We observed that there are regions with high CG lightning occurrence, such as the city of Cumaru do Norte with annual average of lightning density equal to 14.2 lightning/km²/year. In this way, it was possible to map the cities where there is a great tendency of incidence of CG lightning. The second part of this paper showed a case study of lightning occurrence in November 15, 2018. On this day the LDWSS installed at UNIFESSPA recorded 3065 events (5ms window), being 54% ICs, 9% CIDs, and 37% CGs. For a more concrete conclusion about the lightning behavior in the southeastern region of Pará, a more significant database originated by the LWDSS is necessary. Therefore, it is still necessary to continue the investigation to better understand the lightning behavior in the southeastern region of Pará.

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