Lightning Deaths and Injuries in the Brazilian Amazon Region in the Period of 2009-2019

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Abstract*—This paper investigates humans accidents caused by lightning in the Legal Amazon region in Brazil. The main goal of this work is to develop statistical analyses of lightning deaths and Injuries, in order to measure an extension of the damage caused by this natural phenomenon to the local people. In addition, this paper presents a specific case study in which 4 humans beings were killed by lightning. This study considered 80 incidents obtained with our own search methodology and 38 reported by the Atmospheric Electricity Group (ELAT) of the Brazilian National Institute for Space Research (INPE) for the period of 10 years (2009-2019). This study also related the number of deaths and accidents with the occurrence of lightning in the region. In addition, it was possible to observe that about 38% of people struck by lightning in the region died. This study updates the statistics about lightning deaths and injuries in the Amazon Region, besides that it can be used to improve some actions to protect people against this natural phenomenon.

***Keywords*— Lightning deaths; lightning injuries; Legal Amazon Region.**

I. INTRODUCTION

The Brazilian legal Amazon region was instituted on January 6, 1953, according to the law nº 1806. It has a population rate of about 21,5 million inhabitants, and it is an area of approximately 5 million km², this corresponds to about 60% of the Brazilian geographic territory [1]. The high temperature and humidity characteristic of the humid equatorial climate, favor the formation of CB clouds [2]. Due to this climate, the *Cumulonimbus* clouds are formed easily in this region and consequently, the lightning occurrence is intense.

Atmospheric discharges or lightning are an intense electrical discharge in an atmosphere. They are a complex phenomenon, which is characterized by an impulsive current with high intensity, whose path leaves the cloud and, in some cases, can reach the Earth surface [3].

Figure 1 shows the region where this study is dedicated. The main interest of this research is in cloud-to-ground lightning, which can hit humans that live in this area. Part of the data used in this research was provided by the Sferics Timing And Ranging Network - STARNET [4]. STARNET operates in the VLF frequency band and detects essentially cloud-to-ground lightning. The data provided by the lightning location network (LLS) compared to lightning deaths and injuries data can provide valuable information.

Figure 1 - Amazon region. Adapted from [5]

Several studies related to lightning incidence in the Amazon region have been developed in recent decades. The majority of the studies were dedicated to the lightning characteristics in the region [6], [7] and their implication on the electrical and communication systems [8], [9]. Recently, Leal et al. [10], [11] investigated some atmospheric discharges in the Amazon region using lightning electric field measurements.

II. METHODOLOGY

A. Motivation and origin of the data used in this research

Due to the danger provoked by lightning occurrence, it has become necessary to investigate the impact of them on humans lives in the Amazon region. In order to obtain lightning deaths and injuries data, we developed a methodology for data searching on the internet. The data was found in newspapers, blogs, and magazines webpages. The period of observation was between 2009 and 2019. The list with all news accessed is found in the Appendix.

B. Data filtering

The main search tool used was the Google search engine. We used the Google date adjustment tool. Additionally, it was applied keywords such as, “accidents”, “lightning”, ”State”,

this last keyword corresponds to the States of Legal Amazon region. In addition, a considerable part of the data was obtained from the Atmospheric Electricity Group – ELAT. Thus, it was possible to catalog a considerable number of occurrences in this region and perform statistical calculations.

C. *Classification of the reported content*

After data searching, the reported content was cataloged according to the following criteria: a) day; b) month; c) year; d) city; e) State; f) gender (for fatal victims); g) age (for fatal victims); and h) survivors. The incidents were counted and organized in a tabular form for statistical analyses.

III. RESULTS

A. *Overall results*

Among the incidents, some statistical calculation was performed according to the following topics: a) Deaths and incidents per year; b) Deaths and incidents per month; c) Deaths and victims per month; d) Deaths per age group; e) Deaths per month and gender; f) Percentage of deaths per gender; g) Deaths and incidents per state.

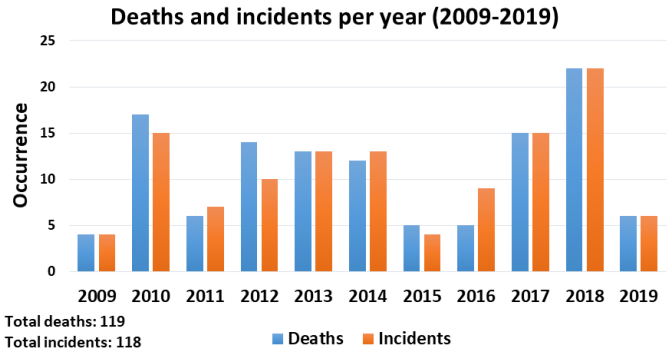

Figure 2 - Deaths and incidents per year.

Cases with fatalities had two distinct moments over 10 years. It was observed that during the years 2012 to 2015, the number of deaths decreased while the number of incidents increased. Between 2016 and 2018, the number of deaths increased considerably – reaching the highest value in 2018 – while the number of incidents also increased. A possible explanation for this is the growth of the use of means of communications, which make the number of reported cases higher. It is important to mention that in the year 2019, already has 6 fatalities in only 4 months of observation.

According to Fig. 3 October shows the highest number of deaths, reaching 22 fatal victims, followed by the months of November and March, with 14 and 13 fatal victims, respectively. The number of deaths and incidents per month are the average for the period between 2009 and 2019.

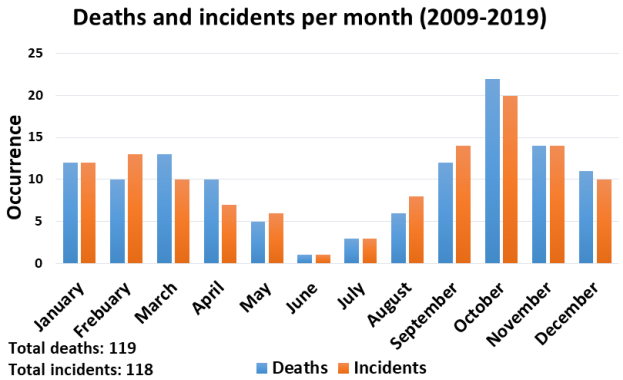

Figure 3 - Deaths and incidents per month.

The results shown in Figure 3, agree with the monthly lightning density calculated with STARNET reprocessed data for the period of 2013 to 2017 (see Fig. 4) and for the same region (Legal Amazon). The data shows three distinct periods, one of them at beginning of the year (January to April) with relatively high lightning density, another in the middle of year (May to July) with low lightning density, and the last at the end of the year (September to December) with high lightning density.

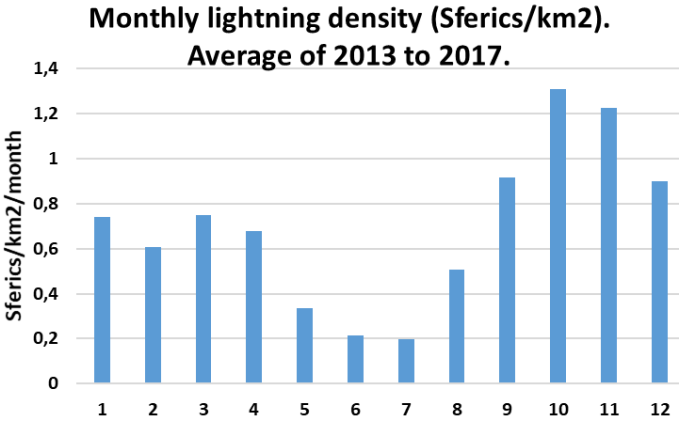

Figure 4 - Monthly lightning density for legal Amazon region.

The total number of victims (deaths + survivors) per month for the period of 2009 to 2019 is shown in Fig. 5. The peak in February is due to single lightning that struck about 50 people in a soccer game in the Mosqueiro, a small island that belongs to the city of Belém – PA [12].

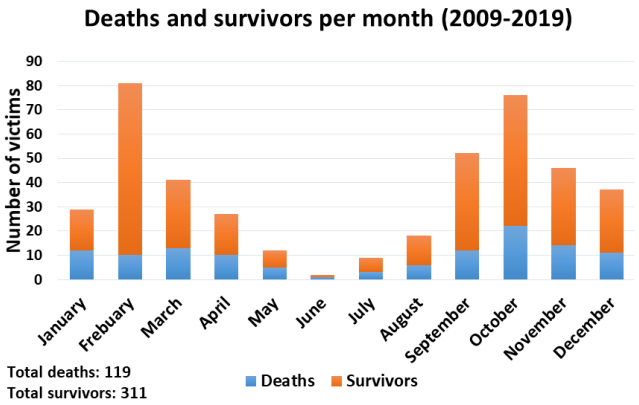

Figure 5 - Deaths and survivors per month.

For October, the month with the highest number of fatalities, about 40% of people struck by lightning died. Overall, 38% of people involved in lightning accidents in the legal Amazon region die. This number is much higher than the ones found in developed countries in which only 10% of the victims die [13]. This discrepancy is most likely due to the absence of lightning protection systems and the lack of knowledge about lightning protection delivered for the local community. In addition, about 40% of incidents in this region involve more than one person. Data from other countries, such as the United States, show that only 10% of cases involve more than one person [13].

Table 1 shows the percentage of deaths per age group. The majority of the deaths occurred among adults between 29 and 59 years old, representing 40.4 % of all deaths.

TABLE 1 – DEATHS PER AGE GROUP.

Age group	Deaths	Percentage
Child (0 – 9 years old)	5	4,2%
Teen (10 -17 years old)	22	18,4%
Young (18 – 28 years old)	26	21,8%
Adult (29 – 59 years old)	48	40,4%
Elderly (+60 years old)	9	7,6%
Age not identified	9	7,6%

Figure 6 shows the deaths per month according to gender. Deaths of men are the majority in every month. In October, deaths of men are 4 times higher than the death of women.

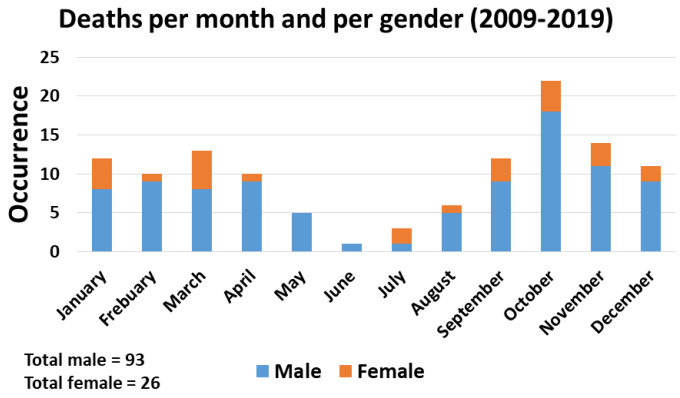

Figure 6 - Deaths per month – Gender.

Figure 7 shows the total deaths according to urban and rural area and according to gender.

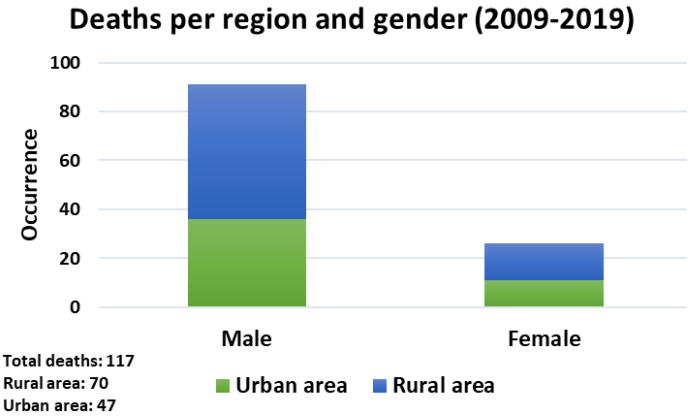

Figure 7 - Deaths per region and gender. The total deaths of 117, is lower than one shown in the other figures because in 2 deaths it was not informed whether the accident occurred in the Urban or Rural area.

According to Fig. 7, about 60% of the deaths occurred in the rural area. Besides that, the numbers of deaths of men are more than triple in relation to the number of deaths of women. The deaths of men represent 78% of the total number of deaths. According to the coordinator of the ELAT (Grupo de Eletricidade Atmosférica – Inpe), Osmar Pinto Júnior, this superiority in the number of occurrences is due to the fact that there are more men working in outdoor activities than women. Additionally, in rural areas, there are 85% more chances of this type of accident [14].

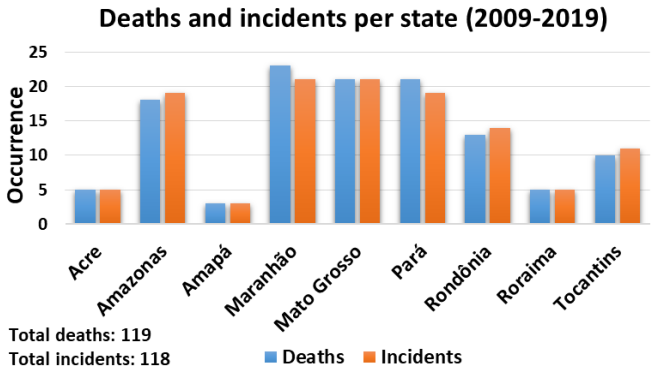

Figure 8 - Deaths and incidents per state.

According to Fig. 8, in the legal Amazon region of Brazil, the State of Maranhão leads the number of lightning deaths, with 23 deaths, followed by the States of Mato Grosso, Pará, and Amazonas with 21, 21 and 19, respectively. The ground flash density in the state of Amapá is low (as indicated in Figure 9) and this also contributes to the relatively low number of deaths in comparison to the other states

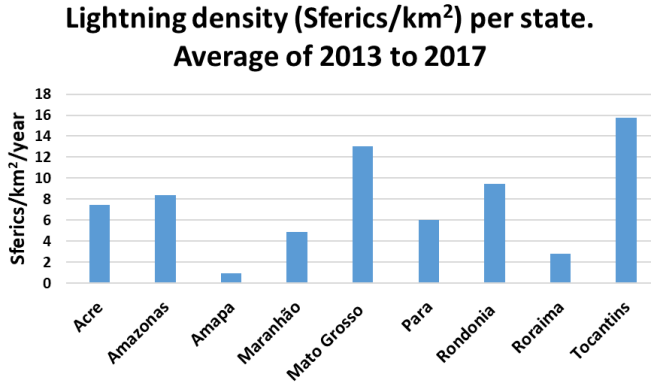

Figure 9 - Lightning density per state.

Figure 9 shows the average lightning density per State for the period of 2013 to 2017. Comparing Fig. 8 with Fig. 9, we can see that the leading state of lightning deaths, Maranhão, has a relatively low lightning density. However, in the metropolitan region of São Luís do Maranhão (capital of the State), as well as in the southern region of the state, the lightning density reaches more than 10 Sferics/km²/year. Moreover, in the legal Amazon region, the State of Maranhão has the highest population density, with about 21 inhabitants per km² [1], as shown in Fig. 10.

States with a low number of deaths have smaller territorial areas compared to States with high numbers of deaths. In the State of Maranhão, there is a rate of 3.5 deaths per million inhabitants. In the completely legal Amazon region, this number becomes higher, about 4.15 deaths per million of inhabitants.

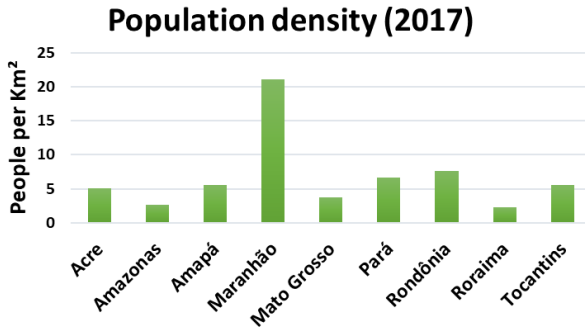

Figure 10 – Population density per state. Adapted from [1].

B. *Case Study*

In the State of Acre, despite the low number of incidents, a particular case with a high number of deaths was reported. A boat used to transport students in riverside communities was struck by lightning in the Sena Madureira city on October 10, 2018. The lightning killed 4 people of a total of 11 people that were in the boat [15]. Figure 11 shows two examples of boats similar to the one struck by the lightning, and the hole that the lightning made in the ceiling of the boat.

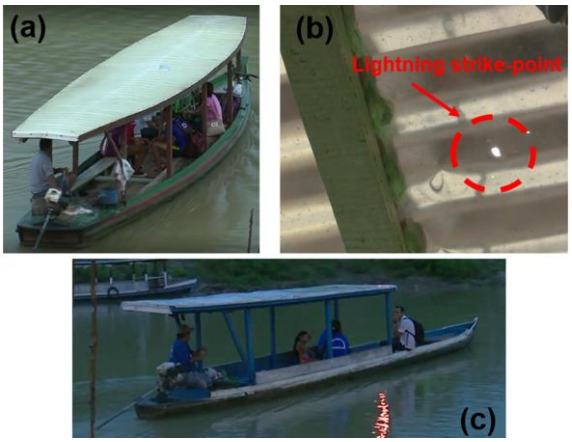

Figure 11 – Examples of boats similar to the one that was struck by lightning in the accident (a), (c). The hole made by lightning in the ceiling of the boat. [Appendix, 2].

In the period from 2009 to 2019, only five incidents were cataloged in the State of Acre. Thus, a specific analysis is necessary for this occurrence. For the day and time of the event (roughly), Fig. 12 shows the infrared image of the GOES-16 satellite at 19:15 UTC.

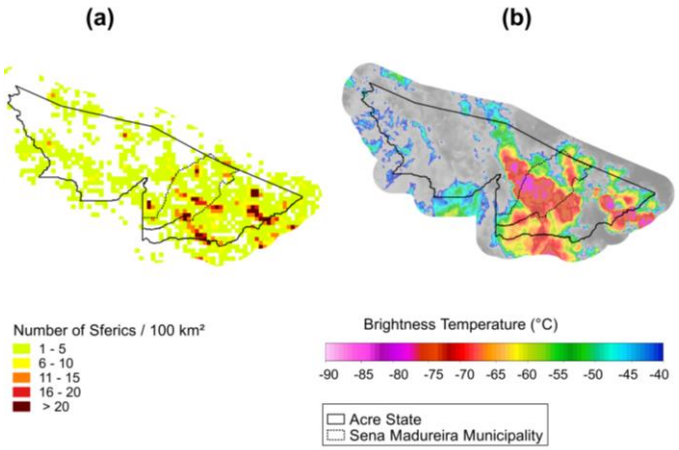

Figure 12 - Weather conditions on October 10, 2018. (a) Daily lightning density from STARNET. (b) Infrared channel 13 from GOES-16 satellite at 19:15 UTC.

The color scale represents the brightness temperature at the top of the cloud. Temperature below –40ºC for convective clouds is associated with a Cumulonimbus cloud type [16]. Hence, high chances of lightning occurrence. According to STARNET data, on the day of the incident, 740 lightning were located in Sena Madureira city. Daily lightning density for the day of the accident is shown in Fig. 12(a). The monthly lightning density for 2018 (year of the fatality) in this city is shown in Fig. 13. According to Fig. 13, the month with the second-highest lightning density is October, in which the fatalities occurred.

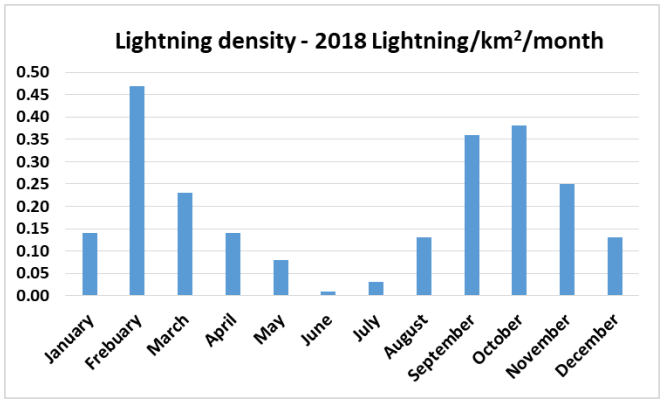

Figure 13- Lightning density - Sena Madureira (2018).

The majority of the boats in riverside communities in the Amazon region are made with a mix of metal and wood materials. Their ceiling is made frequently with metal plates (see Fig. 11). The lightning struck the metal plate at the top of the bolt. Most probably, people that were killed by the lightning were touching metal parts of the boat. This accident shows that it is not necessary to have a high lightning density or even a large territorial area to happen huge fatalities.

IV. Summary

In this paper, we investigated lightning deaths in the Amazon region that occurred between 2009 and 2019. It was found that 2018 was the year with the highest number of deaths. In addition, October was the period of the year with the highest number of occurrences. It was calculated that 38% of people struck by lightning in the Amazon region were killed and 40% of accidents involve more than one person. Most of the victims, about 40% has the age between 29 and 59 years old. It was observed that 60% of the cases occur in the rural area and 78% of deaths are men. The State of Maranhão was the State with the highest number of deaths, 23. The death rate in all Amazon region is about 4 deaths per million habitants. The case study showed that the State of Acre, despite the low lightning density, recorded 4 deaths in a single accident.

Appendix

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