Lightning in the city of São Paulo

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Abstract – Lightning documented observations in the city of São Paulo has a long history, since the first visual (naked eye) observations in the summer of 1554 by the Portuguese Jesuit priest José de Anchieta. It was only about 300 years later than another kind of indirect (thunder) lightning observations begun to be routinely made to get globally information of thunderstorm days. In the middle of the twenty century there was annually about 60 days with lightning in the city. By the end of the twenty century, when the number of days with lightning inferred from thunder observations had increased by about 90, lightning direct (electromagnetic radiation) observations by Lightning Locating Systems begun. Gradually, these observations were becoming more accurate, so that, by the year of 2011 information obtained by a combination of many systems (called BrasilDAT Dataset) provides cloud-to-ground lightning counts in the city with a confidence larger than 95%. This article describes some interesting results obtained from the analysis of the BrasilDAT data after 2011. We find strong evidences that the maximum daily number of cloud-to-ground lightning has been increasing continuously after 2011. The meteorological conditions responsibly for the lightning occurrence in these days are presented. Possible explanations to this behavior are speculated.

Keywords— Lightning; São Paulo; Lightning Detection Systems; Brazil

I. INTRODUCTION: EARLY OBSERVATIONS

São Paulo is the largest city of Brazil and South America with a population larger than 10 million people. By the time of SIPDA 2019 event the city was completing 465 years from its foundation in 1554 with the name of *Vila de Piratininga*. Along this period my lightning observations were made [1].

The first visual (naked eye) observations were done in the summer of 1554 by the Portuguese Jesuit priest José de Anchieta. He wrote your observations in a letter to Portugal: *The thunder nevertheless makes so great a boom, that they cause great terror, but they rarely throw lightning; the lightning strikes so much light that it dims and completely blinds the view, and they seem to somehow dispute with the day in the clarity.*

It was only about 300 years later than another kind of indirect (thunder) lightning observations begun to be routinely made to get globally information of thunderstorm days. In the middle of the twenty century there was annually about 60 days with lightning in the city. By the end of the twenty century, the number of days with lightning inferred from thunder observations had increased by about 90 (see Figure 1).

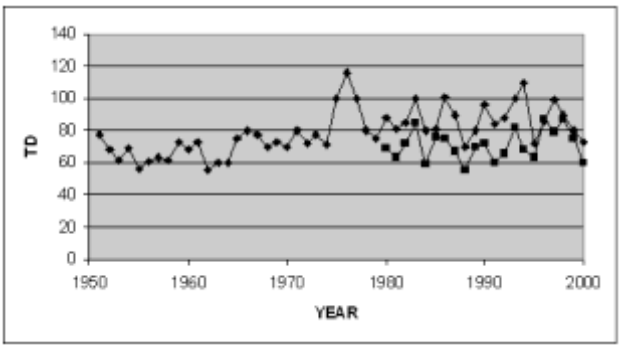

Fig. 1. Thunderstorm days in the city of São Paulo of Brazil based on observations in the first half of the twenty century.

Lightning direct (electromagnetic radiation) observations by Lightning Locating Systems in São Paulo begun in 1997, when the Atmospheric Electricity Group (ELAT) install a sensor in the state of São Paulo, integrated with other sensors installed in the state of Minas Gerais (see Figure 2).

Fig. 2. IMPACT sensor installed in Cachoeira Palista, state of São Paulo in 1997.

Figure 3 shows a computer screen with almost real time lightning locations in the region of the city of São Paulo in 1997.

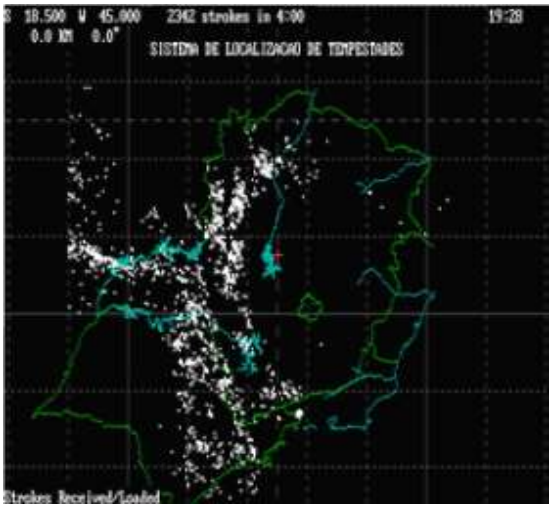

Fig. 3. The first computer screen with almost real time lightning locations.

This article describes some interesting results obtained from the analysis of the BrasilDAT data after 2011. We find strong evidences that the maximum daily number of cloud-to-ground lightning has been increasing continuously after 2011. The meteorological conditions responsibly for the lightning occurrence in these days are presented. Possible explanations to this behavior are speculated.

II. OBSERVATIONS WITH LIGHTNING LOCATING SYSTEM: 1998-2011

From 1998 to 2010 many different lightning locating system were deployed in Brazil (RINDAT, BrasilDAT, BLDN, WWLLN, STARNET and GLD360), each of them with different technical characteristics and providing information with different reliability. Such differences result in different lightning detection efficiency of the systems, Observations with high speed cameras in the region of the city of São Paulo has shown that the detection efficiency can vary from about 20% to 80% for individual systems [2]. Such large changes put strong limitations in the studies that try to identify time changes in the cloud-to-ground flash incidence, although they are less important in terms of the spatial distribution of the flashes [3]. Figure 4 shows the spatial distribution of cloud-to-ground lightning over the city of São Paulo, showing a clear relation with the urban heat island [4}.

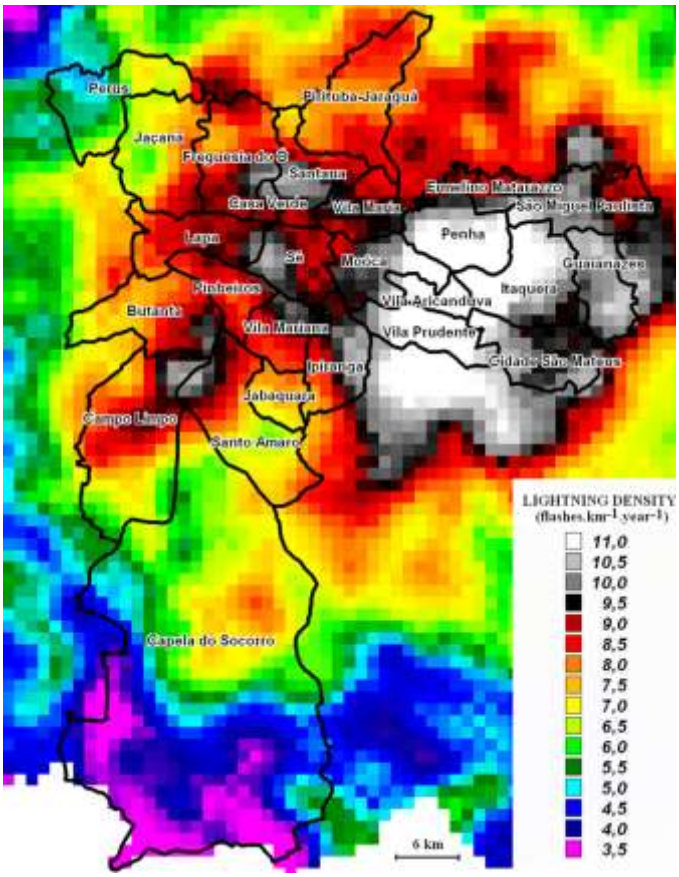

Fig. 4. Cloud-to-ground lightning incidence in the city of São Paulo obtained for the first time by lightning locating systems.

III. BRASILDAT DATASET: 2011-PRESENT

After using data from three different lightning locating systems for a few years, we realize that all systems measured part of the flashes that really happens and that in most cases they are complementary each other. Motivate by this finding we decide to join data from the three different technologies in just one dataset, following some specific criteria. This dataset was named BrasilDAT Dataset and its information is available since 2011 [5]. We found data using this dataset we can explain in details more than 90% of the lightning-related events like transmission line faults, lightning fatalities or lightning damages to property that happened in the last two years. In the case of the city of São Paulo BrasilDAT Dataset provides cloud-to-ground lightning counts in the city with a confidence larger than 95%.

IV. RESULTS

Cloud-to-ground lightning data from the BrasilDAT Dataset from 2011 to 2018 in the city of São Paulo were analyzed in terms of daily counts. Table 1 shows the days

when were recorded more than 1500 cloud-to-ground flashes, ordered from the lowest to the highest value.

Table 1 – Daily counts of cloud-to-ground flashes in the city of São Paulo.

Day	CG Flashes	Meteorological System
20/03/2018	4329	SACZ
21/12/2016	3762	BCN
27/01/2016	3089	SACZ
14/02/2013	2984	SACZ
24/12/2012	2779	LC
12/01/2015	2732	LC
08/03/2013	2444	BCN
25/02/2015	2428	SACZ
24/01/2014	2349	BCN
16/03/2015	2161	BCN
15/02/2016	2008	BCN
19/02/2016	1928	LC
01/03/2018	1898	BCN
10/03/2012	1726	BCN
25/12/2014	1725	SACZ
10/01/2018	1725	SACZ
06/02/2017	1687	LC
19/12/2014	1579	BCN

SACZ: South Atlantic Convergence Zone
BCN: Band of Convective Nebulosity
LC: Local Convection

We can see in Table 1 that the first year when the daily number of cloud-to-ground flashes was larger than 2000 flashes was 2012; the first year when the daily number of cloud-to-ground flashes was larger than 3000 flashes was 2016; and the first year when the daily number of cloud-to-ground flashes was larger than 4000 flashes was 2018. Considering that there are no changes in the BrasilDAT Dataset integrated detection efficiency during this period, we are lead to conclude that the maximum daily number of cloud-to-ground flashes is increasing in the city.

Table 1 also indicates the meteorological conditions for each day. Most of the days are related to a band of convective nebulosity (BCN) that extends generally from the south of the Amazon to the southwest Atlantic Ocean [6]. When this BCN has a northwest-southeast diagonal orientation of cloudiness and a minimum duration of three or four days, it is .known as the South Atlantic Convergence Zone (SACZ) [7]. Figure 5 shows a satellite infrared image of one of the SACZ event. During the lightning season (October-March) over the southeast of Brazil SACZ generates high accumulations of rain, causing serious damage to society.

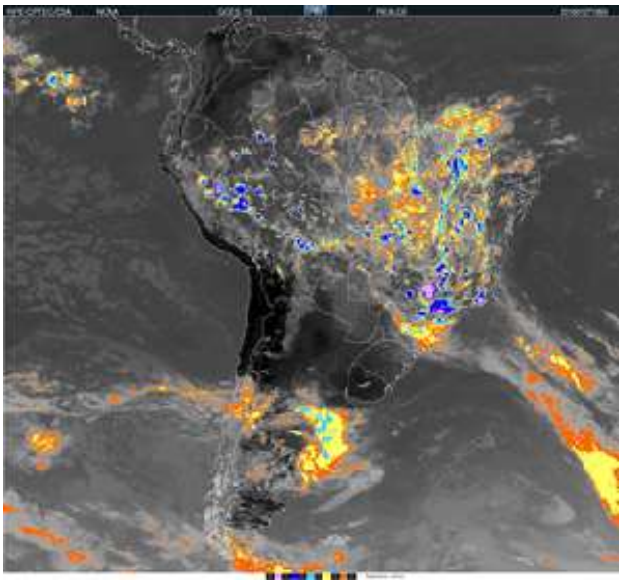

Fig. 5. Infrared GOES 13 satellite image for 18:00 UT of 27 January 2016, indicating a SACZ event.

Figure 6 shows a day when the meteorological conditions are related to local convection.

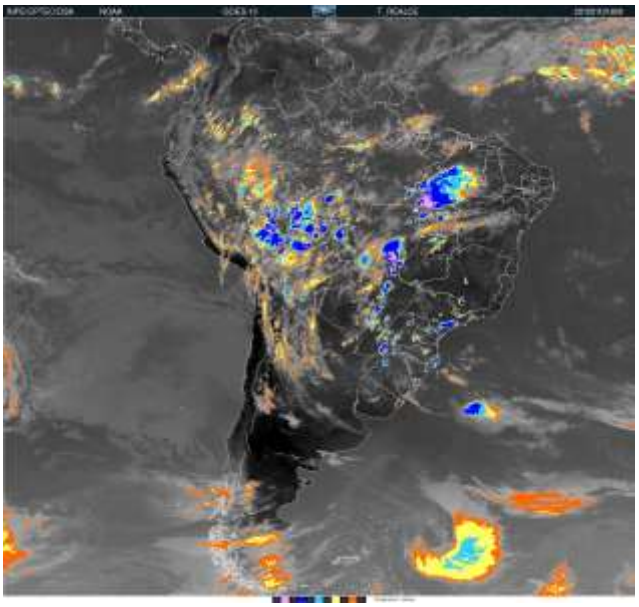

Fig. 6. Infrared GOES 13 satellite image for 18:00 UT of 12 January 2015, indicating a local convection event.

Although, at present time, it is premature try to explain the increase in the maximum daily number of cloud-to-ground flashes in the last eight years, some points are worth reporting: from the analyses of Table 1. All events with cloud-to-ground flash daily counts in excess of 3000 occurred recently (after 2015) in association BCN or SACZ, that is, under the influence of nebulosity coming from the Amazon region and reaching São Paulo. So, we can speculate that changes in the nebulosity characteristics (such as a larger humidity associated with the increase of the surface temperature of the equatorial Atlantic Ocean) can be explain these events. However, we

cannot disregard that the events are a result of an intensification of the urban heat island over the city. More research can be done to investigate further this issue.

V. CONCLUSIONS

In this article we describe briefly the history of lightning observations in the city of São Paulo and indicated that the maximum daily number of the cloud-to-ground has increase in the last decade, a period when the observations are based on simultaneous use of data from different lightning locating systems and, in consequence, more reliable than before.

The reason for the increase in the maximum daily number of the cloud-to-ground is not clear yet, but may be related to large scale changes in the meteorological conditions between the Amazon region and the Southeast region and/or to local changes in the meteorological conditions associated with urban aspects. More research is need to get an explanation to this increase.

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