

## HOW GROUND FLASH DENSITY OBTAINED BY LIGHTNING LOCATION NETWORKS CAN BE USED IN LIGHTNING PROTECTION STANDARDS: A CASE STUDY IN BRAZIL

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### 1. INTRODUCTION

The annual number of lightning flashes influencing an object to be protected depends on the thunderstorm activity of the region where the object is located and on its physical characteristics. It is generally accepted that this number can be evaluated multiplying the lightning ground flash density, that is, the number of flashes per square kilometer and per year, by an equivalent area of the object. In the past, due to the lack of direct lightning measurements, the ground flash density was generally inferred from the thunderstorm days per year, or the keraunic index, through an equation containing empirically derived constants. This index is available with very low resolution in almost all countries around the world. This practice is still adopted in many lightning protection standards, including the Brazilian lightning protection standards. However, over the last years, ground flash density based on lightning detection networks with high detection efficiency and resolution (up to 1 km) has become available in many countries, including Brazil. If, on one hand, there is no doubt that this information is much more accurate than the keraunic level, on the other hand, there are no specifications on how to determine the ground flash density from lightning network measurements in terms of spatial resolution and minimum time interval of observations. The situation is complicated by the fact that the characteristics of the networks vary significantly at different countries. With respect to the spatial resolution, the ground flash density depends on the assumed resolution. In general, the low is the resolution, the high is the maximum flash density. With respect to the time interval of observations, a minimum number of years should be considered in order to minimize short-term variations, which is dependent on the meteorological conditions prevalent in each region.

In this paper, lightning data in the region of the city of São Paulo for a period of five years, from 1999 to 2004, obtained by the Brazilian Integrated Lightning Detection Network

(RINDAT) are used to discuss how the ground flash density should be considered in terms of spatial resolution and minimum time interval of observations, in order that it can be included in the Brazilian lightning protection standards in the future, replacing the keraunic index. The region was chosen because the large variations in the flash density associated with urban effects (Naccarato, 2005). Similar effect was observed in other large cities (e.g., Orville et al., 2001; Pinto et al., 2004).

### 2. RINDAT DATA

Data from the Brazilian Integrated Lightning Detection Network (RINDAT) from 1999 to 2004 were used in this analysis. During this period the network was composed initially by 20 sensors and at the end by 24 sensors (8 Impact and 16 LPATS sensors), as indicated in Figure 1. Data from the sensors were sent to a LP2000 central processors where they were stored and, later, reprocessed to recovery data losses by possible delays in the communication links. More details about RINDAT can be found in Pinto (2003, 2005) and Pinto et al. (1999a, b; 2003a, b).

### 3. DATA ANALYSIS AND RESULTS

For this analysis, ground flash densities in the region of the city of São Paulo were computed for different spatial resolutions from 10 km up to location accuracy of the network in this region, approximately 1 km. Figure 2 shows the map of flash density with 10 km resolution in the Southeastern Brazil. It can be seen that the region of largest flash density is coincident with the region around the city of São Paulo, with a maximum of 14.3 flashes.km<sup>-2</sup>.year<sup>-1</sup>. Figure 3 shows this region in more details, with a 1 km resolution. The flash density inside the city varies by a factor larger than three, from 3.5 to >11 flashes.km<sup>-2</sup>.year<sup>-1</sup>. For this resolution, the maximum flash density is 17.5 flashes.km<sup>-2</sup>.year<sup>-1</sup>. Ground

flash densities were also computed for time intervals from one to 6 years. The same flash density pattern was observed for all years. Average flash densities were almost unchanged after a period of 5 years. The results suggest that the average ground flash density values obtained for 1 km resolution and for the whole period of 6 years should be used to generate practical values to replace the keraunic level in the Brazilian standards. To do that, the results were compared to the average keraunic level of 70 adopted in the Brazilian standards. The comparison suggests that, from the practical point of view, two different ground flash densities for the city of São Paulo should be considered, one for the South region of the city ( $10 \text{ flashes.km}^{-2}.\text{year}^{-1}$ ) and one for the other regions ( $20 \text{ flashes.km}^{-2}.\text{year}^{-1}$ ). This approach is quite different from that adopted in the Brazilian standards, with assumes a constant keraunic level of 70, which corresponds to a flash density of approximately  $7 \text{ flashes.km}^{-2}.\text{year}^{-1}$ , using the empirical relationship between keraunic level and flash density.

#### 4. CONCLUSIONS

The flash density in the city of São Paulo is quite different from that obtained from the keraunic level. The results of this study suggest that two different ground flash densities should be considered, one for the South region of the city ( $10 \text{ flashes.km}^{-2}.\text{year}^{-1}$ ) and one for the other regions ( $20 \text{ flashes.km}^{-2}.\text{year}^{-1}$ ), should be adopted. This approach is quite different from that adopted in the Brazilian standards, with assumes a constant keraunic level of 70, which corresponds to a flash density of approximately  $7 \text{ flashes.km}^{-2}.\text{year}^{-1}$ , using the empirical relationship between keraunic level and flash density.

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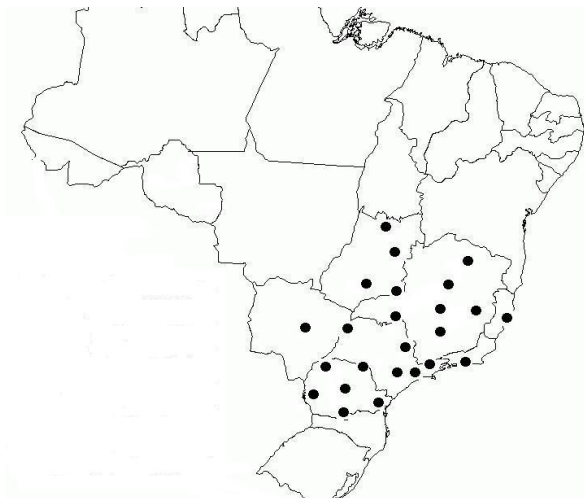


Figure 1. RINDAT sensors at the time of this study.

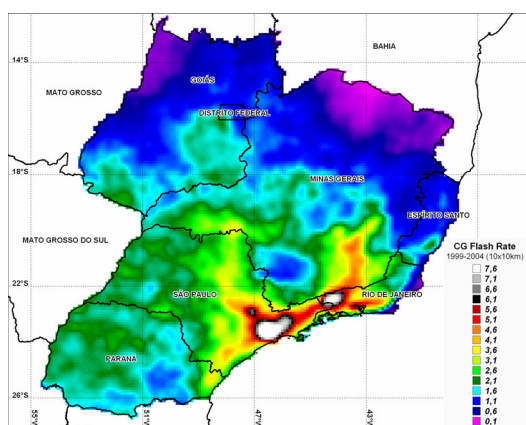


Figure 2. Flash density map for 10x10 km resolution.

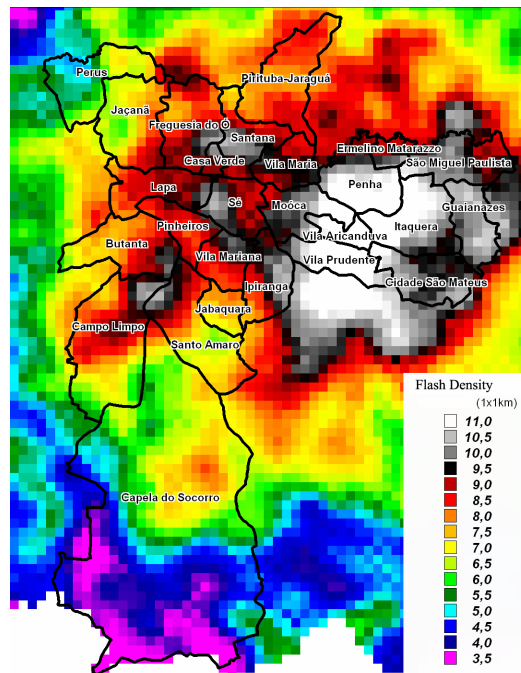


Figure 3. Flash density map for the region of the city of São Paulo for 1x1 km resolution.