2010
21st International Lightning Detection Conference
19 – 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 – 22 April • Orlando, Florida, USA

REVISITING LIGHTNING DATA OF LARGE PEAK CURRENT NEGATIVE FLASHES OBSERVED BY THE BRAZILIAN LIGHTNING LOCATION NETWORK

O. Pinto Jr.
Brazilian Institute of Space Research – INPE
São José dos Campos, Brazil

1. INTRODUCTION

Lightning detection systems throughout the world have estimated from remotely measured electric and magnetic fields peak currents of negative cloud-to-ground (CG) flashes in excess of 500 kA, even though the largest directly measured peak currents of negative flashes do not exceed 200 kA. Basically, three uncertainties related to these estimations have been pointed out.

The first uncertainty is that the large estimated negative peak current values are, in fact, related to specific cloud flashes, known as compact intracloud discharges (CID). Compact intracloud discharges some time called narrow bipolar pulses are known to be the strongest sources of HF and VHF radiation from thunderstorms (Willett et al., 1989; Eack, 2004; Wiens et al., 2008). Nag and Rakov (2009) infer based on experimental evidence of multiple reflections that CID are essentially a bouncing-wave phenomena. The shortest radiating-channel length appears to be about 100 m and from modeling CID as a wave traveling on an elevated vertical transmission line the upper bound on channel length is about 1000 m. Nag and Rakov (2009) found that most CID occur alone, only 9% are associated with cloud-to-ground flashes and only 4% occur in group.

The second uncertainty is that the large estimated negative peak current values are, in fact, related to radiation fields produced by cloud-to-ground positive flashes arriving in the sensors after reflecting on the ionosphere instead of propagating on ground (Diendorfer and Schulz, 2008). In such a case, the negative CG flash is closely in time related to the positive CG flash.

The third uncertainty is that the large estimated negative peak current values are a consequence of the use of an empirical formula that assumes a linear relationship between the peak field and the peak current, derived from the transmission line model applied to the return stroke and assuming that the return stroke velocity is independent on the peak current, although the validity of these assumptions has only been tested for negative subsequent strokes of triggered flashes with peak currents up to 60 kA.

In this paper, we use appropriate thresholds for some parameters associated with the lightning data in order to eliminate the ambiguous identification related to the first two uncertainty cited above. The methodology is applied to a data set of cloud-to-ground flashes with peak currents above 100 kA recorded by the Brazilian Lightning Detection Network in the Southeast Brazil from 1999 to 2005. After this procedure, we investigate the dependence of these flashes on the type of meteorological system involved (frontal systems or local convection) and, in case of frontal systems, to the region in the system where they are located (convective or stratiform), following the ideas discussed in Zepka and Pinto Jr. (2008). Also, we investigate the dependence of the peak current of theses flashes on the altitude.

2. DATA

Lightning data obtained by the Brazilian Lightning Detection Network (BrasilDat) from 1999 to 2005 in the Southeast region of the country were studied. Figure 1 shows the location of the lightning sensors that participating in the data used in this analysis and Figure 2 shows the cloud-to-ground (CG) lightning density for a spatial resolution of 10 km ×10 km in the region and period of this study. More than 5 million negative CG flashes were recorded during the period. CG lightning density is clearly modulated by altitude of the terrain that, in this region, varies from sea level to about 1500 meters, as shown in Figure 3.

Figure 1. Lightning sensors operating during the period of the study.

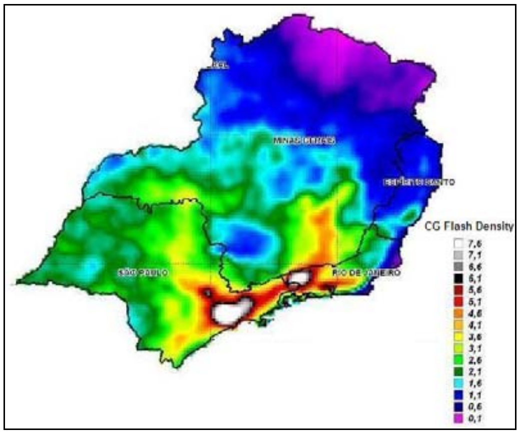

Figure 2. CG lightning density in the Southeast region of Brazil from 1999 to 2005 for a spatial resolution of 10 km ×10 km.

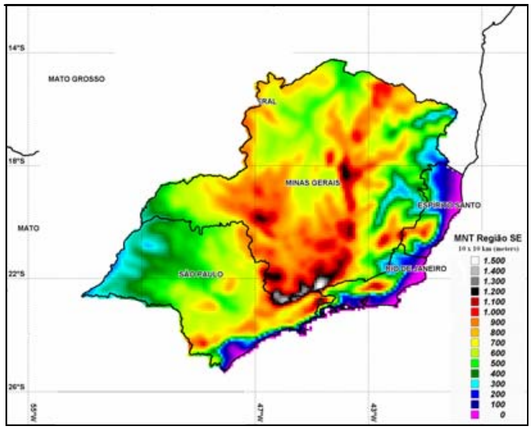

Figure 3. Altitude of the terrain in the region of study.

The methodology used in this analysis to eliminate the ambiguous identification related to the first two uncertainty cited previously consisted of: first, filtered the original data to consider only CG negative flashes above 100 kA (about 1% of the total); second, filtered the new (above-100 kA) data set using the following thresholds:

1. Multiplicity should be higher than 1 to eliminate negative peak current values related to radiation fields produced by cloud-to-ground positive flashes arriving in the sensors after reflecting on the ionosphere instead of propagating on ground. Such criterion can even be refined by neglecting only single negative CG flashes that occur after a short time (for instance 100 μs) period after a positive CG flash. However, no significant changes were found.
2. Number of sensors higher than 4 (a value adequate for this particular network) and chi-square value should be less than 5 to eliminate intense intracloud flashes like CIDs, which generate radiation fields at high altitudes and not near ground like CG flashes.

After this procedure, we investigate the dependence of these flashes on the type of meteorological system involved (frontal systems or local convection) and, in case of frontal systems, to the region in the system where they are located (convective or stratiform), following the ideas discussed in Zepka and Pinto Jr. (2008). Also, we investigate the dependence of the peak current of theses flashes on the altitude.

3. RESULTS AND DISCUSSION

After applying the methodology described previously, it was found that about 67% of the negative CG flashes above 100 kA in the original data set were rejected. The maximum peak current that in the original data set was 1266 kA in the new data set was 344 kA. Regarding the “valid” negative CG flashes above 100 kA, it was observed that 88% of the flashes occur in the spring and summer season, 88% of the location of the flashes was coincident with convective regions of the storms as identified by satellite infrared images, while only 12% was coincident with stratiform regions, and 65% of the flashes occurred during storms associated with frontal systems, while 35% occurred in storms associated with local convection. All these percentages, however, are almost the same for all negative CG flashes.

Finally, the altitude related to the location of the “valid” CG negative flashes above 100 kA were identified in order to verify if the peak current has a altitude dependence, as suggested by Cooray (2009). Even though the altitude varied for more 1000 meters, no dependence was found, suggesting that if the largest peak currents tend to occur for lower altitudes, as can inferred from Cooray (2009), the effect is not sensitive to altitudes changes as those reported in this study.

The results presented in this paper suggest that lightning location networks should use some criteria like those suggested here in their default configuration, in order to avoid miss interpretation of their data by operational customers.

4. REFERENCES

Cooray, V., On the upper limit of peak current in return strokes of lightning flashes, Proceedings of the X International Symposium on Lightning Protection (SIPDA), November, 2009.

Diendorfer, G., and W. Schulz, Critical analysis of LLS detected very large peak current lightning strokes, Proceedings of the International Lightning Detection Conference (ILDC), Tucson, AZ, 2008.

Eack, K. B., Electrical characteristics of narrow bipolar events, Geophys. Res. Lett., 31, doi:10.1029/2004GL021117, 2004.

Nag, A., and V. A. Rakov, Compact Intracloud Lightning Discharges: Conceptual Mechanism, Modeling, and Electrical Parameters, Fall Meeting, American Geophysical Union (AGU), San Francisco, Dec. 2009.

Wiens, K.C., T. Hamlin, J, Harlin, and D.M. Suszcynsky, Relationships among narrow bipolar events, “total” lightning, and radar inferred convective strength in Great Plains thunderstorms, 113, D05201, doi:10.1029/2007JD009400, 2008.

Willett, J. C., J. C. Bailey and E. P. Krider, A class of unusual lightning electric field waveforms with very strong high frequency radiation, J. Geophys. Res., 94, 16,225-16,267, 1989.

Zepka, G. dos S., and O. Pinto Jr., About the peak currents above 300 kA observed by lightning location systems, Proceedings of the International Lightning Detection Conference (ILDC), Tucson, AZ, 2008.