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

# THE EFFECT OF DIFFERENT CONFIGURATIONS OF THE BRAZILIAN LIGHTNING DETECTION NETWORK ON THE CLOUD-TO-GROUND LIGHTNING SPATIAL DISTRIBUTION

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## 1. INTRODUCTION

The spatial distribution of cloud-to-ground (CG) lightning obtained from VLF/LF lightning location systems (LLS's) through lightning density maps has been used in many applications. This distribution is often explained by physical effects, like the relations between lightning and elevation or urban heat islands (Orville and Silver, 1997; Naccarato, 2003; Pinto Jr *et al.*, 2003; Pinto *et al.*, 2004; Bourscheidt *et al.*, 2009; Farias *et al.*, 2009).

However, depending on the network uptime, some effects of the network geometry (i.e. the detection efficiency) may be expected to cause a significant variation on the resulting lightning distribution. These effects are normally evaluated by a detection efficiency (DE) model, which can be developed based on physical and/or empirical relationships. Empirical relative DE models using own network data have been used to evaluate the Brazilian Lightning Detection network and have reproduced the network conditions very well (Naccarato and Pinto, 2009). Such models are in constant development in order to evaluate (spatially) the performance of individual sensors with the best temporal resolution, providing as result the probability of detection integrated for all network as a function of distance and peak current.

Here an interesting application of the Vaisala Inc. LLS's processing central might became interesting: the network evaluation through different scenarios. The scenarios can be chosen by the user and might bring some features in the lightning density maps that are not evaluated by the DE models (Naccarato, 2006). The results obtained in this analysis might help to understand the importance of each participating sensor in a hybrid network and help to make spatial distribution analysis more reliable for these conditions.

## 2. DATA AND METHODOLOGY

Evaluate the effects of the network conditions may be a complex task in some cases and an adequate methodology is essential. In our case, we adopted 10 sensors with high uptime – 3 IMPACT and 7 LPATS – distributed over the Southeast region as a reference network configuration, as showed in the Figure 1. These 10 sensors have been chosen by a combination analysis, where each possible combination among the working sensors was evaluated in terms of uptime for the summer periods between Jan 2003 to Dec 2008. Some configurations have been chose by this process, but the final network configuration should include adequate geometry and also include sensors with different technology. So, the final configuration was chose intending to include all those aspects. The resulting reference network did occur in 476 days (52% of the time).

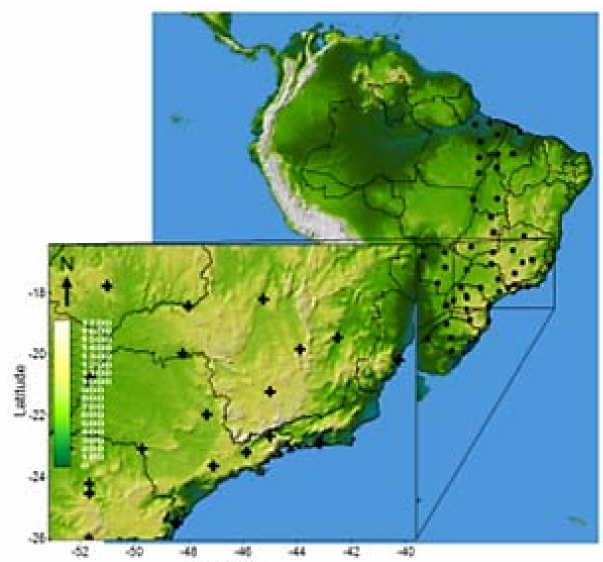


*Figure 1. The studied region: sensors are represented by black dots. Green to yellow indicates increasing altitudes.*

With the reference network defined, we have considered four different scenarios to evaluate the effects on CG lightning distribution:

- First scenario: the reference scenario described early;
- Second scenario: the 10 sensors using only time information;
- Third scenario: 9 sensors, removing one IMPACT sensor (São José dos Campos);
- Fourth scenario: 9 sensors, removing the core sensor (Lavras).

For each scenario, other aspects were evaluated: the maximum semi-major axis (SMA) of the confidence ellipses, set to be 50 or 15 km, and the IC/CG flag, set as 1 or 0.

Using these scenarios, the data were reprocessed and then analyzed qualitatively through maps. These maps include the spatial distribution for all CG lightning and also the data separated by polarity (+CG and -CG).

## 3. RESULTS AND DISCUSSION

### 3.1 Scenarios and CG lightning density

The results that we have obtained from the different scenarios are in agreement with the expected for a hybrid lightning detection network. Figure 2 shows the lightning distribution for the first scenario. The sensors (and its different location technology) are also showed in the figure. Highlighted regions are used to show the most important variations.

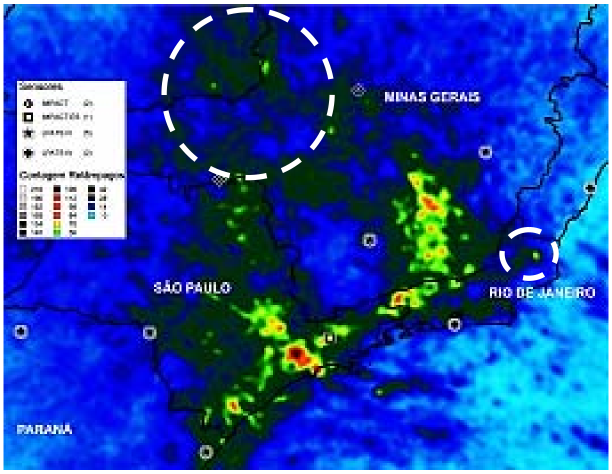


*Figure 2. CG lightning count for the first scenario.*

The distribution shows a large variation over the region, which need to be analyzed carefully due the small period of data used (only 476 days of lightning data).The only physical aspect that seems to be clear is the higher lightning density over the São Paulo metropolitan region.

Figure 3 shows the lightning distribution for the second scenario. A initial comparison between the first and the second scenario shows the variations resulting from the use of angle an time (IMPACT and LPATS sensors) and just time (as LPATS sensors) in the solutions. The main effect is the increasing in the solutions in the North part of the map when using angle and time, a condition that requires fewer sensors to give a solution.

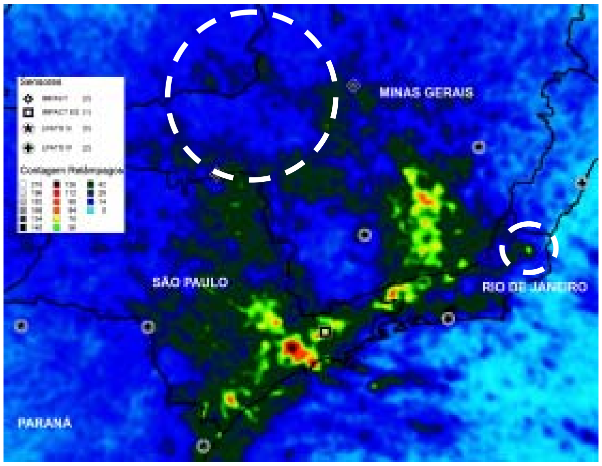


*Figure 3. CG lightning count for the second scenario.*

For the third scenario, showed in Figure 4, a clear reduction in the solutions can be observed, especially for the São Paulo metropolitan region and the South of Minas Gerais state. This effect reflects the importance of the IMPACT sensor in São José dos Campos. In the fourth scenario, the reduction is not so expressive (Figure 5).

The main effect observed with this configuration (fourth scenario) is the elimination of the small feature (highlighted) over the North limit of the Rio de Janeiro state, region where the remaining sensors are all LPATS (it means that it is required more sensors to have a solution).

The effects when changing the IC/CG and the ellipse condition are not significant on this first analysis, leading to small changes with no clear impact on the spatial distribution.

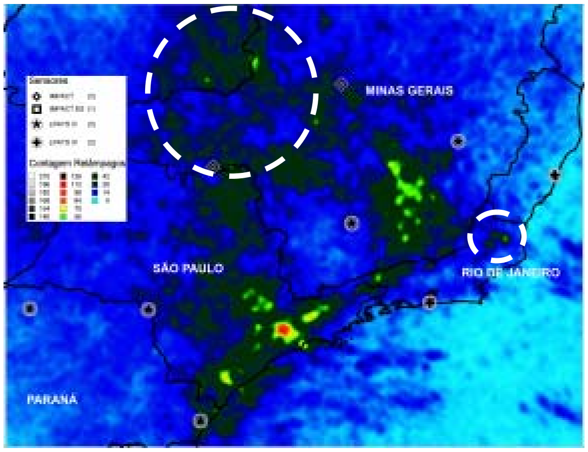


*Figure 4. CG lightning count for the third scenario.*

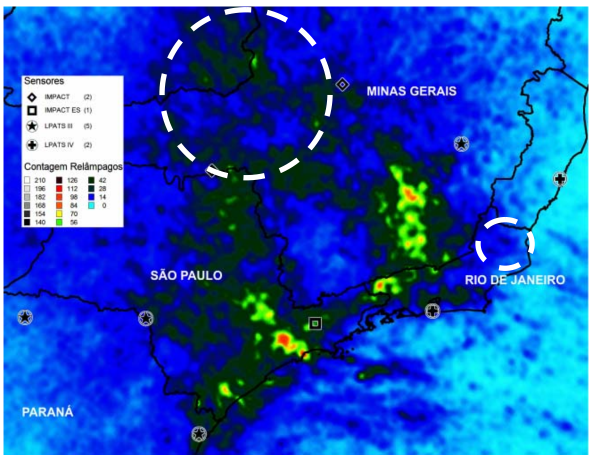


*Figure 5. CG lightning count for the fourth scenario.*

### 3.2 Scenarios and CG lightning polarity

Other aspects that we have considered are the 4 scenarios divided by polarity (CG+ and CG-) and a map was created for each one of this new scenarios. The results basically follow the early pointed results for all scenarios. Negative CG dominate the total of CG lightning and are also responsible by almost all spatial features. Figure 6 shows the results for -CG for the first scenario.

Figure 7 shows the +CG lightning for the first scenario. Some special features occur for this case: a large number of +CG lightning are found in Middle East region. This may result from intracloud (IC) contamination, because the large amount of +CG are in the middle of four LPATS sensors. The elimination of flashes flagged as IC for +CG in the Figure 8 cause a major reduction on the number of flashes at that region.

The scenarios 2 and 3 have presented almost the same behavior as the first scenario when analyzing the polarity.

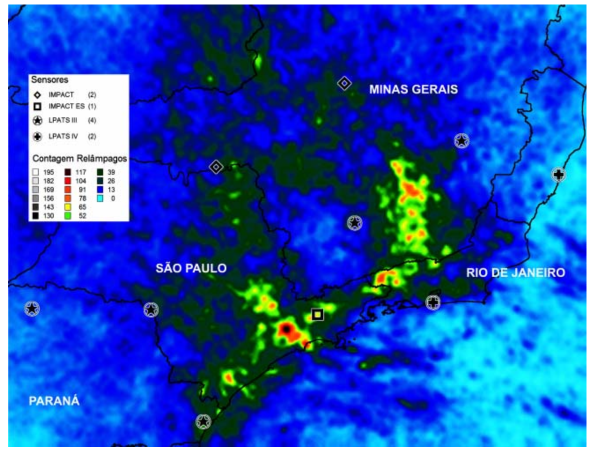


*Figure 6. -CG lightning count for the first scenario.*

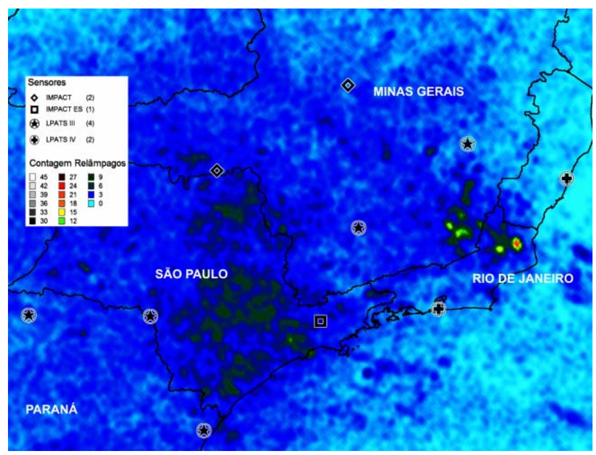


*Figure 7. +CG lightning count for the first scenario.*

In the case of the fourth scenario, a significant difference on the +CG in the North part of the Rio de Janeiro state was found (Figure 9). For the -CG this effect was smaller, but still observed (Figure 10). As mentioned early, this is possibly associated to the exclusion of the LPATS sensor in the center of the network, indicating that this sensor is essential to the solutions at this region.

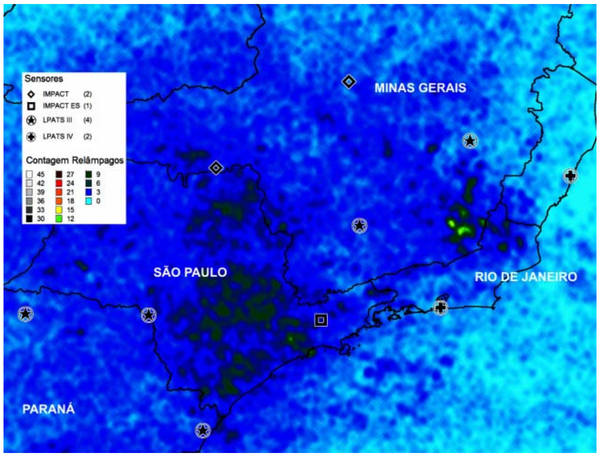

*Figure 8. +CG lightning count for the first scenario without solutions flagged as IC.*

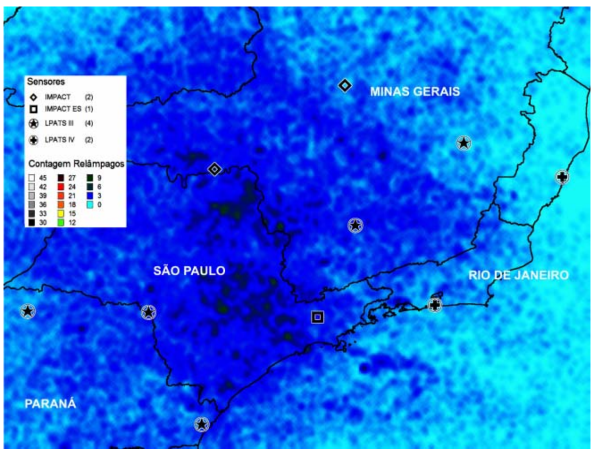

*Figure 9. +CG lightning count for the fourth scenario.*

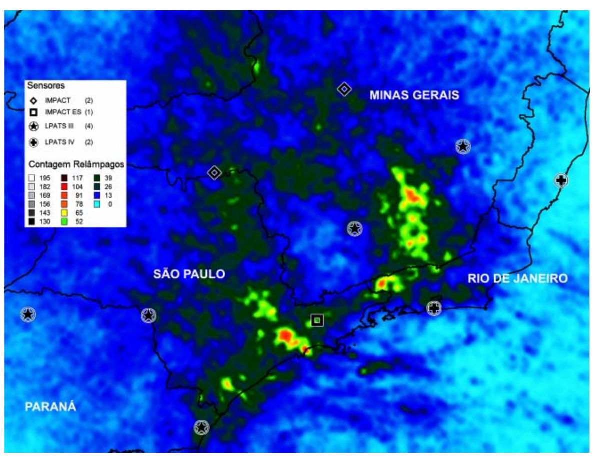

*Figure 10. -CG lightning count for the fourth scenario.*

Finally, the maps with the effects of changing the ellipse size (not showed) did not show significant variations on the CG lightning distribution. Some small variations have been observed for solutions outside of the group of sensors. So there would be no effect on the distribution when changing this parameter, being interesting to use the 15 km limit to have more reliable results.

## 4. CONCLUSIONS

The possibility of use different data reprocessing scenarios is very interesting and useful, especially for hybrid networks. In our case, each scenario has its peculiarities and the results show some especial (and expected) characteristics:

- The spatial distribution depends mostly on the negative CG lightning;
- The use of only time criteria in the data processing reduce the solutions for boundary regions (more sensors are necessary to give a solution on this case);
- An IMPACT sensor could have great importance for an hybrid network when rounded by LPATS sensors;
- For regions cover by LPATS sensor, the omission of one sensor could have large effect on the lightning distribution;

Others features that we have observed are related to the polarity: significant variations occur for +CG when changing the criterion regarding the IC/CG flag and also when using the fourth configuration. For the -CG, as well as on the total distribution, the effects are not so representative. As most low peak current +CG have been suggested to be associated to intracloud contamination, it seems interesting to remove data flagged as IC. The ellipse criterion have not shown great effects on the lightning distribution and seems interesting remove data with ellipse size large than 15 km to have more reliable density maps.


## 4. ACKNOWLEDGMENTS

The results are all part of a PhD Thesis of the first author (in preparation). The authors would like to acknowledge the National Council for Scientific and Technological Development (CNPq) and the CAPES (Coordenação para Aperfeiçoamento de Pessoal de Nível Superior).

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