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DEPENDENCE OF CG LIGHTNING DENSITY ON ALTITUDE, SOIL TYPE AND LAND SURFACE TEMPERATURE IN SOUTH OF BRAZIL

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1. INTRODUCTION

The use of lightning spatial products has brought new possibilities to the spatial analysis, making possible the comparison of different environmental (dynamical) variables and the development of GIS tools for many statistical analyses.

The relations between lightning spatial patterns and the environment variables which it depends on, has been showed in many conferences and journal papers. Altitude and temperature are commonly referred as important variables on the lightning distribution (De Pablo & Soriano 2002; Naccarato et al. 2003; Pinto et al. 2004; Pinto Jr et al. 1999; Reap 1986; Schulz & Diendorfer 1999; Soriano & Soula 2001; Soriano & de Pablo 2002).

Soil seems not to be effective as the other variables on affecting the lightning distribution, but it can be important when considering the exposed soil, as well as the land surface coverage. It can affect the meteorological conditions favorable to thunderstorm development (Pielke 2001). Other aspect refers to its effect (not fully explained yet) on the peak current estimative (Orville 1991; Orville & Huffines 2001). Furthermore some effects on thunderstorm charge formation have been proposed, despite not evidenced (Chauzy & Soula 1999).

All these variables together with the lightning data could give us a better understanding of thunderstorm dynamics and also on lightning and atmospheric electricity knowledge.

2. DATA AND METHODOLOGY

The analyzed region is indicated in the Figure 1 and refers to the State Rio Grande do Sul.

Four dataset have been used in the analysis. The lightning data was obtained by the Brazilian National Lightning Detection network (BrasilDAT) for the period of Jun 2005 to May 2007. Elevation data results from USGS SRTM (Shuttle Radar Topography Mission) Digital Elevation Models (DEMs), with a resolution, vertical and geolocation error of about 90, 10 and 20 meters, respectively. Land Surface Temperature (LST) results from MODIS satellite monthly products, from Out 2005 to Dec 2006. Errors for these images refer especially to acquisition loss due clouds covering the region. Finally, the soil data gathered from EMBRAPA and IBGE agencies online database (EMBRAPA 2007; IBGE 2007).

Lightning data was splitted into density classes for the altitude and LST data. In other words, mean values for altitude, declivity and LST (considering the 2006 annual LST mean for this case) have been calculated for each lightning density class. A profile was computed for the altitude and lightning densities DEMs. CG lightning DEMs were obtained by interpolation over the density grid. The profile was done by looking the preferential direction of the wind at the elevated region (SEMC 2002).

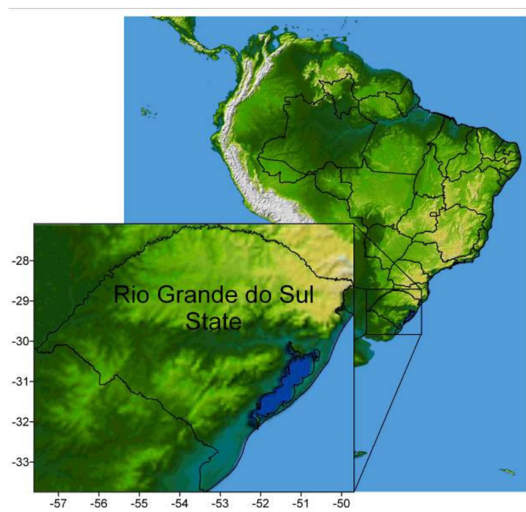

Figure 1. Study region: Rio Grande do Sul, southern Brazilian State. Color scale from green to yellow indicates increasing altitudes.

For the soil analysis, the mean positive, negative and total CG lightning density, as well as the mean peak current for both polarity, was obtained for each soil type class. Soil information (granulometry and metal concentration) was obtained at EMBRAPA website and was used as a parameter to analyze soil conductivity.

Altitude effects on lightning activity was also been analyzed on a temporal perspective. Lightning time frequencies were made over higher regions (over 900 meters) and lower regions (up to 500 meters).

3. RESULTS AND DISCUSSION

3.1 Topographic Effects on Lightning

The Figure 2 shows the CG lightning distribution over the topography of the studied region. By analyzing the entire region, CG lightning seems not to have any correlation to the altitude, except at the Middle-East region, where it can be seen an increase on CG lightning density, which could result from the altitude features (which present relative high values at this region and also a particular shape which leads to a air flux canalization). The analysis inside this region (defined by the black rectangle in the Figure 2) do not show relations for the lightning activity related to the altitude variations, but gives us interesting results when considering the slope mean inside each CG lightning data class (Figures 3 and 4).

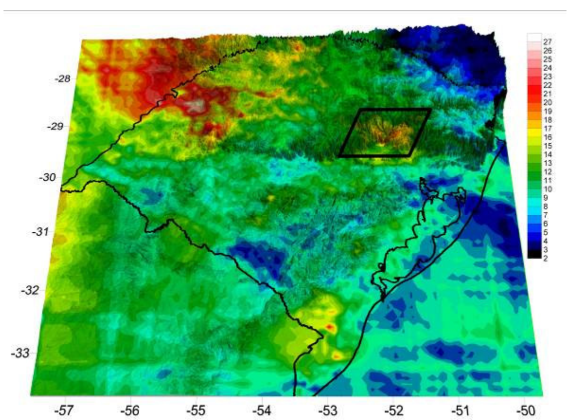

Figure 2. Lightning density overlaid to altitude variations.

These results indicate that the elevation slope has a stronger effect on the beginning of convection and thunderstorm occurrence compared to the altitude. It is explained especially by the orographic forcing mechanism of topography (especially for a conditionally unstable atmosphere, by increasing the flux vertical component) and also could result of differential heating at these regions (Chu & Lin 2000; Smith 1979).

It was also observed an increase in the –CG lightning densities compared to the +CG lightning, following the total CG lighting densities over the elevated region, as it is showed on the profile at Figure 5.

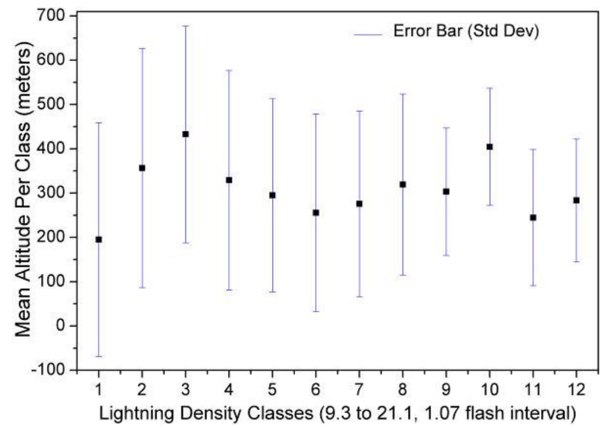

Figure 3. Mean altitude per Lightning density classes.

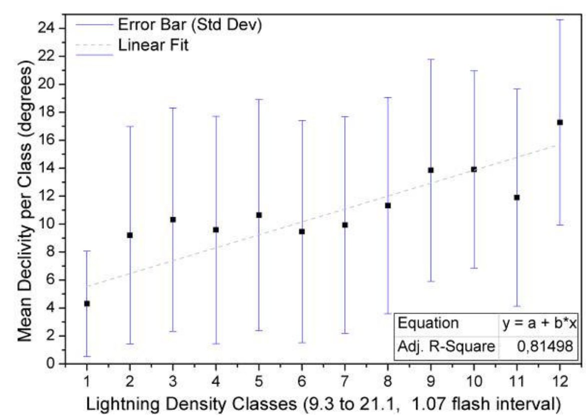

Figure 4. Mean declivity per Lightning density classes.

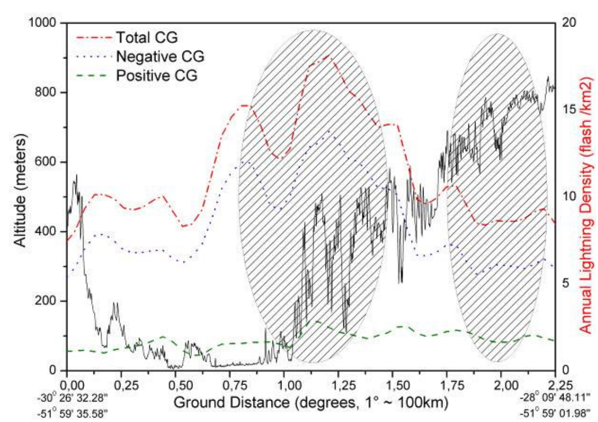

Figure 5. Profile for total, positive and negative CG lightning density and for altitude.

The explanation could be the effect of altitude on the distance of the negative charge center to the ground and was proposed previously by other authors (Schulz & Diendorfer 1999). This idea is supported by the knowledge of the negative charge typical altitude (around -10℃ isotherm) (Krehbiel 1986): over the mountains, isotherms are compressed and the -10℃ isotherm will be nearest to the surface and so, also, the negative charge center. Thus, distance from charge centers and surface will be smaller and could affect lightning occurrence. Also, the orographic forcing described early can be acting, indicating that both effects could occur together on the increase of lightning density.

The temporal variations of CG lightning activity due to altitude show some differences on lightning when considering higher and lower regions (Figure 6). The CG lightning diurnal activity peak occurs early for higher altitudes with a larger value at afternoon when compared to the diurnal activity peak for lower altitudes. This possibly results from the variation on the CG dynamics and similar results have also found early by other authors (Reap 1986, 1991). The smaller amplitude on the two daily peaks for lower regions could result from the Mesoscale Convective Systems dynamics over the Northwest, which have large time duration and reduce the effect of local convective systems on the diurnal peak.

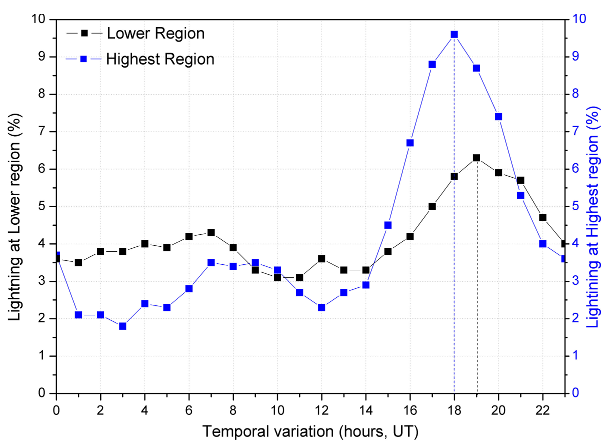

Figure 6. Diurnal variation on lightning activity over highest and lower regions.

3.2 LST Effects on lightning

A first qualitative analysis of the temperature versus CG lightning indicates that no effect of “heat island” appears at the metropolitan region of Porto Alegre (Rio Grande do Sul State’s capital) as it occurs in other large urban areas in Brazil and Europe (Naccarato et al. 2003; Pinto et al. 2004; Soriano & de Pablo 2002). This absence of heat island could possibly result from the shape of the urban area, which appears intercalated with foresting areas (Figure 7) and to the vicinity of the sea. The shape of the urban area affects the increase (or decrease) on the flux convergence resulting from the surface temperature gradient. When analyzing all the RS State considering the mean temperature versus CG lightning classes (Figure 8) it is possible to see a clear increase on the CG lightning activity over regions of higher LST.

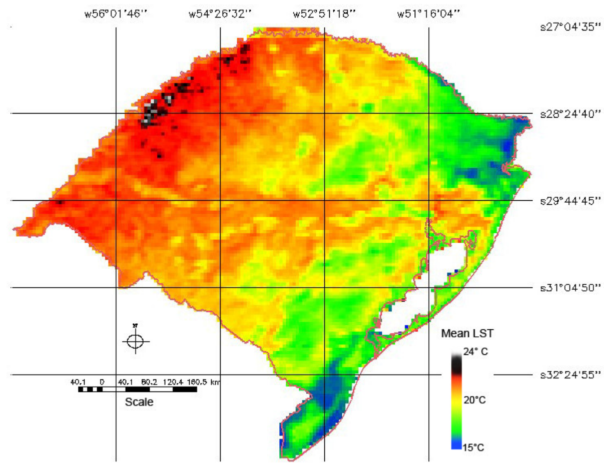

Figure 7. Land Surface Temperature (LST) annual composition (2006). Closed area shows the metropolitan region of Porto Alegre and the urban area shape.

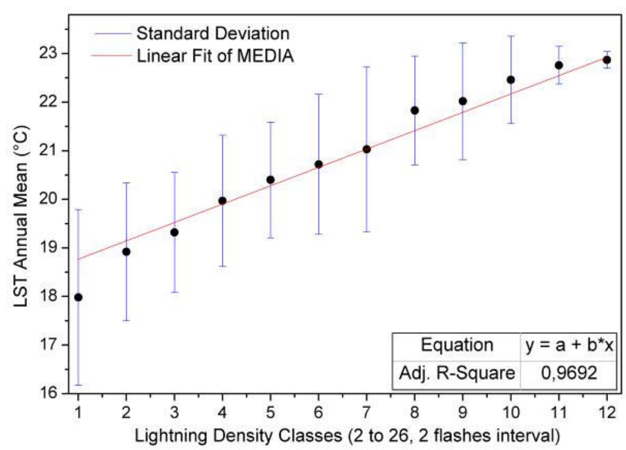

Figure 8. Mean LST per CG lightning density class (2 flashes interval between classes).

The result shows that the LST might have a higher influence on the CG lightning activity, particularly when considering its effects on the thunderstorm development. Some authors have found the same increase on CG lightning activity related to sea surface temperature (SST) and air temperature (De Pablo & Soriano 2002; Price 1994). Also studies regarding the Global Electric Atmospheric Circuit response to the air surface temperature were made and have shown similar results (Williams 1994). It is interesting to point out that the region with the higher temperature coincide to the regions where the Mesoscale Convective Systems (MCS) occurs (Velasco & Fritsch 1987). Thus, the temperature might be related to the development and duration of these large meteorological systems.

3.3 Soil Effects on Lightning Distribution

The soil correlations to CG lightning activity were analyzed regarding the average concentration of metals (g/kg) on each soil class, which is used as a parameter to evaluate its conductivity. The soil was not found to have an influence on CG lightning distribution in this study (Table 1). Total, positive and negative CG lightning have presented small correlations to the soil types.

TABLE 1 – Correlation Index (R) for different lightning parameters.

Variable	*R index*
Total CG density	-0.157
Positive GC density	0.291
Negative CG density	0.015

An interesting analysis refers to the relations between metal concentration and soil granulometry. The results show that, for increasing particle size, a decrease on metal concentration occurs. These agree with the results obtained early and whose theory has solid basement, where clay appear to have more metal concentration and is more efficient on the ionic and cationic exchanges, turning it more conductive. Sand, which is formed by silicates, is more resistive (Becegato & Ferreira 2005).

Although studies in laboratory have shown that conductive increase for soil with higher moisture content, as well as more compacted (Song et al. 1999), the results for this case give indications that moisture effect on conductivity could be less significant. Sandy soils, which are perennial, have also less conductivity. Clayey soils have more water store capacity and, also, are more conductive. So, for regions where rain is occurring, the increase in the conduction will be more expressive for clayey soils than for sandy soils.

TABLE 2 – Correlation Index (R) soil granulometry and metallic material concentration.

Variable	*R index*
Coarse Sand (2 a 0,2 mm)	-0.86357
Sand (0,2 a 0,05 mm)	-0.84335
Silt (0,05 a 0,002 mm)	0.54336
Clay (< 0,002 mm)	0.94357

4. CONCLUSIONS

The results show that altitude and surface temperature might affect the CG lightning distribution in different scales.

The effect of altitude seems to be effective particularly in terms of slope, which act as an orographic forcing, and over a small area where the conditions are more favorable. The altitude could also affect the CG lightning occurrence by a reduction in the distance between charges centers and surface closer to higher elevations.

On a temporal perspective, higher elevation regions appear to trigger thunderstorm occurrence few early than lower regions. Small amplitude on the two daily peaks for lower region seems to be related to the Mesoscale Convective Systems occurrence.

LST has a positive correlation with CG lightning classes and possible affects the MCS occurrence on the North-west of the State, probably leading to stronger systems and extending their duration.

Soil does not show spatial correlation to CG lightning distribution. Finally the granulometry analysis, which is related to the conductivity, showed that moisture could be less important on the conductivity variations for regions where precipitation occurs, since the clayey soils always are more conductive than sandy soils.

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