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The influence of topography on the cloud-to-ground lightning density in South Brazil

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ABSTRACT

A comparative analysis between cloud-to-ground (CG) lightning density and terrain parameters (altitude and terrain slope) in South Brazil is presented. This region is characterized by a contrasting topography, where a mountain chain separates lower (depression) and higher (plateau) landscapes. The altitude and terrain slope data were obtained from the Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM). Two years of CG lightning data (from June 2005 to May 2007) obtained by the Brazilian Lightning Detection Network (BrasilDAT) were used in the study. To avoid intracloud contamination, positive CG flashes with peak currents less than 20 kA were removed from the data set. A relative detection efficiency model was used to correct the lightning data. The results indicate that, for localized areas (following the mountain shape) within this region of Brazil, the CG lightning density is correlated with the terrain slope and not the altitude. This suggests that terrain slope has more influence than altitude on the thunderstorm occurrence and lightning activity. In addition, a temporal analysis shows that over high altitude regions the diurnal variation (amplitude) of lightning activity is stronger and the peak occurs 1 h earlier than over low altitude regions.

1. Introduction

The topography effects on the atmospheric circulation and precipitation are well documented, especially for convective systems, frontal systems (frontogenesis or frontolysis) and for lee cyclogenesis (Egger and Hoinka, 1992; Smith, 1979). Smith (1979) suggested a linear regression that described the increase of the annual precipitation related to the altitude. On the other hand, many other works describe a linear relationship between lightning activity and precipitation (e.g. Ezcurra et al., 2002; Jayaratne and Kuleshov, 2006; Soula and Chauzy, 2001). In consequence, it is reasonable to assume that the same relation can be used to explain the effect of mountains (topography) on lightning activity. This assumption, however, must be understood as a very simple one, since it does not take into account the effects of other variables that may act simultaneously in the formation of thunderstorms and precipitation. A more appropriate model would be one that takes into account different environment variables, giving a better treatment of the altitude effect on both thunderstorm occurrence and precipitation (Smith, 1979). In addition, it is very important to know the prevailing wind direction and how this wind interacts with the mountains. The effects of topography also depend on the orographic jets, which occur under favorable conditions, such as sufficient slope steepness and mountain altitude (Egger and Hoinka, 1992). The topographic effects seem to be particularly related to the local terrain slope, which acts directly in the upward drafts that might trigger thunderstorms.

Some authors have suggested an effect of the altitude on lightning spatial distribution. Pinto Jr. et al. (1999) analyzed the lightning spatial distribution over Southeast Brazil and found a significant relationship between lightning and altitude. Schulz and Diendorfer (1999) found a non-linear relationship between lightning activity and altitude in Austria, with an increase in the CG lightning activity up to 1300 m and a decrease in higher altitudes. Wagner et al. (2006) found a good relationship between lightning and altitude, associated

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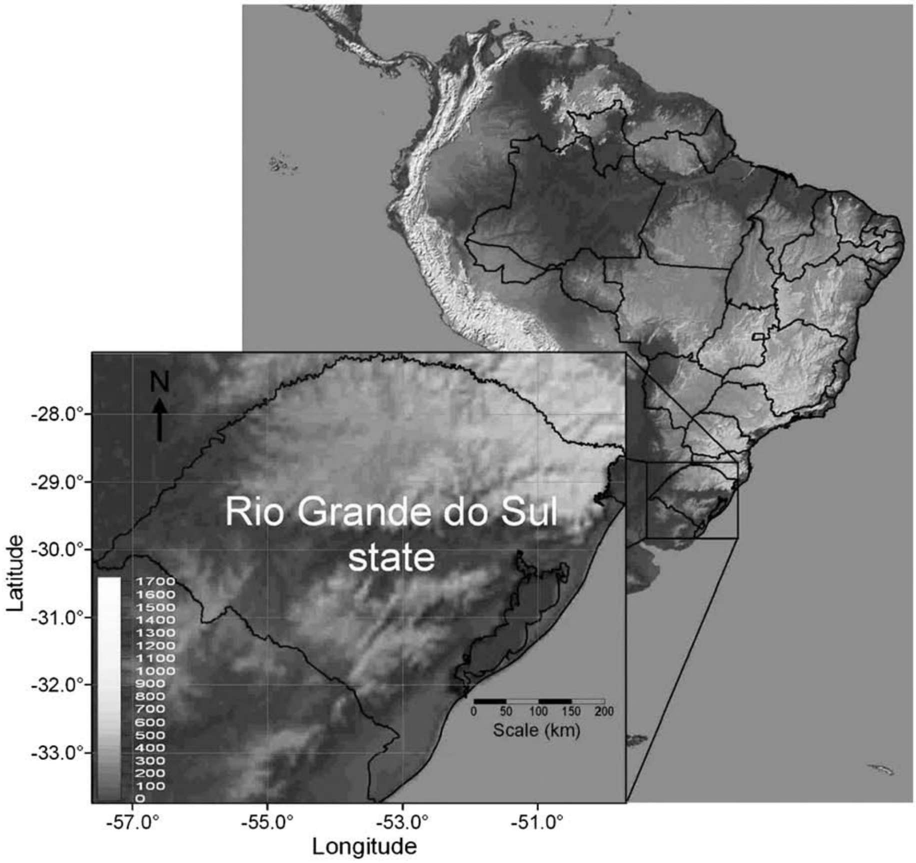

Fig. 1. The region of study: Rio Grande do Sul state. Gray scale (from gray to white) indicates increasing altitudes.

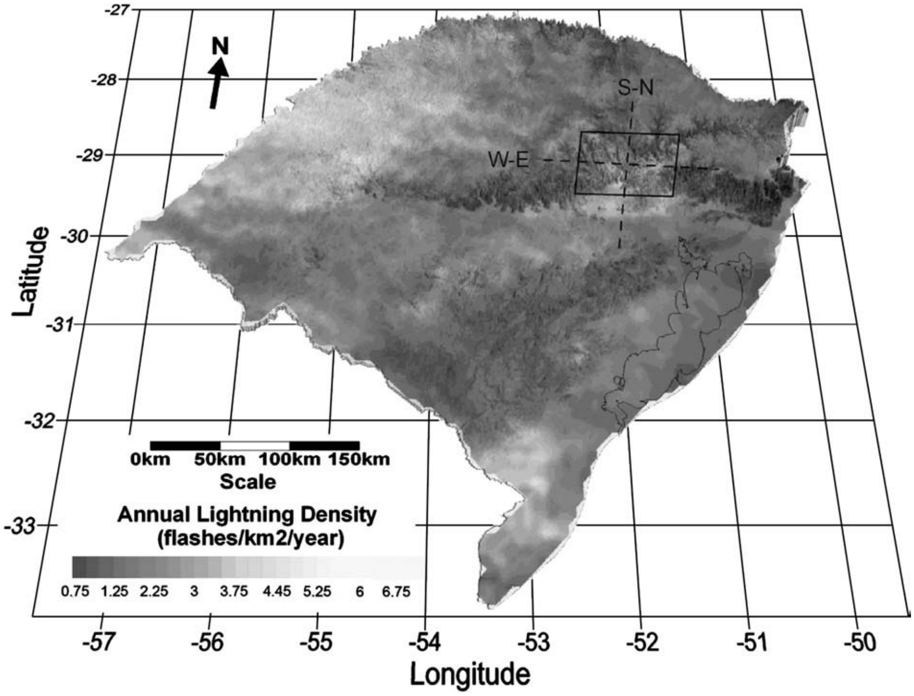

Fig. 2. Double layer map: CG lightning density overlaid to a 3D surface. The black rectangle indicates the high density in elevated regions, which is selected for the analysis of altitude and slope effects. The dashed lines indicate the two topographic profiles also used in the analysis (directions: S–N and W–E).