About the variations of thunderstorm days over the city of Belém, located near the equator, in the last 50 years

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ABSTRACT: Belém is the capital of the state of Pará, in the North region of Brazil. It is located at 1°27'S 48°30' W, near to the equator. The thunderstorm activity in this region receives direct influence of global climatological parameters like ENSO (El Niño Southern Oscillation) and Tropical Atlantic Dipole. It may be also influenced by variations in solar activity, large scale volcanic eruptions, anthropogenic activity (Greenhouse Gases GHG), PDO (Pacific Decadal Oscillation), QBO (Quasi-biennial oscillation), average global air temperature (from Climatic Research Unit), and local air temperature. To find the relative influence of these parameters on atmospheric electrical activity in Belém, thunderstorm days (TD), also called keraunic level, records were used. The TD observations began in the 1950s and continued until nowadays allowing a robust statistical multivariate regression of the keraunic level in the city with respect to these parameters. Preliminary results show a positive trend of TD over the period that is correlated mainly with anthropogenic activity, followed by temperature of the city, ENSO and average global temperature. The monthly average TD presents its maximum in autumn and minimum in spring, while the monthly average air temperature of the city has a maximum in spring and minimum in summer. It was also found a strong (weak) trend to observe high TD in summer (winter) in La Niña events as compared to El Niño events.

1. INTRODUCTION

The damage caused by lightning is evident in Brazil cities. Pinto Jr. [2005] estimated that the damage caused by lightning is approximately US$ 300 million each year. This was one of the motivations to study the influence of climatic variations in atmospheric electricity.

According to the IPCC [2007], the projected temperature increase is of 1° to 4°C in the XXI century, mainly due to the increased concentration of greenhouse gases. Thus, is it possible to project the variation of thunderstorm days in Belém in the future?

Thunderstorm days (TD) serve as tool to analyze the behavior of the global electric circuit [Molinié and Pontikis, 1995]. For this reason, they were studied in several regions of the globe, aiming to classify the behavior of lightning.

In the United States, Changnon Jr., [1985, 1988a, 1988b and 2003] mapped the temporal and zonal characteristics of lightning at various stations in the United States based on the values of TD. The author divided the United States in five areas of similarities of thunder events. In Poland, Bielec, Z., [2001], based on 100 years

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of observations correlated TD with precipitation. In China, Zheng et al. [2010] performed climatological analysis using data from various weather stations identifying that thunder occurrences was highest during the 1980s, decreased during the 1990s, and increased slightly afterwards.

In Brazil, Pinto and Pinto [2008] used data from TD and lightning activity in São Paulo to determine an increase in lightning activity with temperature.

If by one side thunder events are used for the analysis of lightning activity, by another side, Lean and Rind [2008, 2009] used the most recently available characterizations of ENSO, volcanic aerosols, solar irradiance and anthropogenic influences, to model the variation of global temperature.

The aim of this study is to compare TD with local and global parameters to find convergences and similarities, drawing and designing a climate evolution in the near future.

2. METHODOLOGY AND DATA

The empirical model is constructed by the characterization of the variables described below, where all variables have the average equals zero, and the standard deviation is one. Then multiple linear regression analysis was performed to best fit the monthly mean thunderstorm days (TD) since 1953 (Figure 1), attributing the relative contribution of each variable:

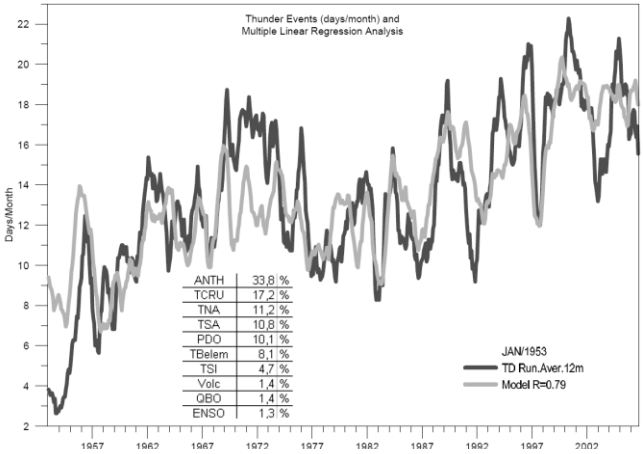

Figure 1 – TD monthly values and the corresponding best fit values obtained from multiple regression for the period from 1953 to 2006.

ANTH: Anthropogenic data are the net effect of 8 components, GHG, land use, snow albedo changes, tropospheric aerosols and others [Hansen et al., 2007);

TCRU: Global temperature constructed by the University of East Anglia Climatic Research Unit [Brohan et al., 2006];

TNA: Tropical North Atlantic Ocean is an indicator of the surface temperatures in the box 55°W - 15°W, 5°N - 25°N [Enfield et al., 1999];

TSA: Tropical South Atlantic Ocean is an indicator of the surface temperatures in the box 30°W - 10°E, 20°S - 0° [Enfield et al., 1999];

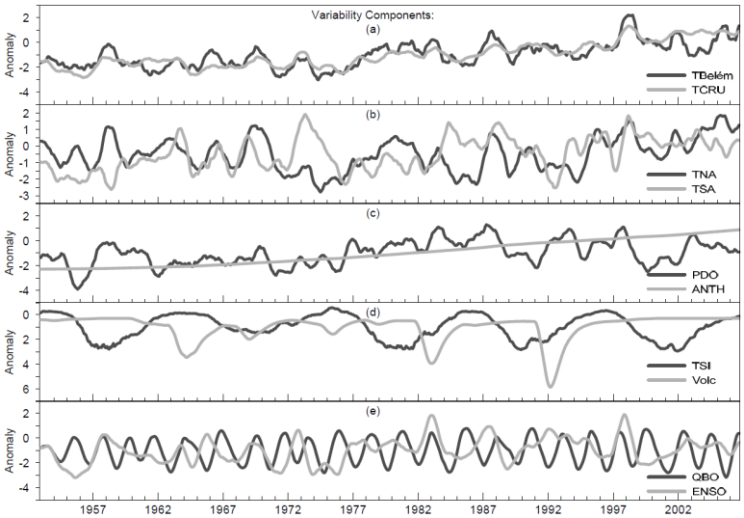

Figure 2 – Anomaly values of the different variables used in the regression in Figure 1.

PDO: Pacific Decadal Oscillation is defined by the leading principal component of monthly SSTs in the North Pacific poleward of 20°N [Zhang et al. 1997];

TBelém: Mean Monthly Temperature of the military airport in Belém city;

TSI: Solar data are consistent with IPCC [2007], the monthly irradiance are estimated from competing effects of sunspots and faculae in observations made by space-based radiometers, extended into the past using solar flux transport simulations [Wang et al., 2005].

Volc: Vocanic aerosols in the stratosphere are compiled by Sato et al., [1993] and updated from giss.nasa.gov;

QBO: Quasi-biennial Oscillation are the easterly and westerly phases of stratospheric zonal winds over the Tropics, calculated at PSD (from the zonal average of the 30mb zonal wind at the equator as computed from the NCEP/NCAR Reanalysis);

ENSO: El Niño Southern Oscillation are a weighted average of the main ENSO features contained in sea-level pressure, surface wind, surface sea, air temperature and cloudiness [Wolter and Timlin, 1998].

The average monthly data of each variable is shown in Figure 2.

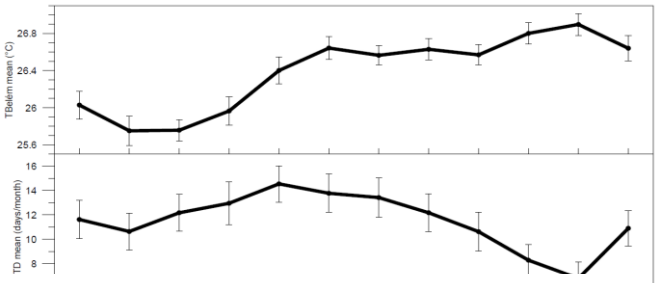

Figure 3 – Seasonal Mean (1950 to 2006) of TD and

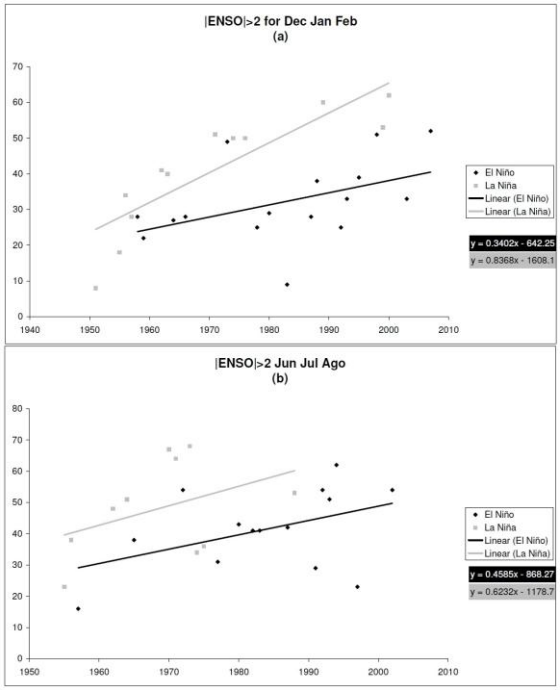

Figure 4 – TD in El Niño and La Niña events, (a) Summer and (b) Winter.

3. RESULTS

Although the model results in Figure 1 fits quite well the observations, there are some disagreement in two periods: from 1953 to 1956, when the first observations were done and some variations in the measurement procedure can be expected; and from 1970 to 1975, when it is believed that another factor not listed as an input into the model can be acting.

Figure 2a shows the temperature in Belém and the global temperature. We can observe a good similarity, suggesting a significant influence of global scale in a local scale.

The seasonal means in Figure 3 shows highest TD in May, while the highest temperatures in Belém occur in November with lowest TD.

Finally, the comparison in Figure 4 indicates that in summer (Dec, Jan and Feb) the influence of La Niña is significantly larger than El Niño, while in winter (Jun, Jul and Aug) the difference between El Niño and La Niña is not so significant.

4. CONCLUSIONS

Analyzing the results, it is observed that Belém, a city located in the tropical region, has high values of TD, which can be described as influenced by various factors. The annual variation of local monthly average temperature roughly follows the global temperature. The phenomenon La Niña increases the days of thunderstorms mainly during the summer months.

The methodology presented here should be applied to other cities in the tropical region of Brazil in a near future, contributing to this study.

ACKNOWLEDGMENTS

Appreciated are the efforts of the many scientists like Judith L. Lean and Marco A.S. Ferro, and CNPq for financial support.

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