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ANALYSIS OF EXTREME EVENTS OF LIGHTNING AND RAINFALL ON THE PARAGUAY BASIN

Robson Jaques[1,2], Haroldo Atanasio de Souza Pereira Leite[1], Moacir Lacerda[1,2], Julio Cesar Paro[1,3] Clovis Lasta Fritzen[1,2]
[1] Laboratório de Ciências Atmosféricas – LCA – CCET – UFMS (www.lca.ufms.br)
[2] Programa de Pós Graduação em Tecnologias Ambientais – PGTA – CCET – UFMS
[3] Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso do Sul – IFMS/Campo Grande

Abstract – It is presented a methodology for analysis of extreme events in the Paraguay River Basin. The number of electric discharges and stratiform and convective precipitation data are crossed in the search for correlations between them. Extreme events can be found from the establishment of average precipitation and the number of discharges recorded in the same area. Spatial patterns of distribution for electric discharges are detected and some causes for these patterns are discussed. There is a high correlation between precipitation and the number of lightning. The results indicate also that orography and the flooded area may be important factors in defining patterns of precipitation and electric discharges.

1 - INTRODUCTION

The starting point of this work was to analyze the accumulated precipitation, electric discharges, stratiform precipitation and convective precipitation, from September 2007 to July 2010, totalizing 35 months of row data in the Paraguay River Basin (BP). The main objectives were:

a) to show the spatial distribution of the accumulated precipitation; incidence of electric discharges; stratiform precipitation and convective precipitation, and by this study to present the behavior of these variables, establishing a correlation between the number of electric discharges and the convective precipitation in the BP;

b) to detect both extreme precipitation and electric discharges events in the studied area.

The data structure was provided by the data network STARNET/IAG/USP (STARNET, 2010) [1] and the sensor TRMM/NASA [2]. The software XPLOT was developed in the LCA (Laboratory of Atmospheric Sciences) to organize and distribute all the information collected during the study period. It is possible to correlate the evolutive process of the mean convective precipitations and the number of electric discharges, both for the dry period as well as for the rainy period in the region of study.

2 - BASIC CONSIDERATIONS

2.1 INTRODUCTION

The study region is located between latitudes 14° S and 28° S and longitudes 51° W and 68° W in the southern hemisphere. It covers the states of Mato Grosso and Mato Grosso do Sul in Brazil and also other neighboring countries: Argentina, Paraguay and Bolivia.

The basis of our study was to organize data of accumulated precipitation, stratiform and convective precipitation and the number of electric discharges. For this process it was used the data obtained from the networks and the XPLOT platform to accomplish the detection and correlation analysis of extreme events.

2.2 - BASIC CONSIDERATION

The XPLOT platform is a software for data processing mainly used to work with the variables involved in our study. The main function of this platform was to distribute the data spatially and temporally on the BP during the study period, and thereafter classify the data collected monthly.

The distribution process of each measurement was: a) temporally separate in intervals of three hours, which corresponds to time intervals provided by the sensor PR of TRMM/NASA for the rainfall measure; b) for each measured point in the basin, the corresponding pixel had a distance of 0.25° of latitude by 0.25 ° of longitude, resulting in an area of approximately 713 km ² per quadrant; c) for each point of this area, it was 3-hour measurement time during the whole period.

From this point the images containing accumulated precipitation; electric discharges; stratiform precipitation and the convective precipitation were processed for each of the 35 months. To illustrate this procedure, Figure 1 presents an example of data processing that exemplify the dry period (dry season) and the rainy period in the BP region in September 2007 and December 2007 respectively.

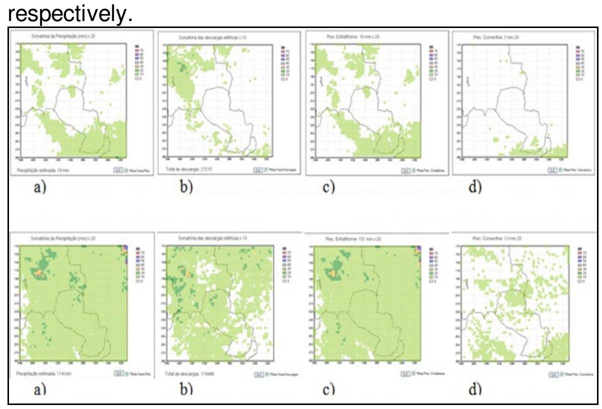


Figure 1 – Top: dry period September 2007; bottom: rainy period December 2007. a) accumulated precipitation; b) electric discharges; c) stratiform precipitation; d) convective precipitation

The next figure, Figure 2, exhibits the monthly distribution of the variables during the period of study.

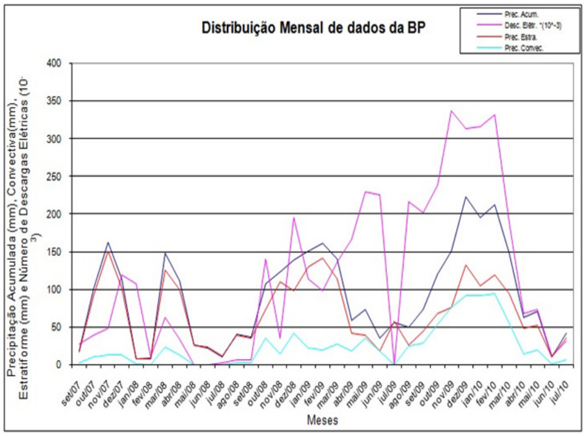


Figure 2 - Monthly distribution of the variables during the period of study. In the right up corner: Accumulated Rainfall (Prec. Acum), Electric discharge * 10^3 (Desc. Eletr.), Stratiform Rainfall (Prec. Estra.), Convective Rainfall (Prec. Convec.) (mm).

3 – DEVELOPMENT

The total amount of non-zero measurements processed in this study is about 30 million. These measurements were analyzed according to the method proposed by Collischonn (2001), considering as extreme events the periods where the mean precipitation reaches 100 mm daily and when the average daily precipitation is around 30 mm [4]. After analyze the accumulated, convective and stratiform precipitation, and the number of electric discharges for the period of study, the correlation was made between the data of convective precipitation and the number of electric discharges. The data is divided in two periods: the dry and the rainy period. Due to some lack of information in some months according to STARNET, we performed a correction in the data using the moving average procedure to eliminate possible distortions.

4 - RESULTS

After detecting points where extreme events occurred, each point was analyzed in the spatial and temporal contexts. After that it was possible to locate the storm that originated the extreme event and the history of the measurements in this point. This is shown in table 1 and 2 and Figures 3 and 4. Tables 1 and 2 list the four extreme events that occurred in the studied period.

Time	DD/MM/YY	Lat.(º)	Long.(º)	Electric discharges (period of 3 hours)
3PM-6PM	11/5/2009	-24,5	-57,75	1294
6PM-9PM	25/5/2009	-24,25	-51,25	1604
3PM-6PM	14/10/2009	-14,5	-51,5	1470
6AM-9AM	22/2/2010	-24,25	-59,25	1416

Table 1- List of electric discharges extreme events.

Time	DD/MM/YY	Lat.(º)	Long.(º)	Prec. (mm)
9AM-12PM	9/2/2010	-19	-57,75	220
6AM-9AM	11/2/2010	-20,5	-51,25	186
9PM-0AM	29/3/2010	-25,5	-51,5	201
9PM-0AM	29/3/2010	-25,5	-59,25	202

Table 2 – List of precipitation extreme events.

Figures 3, 4 and 5 show the location of the extreme events listed in Tables 1 and 2.

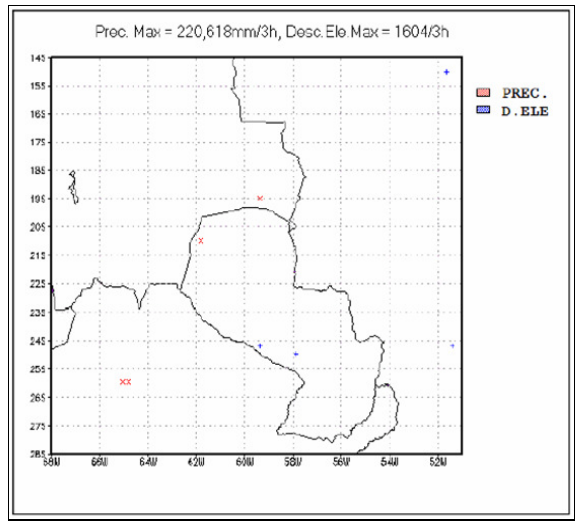


Figure 3 – Location of the most significant extreme events in the Paraguay River Basin. The red x indicates extreme events of precipitation and the blue + represents the extreme events of electric discharges.

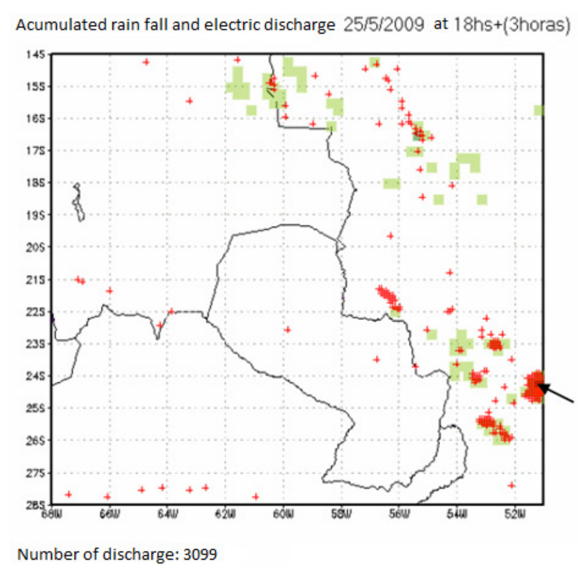
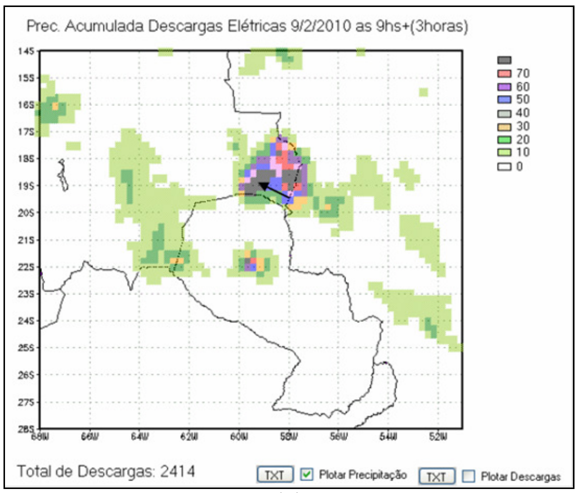


Figure 4 – Extreme event occurred on 2009/05/25 from 6 PM to 9 PM totalizing 1604 electric discharges (red plus signs, pointed by arrow) and Accumulated rainfall (green squares) (0 to 10 mm).

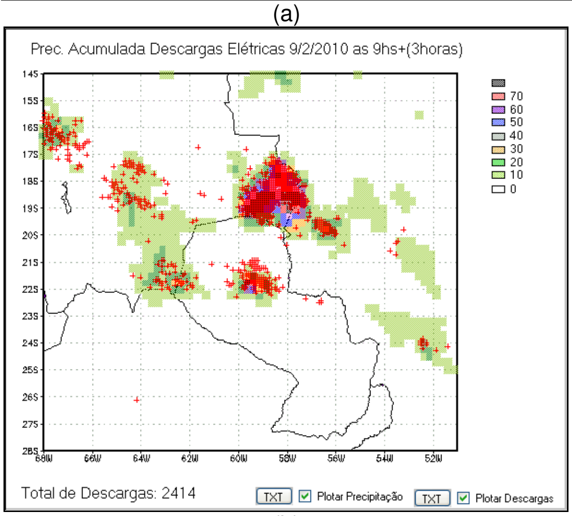
The next step was to study the possible correlation between convective precipitation and electric discharges. A process of correction of moving average was necessary due to some lack of information where no electric discharges were detected.

Figure 6 shows the distribution of electric discharges and the convective precipitation during the dry season. In the sequence, Figure 7 presents the correlation between these data.

As we can see in Figure 7, that the R factor of the correlation between the convective precipitation and the number of electric discharges during the dry period is 93.2%.



(a)



(b)

Figure 5 – Extreme event that occurred on 2010/12/09 from 9 AM to 12 PME. a) Accumulated rain fall; b) Accumulated rain fall and lightning. There were 2414 electric discharges during 3 hours.

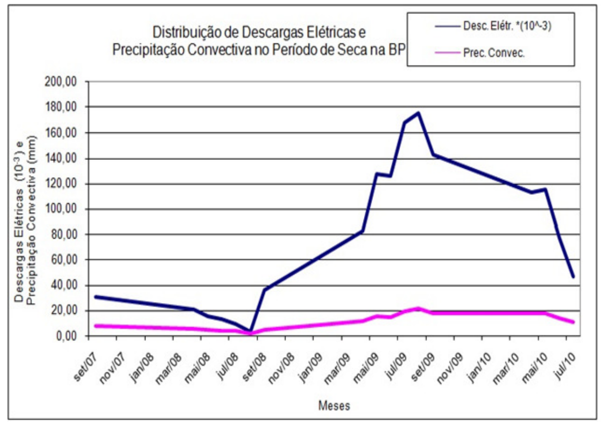


Figure 6 – Distribution of convective precipitation and electric discharges during the dry season in the Paraguay River Basin. Electric Discharge (Desc. Eletr.*10^3) and Convective Rain Fall (Prec. Convec.).

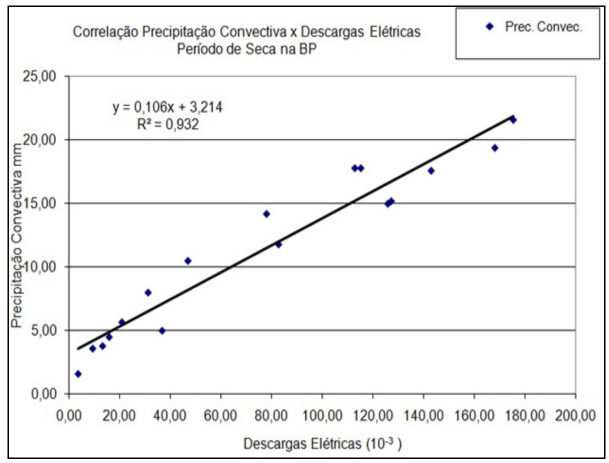


Figure 7 – Correlation between convective precipitation (y axis) and electric discharges (x axis) in the dry period.

Figure 8 and Figure 9 present the same situation, now during the rainy period.

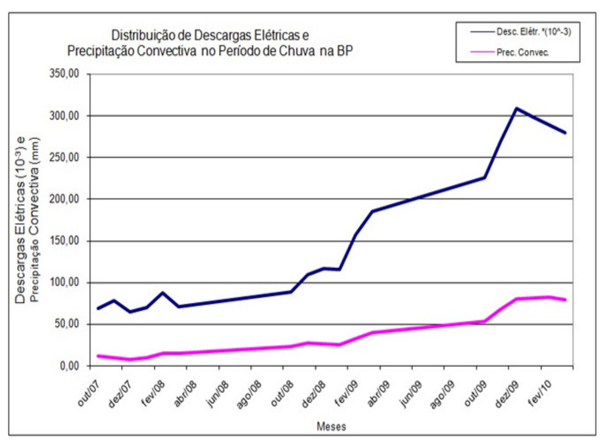


Figure 8- Distribution of convective precipitation and electric discharges during the rainy season in the Paraguay River Basin. Electric Discharge (Desc. Eletr.*10^3) and Convective Rain Fall (Prec. Convec.).

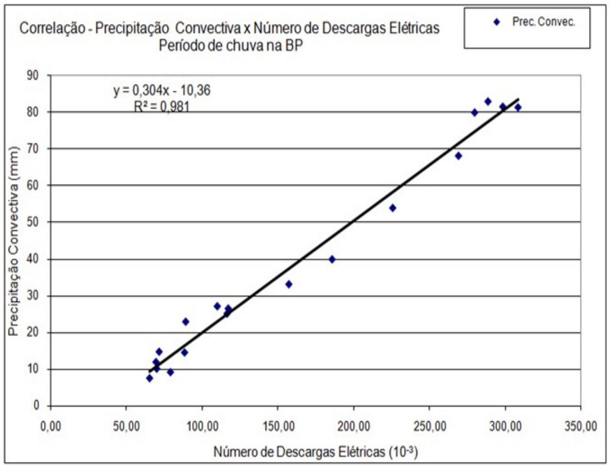


Figure 9 – Correlation between convective precipitation (rainfall) (y axis) electric discharges (x axis) in the rainy period.

During the rainy period, the correlation between the convective precipitation and the number of electric discharges, the correlation coefficient is 98.1%.

We also analyzed the data without performing the correction with the moving average method. We considered all the data during the study period, including the dry and the rainy periods.

In this case the correlation between the convective precipitation and the number of electric discharges is 79.8%. Figure 10 presents this information.

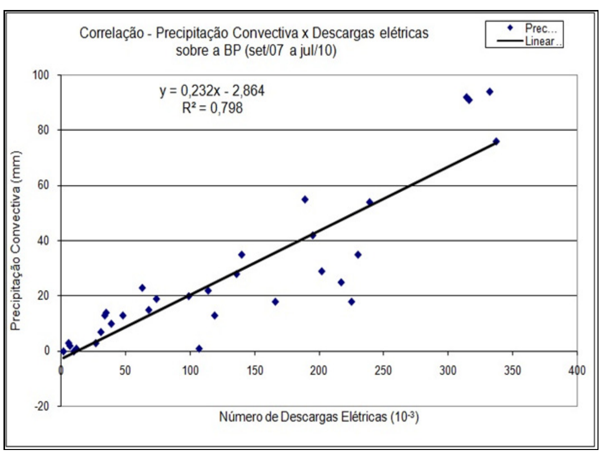


Figure 10 – Correlation between the convective precipitation and the number of electric discharges during all the study period without corrections

The figure 11 shows the dispersion diagram between the rainfall measured on ground and rainfall estimated by PR of TRMM. This way, it is possible to correct the data obtained each month by the sensor TRMM in order to obtain a measurement for the accumulated precipitation on ground. Because of the correlation between the number of electric discharges and estimated precipitation and the estimated precipitation and measured precipitation on ground, it is possible to estimate the measured precipitation by measuring the electrical discharges [5].

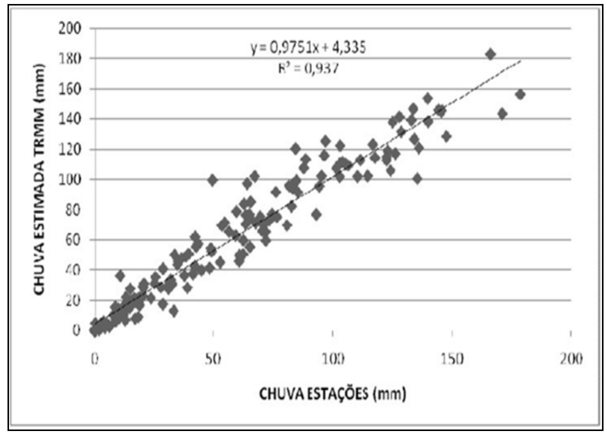


Figure 11 – Diagram showing the dispersion with average precipitation data, from ground stations and average data about the estimated precipitation from TRMM for the Paraguay River Basin (Padovani, 2010). Measured rainfall (mm) (x-axis). Estimated rainfall by PR-TRMM (y-axis).

5 - ANALYSIS OF THE RESULTS

As shown in Figure 1, the data imply that the spatial distribution of accumulated precipitation is similar to the stratiform precipitation. It is also noticed that amount of stratiform precipitation is higher than the convective precipitation amount. The spatial distribution of electric discharges (observed in samples) does not resemble the distribution of accumulated precipitation, except for the fact that in the central region of the Paraguay River Basin the amount of precipitation and electric discharges are equally low during the dry and the rainy period.

The accumulated precipitation is concentrated mainly in the north and south regions of the studied area. The electric discharges are concentrated in north and in the west of the Paraguay River Basin, especially on the Andes Cordillera.

Extreme events were not detected in sequential samples of three hours. These events occurred in short intervals of duration, as found in [4].

The samples show that the convective precipitation is concentrated in the southeast end of BP for both periods: dry and rainy.

According to the data, the spatial distribution of these quantities depends preponderantly on the region of the basin. We can infer that this occurs due to the physical characteristics of each region that favor or not the occurrence of extreme events. The Andes favor the electric discharges where as the southeast region of the basin favors the convective precipitation.

Dividing the study period in the dry and rainy periods the data show a strong correlation between the convective precipitation and the number of electric discharges. For the dry season the correlation is 93.2% (Figure 7) and it is 98.1% (Figure 9) for the rainy period.

Finding a way to verify these correlations for other periods or for a longer period of time is a subject for future studies. All this information could help cutting down expenses on the installation of pluviometers through the basin and also, provides information about extreme events that could help the population.

6 - CONCLUSION

For the 35-month period of analyzed data, the obtained correlations between the convective precipitation and the number of electric discharges are 98.1% for the rainy period and 93.2% for the dry period in the Paraguay River Basin. This allow the determination of rainfall amount by analyzing the number of electric discharges. The extreme events presented no correlation between the electric discharges and the amount of precipitation.

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Main author
Name: Moacir Lacerda
Address: UFMS- CCET
Av. Gen. Costa e Silva, sn Cidade Universitária – Campo Grande MS - Brasil
Fax: +55 67 99810503 (Mobil) +55 67 3345 7540 or 33457035 E-mail: moacir.lacerda@ufms.br
copy to moacirlacerda@gmail.com