

Variability space-temporal of annual precipitation of wet and dry period in the Paraíba state

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Abstract

Rainfall is considered an important climatological variable in the semiarid region of Brazil, mainly due to irregularity in its temporal and spatial distribution. It has been aimed at achieving the analysis of spatio-temporal variability of rainfall, maximum, minimum and average annual for the State of Paraíba. Data were used with 30 or more years of observation, analysis was carried out for consistency and homogeneity. To analyze the spatial distribution was used Surfer and their statistical software using the Kriging interpolation method which is considered a good data interpolation methodology and producing maps. From the results it is observed that in January were the most significant rainfall and isolated regions of the Sertão and Alto Sertão Paraíba. In February the distribution already became homogeneous. The months of March and April are the rainy months in every state and from May to Augusts the highest rainfall concentrated in the eastern and southern coastal strip. September considered the driest month and throughout the year rainfall occurred in isolation. The annual distribution showed high spatial variability of rainfall in the central sector of the state with minor fluctuations ranging from 300 to 500mm, in the Sertão and Alto Sertão flowed from 700 to 900mm; in Brejo and Agreste from 700 to 1,200 mm; and Litoral of 1,200 to 1,600mm.

Keywords: Rainfall, geostatistics, kriging, spatial distribution.

1. Introduction

Rainfall is important climatological variable in the semiarid region of Brazil, mainly due to irregularities in the temporal and spatial distribution, being considered limiting factors to further development and stabilization of agricultural production (Moraes, 2005).

The spatial and temporal variations are inherent characteristics of the weather and climate. The temporal variation is a feature that should be studied with particularity and in chronological different scales. These studies will

allow the climate of knowledge in the past, present, and even calculating prognoses and diagnoses for future climate situations from mathematical models used (Fernando, 2008).

Rainfall in Northeast Brazil (NEB) results from the coupling of various weather systems of various scales almost periodic, as the Intertropical Convergence Zone (Uvo, 1989), Vortice of Superior Air (Kousky and Gan, 1981), the Front Systems (Kousky, 1979), and the Eastern Disorders (Espinoza, 1996), that can be modified by the physiographic characteristics of the region and atmospheric anomalies planetary scale, stand out the dipole of the Atlantic and the ENSO,

which modify the frequency, intensity and spatial distribution of these systems, directly affecting agriculture, livestock, irrigation and water resources (Araújo et al., 2006). Thus, Brazil's Northeast region is considered as an anomalous region with regard to the spatial and temporal distribution of precipitation throughout the year (Souza et al., 1998).

In Northeast Brazil (NEB), is found throughout the year a short period of 3 to 4 months with rainfall and a long period, usually called dry season, exhibiting high capacity evapotranspiration throughout the year, featuring a semi-arid climate. The semi-arid northeast stands out for very irregular annual average rainfall and with great spatial variability. The average rainfall ranging between 200-700 mm.year⁻¹, compared to other semi-arid regions of the world, these rainfall is not so low, however the temperatures are high, and losses by evapotranspiration are accentuated (Cabral and Santos, 2007). According to Araújo et al. (2008) is little known that Paraíba is the Northeastern state that has the highest spatial variability in rainfall, since the Agreste/Coast has an average annual rainfall above 1083.4 mm.year⁻¹, followed by Sertão with mean values of 821.9 mm.year⁻¹, and finally Cariri/Curimataú mean reaching up to 516.1 mm.year⁻¹.

As Meis et al. (1981), may analyze precipitation over time of different ways, enabling the recognition of their general behavior of their usual and extreme standards. According to Medeiros et al. (2014), based on irregular rainfall it is necessary monitoring through the use of climate indices, being able to develop a monitoring system of the characteristics of periods of dry or rainy, with annual, seasonal or monthly information, with which it can deeply know the weather of a region, and verify the impact that global climate cause on local rainfall distribution, ie, the regionalization of the precipitation for a given location. As an example of work that analyzed the spatial and temporal distribution of precipitation, can cite the studies of Silva et al. (2010), Nery et al. (1998), Andrade

et al. (1999), Sousa and Nery (2002), Keller et al. (2005) and Nery and Alves (2009).

Kriging geostatistical comprises a set of tuning techniques used to approximate data by the principle that: fixed point in space, the points in its surroundings are more relevant than those further away. This presupposes the existence of dependence between data, demanding to know how far this spatially correlated matter (Isaaks and Srivastava, 1989). The technique consists in estimating mean values and also a measure of accuracy of the estimate. Their weights are calculated based on the distance between the sample and the estimated point; the geometric and spatial continuity of the joint arrangement (Bettini, 2007).

As Jakob (2012), the kriging is considered a good data interpolation methodology. It uses the tabular data and its geographic position to calculate the interpolations. Using the principle of Tobler's First Law of Geography, who says closer analysis units to each other are more alike than more remote units, the kriging uses mathematical functions to add greater weight in positions closer to the sampling points and lower weights in more distant locations, and thus create new points interpolated based on those linear combinations of data.

So this work aims at realization of the analysis of spatial and temporal variability of rainfall, the maximum, minimum and average annual for the State of Paraíba.

2. Materials and methods

The state of Paraíba which is located in northeastern Brazil, and has an area of 56,372 square kilometers, which corresponds to 0.662% of the country. Its position is between parallels 6°02'12" to 8°19'18" S and between the meridians 34°45'54" and 38°45'45" W. To the north, borders on the state of Rio Grande do Norte; east, with the Atlantic Ocean; west with the state of Ceará; and south, with the state of Pernambuco (Francisco, 2010).

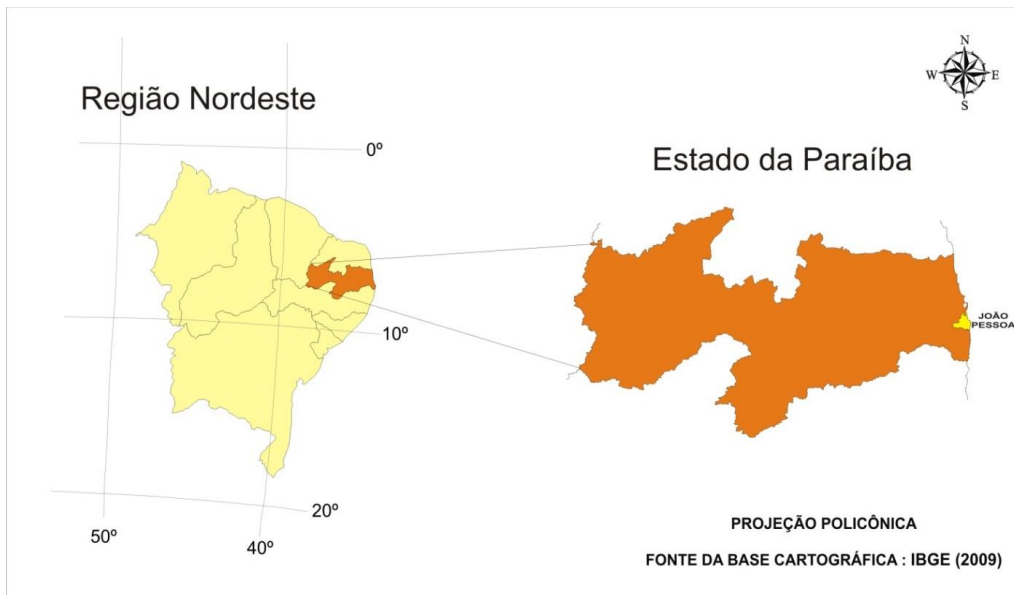


Figure 1 - Location of the study area. Source: Adapted from IBGE (2009).

The climate is characterized by high averages temperatures between 22 to 30°C and a very small annual temperature range, due to the low latitude and elevation (<700m). Rainfall varies from 400 to 800mm annually, in semi-arid inland areas and the coastal region, wetter, and can exceed the 1600mm (Varejão-Silva et al., 1984).

The terrain of the State of Paraíba (Figure 2) presents a well-diversified general, becoming for different forms of relief worked by different processes, acting under different

climates and on little or very different rocks. With regard to the geomorphology, there are two groups formed by climatic types more significant Status: humid, sub-humid and semi-arid. The current use and vegetation cover characterized by forest formations set to open tree shrubby savanna, shrubby savanna tree closed, closed savanna tree, coastal tableland, swamps, humid forest, lowland forest, rainforest and restinga (PARAÍBA, 2006).

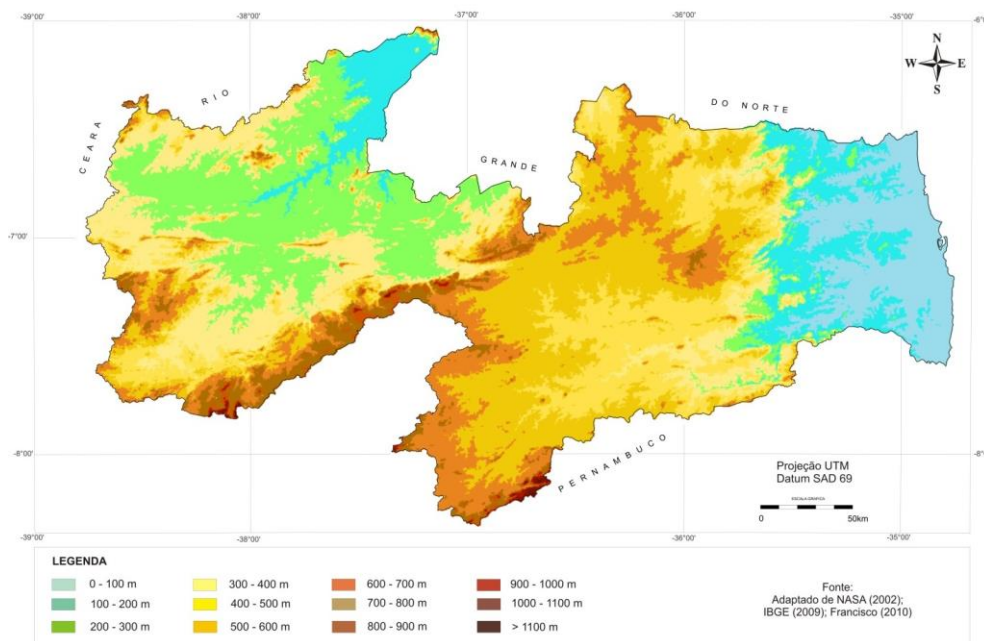


Figure 2 - Hypsometric map of the state of Paraíba. Font: Francisco et al. (2014).

The methodology used up the monthly totals of precipitation obtained from rain gauges the Basic Northeast Network, first implemented by the Northeast Development Agency (SUDENE, 1990), later in 1992 the rainfall network was transferred to the State of Paraíba for the Executive Agency Management of the state of Paraíba Waters

(AESAPB), there were joints of such series and by selecting the stations that have 30 or more years of observations. This fact was the choice for unifying intervals between stations, seen that the spacings are large, as spatiotemporal distribution demonstrate in Figure 3.

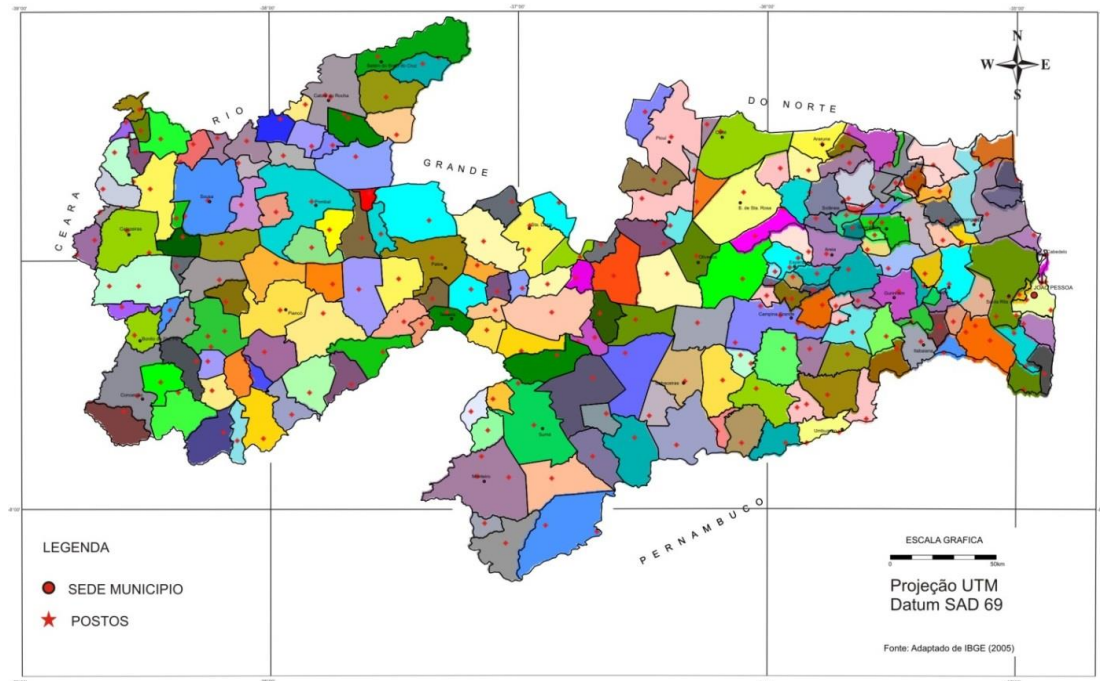


Figure 3 - Spatial distribution of rainfall stations in the state of Paraíba.

Use of the data is elapsed analysis regarding the consistency, homogeneity and gap filling in each series, in addition to the series ever published by SUDENE by the year 1985. It was not possible to adopt in this work, a period of common observation all locations, given the difference in the number of years and/or even the number of posts that entail such procedure due to start difference operation between stations. Thus, for each locality with the series of observation greater than or equal to thirty years, it has been considered for the available period, independently from the beginning.

A spreadsheet with the data obtained and calculated monthly and annual averages was prepared. The wet and dry quarter were defined using spreadsheets of monthly rainfall of all the municipalities and defined as the

largest and smallest values of rainfall, thus following the rainfall patterns in the state of Paraíba.

To analyze the spatial distribution of rainfall was used called Kriging interpolation method to determine the monthly average, annual mean, standard deviation, coefficient of variation, and seasonal averages of dry and rainy seasons. According Flores (2000), this method enables better representation of the continuity of geographic phenomena and, more specifically, the rain and heat phenomenon, thus enabling a better spatial distribution of rainfall regimes prevalent in the study area at different scales of analysis. According to Silva et al. (2010) This method was chosen because it is one of the most efficient and used in studies on spatial data interpolation (Mello et al., 2003; Remacre et

al., 2008). The kriging estimator is obtained, according Matheron (1963), according to equation 1:

$$Z^*(x_0) = \sum_{i=1}^n \lambda_i Z(X_i) \quad (1)$$

where: $Z^*(X_0)$ is the attribute of the estimated variable at the point; λ_i are the weights of kriging; $Z(X_i)$ is the observed value of the variable Z in i -th point.

For ordinary kriging should be satisfy the condition that:

$$\sum_{i=1}^n \lambda_i = 1$$

The weights are obtained by solving a system of linear equations of the type $AX = B$, called the kriging system according Rocha et al. (2007) can be written as follows:

$$\begin{bmatrix} \gamma(x_1; x_1) & \cdots & \gamma(x_1; x_n) & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \gamma(x_n; x_1) & \cdots & \gamma(x_n; x_n) & 1 \\ 1 & \cdots & 1 & 0 \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \vdots \\ \lambda_n \\ \mu \end{bmatrix} = \begin{bmatrix} \gamma(x_1; x_0) \\ \vdots \\ \gamma(x_n; x_0) \\ 1 \end{bmatrix}$$

Where: $\gamma(x_n, x_n)$ is the spatial variance of the n -th sample with respect to itself; μ is the Lagrange Multiplier; $\gamma(x_n, x_0)$ is the spatial variance between the n th sample and the point x_0 to be estimated.

Using Surfer 9.0 software statistic was drawn using the kriging interpolation method and produced the monthly maps and the map of annual averages, and all cut using the state limit of Paraíba (IBGE, 2009).

3. Results and discussion

Figure 4 shows the spatial and temporal distribution of average rainfall of the rainy season the last 52-102 years they are contained in the rainfall stations with over 30 years of observed data values.

Figure 5 shows that in the wetter quarter its values flow from west to east, that is in the region of the Alto Sertão, Sertão, Cariri/Curimataú focuses damp distribution with fluctuations between 20 and 80 $\text{mm}\cdot\text{month}^{-1}$ (dark red to light red). In the region of Agreste (yellow and light orange) monthly rainfall flow between 80-100 $\text{mm}\cdot\text{month}^{-1}$. In the region of Heath (green) monthly rainfall floatability occurs in the range of 100 to 160mm. The coastal region (dark blue and purple) monthly fluctuations have a better homogeneous distribution and its oscillations occur between 200 to 260mm. It is noted that the regions of Agreste, Brejo and Litoral are the areas of greatest rainfall homogeneous concentrations within the state.

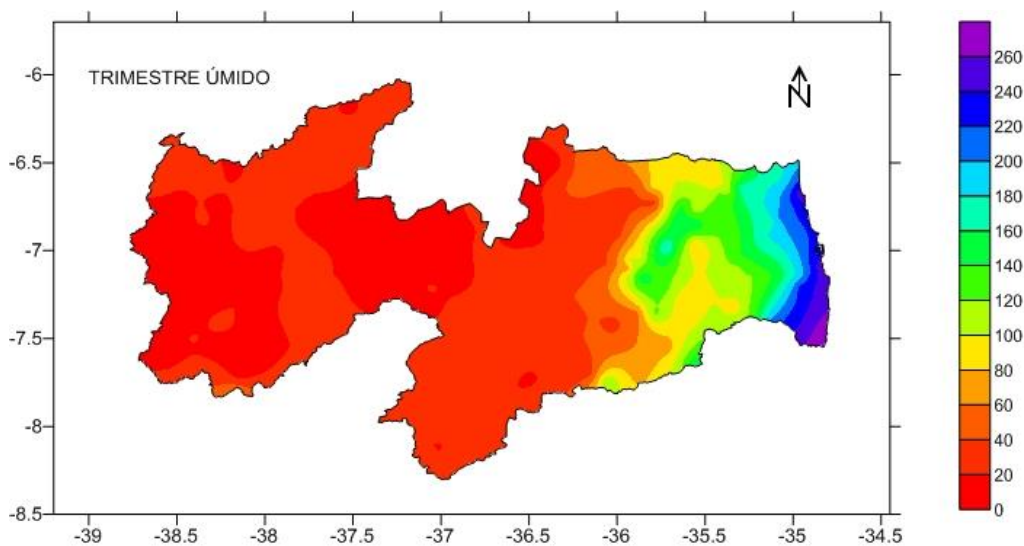


Figure 4 - Average Rainfall for the last rainy season 52-102 years (mm).

In Figure 5 we have the distribution of the average rainfall of the dry period of the last 52-102 years and their inclusion in rainfall

stations with over 30 years of rainfall observations.

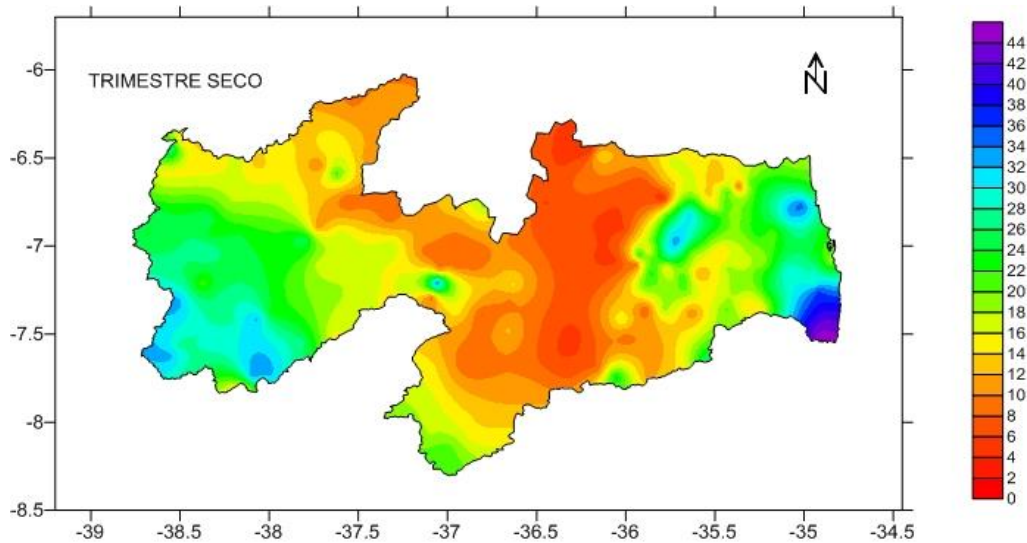


Figure 5 - Average rainfall the dry period of the last 52-102 years (mm).

It is noted that this distribution occurs extreme standards due to the occurrence of the weather to be very small, and when adverse events occur in the areas referenced characteristics change according to the recorded rainfall or occurred for the reviewed period. The region of Cariri/Curimataú is what is presented in the critical range of rainfall for dry quarter. Are observed isolated points with anomalous rainfall in the areas of Alto Sertão, Sertão, Agreste, Brejo and Litoral.

distribution of rainfall for the area of study. Variability ranges from 300 to 1,900mm, the lower rainfall occurring in the west and in the central region as well as the highlight of greater oscillations of the parameter referenced Litoral. They observed higher values in isolated areas such increases are due to the active factors in the atmosphere as the low intensity of sunlight and high cloud cover, irregular fluctuations in relative humidity and the fluctuation of atmospheric pressure.

In Figure 6 is observed the temporal

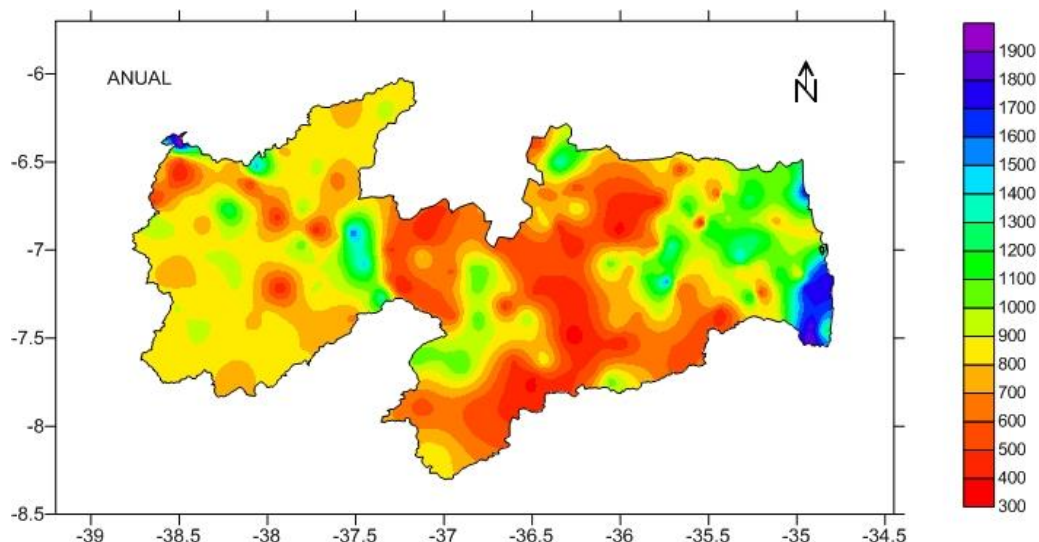


Figure 6 - Average annual rainfall of the last 52-102 years (mm).

Minors were recorded rainfall for the cities of Aroeira with 600.9 mm.year⁻¹; Montadas 519.5 mm.year⁻¹; Queimadas 478.5 mm.year⁻¹; Algodão de Jandaíra 363.6 mm.year⁻¹; Barra de Santa Rosa 392.9 mm.year⁻¹; Barra de Santana 483 mm.year⁻¹; Cabaceiras 332 mm.year⁻¹; Caraúbas 389 mm.year⁻¹; Casserengue 375.2 mm.year⁻¹; Pedra Lavrada 391.4 mm.year⁻¹; Picuí 362.6 mm.year⁻¹; and Pocinhos 385.3 mm.year⁻¹.

The variability of weather systems are due to large scale active in these locations. For the Paraíba state area under study is not observed long-term trend, but there is variability inter decennial with drier decades

receded by the wettest decades and vice versa.

Table 1 shows the statistical statement and its floating of rainfall parameters of the state of Paraíba. The average rainfall flows between 11mm in October to 152mm in March with an annual average of 852,6mm. In absolute minimum precipitation for the state their contents flow between 1 to 60mm, as its climatology is low any rainfall occurred overcome their values. In absolute maximum rainfall its oscillations occur between 38 to 369mm, they observe best spatiotemporal distributions in the months from January to September to coincide with the rainy season throughout the state.

Table 1 - Variability of rainfall statistical parameters

Monthly	Variability of parameters (mm)						
	Minimum	Median	Maximum	Average	Standard Deviation	Variance	Variance Coefficient
January	13	71	176	71	30,52	931,95	0,42
February	33	94	191	99	38,50	1482,64	0,38
March	40	145	272	152	51,81	2684,75	0,34
April	60	153	254	148	41,98	1762,49	0,28
May	36	89	305	103	53,35	2846,73	0,51
June	14	48	369	91	81,19	6592,91	0,88
July	1	32	298	73	69,60	4844,41	0,95
August	1	13	179	39	43,95	1932,13	1,11
September	1	7	103	20	22,49	506,23	1,10
October	1	9	38	11	7,19	51,77	0,62
November	1	13	48	14	8,5	72,44	0,59
December	6	26	93	29	13,27	176,31	0,45
Annual	332,0	834	1979	852	320	102404	0,37

The median is the most representative value of the precipitation occurring for years, it should be noted that these figures may change when the performance of the large-scale El Niño.

The variance, the variance coefficient is the possibility of rains occurs between the mean and standard deviation.

4. Conclusions

In January occur significant rains and isolated regions the Sertão and Alto Sertão of Paraíba. In February this distribution has become homogeneous. The months of March

and April are the rainy months in virtually every state and from May to Augusts total greater focus on range mainly in the south and east coast. September is considered the driest month and throughout the year the rains occur in isolation.

The distribution of the rainfall occurs irregularly and with great variation throughout the year and demonstrating the high spatial variability of rainfall in the central sector of the state with lower values around 300 to 500mm, and the Hinterland and High Sertão around 700 the 900mm; in Brejo and Agreste from 700 to 1,200 mm; and Litoral averaged 1,200 to 1,600mm.

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