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Thermal Behavior and Rain Contribution in Lagoa Seca, Paraíba State, Brazil, from 1981 to 2019

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ABSTRACT

The thermal oscillations of the air cause direct effects on the production of horticultural products whose economy is based in the municipality of Lagoa Seca. The objective of this work is to study the variability of thermal behavior for the hot and cold semesters, followed by its anomalies and rainy and dry rainfall and its anomalies in the seasons of the period 1981-2019, in the municipality of Lagoa Seca, Paraíba state, Brazil. Rainfall data were acquired from the Paraíba water agency and thermal data were estimated by the use of the software Estima – T, for the same period under study. The fluctuations of absolute maximum and minimum temperatures and precipitation should be studied for different regions of the globe, since both precipitation and local temperature have high rates in the rainy period (March to August), followed by the dry period (September to April) that register higher temperatures with some moments of accentuated reductions. Large and mesoscale atmospheric systems, aided by regional and local systems that influence the temperature and precipitation elements in the study area, should provide subsidies to government decision-makers, planners, and project developers aiming at better preparation for the use and exploitation of water resources.

INTRODUCTION

Marengo (2009) stated that extreme weather events are recorded in different ways and forms, such as floods, landslides, prolonged droughts, whirlpools, fires, and heatwaves. These events have been characterized by sudden changes since the last half-century. The anthropic action stands out as one of the causes of these events, which have been intensifying and occurring with greater frequency. Excessive rainfall can cause adverse events that could harm the following sectors: agriculture, agribusiness, socioeconomic, damming, and water supply (ALVARENGA, 2012).

The devastating consequences of weather events on the population in urban and rural areas, such as those caused by floods, and collapse of cliffs, occur due to the lack of experience in planning developments and the incorrect use of occupied areas (BRITO et al., 2015), which could be avoided and/or corrected with knowledge of historical meteorological elements and correct urban/rural planning.

The detection of climate change in time series on climate change in hydrometeorological systems has become of fundamental importance for the development of future planning in water resources and food production (OBREGÓN et al., 2007).

In the last century, several studies were carried out on climate oscillations and their changes, using the global average temperature to establish the degree and direction of climate change (SILVA *et al.*, 2006).

Climatic anomalies are meteorological and climatological events that deviate from average values, such as precipitation, which can be much higher than the average value or much lower, generating an anomaly that can cause floods to long periods of drought (PEREIRA et al., 2007).

The air temperature expresses the energy contained in the medium. Over a day, the energy available to the environment fluctuates between two extreme values, that is, between the minimum and the maximum temperature. As this energy goes from one extreme to the other, it acts in the continuous stimulation of vital physiological processes in living beings, such as the development and growth of plant species, such as transpiration, respiration, germination, growth, flowering, and fruiting. At each stage of plant development, there are adequate temperature ranges for perfect development (COSTA et al., 2011).

Estimates of the maximum, average and minimum monthly and annual air temperature, based on geographic coordinates, have been studied in the states of Minas Gerais (COELHO et al., 1973; SEDIYAMA et al., 1998), Espírito Santo (FEITOZA et al., 1998), Espírito Santo (FEITOZA et al., 1980) and in the Northeast Region of Brazil (CAVALCANTI et al., 2006; CAVALCANTI et al., 1994). In several studies on multiple regression models covering, above all, states and regions (OLIVEIRA NETO et al., 2000), for agroclimatological zoning purposes (BARBARISI et al., 2006; BARDIN et al., 2010) used the estimated temperature for carrying out their studies.

Medeiros et al., (2018) performed the analyzes of the spatial-temporal variability of the average air temperature in the State of Pernambuco distributed over the homogeneous regions. They showed that the results of thermal fluctuations are related to elevation and latitude, being one of the physiographic variables that best explain the monthly and annual temperature variation in the study area. The average temperature fluctuations result from the synoptic systems acting during the rainy and dry periods, as well as from the impacts on the environment. Temperature reductions occurred following the displacement of the rainy season and the actions and/or contributions of regional and local effects.

Temperature observations (maximum, average, and minimum) indicated an increase of 0.74 ºC between the years 1906-2005 (SMITH et a*l*., 2008) and are related to anthropogenic emissions of greenhouse gases and aerosols. Extreme temperatures (maximum and minimum) have been increasing in frequency and intensity in most regions of the globe since the 1950s. The positive trends in the increase of these elements cover larger areas than the negative trends (COLLINS et al., 2009; REGUERO et al., 2009; REGUERO et al., 2019). In South America, studies are focused on understanding the climatic variations that occur specifically in certain regions, such as the Amazon region (LLOPART et al., 2018), the La Plata Basin (BETTOLLI et al., 2018; MONTROULL et al., 2018), the southernmost regions of the continent (KAYANO et al., 2018; DETZER et al., 2019), in addition to the Southeast (COELHO et al., 2016), Northeast (OLIVEIRA et al., 2017) and South (CORDEIRO et al., 2016) of Brazil.

The objective of this research is to study the variability of thermal behavior for the hot and cold semesters, followed by its anomalies, and rainy and dry seasons and its anomalies, in the period 1981-2019 for the municipality of Lagoa Seca, Paraíba state, Brazil.

MATERIALS AND METHODS

Lagoa Seca is located in the Microregion with the same name and Mesoregion Agreste Paraibano. The city is limited by the municipalities of Campina Grande, Massaranduba, Matinhas, São Sebastião de Lagoa de Roça, Montadas, Puxinanã and Esperança. The municipal headquarters is located at Latitude 07º 10’ 15’’ S; Longitude 35º 51’ 13’’ W of Greenwich with an altitude of 634 meters (Figure 1).

Figure 1 - Positioning of Lagoa Seca municipality in the state of Paraíba.

Source: Medeiros (2021).

The southern part of the municipality is located in the domains of the hydrographic basin of the Paraíba river, in the lower Paraíba region, with its main watercourse being the Marinho stream. The northern and eastern parts are located in the Mamanguape river basin. All watercourses have an intermittent flow regime and the drainage pattern is of the dendritic type.

According to Köppen (1928), and Köppen et al.,(1931) the climate is of the “As” type, classified as hot and humid Tropical rainy. Studies such as the one by Alvares et al., (2014) corroborate the type of climate for the studied area. The climate classification by Thornthwaite (1948; Thornthwaite et al., 1955) is of the type C1ADa', dry subhumid, mega thermal, with little or no excess water and ETP (Potential Evapotranspiration), with 29.66% of the annual ETP concentrated in the warmest quarter of the year (November, December, and January). Thermal amplitudes vary according to latitude, altitude, and degree of continentality (effects of mountains, valleys, hills, etc.).

The rainfall regime falls within the isohyet range (a line that unites the same precipitation value) from 1,100 $mm.year^{-1}$ to 1,200 $mm.year^{-1}$ (MEDEIROS, 2016). The rains start around the second half of March, increasing in volume in the first days of April and lasting until August, being the wettest quarter between May and July. In the municipality studied, specifically, rainfall is fundamental for the proper development of the regime of perennial rivers, streams, lakes, and ponds, as well as for land use. The knowledge of its dynamics is essential for the planning of any activity.

The complements of the rain causing factors in the municipality are the formation of instability lines on the coast and transported inland by the northeast trade winds, development of convective clusters, from the heat stored on the surface and transferred to the atmosphere, orography, contributions from the formation of cyclonic vortices, and having as the main system the positioning of the Intertropical Convergence Zone. Usually, the rains have moderate intensity followed by irregularities due to the failures of the active meteorological systems. It should be noted that the occurrence of dry spells (occurrences of several consecutive days without rain during the rainy season) in the rainy four-month period (April to July) is possible and varies from year to year. Its magnitude varies depending on the season and meteorological factors. Occurrences with periods of summers greater than 17 days per month have been registered in the time interval that occurred within the four months (MEDEIROS, 2016).

For the development of this article, monthly and annual precipitation data series were used for the period of observed data (1981-2019), provided by the Executive Agency for Water Management of the State of Paraíba (ASEA, 2020).

The values of maximum, average and minimum temperatures were generated by the Estima_T software (CAVALCANTI et al., 1994; CAVALCANTI et al., 2006). This information was necessary due to the fluctuation that the temperature presents throughout the day in low latitudes, causing great fluctuation between dawn and early afternoon.

The coefficients of the quadratic function were determined for the maximum, average, and minimum monthly temperatures as a function of local coordinates longitude, latitude, and altitude (CAVALCANTI et al., 2006), given by:

$$T = C0 + C1\lambda + C2\emptyset + C3h + C4\lambda 2 + C5\emptyset 2 + C6h2 + C7\lambda\emptyset + C8\lambda h + C9\emptyset h$$

Where: C0, C1, ..., C9 are the constants; λ, λ2, λ Ø, λ h longitude; Ø, Ø2, λ Ø latitude; h, h2, λ h, Ø h height.

Also was estimated the temperature time series, adding to this Tropical Atlantic Ocean temperature anomaly (SILVA et al., 2006).

$$Tij = Ti + AATij;\ i= 1, 2, 3, ...,12;\ j = 1950, 1951, 1952, ...,2015$$

On what:

$$I = 1,2,3, ...,12;\ j = 1950, 1951, 1952, 1953, ..., 2018.$$

The analyzes demonstrate the variability of the annual behavior of the time series for the period 1981 to 2019, followed by the occurrences of rainy and dry semesters, and in the four seasons of the year (summer, spring, autumn, and winter), for temperature and precipitation, aiming to detect the thermal pattern and rainfall interference.

The methodology of standard years was applied and it was used to classify the precipitation established in five classes of thermal framing for the years, semesters and quarters worked: Hot, when the deviation from the period mean was greater than 1 °C; Warm Trend, when it fluctuated above 0.5 °C and 1°C; Normal, when the temperature did not distance more than 0.5 °C positive or negative from the mean; Cold Trend, when the deviation was between negative 0.5 ºC and 1 ºC; Cold when the loss to the average exceeded 1 ºC (Table 1).

Table 1

Methodology - Standard years		
Classification	Thermal standards	Deviation (±) in percentage
Hot years	Hot (H)	> 1 ºC
	Hot trend (TH)	> 0,5 ºC / 1 ºC
Regular Years	Normal (N)	0 ºC / 0.5 ºC
Cold years	Cold (C)	< 1ºC
	Cold Trend (TC)	-0.5 ºC / -1 ºC

RESULTS AND DISCUSSIONS

The climate of a region has an annual change in its characteristics (SORIANO, 1997), so the WMO (World Meteorological Organization, 1989) established that in climate studies, averages of at least thirty years of observed data are used. For short periods, ten years, the so-called provisional normal can be used to assess the behavior of the climate, since working with successive years.

Figure 2 shows the variability of maximum, average, and minimum temperatures per hot and cold semester respectively for the municipality of Lagoa Seca – PB, in the period 1981 - 2019. The hot semester corresponds to September to February which is known as the dry period; the cold semester corresponds to March to August and corresponds to the wettest months in the study area.

With oscillations between 27.5ºC to 28.7ºC and an annual average of 28.6ºC, were the fluctuations recorded in the warm semester of the maximum temperature with a 1.2ºC increase. The years with the highest thermal values for the hot semester are highlighted: 1982, 2006, and 2009 with 28.4ºC. The years 1998, 2003, 2004, and 2016 recorded 28.5 ºC. In the years 1987 and 1997 the temperature was 28.6ºC and the year 2015 with the temperature of 28.7 ºC. In the cold semester, the maximum temperature showed fluctuations ranging from 26.4ºC to 25.1 ºC, with this quarter registering an increase of 1.3 ºC. The years with less cold temperature within the studied semester are highlighted: 1985 (25.1°C); 1983, 1987, 2010 and 2016 with 25.8 ºC; 2015 (25.9 ºC); 1997, 2005, 2009 and 2017 with 25.7°C; 1981, 1984, 1989 and 1999 with 25.2 ºC; and the year 2022 with 26.4 ºC. According to some authors (COLLINS et al., 2009; REGUERO et al., 2019) the positive trends in temperatures with occurrences of increase, have larger areas than those of negative trends, which corroborate the results discussed here in this work.

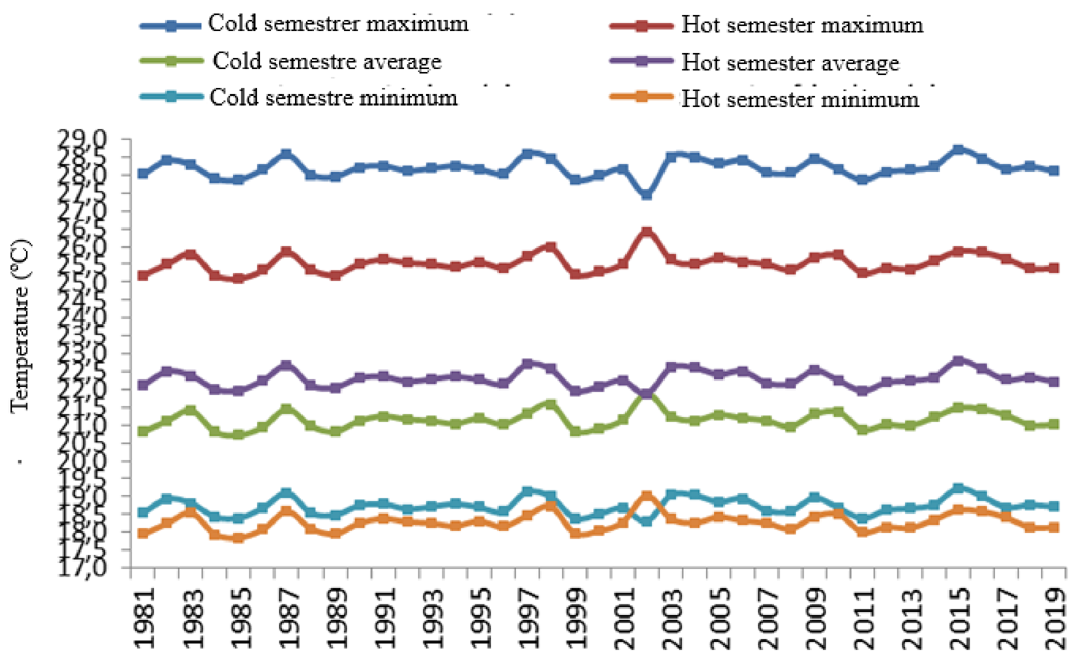

Figure 2 - Variability of maximum, average, and minimum temperature in the hot and cold semester of the 1981-2019 period in the municipality of Lagoa Seca – PB.

Source: Medeiros (2021).

In the cold semester of the average temperature, fluctuations between 21.9ºC and 20.7 ºC were registered, with an average of 21.2 ºC and a thermal increase in the semester of 1.2 ºC. The years 1981 stand out; 1984, 1989 and 1999 with 20.8°C; 1985 with 20.7 C; the years of 1987, 2015 and 2016 with 21.5 °C; 1998 with 21.6 ºC and 2002 with 21.9 ºC. In the warm semester, the mean temperature fluctuated between 21.9ºC and 22.8ºC, with an increase of 0.9 ºC and an average of 22.3 ºC, with 21.9°C (2002); 22.7°C (1987; 1997); 22.6 ºC (1998; 2003; 2004 and 2016) and with 22.8 ºC in 2015. Studies that corroborate the results discussed here are those by MARENGO et al., (2011), MARENGO et al., (2008), and MEDEIROS et al., (2017).

In the warm semester of the minimum temperature, temperatures ranged from 19.2 ºC to 18.3 ºC with an increase of 0.9 ºC and an average of 18.7 ºC. The year 2002 with 18.3 ºC; 1982 and 2006 with 18.9 °C; 1983, 1990, 1991 and 2018 at 18.8°C; 1986, 1992, 1993, 1995 2001, 2010, 2013, 2017 and 2019 with 18.7; 1997 with 19.1 °C, and 2015 with 19.2 °C. In the cold semester of the minimum temperature, temperatures ranged from 19.0 ºC to 17.8 ºC with an average of 18.3 ºC and an increase of 1.7 ºC. The years with the lowest minimum temperatures recorded were 1981, 1984, and 1985 with 17.9 °C. In 1987 and 2010 occurred 18.5°C; 1998, 2015, and 2016 occurred 18.7 °C, and 2002 occurred 19.0 °C.

Studies such as those by Ometto (1981) and Pereira et al., (2002) showed that the fluctuations of the maximum and minimum air temperature indices remain integrated with the amount of solar energy received, cloud cover, relative humidity of the air and soil, wind and the orography parameters, altitude, and local latitude. These studies corroborate the results and discussions debated here.

Figure 3 shows the oscillations of temperature anomalies: maximum, average, and minimum for the period 1981-2019 in Lagoa Seca – PB. The fluctuations of maximum temperature anomalies ranged from -0.4 ºC in the years 1984, 1985, 1999, and 2015; and at 1.5 ºC in 2002. It can highlight the years 1999, 1995, 2014, and 2017 where no anomalies were recorded, that is, its value was 0.0 ºC. The year 2018 registered the biggest anomaly with -2.4 ºC. These oscillations are in agreement with the studies by (MARENGO et al.,2007; MEDEIROS et al.,2018); MEDEIROS et al.,2016).

In average temperature anomalies, fluctuations were registered between 0.3ºC (1981, 1987, and 1998) and -0.5ºC (1985 and 2002). The years 1982, 1991, 2010, 2014, and 2017 did not register oscillations in its anomalies.

In the minimum temperature anomalies, the oscillations were registered between 0.4ºC in the years 1998 and 2018, to -0.4ºC, in the year 1985. Without variability of anomalies were registered in the 1990s, 1992 to 1995, 2001, 2018, and 2019. These fluctuations are accentuated and should be evaluated aiming at better adaptations to human beings, which may cause respiratory diseases, dehydration, especially in newborns and elderly people. In agricultural activities, it causes greater evapotranspiration powers, soil dryness, stress, poor fruit, and grain quality reduced productivity, and the possibility of fire.

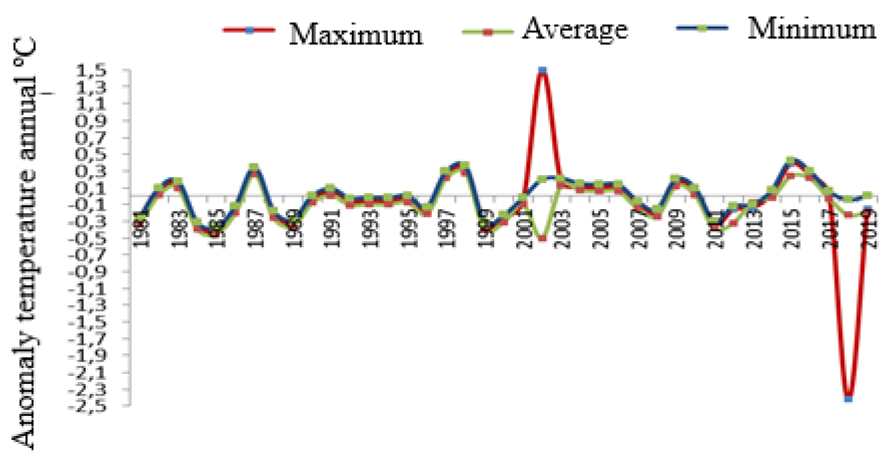

Figure 3 - Variability of maximum, mean, and minimum annual temperature anomalies for the period 1981-2019 in the municipality of Lagoa Seca – PB

Source: Medeiros (2021).

Studies such as the (IPCC 2014; ASSAD et al. 2008) in Brazil and the world, on global warming and food security, indicate that climate change can affect food production and cause risk areas to increase. Studies such as those by some authors (MARENGO et al., 2007; MARENGO et al., 2008; IPCC, 2007; IPCC, 2011; IPCC, 2014; MEDEIROS et al., 2018; MEDEIROS et al., 2017), corroborate the discussions and results found in this article.

Fluctuations of climatic elements over continents can be deflected by local, regional, or remote extreme events. These anomalies are driven in time and space by the teleconnections of the climate system involving atmospheric circulations and ocean currents. Through the analysis of affinities between ocean and atmosphere, teleconnection patterns can be useful and lead us to understand the scope of anomalous events in distant areas, triggered by local or regional forcings (GARREAUD et al., 2008; BYRNE et al., 2018). This result explains the anomalous fluctuations recorded in the study area.

Figure 4 shows the oscillations of maximum, average and minimum temperatures during the rainy and dry semesters in Lagoa Seca between the period 1981-2019.

The maximum temperature fluctuation for the rainy semester ranged from 26.4 ºC to 25.1 ºC with an average of 25.5ºC. The years that presented the highest and lowest temperatures for the rainy semesters were: 1998 with 26.0ºC; 2002 with 26.4 ºC; 1984, 1989 and 1999 with 25.2 ºC and 1986 with 25.1 ºC. The maximum temperature fluctuations in the dry semester ranged from 28.7 ºC to 27.5 ºC with an average of 28.2 ºC. The highest temperatures recorded in the dry semester with maximum temperature were 1987 with 28.6 ºC; 1997 with 28.6 ºC and 2015 with 28.7 ºC, and the lowest maximum temperatures in that semester were 1984, 1985, 1999 and 2011 with 27.9 ºC, and the year 2002 with 27.5 ºC.

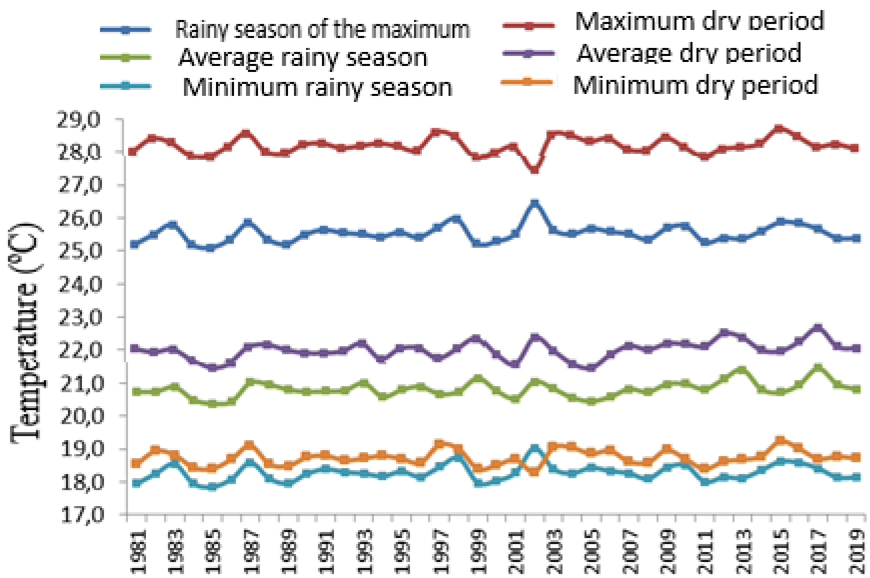

Figure 4 - Maximum, mean, and minimum temperature fluctuations during the rainy and dry season in Lagoa Seca between 1981-2019.

Source: Medeiros (2021).

Studies such as those by some authors (MARENGO et al., 2007; MARENGO et al., 2008; IPCC, 2007; IPCC, 2011; IPCC, 2014; MEDEIROS et al., 2018; MEDEIROS et al., 2017), corroborate the discussions and results of this article.

Table 2 shows the variability of statistical parameters of maximum, average, and minimum temperatures (°C) in the rainy and dry season for Lagoa Seca – PB, between 1981 – 2019.

The maximum, average, and minimum temperatures of the rainy season were 25.5 °C, 21.1 ºC, and 18.3 ºC, respectively. In the dry period, there was a maximum temperature of 28.8 ºC, an average of 22.3 ºC, and a minimum of 18.7 ºC. The median has a better-than-average representative for both the wet and dry seasons. Standard deviation and coefficient of variance were equal for both periods under study. In the absolute maximum values, the maximum and minimum temperature fluctuations for the dry period and the minimum temperature fluctuations during the rainy period stand out.

Table 2 - Statistical parameters of maximum, average and minimum temperatures (ºC) in the rainy and dry season for Lagoa Seca – PB, between 1981 – 2019.

Parameters/Elements	Average	Median	Standard Deviation	Coefficient Variance	Absolute Maximum	Absolute Minimum
Temp. max. per. rain	25.5	22.2	0.2	0.01	26.4	25.1
Temp. max. per. dry	28.2	28.4	0.2	0.01	28.7	27.5
Temp. average per. rain	21.1	20.9	0.2	0.01	21.9	20.7
Temp. average per. dry	22.3	22.1	0.2	0.01	22.8	21.9
Temp. min. per. rain	18.3	18.1	0.2	0.01	19.0	17.9
Temp. min. per. dry	18.7	18.8	0.2	0.01	19.2	18.3

Abbreviation meaning: Temp. max. per. Rain = Maximum rainy season temperature; Temp. max. per. Dry = Maximum dry period temperature; Temp. average per. rain = Average temperature in the rainy season; Temp. average per. dry = Average dry period temperature; Temp. min. per. Rain = Minimum rainy season temperature; Temp. min. per. Dry = Minimum dry period temperature.

Source: Medeiros (2021).

Studies such as those by some authors (MARENGO et al., 2007; MARENGO et al., 2008; IPCC, 2007; IPCC, 2014; MEDEIROS et al., 2018; MEDEIROS et al., 2017), corroborate the discussions and results found in this article.

Increases in extreme temperatures (maximum and minimum) and evaporative indices cause extreme rainfall events of short time and high intensity, being harmful to vegetables. (FRANÇA et al., 2019).

Marengo et al., (2011) explain that the increase in temperature influences the loss of soil moisture as a consequence of the increase in evapotranspiration. Souza et al., (2006) explained that the availability of water in the soil is influenced by thermal fluctuations and the temporal distribution of rainfall. These studies corroborate the results of the research in discussions.

Table 3 shows the frequency variability of the maximum, average, and minimum temperature classes for the series from 1981 to 2019 in the municipality of Lagoa seca – Brazil.

In the respective worked classes, it is highlighted that for the maximum temperature, the normal class with 14 frequencies predominated; in the minimum temperature, the cold class prevailed with 12 frequencies; the hot classes were not registered and tending to hot for the minimum temperature fluctuations; the highest frequency registered for the minimum temperature was 20 times. It is noteworthy that in Lagoa Seca the dawns still present temperatures lower than the climatological average for the normal classes.

Table 3 - Frequencies of the maximum, average, and minimum temperature classes for the series from 1981 to 2019 in the municipality of Lagoa seca – Brazil.

	Maximum Temperature			Average Temperature			Minimum Temperature		
Classe	Freq	%	Class	req	%	Class	Freq	%	Class
Warm	9	0.23	2º	3	0.08	4	0	-	-
Tending to hot	8	0.21	3º	4	0.105	3º	0	-	-
Normal	14	0.36	1º	6	0.158	2º	20	0.53	1º
Cold	4	0.10	5º	12	0.316	1º	1	0.03	3º
Tending to cold	5	0.13	4º	12	0.316	1º	18	0.47	2º

Abbreviation meaning: Freq = Annual frequency (how many times occurred); % = percentage value; class = classification; (-) without occurrence.

Source: Medeiros (2021).

Table 4 shows the greatest variability of maximum, average and minimum annual temperatures, followed by their years of records, for the classes: cold, normal, and hot in Lagoa Seca, between 1981 and 2019.

Table 4 - Annual maximum, average, and minimum temperature (°C) followed by the years of records in the municipality of Lagoa Seca – PB, in the period from 1981 to 2019.

Annual	Cold	Normal	Hot	Period (1981-2019)
Maximum Temp.	2018 (24.5)	2008 (26.7)	2002 (28.4)	2002 (28.4)
Average Temp.	1985 (21.3)	2006 (21.9)	1988 (21.5)	1991 (23.0)
Minimum Temp.	1981 (18.2)	2009 (18.7)	2015 (18.9)	1985 (18.1)

Abbreviation meaning: Temp. = temperature (°C).

Source: Medeiros (2021).

These fluctuations caused moderate to heavy rains in a short period and with high magnitude, being harmful to fruit and vegetable crops, following the studies by MARENGO et al., (2011), SOUZA et al., (2006), and FRANÇA et al., (2019).

Table 5 shows the oscillations of the maximum, average, and minimum temperatures (ºC) in the rainy and dry periods, followed by years of records in the municipality of Lagoa Seca – PB, in the period 1981 to 2019. There were temperature differences around 2.5 ºC between the rainy and dry periods, at maximum temperature, and 1.2 ºC at a minimum and average temperatures (Table 5).

Table 5 - Variations of maximum, average and minimum temperatures (°C) in the rainy and dry periods, followed by their years of records in the municipality of Lagoa Seca - PB, in the period 1981 to 2019.

Temperature (ºC)	Period Rainy	Period Dry	Average period Rainy	Average period Dry
Maximun	26.4 (2000)	28.7 (2015)	25.5	28.2
Average	21.9 (2000)	22.9 (2015)	21.1	22.3
Minimum	19.0 (2002)	19.2 (2015)	18.3	19.2

Source: Medeiros (2021).

Temperature variability on the globe is influenced by several factors such as the distance between water bodies, incident radiation, orography, prevailing winds, and ocean currents. Figure 5 shows the temperature distributions and their maximum, average and minimum anomalies in the summer season in the municipality of Lagoa Seca – Paraíba.

The maximum temperature in the summer season registered an average of 28.9 ºC. The years that registered a maximum temperature above 29 ºC were 1982, 1983, 1987, 1991, 1994, 1995, 1997, 1998, between 2002 to 2007, 2009, 2010, 2015, and 2016. In the other years, the maximum temperature flowed below 29 ºC. The average temperature had a historical average of 23 ºC and the years with a temperature above the average (23 ºC) were: 1982, 1983, 1987, 1988, 1991, 1992, 1994, 1995, 1997, 1998, 2003, 2004, 2005, 2006, 2007, 2009, 2010, 2015, 2016 and 2019. For the years not mentioned, the average was below 23 ºC.

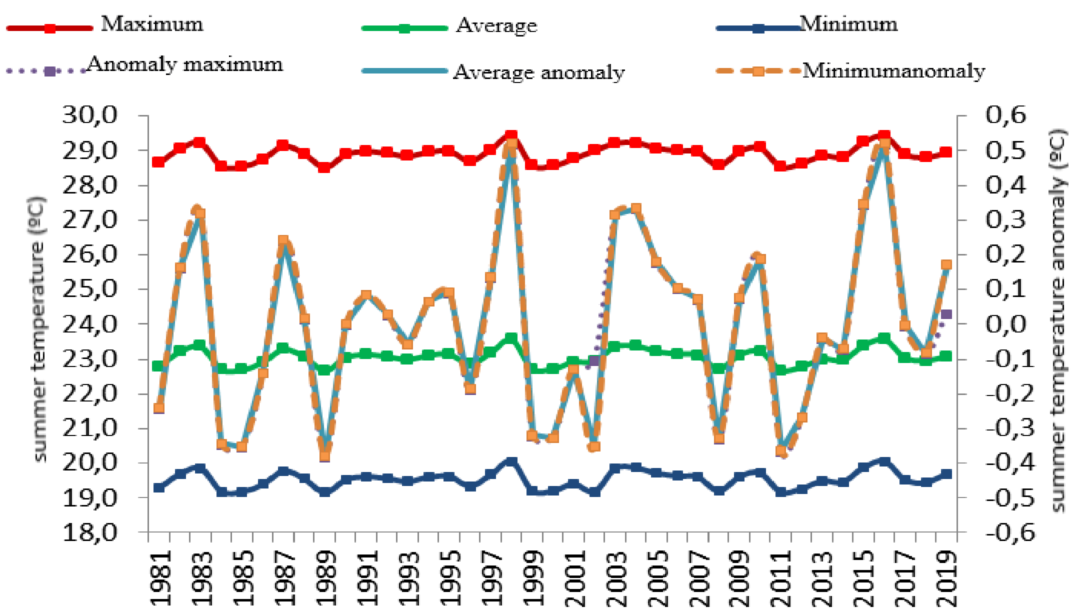

Figure 5 - Temperature distributions and their maximum, average, and minimum anomalies in the summer season in the municipality of Lagoa Seca – Paraíba

Source: Medeiros (2021).

The minimum temperature recorded was 19.5 ºC and the years with a minimum temperature above the average are 1982, 1983, 1987, 1988, 1991, 1992, 1994, 1995, 1997, 1998, 2003 to 2007, 2009, 2010, 2015, 2016, and 2019.

The variability of anomalies in maximum, average, and minimum temperatures was practically equal throughout the period studied. These fluctuations are in agreement with the (IPCC 2014; MARENGO et a*l.*,2013; MARENGO et al.,2015).

The distribution of temperatures and their maximum, average and minimum anomalies in the autumn season in the municipality of Lagoa Seca – Paraíba (Figura 6), shows an average of 27 ºC and an absolute maximum of 28.2 ºC and its absolute minimum of 26.6 ºC. The years that registered a maximum temperature above 27 ºC were 1983, 1987, 1991, 1992, 1995, 1998, 2002, 2003, 2004, 2005, 2010, 2015, 2016 and 2017. In other years, the maximum temperature flowed below 27 ºC.

The average temperature was 22.4 ºC and the years with the highest average temperature were 1983, 1991, 1992, 1995, and 1998. The maximum and minimum values relative to the autumn season were 23.1ºC and 22 ºC.

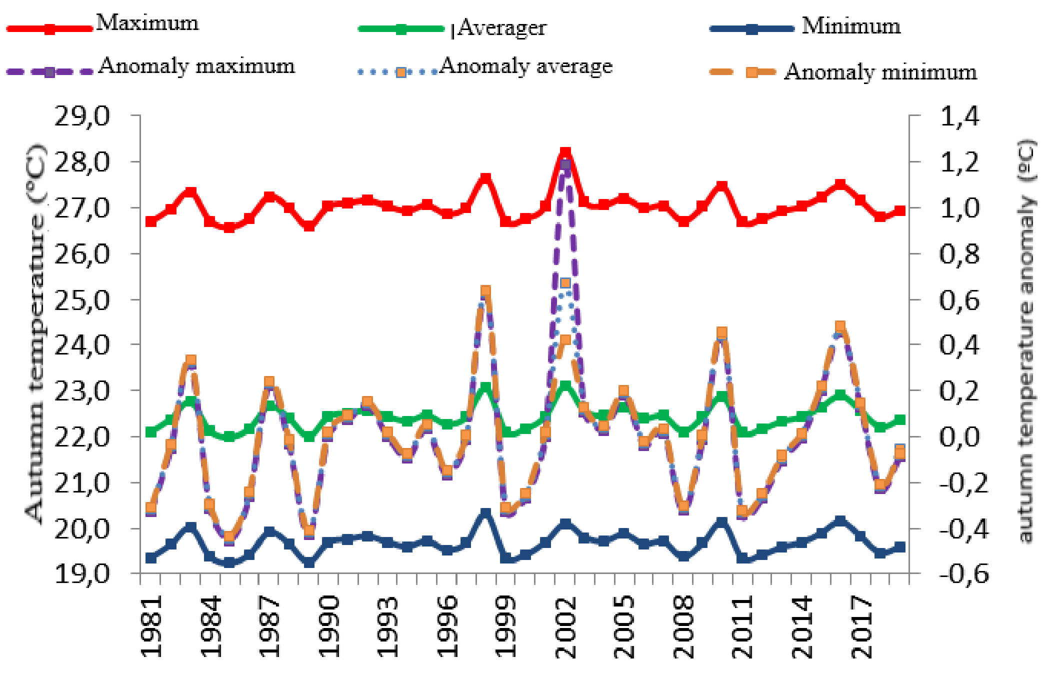

Figure 6 - Temperature distributions and their maximum, average and minimum anomalies in the autumn season in the municipality of Lagoa Seca – Paraíba.

Source: Medeiros (2021).

The minimum temperature fluctuations ranged from 20.3 ºC to 19.2 ºC. It recorded an average of 19.7 ºC. The years that surpassed the average value were 1983, 1987, 1991, 1992, 1998, 2002, 2005, 2010, 2015, 2016, and 2017.

The maximum, average, and minimum anomalies flowed equally for the respective variability, except for the year 2002, which exceeded the normal pattern of the other anomalies.

Figure 7 shows the distributions of maximum, average and minimum temperatures and their anomalies in the winter season in the municipality of Lagoa Seca – Paraíba, from 1981 to 2019. The maximum, average, and minimum temperatures had an average of 24.0 ºC, 19.9 ºC, and 16.9 °C, respectively. The mentioned temperature anomalies were the same in all years, except for the year 2003 with different temperatures.

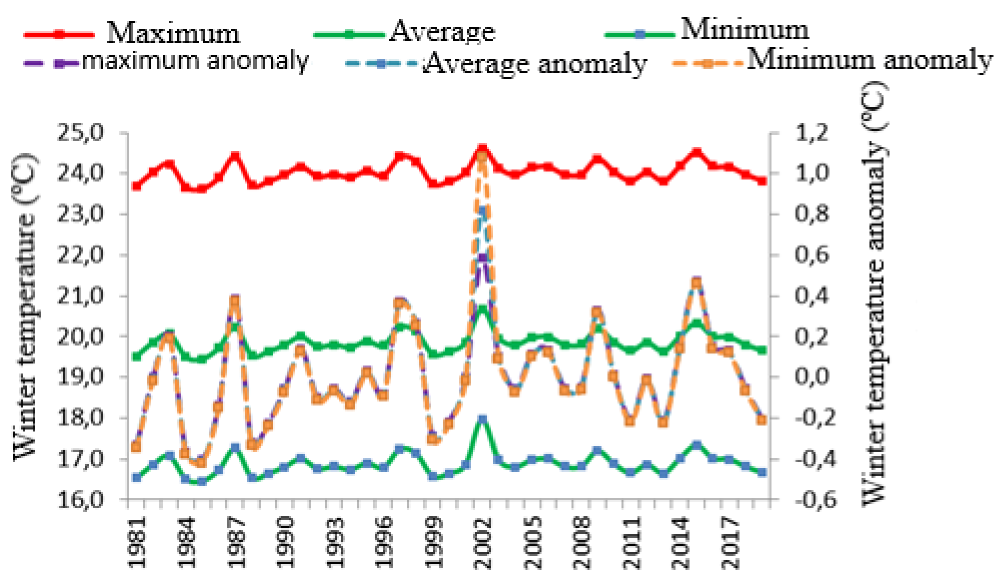

Figure 7 - Temperature distributions and their maximum, average and minimum anomalies in the winter season in the municipality of Lagoa Seca – Paraíba.

Source: Medeiros (2021).

The temperature distributions and their maximum, mean and minimum anomalies in the spring season are represented in Figure 8. The maximum temperature was 27.5 ºC and its interannual fluctuations flow between 28.2 ºC in the years 1997 and 2015 to 26.3 ºC in the year 2002. Its absolute maximum and minimum values are 28.2 ºC and 26.3 ºC, respectively. The average temperature was 21.6 ºC and its interannual fluctuations ranged from 22.2 ºC in 1997 and 2015, to 20.8 ºC in 2002. Its absolute maximum and minimum values were 22.2 ºC and 20.8 °C respectively. The annual minimum temperature was 17.9 ºC and its fluctuations occurred between 18.6 ºC in 1997 and 17.4 ºC in 2002. The maximum and absolute minimum values recorded were 18.6 ºC and 17.9 °C.

The maximum, mean and minimum temperature anomalies differ in the following 1990, 1991, 1998, 2001, 2012, and 2016. In the other years studied, the anomalies were equalized.

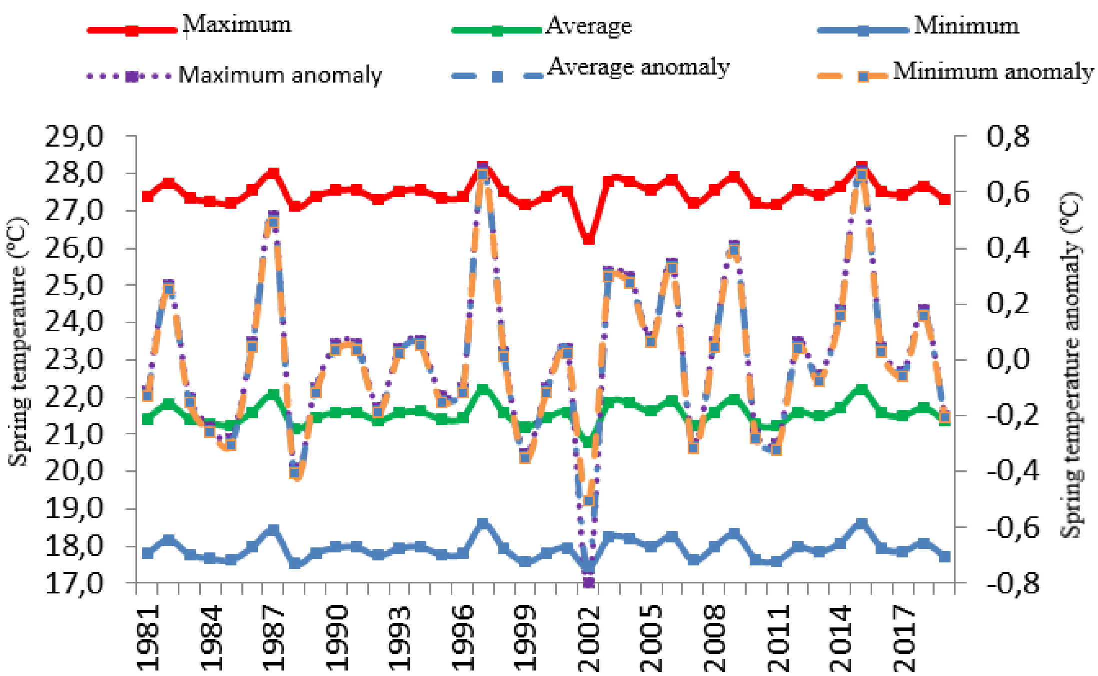

Figure 8 - Temperature distributions and their maximum, average and minimum anomalies in the spring season in the municipality of Lagoa Seca – Paraíba.

Source: Medeiros (2021).

Table 6 shows the oscillations of the statistical parameters of maximum, average, and minimum temperature (ºC) for the seasons of the year in Lagoa Seca – PB, between 1981 - 2019. The median is the parameter that best represents the thermal oscillations of the studied area. The standard deviation presents greater buoyancy for the maximum temperature in the autumn and spring seasons. The absolute maximum and minimum values fluctuated from season to season and their oscillations were recorded by local and regional atmospheric factors with the aid of meso and large scales. The maximum oscillations of the coefficients of variance were registered in the four seasons with the minimum temperature, in the average and maximum temperature in the summer season, the smallest coefficient of variance was registered. The average temperature of the maximum ranged from 24 ºC in (winter) to 28.9 ºC in summer. Average temperatures ranged from 19.9 ºC in winter to 23 ºC in summer. The minimum temperature fluctuations ranged from 16.9 ºC in the winter season to 19.7 ºC in the autumn. These fluctuations are in agreement with the study by (IPCC 2014; MARENGO et al., 2013; MARENGO et al., 2015).

Table 6 - Statistical parameters of temperature (°C) in the seasons of the year in Lagoa Seca – PB between 1981 – 2019.

Station/Parameters	Average	Median	Standard deviation	Coefficient Variance	Absolute maximum	Absolute minimum
Maximum temperature						
Summer	28.9	28.6	0.244	0.008	29.4	28.5
Fall	27.0	26.7	0.313	0.012	28.2	26.6
Winter	24.0	23.7	0.235	0.010	24.6	23.6
Spring	27.5	27.2	0.330	0.012	28.2	26.3
Average temperature						
Summer	23.0	22.7	0.244	0.011	23.6	22.7
Fall	22.4	22.1	0.268	0.012	23.1	22.0
Winter	19.9	19.6	0.253	0.013	20.7	19.5
Spring	21.6	21.2	0.288	0.013	22.2	20.8
Mínimum temperature						
Summer	19.5	19.2	0.251	0.013	22.2	20.8
Fall	19.7	19.4	0.255	0.013	20.1	19.2
Winter	16.9	16.6	0.278	0.016	20.3	19.2
Spring	17.9	17.6	0.274	0.015	18.0	16.5

Source: Medeiros (2021).

The summer season is characterized by an average of 54.6 mm, the standard deviation of 38.8 mm, coefficient of variance of 0.71, and absolute maximum and minimum values of 207.8 mm and 5.8 mm, to rainfall anomalies flowing between 153.3 mm to -48.7 mm (Figure 9).

The winter season records a historical average of 148.3 mm; a standard deviation of 48.6 mm; a coefficient of variance of 0.32. The absolute maximum and minimum values were 261.1 mm and 30.2 mm, respectively. The variability of the pluvial anomaly flowed between 112.7 mm and -118.1 mm (Figure 9).

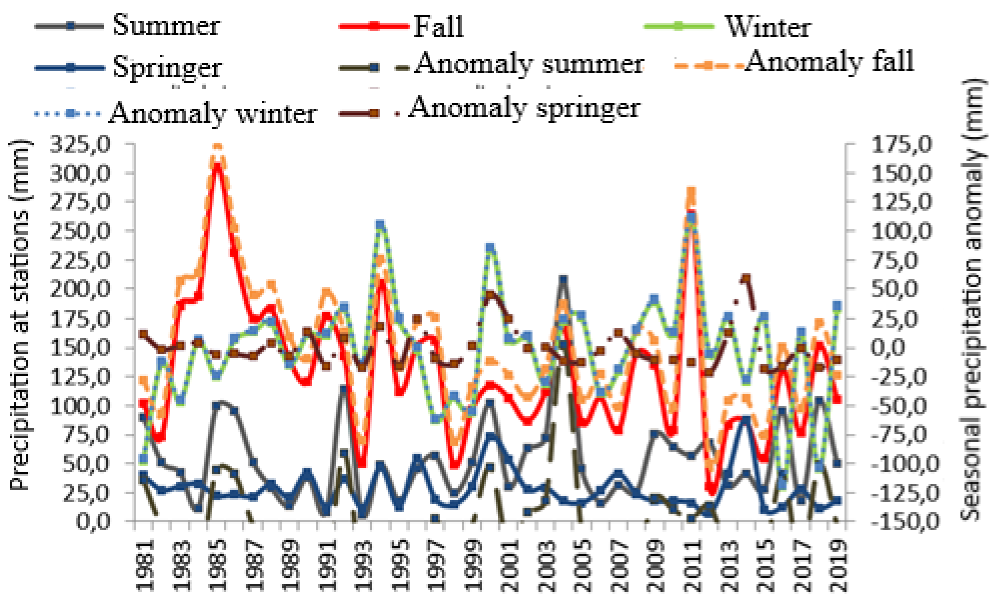

Figure 9 - Distribution of rainfall and its anomalies in the seasons of the city of Lagoa Seca – Paraíba.

Source: Medeiros (2021).

In the autumn season, the historical average was 129.8 mm, the standard deviation of 59.6 mm, the coefficient of variance of 0.46, and the maximum and minimum absolute values were 305.2 mm and 30.3 mm. Rainfall anomalies ranged from 175.4 mm to -99.5 mm.

The spring season variability in the study área showed a climatological mean of 28.6 mm, the standard deviation of 17.1 mm, coefficient of variance of 0.60, and its absolute maximum and minimum values of 87.4 mm and 6.7 mm. Rainfall anomalies flowed from 58.8 mm to -21.9 mm.

The analysis of the behavior of rainfall becomes important since it allows detecting trends or changes in the climate, at local, regional, state, national and continental scales (SILVEIRA et al.,2016; and MARCUZZO et al.,2012), as further the author, the excess or lack of rain can be favorable or harmful to socioeconomic development, but the analysis of rainfall is extremely important, carried out over a historical period.

Cunha *et al.*, (2001) stated that climatic elements are the main determinants of fluctuations in the yields of vegetables, crops, and flexibilities in agriculture. According to the authors, temperature, humidity and precipitation cannot be controlled or modified by man on a large scale.

Table 7 shows the variability of statistical parameters of rainfall (mm) in the seasons of the year in Lagoa Seca – PB, between 1981 - 2019. The summer and spring seasons correspond to the end of the rainy season and the beginning of the dry season for the study area, having averages of 54.6 mm and 28.6 mm. These rainfall indexes were caused by local effects and sensible heat exchange and latent in the region. In the autumn and winter seasons, the rainy season predominates with rainfall averages of 129.8 mm and 148.3 mm, respectively. These rainfall magnitudes recorded in the autumn and winter seasons were caused by large-scale atmospheric variability in the period and its local and regional contributions. The possibility of occurrences of extended summers, longer than twenty-two (22) days in the region, is not ruled out. High rainfall rates were registered in the autumn and winter seasons, as well as for the other elements studied.

Table 7 - Statistical parameters of precipitation (mm) in the seasons of the year in Lagoa Seca – PB, between 1981 – 2019.

Station/Parameters	Average	Median	Standard deviation	Coefficient Variance (%)	Absolute maximum	Absolute minimum
Summer	54.6	50.9	38.8	0.7	207.8	5.8
Fall	129.8	96.6	59.6	0.5	305.2	30.3
Winter	148.3	94.3	48.6	0.3	261.0	30.2
Spring	28.6	30.8	17.1	0.6	87.4	6.7

Source: Medeiros (2021).

Maximum thermal fluctuations in the rainy period tend to reduce in years where rainfall is higher than the average of the series and increases when rainfall rates occur below the median value. The opposite occurs with minimal thermal fluctuations. Atmospheric instability presents regularity without commitment to seasonal changes. The winter season does not undergo sudden changes as in other seasons.

Mearns et al., (1984), Katz (1991), and Katz et al., (1992) demonstrated that the relative frequency of extreme events depends on changes in the standard deviation and not just the mean. Katz (1991) assumes that a change in a climate variable, that has a probability distribution, may result in a change in the shape of its distribution.

CONCLUSIONS

Temperature fluctuations (maximum, average, and minimum) in the autumn and spring seasons have direct influences on the rainfall in the same seasons.

The absolute maximum and minimum precipitation events are related to the maximum and minimum fluctuations of the studied temperatures.

These fluctuations of absolute maximum and minimum temperature and precipitation should be studied for different regions of the globe, since both precipitation and local temperature have high rates in the rainy period (March to August), followed by the dry period (September to April) that register higher temperatures with some moments of accentuated reductions.

Large and mesoscale atmospheric systems, aided by regional and local systems that influence the temperature and precipitation elements in the study area, should provide subsidies to government decision-makers, planners, and project developers aiming at better preparation for the use and exploitation of water resources.

It is suggested a study in greater detail and using information from weather reports, synoptic charts and satellite images, cloud cover charts, and total insolation to accurately verify the evaporative and evapotranspiration powers caused by the atmospheric systems that predominated in the study area.

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