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Extreme Temperature Oscillations in The Pernambuca Mata Zone, Brazil

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ABSTRACT

Temperature is a climatic variable integrated into measurements made in the air, water, and soil, establishing different modalities for synoptic and climatological analyzes of a given region. The objective is to analyze the space-time oscillations of maximum, average and minimum air temperatures in the Zona da Mata Pernambucana and plot its monthly and annual graphs, providing relevant information to researchers and decision-makers in various areas of activity, especially in agriculture, agribusiness, storage and distribution of water to the population. Temperature reductions flow in consonance with the conduct of the rainy season and the actions and/or contributions of regional and local effects, such as the impacts on the environment and the actions of transient synoptic systems of meso and micro-scale. Of the air temperatures studied, the minimum temperature is, notably, the one with the greatest increase and the greatest spatial consistency. The increase in the average air temperature is due to the strong tendency of the minimum air temperature to rise. The 10-year moving average estimates present values of greater significance than for the 5-year ones.

INTRODUCTION

According to estimates by the Internal Displacement Monitoring Center (IDMC, 2017), by 2050 the number of refugees from climate disasters will reach 1 billion people. Recently, there have been displacements due to climate disasters – and they are not few: something around 25 million people have already left their countries due to environmental problems such as droughts, floods, floods, floods, the collapse of barriers, falling trees, storms and forest fires, tsunamis, sea deaths, earthquakes, earthquakes.

There is a consensus among meteorological and related scientists that observed climate trends, especially from the second half of the 20th century onwards, have increased significantly. According to the Intergovernmental Panel on Climate Change (IPCC), these trends observed in the recent past are highly likely to continue in the same direction in the 21st century (IPCC, 2007; IPCC, 2014).

Air temperature measurements at any time, especially at times recommended by the World Meteorological Organization (WMO, 1989), including, in this case, the maximum and minimum air temperatures, verified within 24 hours and in the impossibility of these last measurements, estimation methods according to Dantas et al. (2000).

Nogueira et al. (2012) and Correia et al. (2011) agreed that air temperature stands out among the atmospheric elements most used in the development of environmental impact studies with changes in meteorological and hydrological processes.

The anthropic activities that have been taking place or caused by man are, in the view of many researchers, responsible for changes. Therefore, it needs to be changed in consideration of possible natural climate fluctuations, since the magnitude of the signal associated with it in existing climate records has not yet been well determined (IPCC, 1996; IPCC, 2001).

Mello et al. (2015) analyzed extreme and mean temperature fluctuations in the state of Pernambuco, focusing on such variability as a means of understanding future changes. They stated that knowledge of the climate behavior of a region is important for weather forecasting studies and especially for agricultural planning and that the delimitation of a warmer or colder

period serves as a warning to federal, state, and municipal authorities and decision-makers, with the objective of better planning to improve life.

Souza et al. (2015) carried out the limitation of the maximum air temperature in the hydrographic basin of the Uruçuí Preto river. They delimited the warmest quarter and its monthly and annual values, as well as the absolute maximum and minimum values observed. The results show that in the warm period the possibilities of fire and fire outbreaks increase, and in green areas, it is beneficial to the production of pastures and grain. Such delimitation of the warmest quarters and the information on the seasons with the lowest maximum air temperature served as a warning to federal, state, municipal authorities, and decision-makers for better planning.

Medeiros et al. (2012), calculated the average daily air temperature using different methodologies for the municipalities of Parnaíba, Picos and Gilbués located, respectively, in the coastal area, in the central region, and in the semi-arid region in the cerrado and desert lands of the State of Piauí used four methods to calculate the average daily air temperature, adopting standard the one recommended by the National Institute of Meteorology. The four methods evaluated to the standard had performance classified as "Very good and Great", with a confidence index ranging from 0.83 to 0.98. The results also indicate that in the climatic conditions of the study region, the four methods evaluated to the standard can be used to estimate the average daily air temperatures.

According to researchers Luo et al. (2005); Zhang et al. (2005) and Machado (2009) showed that future climatic conditions have shown an increase in air temperature, resulting in important impacts for different agricultural activities, such as fruit growing, vegetables, and grain production. The Brazilian agricultural production system may support significant changes in the coming years as a result of global warming.

Sousa et al. (2015) showed that the restriction of water resources today is a conditioning factor to socioeconomic and agricultural development, which has been causing numerous challenges to their planning and management.

Matos et al. (2015) used monthly air temperature data for the municipality of Barbalha – Ceará and demonstrated that elevation and latitude are the physiographic variables that best explain the

annual air temperature variation and that the average temperature variability derives from synoptic systems active during the rainy or dry season as well as impacts on the environment.

Medeiros et al. (2015) studied the variability of the historical average monthly temperature in the state of Paraíba over the last thirty years, carried out the mapping, and analyzed its variability. The use of geostatistics presented satisfactory results regarding the estimation of the temperature obtained by the Krigage interpolation method, being consistent with the local climatological characteristics of the region, both in the spatial and seasonal distribution of temperature; the spatial distribution of temperature showed great variability for both months studied, with a variation of approximately 5 ºC in the annual temperature distribution; the month of February presents the highest temperature values with a variation of 2 ºC; in August, it has the lowest temperature values.

According to the IPCC (2013) and Assad et al. (2008) who stated that in Brazil and the world, they indicate that climate change can affect food production and cause risk areas to increase.

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 by the displacement of the rainy season and the actions and/or contributions of regional and local effects.

The objective is to analyze the spatial and temporal oscillations of the maximum and minimum air temperatures in the Zona da Mata Pernambucana and plot its monthly and annual graphs, providing relevant information to researchers and decision-makers in various areas of activity, especially in agriculture, agribusiness, storage and distribution of water to the population.

MATERIAL AND METHOD

The Zona da Mata Pernambucana comprises 44 municipalities, covering an area of 8,738 km2, equivalent to 8.9% of the territory of Pernambuco, limited to the north by Paraíba, to the south by Alagoas, to the east by the Metropolitan Region of Recife, and to the west with the Agreste. It has an estimated population of 1,193,661 inhabitants (EGBI, 2013). Until recently, most of this area was referred to as the "sugarcane region". It is one of the regions with the greatest economic potential in the Northeast, due to the available natural resources (water, soil, etc.), the locational advantages around the Metropolitan Region of Recife, with reasonable economic infrastructure (roads, seaports, airports) and an abundant contingent of manpower. The sugarcane monoculture is concentrated in this region, with an area of approximately 450 thousand hectares and it used to employ more than 200 thousand people during harvest seasons (Figure 1).

Figure No. 1. Geographical representation of the Zona da Mata area painted in green.

Source: Medeiros, (2021).

The studied mesoregion is crossed by the most important rivers in the state, such as the Capibaribe River, the Ipojuca River, and the Ipanema River, in addition to smaller rivers such as the Siriji River. The vegetation is composed of Atlantic Forest, which includes medium and large trees and grasses, with rich fauna.

The main systems responsible for the occurrence of rainfall are the ITCZ Intertropical Convergence Zone (HASTENRATH et al.1977), the Cold Fronts (ARAGÃO, 1976; KOUSKY, 1979; KOUSKY,1981), the Eastern Disturbances or Eastern Waves (YAMAZAKI et al., 1977) and the High-Level Cyclonic Vortexes (NACV). ITCZ is the main meteorological system that provides rainfall in the northern sector of the BEN, where the state of Pernambuco is located. ITCZ normally migrates seasonally from its northernmost position, approximately 12º N, in August-September, to more southern positions, and, approximately 4º S, in March-April (UVO,

1989). It has local and regional contributions such as Formation of instability lines aided by Northeast trade winds, effects of sea and land breezes (MEDEIROS, 2017).

Values of maximum, mean, and minimum air temperature estimated by the Estima_T software were used (CAVALCANTI et al.1994; CAVALCANTI et al.2006). The data obtained by the estima_T software corresponds to the period 1950-2020, were generated by electronic spreadsheets and basic statistical calculations were performed to generate graphs and tables, and other parameters relevant to the development of the study.

RESULT AND DISCUSSION

Table 1 shows the relationships of the municipalities, geographic coordinates (latitude, longitude, and altitude), followed by the climate classification according to the Köppen method for Zona da Mata Pernambucana, where eleven types of climate "Am" and thirty-three are recorded municipalities with “AS” climate.

Table No. 1. Municipalities, geographic coordinates (latitude (Lat, º ‘), longitude (Lon, º ‘), and altitude (Alt, m), followed by the climatic classification according to the Köppen method for Zona da Mata Pernambucana.

Municípios	Lat	Lon	Alt	Clas. de Köppen	Municípios	Lat	Lon	Alt	Clas. de Köppen
Água Preta	-8,7	-35,5	132	Am	Lagoa Carro	-7,8	-35,3	127	As
Aliança	-7,6	-35,2	094	As	Lagoa Itaenga	-7,9	-35,3	139	As
Amaraji	-8,4	-35,4	386	Am	Macaparana	-7,6	-35,4	460	As
Barreiros	-8,8	-35,2	070	Am	Maraial	-8,8	-35,8	305	As
Belém Maria	-8,6	-35,8	323	As	Nazaré Mata	-7,7	-35,2	091	As
Buenos Aires	-7,7	-35,3	166	As	Palmares	-8,7	-35,6	196	As
Buíque	-8,6	-37,2	616	As	Paudalho	-7,9	-35,2	116	As
Camutanga	-7,4	-35,3	213	As	Pombos	-8,1	-35,4	341	As
Carpina	-7,9	-35,2	134	As	Primavera	-8,3	-35,3	367	As
Catende	-8,7	-35,7	256	As	Quipapá	-8,8	-36,0	555	As
ChãAlegria	-8,0	-35,2	136	As	Ribeirão	-8,5	-35,4	151	Am
ChãGrande	-8,2	-35,5	466	As	Rio Formoso	-8,7	-35,2	086	Am
Condado	-7,6	-35,1	079	As	S. B. Sul	-8,8	-36,0	460	As
Cortês	-8,5	-35,5	409	Am	S. Bento Una	-8,5	-36,5	662	As
Escada	-8,4	-35,2	145	Am	S. J. C. Grande	-8,9	-35,1	047	Am
Ferreiros	-7,4	-35,2	098	As	Sirinhaém	-8,6	-35,1	060	Am
Gameleira	-8,6	-35,4	127	Am	Tamandaré	-8,8	-35,1	066	Am
Glória Goitá	-8,0	-35,3	186	As	Timbaúba	-7,5	-35,3	216	As
Itambé	-7,4	-35,1	100	As	Tracunhaém	-7,8	-35,2	112	As
Itaquitinga	-7,7	-35,1	097	As	Vicência	-7,7	-35,3	176	As
Jaqueira	-8,7	-35,8	302	As	Vitória S.Antão	-8,1	-35,3	253	As
Joaquim Nabuco	-8,6	-35,5	236	Am	Xexéu	-8,8	-35,6	167	As

Source: Medeiros, (2021).

Similar results were found by Alvares et al. (2014) in the climate classification for Brazil, which highlights the coast of Northeast Brazil, with "Bsh" climate, in the transition zone and the "As" coastal climate of Ceará, extending to the coast of the State of Pernambuco. The climate

classification according to Köppen for the area under study is by the classifications of (CAMARGO 1961; ALVARES et al.2014; MEDEIROS et al. 2018).

Fritzsons et al. (2008) stated that the air temperature is influenced by altitude and latitude factors and tends to reduce its values with the increase in altitude, in the proportion of 1°C/100m, caused by the ascension movements of the dry air mass submitted to a system of low pressure, resulting in an increase in volume and consequently a reduction in air temperature. Ometto (1981) showed that in the tropical region the temperature difference between small distances occurs due to the variation in altitude and cloudiness and not due to the latitude, registering thermal variations between windward and leeward locations of a mountain. Which corroborates the study results.

The maximum, average, and minimum air temperature, specifically that measured at the surface, is an important parameter for geographic studies. Its dynamics are influenced by spatial and temporal variations, which determine the formation of thermally homogeneous or contrasting environments. Such buoyancy was observed by Brito et al. (2015) for the NEB.

In the case of Pernambuco, evidence of climate change has already been found, showing that the increase in air temperature is increasing, as reported by Lacerda et al. (2010). This report, too, indicates that all of Brazil is expected to become at least 3ºC warmer by the end of the century; rainfall would increase by 30% in the South and Southeast regions and would suffer reductions of up to 40% in the North and Northeast regions.

Duarte et al.2011 showed that for plant species, information about air temperature variability is essential, as their metabolism is dependent on its variation. In agricultural activities, the temperature can be decisive for the thermal comfort of animals, for the choice of the type of crop to be adopted, for the propagation of pathogens, and the growth and development of plants.

Figure 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for January (a); February (b); March (c); April (d); May (e); June (f); July (g); August (h); September (i); October (j); November (k); December (1); annual (m); temperature anomaly (n) and the monthly mean maximum temperatures and their respective monthly percentages (o) for the period 1950-2020.

The month of January is characterized by a trend line with a negative slope and low R2. The municipalities with a maximum temperature of 31 °C and below this value are shown in Figure 2a, Amaraji, Macaparana and Tracunhaém and the municipalities with a temperature equal to or greater than 33°C are Aliança, Chã Grande, Tamandaré and Timbaúba. The month of January has a historical average of 31.7 °C, standard deviation of 0.75 °C, coefficient of variance of 0.024, maximum and minimum values of 33.9 °C and 29.2 °C with a median of 32.2°C.

With a negative trend line and low R2 the months of February behaved (Figure 2b) for the period 1950-2020, for the Zona da Mata Pernambucana. The municipalities of Amaraji, Macaparana, São Bento do Una and Tracunhaém recorded the lowest maximum temperatures, the municipalities of Tamandaré, Sirinhaem, Aliança and Chã Grande recorded maximum temperatures above 32°C. The historical average of the month under study is 31.7 °C, standard deviation of 0.71 and its maximum and minimum values of 33.2 °C and 28.6 °C respectively, coefficient of variance of 0.022, a median of 32 .2°C. Similar results were discussed by Souza et al., (2015).

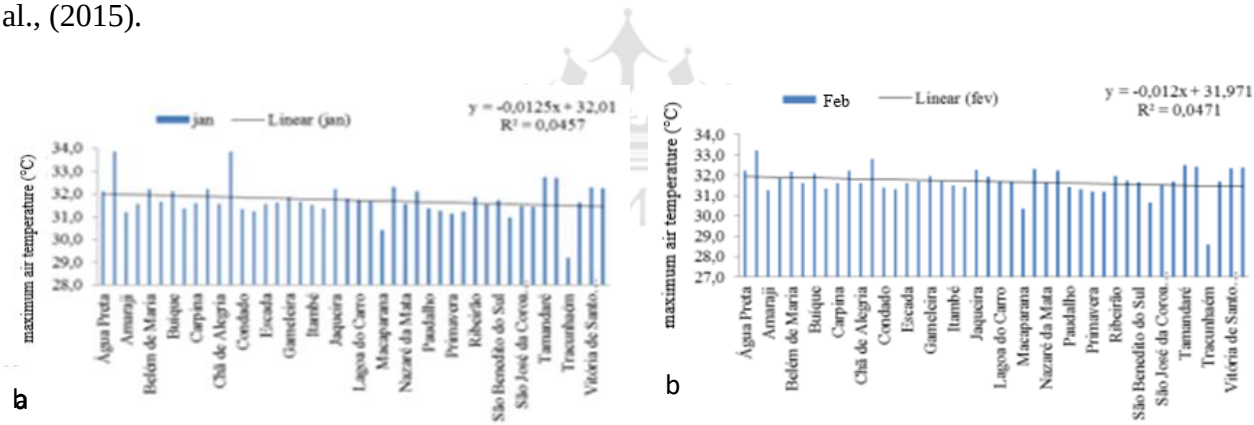

Figure No. 2. The representativeness of the maximum intercity air temperature in the Zona da Mata Pernambucana for January (a); February (b) of the 1950-2020 period.

Source: Medeiros, (2021).

In Figure 2c for March of the 1950-2020 period, there is a historical average of 31.3 °C, the standard deviation of 0.72 °C, coefficient of variance of 0.023, maximum and minimum absolute values of 32, 5 °C and 28.1 °C, respectively, with a median of 32 °C. The trend curve is negative and R^2 Low. Studies such as the one by Medeiros et al. (2018) showed similarities in the results discussed.

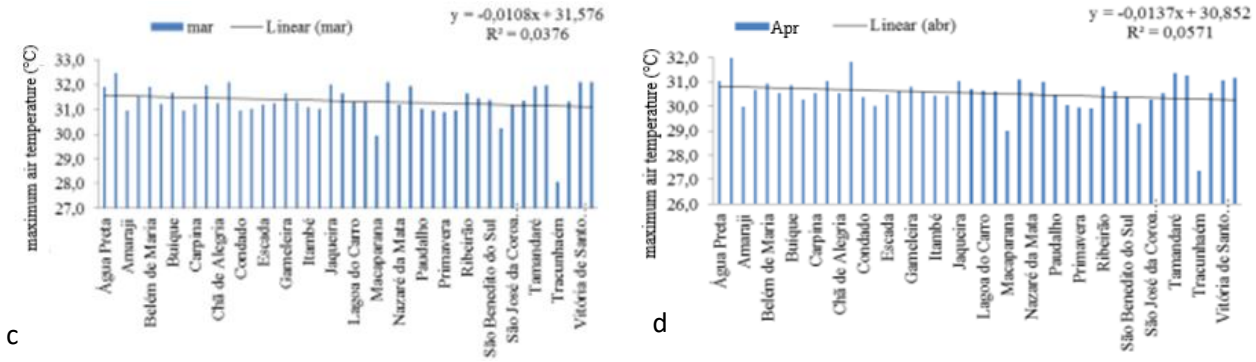

Figure No. 2. The representativeness of the maximum intercity air temperature in the Zona da Mata Pernambucana for March (c); April (d) of the 1950-2020 period.

Source: Medeiros, (2021).

The month of April (Figure 2d) has a historical average of 30.5 °C, the standard deviation of 0.73 °C, coefficient of variance of 0.024, the maximum and minimum absolute values recorded were 32 °C and 27.4 °Ç. The municipalities with low maximum temperatures were Amaraji, Macaparana, Tracunhaém and those with high maximum temperatures were Aliança (30.9 ºC), Chã Grande (30.7 ºC), Tamandaré (29.8 ºC). A straight negative trend and low R^2 are registered.

The month of May registers a straight negative trend and low R^2. The highest thermal indices occurred at 31.1 ºC; 29.9 ºC and the lowest thermal indices were observed for Marapoama and Tracunhaém (Figure 2e). The month of June between the period 1950-2020 registered the highest thermal indexes for the municipalities of Chã de Alegria (30.7 ºC); Tamandaré (29.8 °C) and Tracunhaém (29.6 °C). Similar results were verified in the studies by Luo et al (2005) and Souza et al (2015).

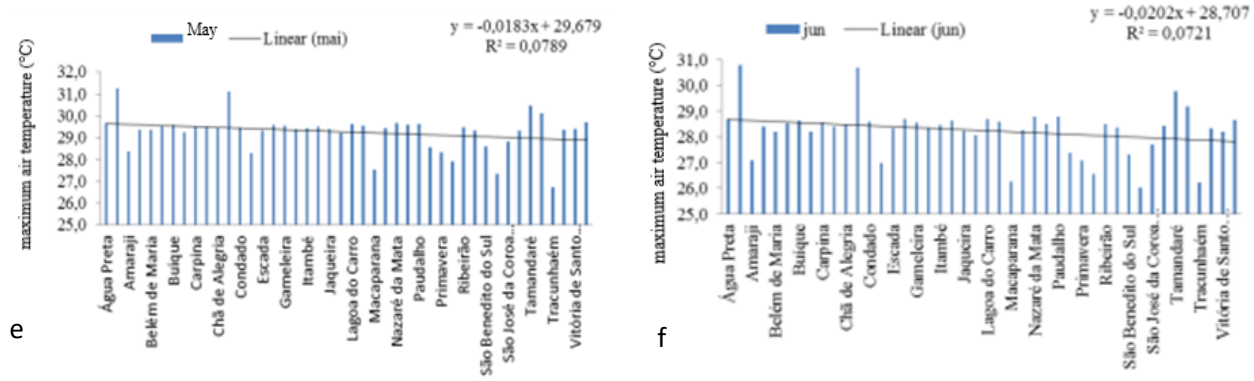

Figure No. 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for May (e); June (f) of the 1950-2020 period.

Source: Medeiros (2021).

In Figure 2f we highlight the municipalities with the highest thermal indexes, Aliança; Joy Tea; Tamandare and tracunharem and the municipalities with the lowest maximum thermal indexes were: Amaraji; Maracapuana; Polite; Quipappa; São Bento do Una, and Tracunharem. The month of July has a negative trend with a low R^2.

The municipalities with the highest maximum thermal indices for July in the Zona da Mata Pernambuca were: Aliança, Cortes, and tracunharem, and those with the lowest thermal indices were restricted to the municipalities of Marapanema and São Bento do Una. A negative trend line with low R^2 is registered. Similar results were found in the studies by Medeiros et al. (2018) and Sousa et al. (2015). (Figure 2g).

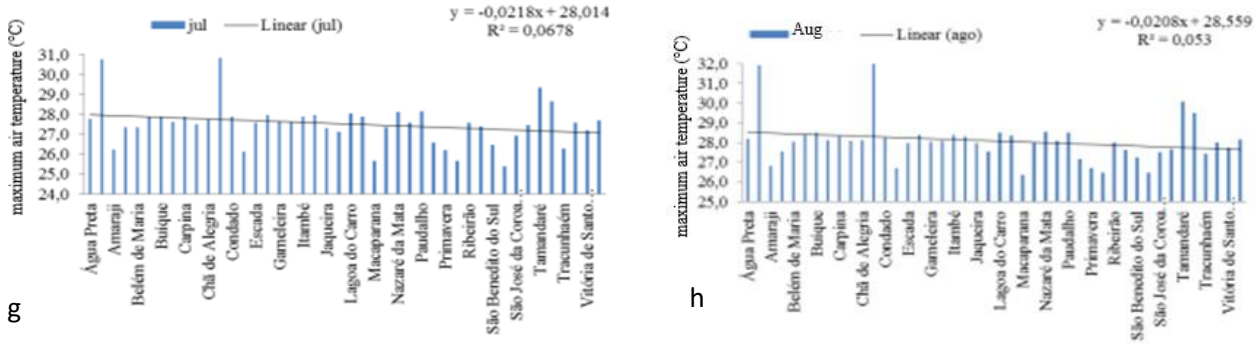

Figure No. 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for July (g); August (h) of the 1950-2020 period.

Source: Medeiros (2021).

Figure 2h shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for August in the period 1950-2020. The municipalities Aliança, Chã de Alegria, Tracunhaém and São Bento do Una registered the highest thermal indexes in the month studied. The municipality of Maracapuana registered the lowest thermal index in the study area. These results corroborate the studies by Medeiros et al. (2018) and Marengo et al. (2015).

Figure 2i shows the buoyancy of the maximum intercity air temperature in the Zona da Mata Pernambucana for September in the period 1950-20120. Trend line with a negative slope and low R2 the months with the highest and lowest thermal indices coincide with those in Figure 2h.

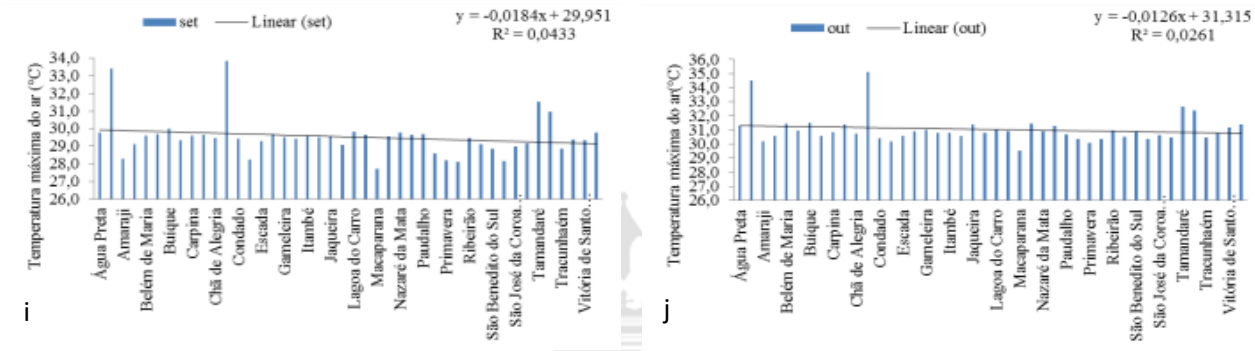

Figure No. 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for July (i); September (j) October of the 1950-2020 period.

Source: Medeiros (2021).

The thermal variability recorded in October (Figure 2j) is very similar to September and October since it is the warmest quarter for the study area. The studies by Medeiros et al. (2018) and Marengo et al. (2015) corroborate the results discussed.

Figure 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for November (k) in the period 1950-20120. This figure practically follows the behavior of the previous figures corresponding to hot months.

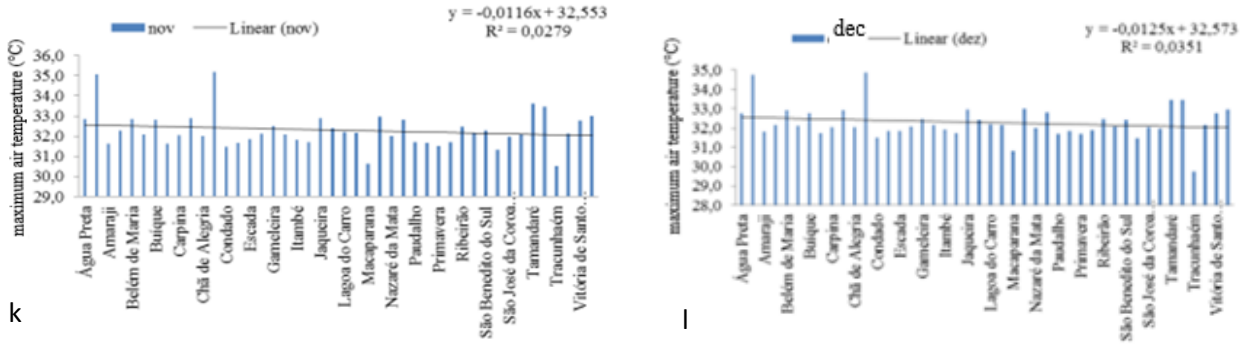

Figure No. 2 shows the representation of the maximum intercity air temperature in the Zona da Mata Pernambucana for November (k); December (l); of the period 1950-20120.

Source: Medeiros, (2021).

Figure 2l corresponds to December with maximum temperature variability ranging between 31 °C and 35 °C. The municipalities of Macaparana and Tracunhaém record the lowest maximum temperature values and the municipalities of Aliança, Tamandaré. The month of December presents a straight negative trend with a low R^2.

The annual variability of the maximum air temperature in the Zona da Mata Pernambucana (Figure 2m) ranges from 28.3 °C to 32.9 °C. The municipalities with the lowest maximum temperature were Macaparana and Tracunhaém. The municipalities with high maximum temperature were: Aliança, Chã Grande, Tamandaré and Timbaúba. The trend line with a negative slope and low R^2. These results corroborate the studies by Marengo et al. (2015) and Medeiros et al. (2018).

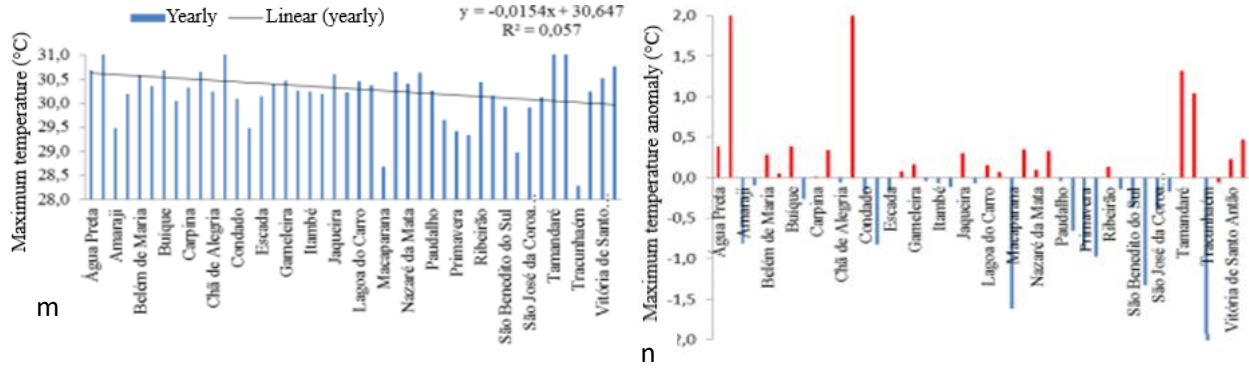

Figure No. 2. The maximum intercity air temperature in the Zona da Mata Pernambucana is represented for the months of annual (m); temperature anomaly (n) and the monthly

mean maximum temperatures and their respective monthly percentages for the period 1950-20120.

Source: Medeiros, (2021).

The maximum inter-municipal temperature anomalies in the Zona da Mata Pernambucna are shown in Figure 2n. With positive anomalies (red color) ranging from 0.1 °C to 2 °C, there are 2 municipalities and 14 municipalities with negative anomalies (blue color) and their oscillations flowing between 0.1 °C and 1.9 °C, these oscillations are by the statements of (MARENGO et al. 2008; MARENGO et al. 2011).

STATISTICAL ANALYSIS OF THE MONTHLY AVERAGE OF THE MAXIMUM AIR TEMPERATURE FROM THE PERIOD FROM 1950 TO 2017 FOR THE AREA OF THE PERNAMBUCA MATA ZONE

Table 2 shows the monthly linear equations, regression determination coefficients (R^2), annual maximum air temperature from 1950 to 2020 for Zona da Mata Pernambucana. The monthly linear equations are presented with a negative slope, the coefficients of determination of the regression (R^2) are of low significance, the months of March, October, November, and December stand out with very low significance. Annual maximum temperatures range from 27.5 °C in July to 32.3 °C in November and December, with an average annual temperature of 30.3 °C.

Table No. 2. Linear equation, regression determination coefficient (R2), and climatological mean of maximum air temperature from 1950 to 2020 for the Zona da Mata Pernambucana area.

Months	Linear equation	R^2	Average
January	y = - 0,0125x + 32,010	0,0457	31,7
February	y = - 0,0120x + 31,971	0,0471	31,7
March	y = - 0,0108x + 31,576	0,0376	31,3
April	y = - 0,0137x + 30,852	0,0571	30,5
May	y = - 0,0183x + 29,679	0,0789	29,3
June	y = - 0,0202x + 28,707	0,0721	28,3
July	y = - 0,0218x + 28,014	0,0678	27,5
August	y = - 0,0208x + 28,559	0,0530	28,1
September	y = - 0,0184x + 29,951	0,0433	29,5
October	y = - 0,0126x + 31,315	0,0261	31,0
November	y = - 0,0110x + 32,553	0,0279	32,3
December	y = - 0,0125x + 30,647	0,0351	32,3
Yearly	y= - 0,0154x + 30,647	0,0570	30,3

Source: Medeiros, (2021).

Table 3 shows the variability of statistical parameters such as: mean, median, standard deviation, coefficient of variance, cost, asymmetry, standard error, absolute maximum and minimum air temperature from 1950 to 20120 for the area of Pernambucana Forest Area.

With an average annual temperature of 30.3 °C and its monthly fluctuations flowing between 27.5 °C in July to 32.3 °C in November and December. The annual median is 30.6 °C and its monthly fluctuations range from 27.3 °C to 32.9 °C in November and December. It is noteworthy that from October to April the possibility of occurrences of thermal indices is average, while in May to September the probability of occurrence of the average is higher than the average.

The mean values with an increase or reduction of standard deviations can be registered or happen by the authors Katz (1991) and Katz et al. (1992) showed that the relative frequency of extreme events depends on changes in standard deviation and not just on the mean.

Table No. 3. Statistical parameters of maximum air temperature from 1950 to 20120 for the Zona da Mata Pernambucana area.

Months	Ave	Med	SD	CV	Kur	Asy	SE	AMx	AMn
January	31,7	32,2	0,75	0,0236	-0,0682	0,0001	0,1131	33,9	29,2
February	31,7	32,2	0,71	0,0224	-0,0682	0,0002	0,1069	33,2	28,6
March	31,3	32,0	0,72	0,0228	-0,0682	0,0000	0,1079	32,5	28,1
April	30,5	31,0	0,73	0,0240	-0,0682	-0,0004	0,1107	32,0	27,4
May	29,3	29,4	0,84	0,0286	-0,0682	-0,0115	0,1260	31,3	26,7
June	28,3	28,2	0,97	0,0343	-0,0682	-0,0378	0,1459	30,8	26,0
July	27,5	27,3	1,07	0,0390	-0,0682	-0,0836	0,1619	30,8	25,4
August	28,1	28,0	1,16	0,0413	-0,0682	-0,0594	0,1750	32,4	26,3
September	29,5	29,5	1,13	0,0384	-0,0682	-0,0102	0,1709	33,9	27,7
October	31,0	31,4	1,00	0,0322	-0,0682	-0,0001	0,1505	35,1	29,5
November	32,3	32,9	0,89	0,0277	-0,0682	0,0019	0,1348	35,2	30,5
December	32,3	32,9	0,86	0,0266	-0,0682	0,0015	0,1293	34,9	29,7
Yearly	30,3	30,6	0,83	0,0274	-0,0682	-0,0015	0,1251	32,9	28,3

Average (Ave); median (Med); standard deviation (SD); Error standard (ES); coefficient of variation (CV); kurtosis (Kur); asymmetry (Asy); standard error (SE); Absolute maximum (Amx); Absolute minimum (Amn).

Fonte: Medeiros, (2021).

Statistically, the variance coefficients do not have expressive indexes of monthly changes, as for the variance parameter, its monthly fluctuations present values with the low significance of monthly occurrences. The kurtosis coefficient presents negative values in all months of the year, while the asymmetry coefficients are variable and stand out in April through October and December being negative. The standard errors are outside the limits indicated according to the

World Meteorological Organization (WMO). The absolute maximum and minimum values are repeatable with variability of 0.7 to 1.4 months.

MÉDIA MÓVEL PARA 5 E 10 ANOS PARA A TEMPERATURA MÁXIMA

The fluctuations of the maximum annual temperatures, historical, moving averages for 5 and 10 years from 1950 to 2020 for the municipalities of Zona da Mata Pernambuco are represented in Figure 3. The maximum annual temperature fluctuates between 28.5°C and 33°C, the average annual temperature is 30.3°C, the 5-year moving average is not very representative while in the 10 years moving average these annual values could be repeated.

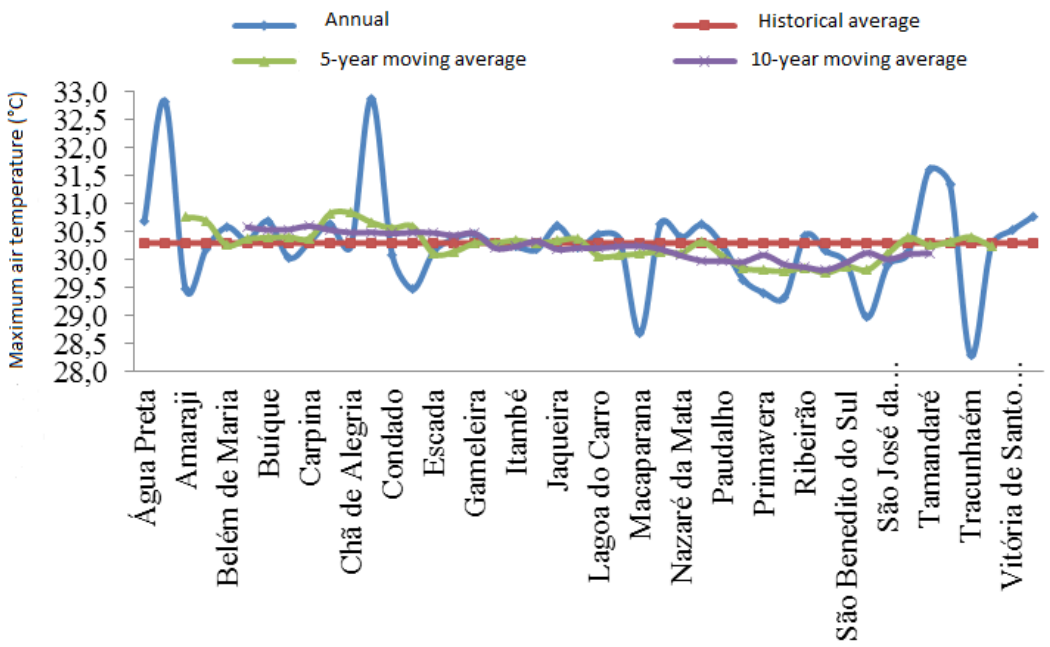

Figure No. 3. Annual maximum temperature, historical, moving averages for 5 and 10 years from 1950 to 2020 for the municipalities of Zona da Mata Pernambucana.

Source: Medeiros, (2021).

Figure 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for January (a); February (b); March (c); April (d); May (e); June (f); July (g); August (h); September (i); October (j); November (k); December (1); annual (m); temperature

anomaly (n) and the monthly mean minimum temperatures and their respective monthly percentages (o) for the period 1950-2020.

The minimum temperatures for January are shown in Figure 4a, with a regression line with a negative slope and R^2 of low significance. The month of January has a historical average of 21 °C and its inter-municipal fluctuations range from 22.1 °C to 19.4 °C. The municipalities of Primavera and São Bento do Una recorded values below the climatological (historical) average, the other municipalities recorded a minimum temperature above the historical average.

The month of February (Figure 4b) has an average of 21 °C, standard deviation of 0.52 °C, the maximum and minimum absolute value of the minimum temperature for the month under study was 21.8 °C and 19.4 ° C, respectively. The municipalities of Amaraji, Cortês, Primavera and São Bento Una recorded a minimum temperature below 20 °C, the municipalities of Baique, Condado, Lagoa do Itaem, Nazaré da Mata, Paudalho and Primavera recorded a minimum temperature above 21.8 °C.

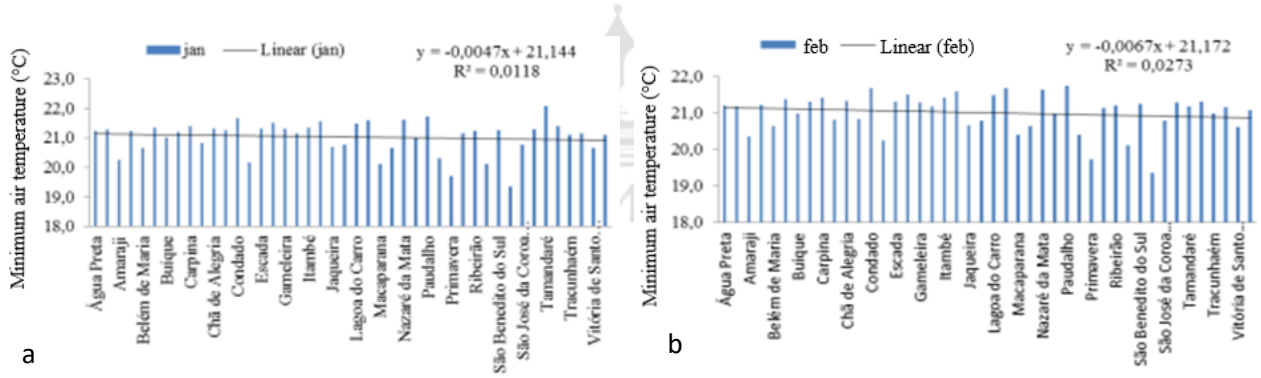

Figure No. 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for January (a); February (b) of the 1950-2020 period.

Source: Medeiros, (2021).

Figure 4c corresponds to March with an average temperature of 21.3 °C, a standard deviation of 0.53 °C, and a coefficient of variance of 0.025 °C. The municipalities of Amaraji, Cortês, Primavera and São Bento Una with a minimum temperature below 20°C and the municipalities of Água Preta, Barreiros, Condado, Nazaré da Mata and Paudalho with a minimum temperature above 21.5 °C.

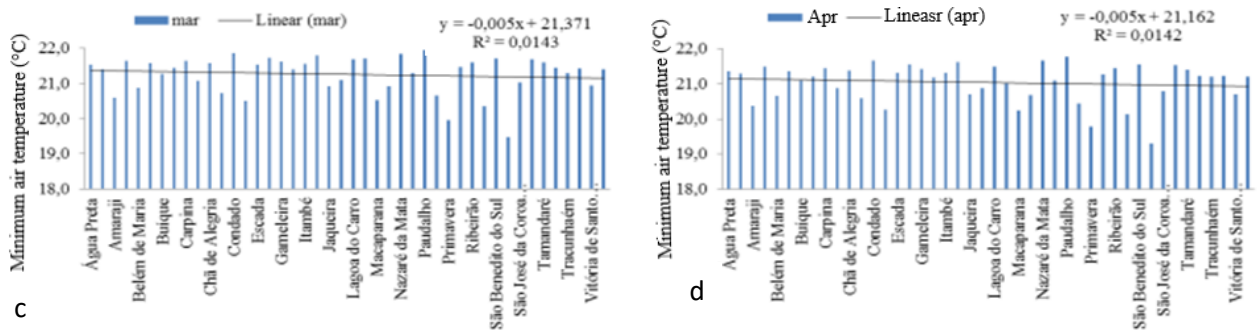

Figure No. 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for March (c); April (d) of the 1950-2020 period.

Source: Medeiros, (2021).

The month of April (Figure 4d) recorded a lower minimum temperature in the municipalities of Amaraji, Cortês, Primavera, and São Bento do Una, the municipalities of Condado, Nazaré da Mata, and Paudalho recorded a minimum temperature above 21.5 °C. It has a mean minimum temperature of 21 °C, the standard deviation of 0.54 °C, and a coefficient of variance of 0.026°C, the maximum and minimum absolute temperatures recorded were 21.8 °C and 19.3 °C, respectively.

Figure 4e shows the variability of the minimum air temperature in the Zona da Mata in Pernambuco for May for the period 1950-2020. Averaging 20.6°C, standard deviation of 0.62 °C and coefficient of variance of 0.030 °C and with absolute maximum and minimum temperature fluctuations of 21.3 °C and 18.5 °C, respectively. The municipalities Primavera and São Bento do Una had a minimum temperature of 18.5°C and the municipalities of Lagoa do Carro, Nazaré da Mata, Tamandaré and Sirinhaém with a minimum temperature above 21 °C.

Figure 4f shows the fluctuations in the minimum temperature for June for the period 1950-2020, the municipalities of Primavera and São Bento do Una with a minimum temperature below 18.5 °C and the municipality of Tracunhaém with a thermal index of 21 °C. The month of June has an average temperature of 19.7 °C, the standard deviation of 0.68 °C, coefficient of variance of 0.035 °C, and absolute maximum and minimum fluctuations ranging from 18.5 °C to 17.5 °C.

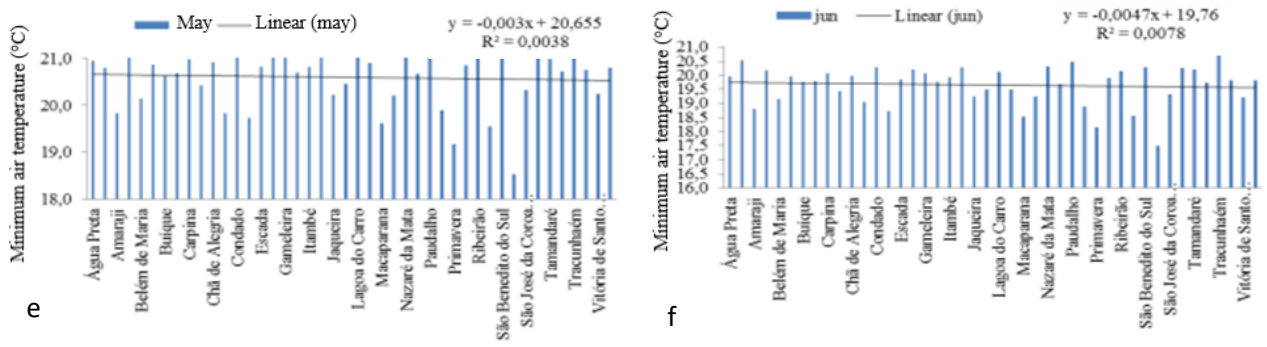

Figure No. 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for May (e); June (f) of the 1950-2020 period.

Source: Medeiros, (2021).

The month of July (Figure 4g) has an average of 18.9 °C, the standard deviation of 0.78 °C and coefficient of variance of 0.041 °C, the absolute maximum and minimum temperatures recorded between 1950-2020 were 19, 9 °C to 16.5 °C respectively. The municipalities of Macaparana, Primavera and São Bento do Una had a minimum temperature of 17.5 °C and the municipalities of Paudalho and Tamandaré with a temperature of 20 °C.

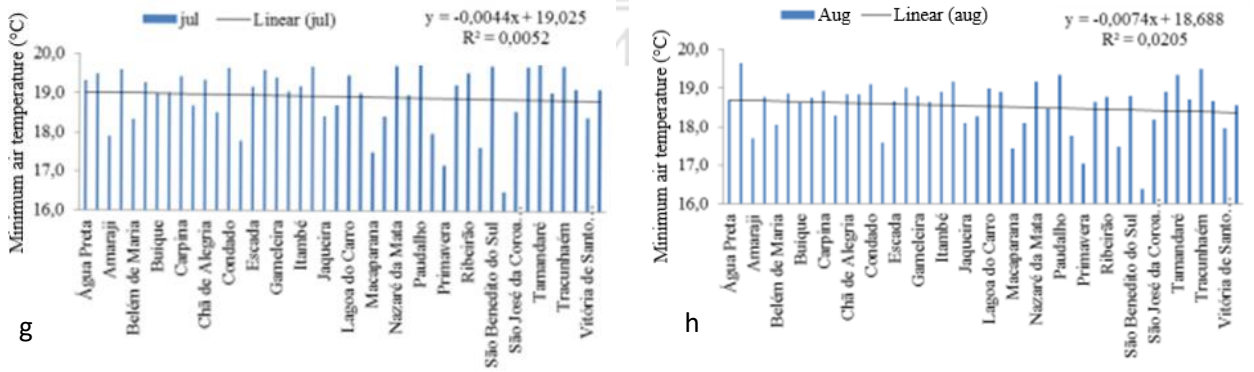

Figure No. 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for July (g); August (h) of the 1950-2020 period.

Source: Medeiros, (2021).

Figure 4h shows the fluctuations of the minimum air temperature in August for the municipalities that make up the Zona da Mata Pernambucana between 1950-2020. The municipality of São Bento do Una has a temperature below 17 °C. The municipalities of Aliança,

Paudalho and Tracunhaém with a minimum temperature above 19.5 °C. The month of August has a minimum temperature of 18.5 °C, the standard deviation of 9.66 °C, coefficient of variance of 0.036, and extreme maximum and minimum temperatures of 19.6 °C and 16.4 °C, respectively.

The month of September (Figure 4i) with a trend line with a negative slope and low R2. The municipalities of Belém de Maria, Catende, Cortes, Escada, Itaquitinga, Jaqueira, Joaquim Nabuco, Macaparana, Marial, Palmares, Primavera, Quipapá, Ribeirão, Rio Formoso, São Benedito do Sul, Vicência and Vitória de Santo Antão with a minimum temperature below of 19°C. The other municipalities record a minimum temperature between 19 °C and 20 °C. A study such as the one by Medeiros et al. (2018). It corroborates the discussed results. i j

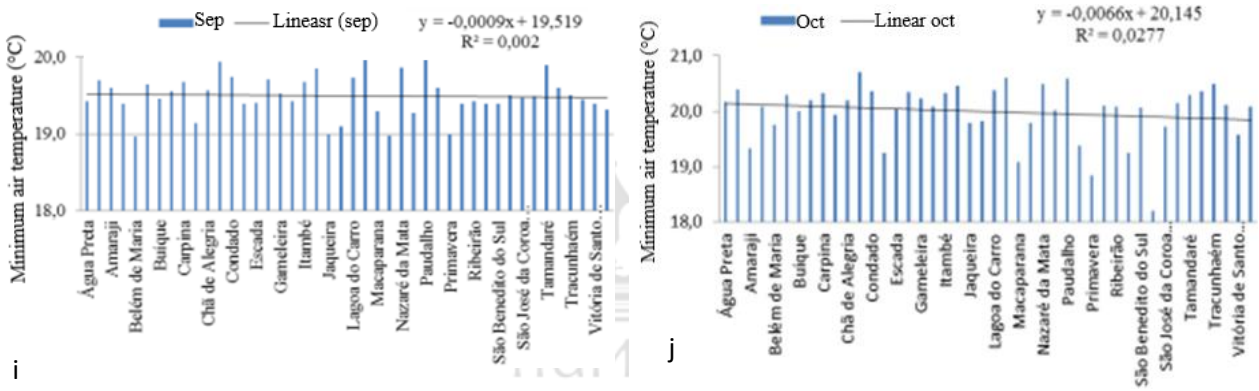

Figure No. 4 shows the representation of the minimum inter-municipal air temperature in the Zona da Mata Pernambucana for September (i); October (j) of the 1950-2020 period.

Source: Medeiros, (2021).

In Figure 4j for October, the municipalities Amaraji, Belém de Maria, Catende, Cortês, Jaqueira, Joaquim Nabuco, Macaparana, Palmares, Pombos, Primavera, Rio Formoso and São Bento do Una stand out with minimum temperature below 20 °C, in the other municipalities, the minimum temperature flowed between 20 °C to 20 °C, the trend line with a negative slope and insignificant R^2.

The municipalities with minimum temperature below 20 °C were Amaraji, Belém de Maria, Cortes, Macaparana, Quipapá, Primavera, São Bento do Una and Vitória de Santo Antão, the

other municipalities with minimum temperature fluctuated between 20.1 °C and 21.5 °C. The month of November represented in Figure 4k has a negative trend line and a low R^2.

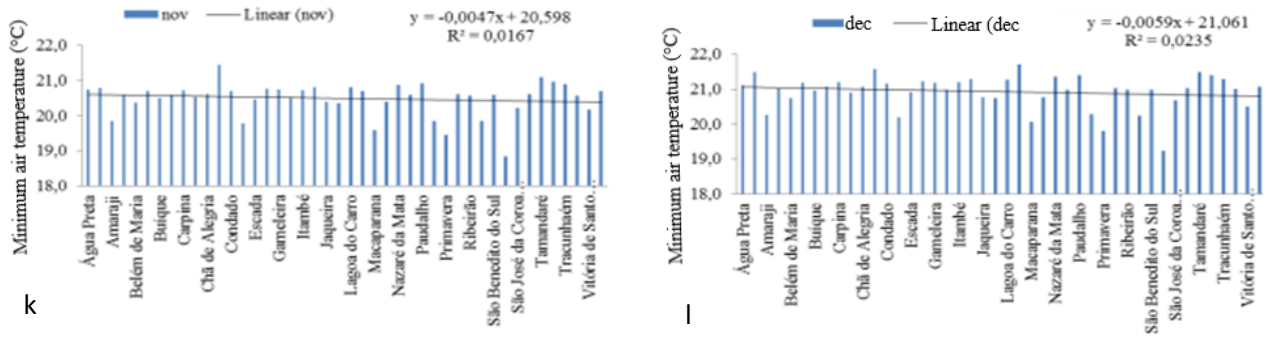

Figure No. 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for November (k); December (1) of the period 1950-2020.

Source: Medeiros, (2021).

In Figure 4l, the minimum temperature fluctuations in the Zona da Mata of Pernambuco for December oscillating between 20.1 °C and 21.5 °C, the month of December presented a trend line with a negative slope and low R^2.

Figure 4m shows the fluctuations of minimum annual temperatures ranging from 18.5 °C in São Bento do Una to 20.7 °C in Paudalho. With a negative linear equation and low significance R^2.

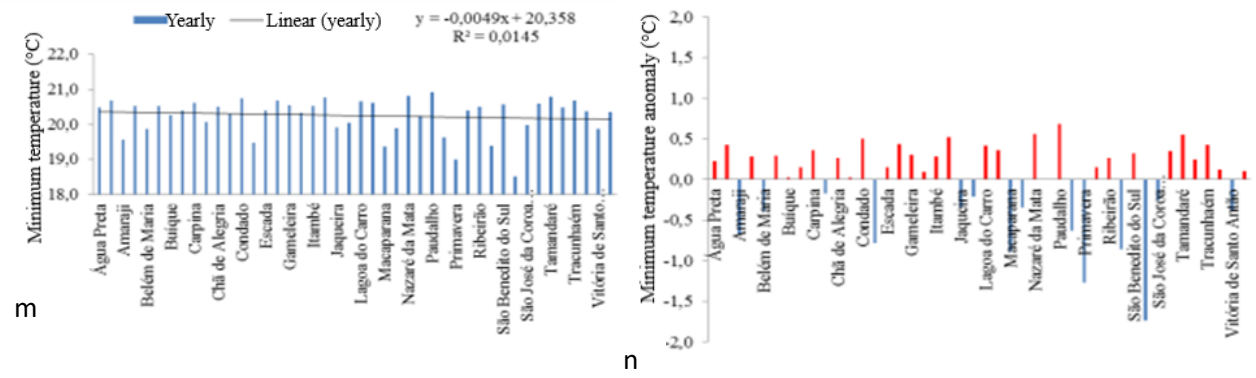

Figure 4 shows the representation of the minimum intercity air temperature in the Zona da Mata Pernambucana for the months of annual (m); temperature anomaly (n) from the period 1950-2020.

Source: Medeiros, (2021).

Figure 4n shows the variability of minimum inter-municipal anomalies ranging from -1.7 °C in the municipality of São Bento do Una to 0.7 °C in Paudalho. The municipalities Amaraji, Belém de Maria, Catende, Jaqueira, Joaquim Nabuco, Macaparana, Marial, Pombos, Primavera, Rio Formoso, São Bento do Una, São José da Coroa Grande and Vitória de Santo Antão have negative minimum temperature anomalies, the others municipalities register positive anomalies.

The variability of minimum temperatures was the ones that suffered most fluctuations such variabilities are by the study by Rossato (2011), these fluctuations are in agreement with the IPCC (2007) and Marengo et al. (2006) and corroborate the results of this research.

Statistical analysis of the monthly average of the minimum air temperature from the period 1950 to 2017 for the area of the pernambuca mata zone.

Table 4 shows the best regression determination coefficients R^2=0.0038 (May), R^2=0.0078 (June), and R^2=0.0052 (July) respectively. Meaning that when the value is higher, it indicates the degree of approximation of the model to the averages, whereas when the value is lower it indicates the degree of distance of the model to the averages. It is concluded that in the other months the model distances itself from the averages.

The annual average minimum temperature is 20.2°C and its monthly fluctuations range from 18.5°C in August to 21°C in January, February and April. Negative linear equations were recorded for all months. (Table 4).

Table No. 4. Linear equation, regression determination coefficient (R2), and monthly mean minimum air temperature from 1950 to 2020 for the Zona da Mata Pernambucana area.

Months	Linear equation	R^2	Average
January	y = - 0,0047x + 21,144	0,0118	21,0
February	y = - 0,0067x + 21,172	0,0273	21,0
March	y = - 0,0050x + 21,371	0,0143	21,3
April	y = - 0,0050x + 21,162	0,0142	21,0
May	y = - 0,0030x + 20,655	0,0038	20,6
June	y= - 0,0047x + 19,760	0,0078	19,7
July	y = - 0,0044x + 19,025	0,0052	18,9
August	y = - 0,0074x + 18,688	0,0205	18,5
September	y = - 0,0009x + 19,519	0,0020	19,5
October	y = - 0,0057x + 20,146	0,0190	20,0
November	y = - 0,0017x + 20,628	0,0011	20,5
December	y = - 0,0013x + 21,151	0,0030	20,9
Yearly	y = - 0,0049x + 20,401	0,0099	20,2

Source: Medeiros, (2021).

Table 5 shows the statistical parameters of the minimum air temperature in the Zona da Mata Pernambucana. With an annual average of 20.6 °C and its monthly fluctuations flowing between 18.9 °C in August to 21.7 °C in March. The annual median is 19.9 °C, with monthly fluctuations ranging from 18.1 °C in August to 20.9 °C in May. The probability of occurrence of the median values is of low insignificance considering its dispersion. The mean values with an increase or reduction of standard deviations can be registered or happen in accordance with the authors Katz (1991) and Katz et al. (1992) showed that the relative frequency of extreme events depends on changes in standard deviation and not just on the mean. Variability of Costis and Asymmetry were negative for all months, including annual values. The variability of the standard error ranges from 0.2381 in May to 0.3035 in November, the annual standard error is 0.2642 being within the reliability ranges. The absolute maximum temperature values have a probability of

occurrence between 1.2 to 2.3 years, the recurrence probability for the absolute minimum values return values are from 0.88 to 1.2 years.

Table No. 5. Statistical parameters of minimum air temperature from 1950 to 2020 for the Zona da Mata Pernambucana area.

Months	Ave	Med	SD	CV	Kur	Asy	SE	AMx	AMn
January	21,5	20,7	1,8	0,086	-0,0682	0,0000	0,2788	31,5	19,4
February	21,5	20,7	1,9	0,087	-0,0682	-0,0001	0,2830	31,8	19,4
March	21,7	20,9	1,8	0,082	-0,0682	0,0000	0,2695	31,5	19,5
April	21,5	20,7	1,7	0,079	-0,0682	0,0000	0,2555	30,6	19,3
May	20,9	20,2	1,6	0,075	-0,0682	-0,0006	0,2381	29,3	18,5
June	20,0	19,2	1,6	0,079	-0,0682	-0,0148	0,2385	28,4	17,5
July	19,2	18,4	1,6	0,083	-0,0682	-0,0430	0,2410	27,3	16,5
August	18,9	18,1	1,7	0,088	-0,0682	-0,0946	0,2494	27,4	16,4
September	19,7	19,0	1,7	0,088	-0,0682	-0,0369	0,2620	29,0	17,3
October	20,4	19,8	1,9	0,091	-0,0682	-0,0097	0,2791	30,4	18,2
November	21,0	20,4	2,0	0,096	-0,0682	-0,0017	0,3035	32,2	18,8
December	21,4	20,8	1,9	0,090	-0,0682	-0,0002	0,2912	32,0	19,2
Yearly	20,6	19,9	1,8	0,085	-0,0682	-0,0043	0,2642	30,1	18,3

Subtitle: Average (Ave); median (Med); standard deviation (SD); Error standard (ES); coefficient of variation (CV); kurtosis (Kur); asymmetry (Asy); standard error (SE); Absolute maximum (Amx); Absolute minimum (Amn).

Source: Medeiros, (2021).

According to Galvani (2011), the standard deviation is important to have information on the "degree of dispersion of values to the average value". The coefficient of variance is used to make comparisons in relative terms and expresses "the variability of each data set normalized to the mean, in percentage."

The occurrence of extreme events of high magnitude and short time intervals is expected, as stated by Marengo *et al.* (2015), these results are by the study in progress.

In scenarios of future changes caused by the increase in gas concentrations in the atmosphere, it is assumed that only the mean can change, with the standard deviation remaining unchanged according to Bem-Gai *et al.* (1998).

MOBILE AVERAGE FOR 5 AND 10 YEARS FOR THE MINIMUM TEMPERATURE

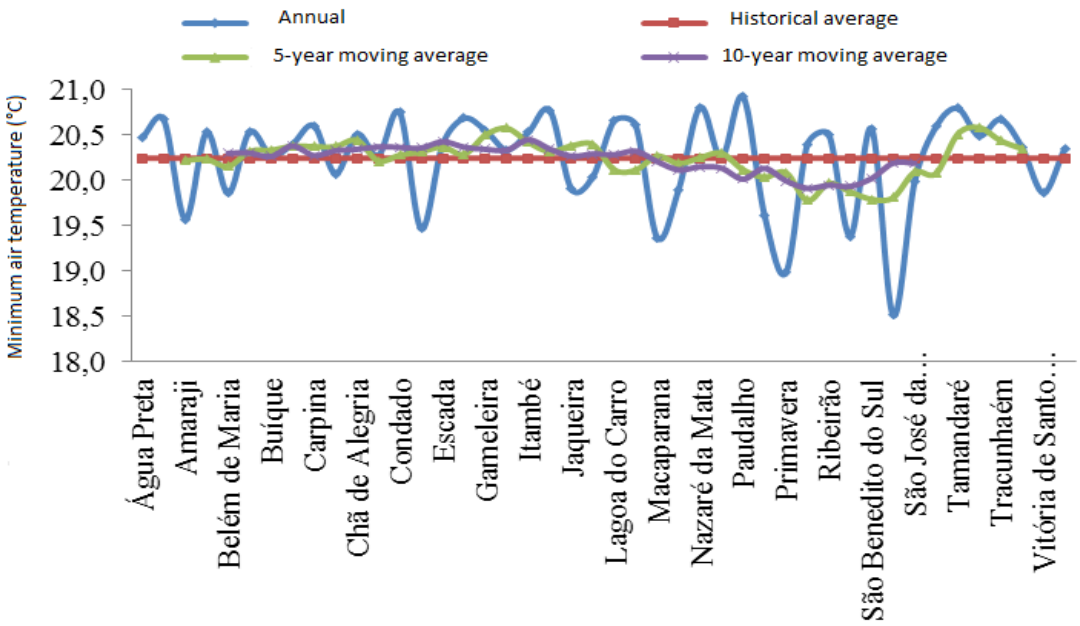

Figure No. 5. Minimum annual temperature, historical, moving averages for 5 and 10 years from 1950 to 2020 for the municipalities of Zona da Mata Pernambucana.

Figure 5 represents the minimum annual temperature, historical, moving averages for 5 and 10 years from 1950 to 2020 for the municipalities in the Zona da Mata Pernambucana. The behavior of the estimated temperature follows the estimates of the moving average for 5 and 10 years, the rhythm of temperatures with a reduction in amplitude and flattening between years. The 10-year moving average estimates present values of greater significance than for the 5-year ones.

Source: Medeiros, (2021).

Laudau et al. 2009 stated that the reduction in the minimum temperature causes an increase in the thermal amplitude, which influences the diversity of regional or local species, as places with a smaller thermal amplitude tend to be stable and present greater diversity.

CONCLUSION

The equations of the Estima-T model estimate the monthly and annual values of the minimum and maximum temperatures with good significance taking into account the relief and the SST anomaly.

Temperature reductions flow in consonance with the conduct of the rainy season and the actions and/or contributions of regional and local effects, such as the impacts on the environment and the actions of transient synoptic systems of meso and micro-scale.

Of the air temperatures studied, the minimum temperature is, notably, the one with the greatest increase and the greatest spatial consistency.

The increase in the average air temperature is due to the strong tendency of the minimum air temperature to rise.

The 10-year moving average estimates present values of greater significance than for the 5-year ones.

Information on air temperature variability helps decision-makers in the agricultural and agribusiness sector, in urban environmental comfort, and various areas of knowledge.

The minimum temperature has higher values between the most recent period 1990-2009 than in 1950-1989.

Air temperature varies significantly between altimetry and over the years in the Zona da Mata in Pernambuco.

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