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Minimum Temperature Oscillations in the Zona Da Mata in the State of Pernambuco, Brazil

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ABSTRACT

Thermal increases result in extreme events and changes in rainfall patterns, with greater events of droughts and floods. This natural imbalance in the ecosystem can lead to the phenomenon of desertification from the impoverishment and degradation of land in arid, semi-arid and sub-humid áreas. The present work aimed to analyze the temporal space fluctuations of the minimum temperatures in the Zona da Mata Pernambucana, and to plot their monthly and annual graphs, providing relevant information. Minimum temperature values were estimated by the Estima_T software. The data obtained by the estima_T software corresponds to the 1950-2020 period, and were generated by electronic spreadsheets. Basic statistical calculations were performed for the generation of graphs and tables and other parameters relevant to the development of this study. The equations of the Estima-T model estimate the monthly and annual values of minimum temperatures with good significance, taking into account the relief and the anomaly of the SST. The temperature reductions flow in line 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 the 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 greatest spatial consistency. Estimates of 10-year moving averages show values of greater significance than for 5 years. The minimum temperature has higher values between the most recent period of 1990-2009 than of 1950-1989. Air temperature varies significantly between altimetry and over the years in the Zona da Mata in Pernambuco.

INTRODUCTION:

When the local atmosphere is stable, the result of the orography is restricted to low levels, closer to the mountains, and implies the occurrence of rain. When unstable, the orographic effect potentiates and redistributes the rainfall volume to larger areas. According to the authors, for the Southeast of Brazil, the main factor responsible for the orographic rain seems to be the airflow, represented by the action of the regional atmospheric systems, with southeast winds, sea breeze and the surrounding convection (Lima *et al*, 2011; Cavalcanti *et al*, 2017; Almeida *et al*, 2014).

According to the (IPCC, 2013; Assad *et al.* 2008), in Brazil and in the world, climate change can affect food production and cause risk areas to increase.

Medeiros (2020) analyzed the decadal variability of the series of precipitation and minimum air temperature, aiming at the water crisis in the municipality of São Bento do Una, between the years 1920 to 2016. The local atmospheric contributions such as the Convergence Zone Intertropical influenced with intensity and caused rain above normal in some decades, registering disasters of moderate to intense proportion. The minimum temperature fluctuated in increments of 0.1 ºC to 0.3 ºC for some decades.

Melo *et al.* (2015) analyzed the oscillations of extreme and average temperatures in the state of Pernambuco, in order to understand future changes. These authors affirmed that the knowledge of the climatic behavior of a region is important for studies of weather forecast and mainly for the agricultural and agribusiness planning and that the delimitation of a warmer or colder period serves as a warning to federal, state and decision makers, with the aim of better planning to improve life.

According to the authors (Luo *et al*. 2005; Zhang *et al*. 2005; Machado 2009) showed that future climatic conditions have shown increases in their thermal indexes, resulting in important impacts for different agricultural activities, such as: fruit, vegetables and grain production.

França *et al*. (2020) analyzed the decadal variability of the minimum temperature time series in the periods of 1963-1972, 1973-1982, 1983-1992, 1993-2002, 2003-2012 and 2013-2020 and compared it with the historical average of 1960-2018. They showed that the minimum temperature in the area has been causing changes in its oscillations in the early morning period,

leaving the weather more unstable and warmer in the last decade. The thermal anomalies recorded in the first two decades were due to natural factors, and over the decades the effect of urbanization and interiorization was notorious, intensifying the effect of anomalies due to anthropic effects.

The restriction of water resources today is a conditioning factor for socioeconomic and agricultural development, which has led to numerous challenges in its planning and management (Sousa *et al*. 2015).

Lima *et al.* (2011) stated that when the local atmosphere is stable, the result of the orography is restricted to low levels, closer to the mountains and implies the occurrence of rain. When unstable, the orographic effect potentiates and redistributes the rainfall volume to larger areas. According to the authors, for the Southeast of Brazil, the main factor responsible for the orographic rain seems to be the airflow, represented by the action of the regional atmospheric systems (southeast winds, sea breeze and the surrounding convection).

Medeiros *et al*. (2018) performed analyzes of the temporal space variability of the average air temperature in the State of Pernambuco, distributed over its homogeneous regions. They showed that the results of thermal fluctuations are related to altitude and latitude, being one of the physiographic variables that better explain the variation of the monthly and annual temperature in the study area. The fluctuations in the average temperature are due to the synoptic systems operating at the time of the rainy and dry periods and also to the impacts on the environment. The authors concluded that temperature reductions occurred in accordance with the displacement of the rainy season and the actions and/or contributions of regional and local effects.

The objective of the present work was to analyze the temporal space fluctuations of the minimum temperatures in the Zona da Mata Pernambucana, and to plot their monthly and annual graphs, providing relevant information to researchers and decision makers in several areas of activity, especially in agriculture, agribusiness, storage grain, water supply for the population and thermal comfort.

MATERIALS AND METHODS:

The Zona da Mata Pernambucana is composed of 44 municipalities, with an area of 8,738 km^2, limited to the north with the state of Paraíba, to the south with the state of Alagoas, to the east with the municipality Recife and to the west with the Agreste region (Figure 1).

Figure No. 1: Geographic representation of the Zona da Mata in the state of Pernambuco, Brazil. Source: Medeiros, (2020).

The mesoregion Zona da Mata 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 Mata Atlântica, which includes medium and large trees and grasses, with a rich fauna.

The main systems responsible for the occurrence of rainfall indexes are the ZCIT - Intertropical Convergence Zone (Hastenrath *et al*, 1977), the cold fronts (Aragão, 1976; Kousky, 1979; 1981), the eastern disturbances or east waves (Yamazaki *et al*, 1977) and the High Level Cyclonic Vortexes (VCAN). The ZCIT is the main meteorological system that provides rain in the northern sector of northeastern Brazil (NEB), where the state of Pernambuco is inserted.

Minimum temperature values estimated by the Estima_T software (Cavalcanti *et al*, 1994; Cavalcanti *et al*, 2006) were used. The following equation was applied:

$$T = C_0 + C_1\lambda + C_2Ø + C_3h + C_4\lambda^2 + C_5Ø^2 + C_6h^2 + C_7\lambda Ø + C_8\lambda h + C_9Øh$$

The data obtained by the estima_T software corresponds to the 1950-2020 period, and were generated by electronic spreadsheets. Basic statistical calculations were performed for the generation of graphs and tables and other parameters relevant to the development of this study.

RESULTS AND DISCUSSION:

Table 1 shows the relations of the municipalities, geographic coordinates (latitude, longitude and altitude), followed by the climatic classification according to the method of Köppen (1928; 1931) for Zona da Mata Pernambucana. Eleven types of "Am" climate (tropical humid or sub-humid climate) and thirty-three municipalities with "AS" type climate (warm climate with winter rain) were recorded.

Table No. 1: Municipalities, geographic coordinates (latitude, longitude and altitude), followed by the climatic classification according to the Köppen method for Zona da Mata Pernambucana. **Source: Medeiros, (2020).**

Municipalityy	Latitude ° ‘	Longitude ° ‘	Altitude meters	Köppen Classification	Municipality	Latitude ° ‘	Longitude ° ‘	Altitude meters	Classificação 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
Chã Alegria	-8,0	-35,2	136	As	Ribeirão	-8,5	-35,4	151	Am
Chã Grande	-8,2	-35,5	466	As	Rio Formoso	-8,7	-35,2	086	Am
Condado	-7,6	-35,1	079	As	S. Bento	-8,8	-36,0	460	As

					Sul				
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

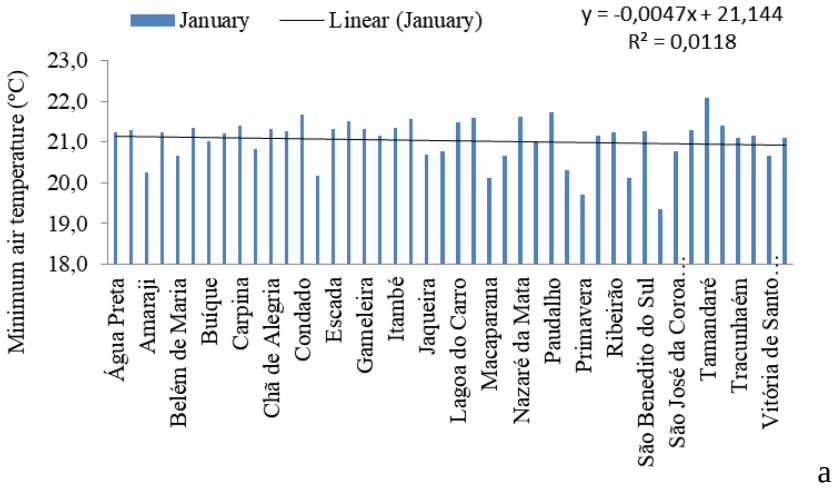
Similar results were found by Alvares *et al*. (2014) in the climatic classification for Brazil, with emphasis on the coast of the Northeast of Brazil, with climate "Bsh", in the transition zone, and the climate "As" Costeiro do Ceará, extending to the coast of the State from Pernambuco. The climatic classification according to Köppen for the study area is in accordance with the classifications of Camargo (1961), Alvares *et al*. (2014) and Medeiros *et al*. (2018).

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

Figure 2 represents the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for the months of January (a); February (b); March (c); April (d); May (e); June

(f); July (g); August (h); September (i); October (j); November (k); December (l); annual (m); temperature anomaly (n) and average monthly minimum temperatures and their respective monthly percentages (o) for the period 1950-2020.

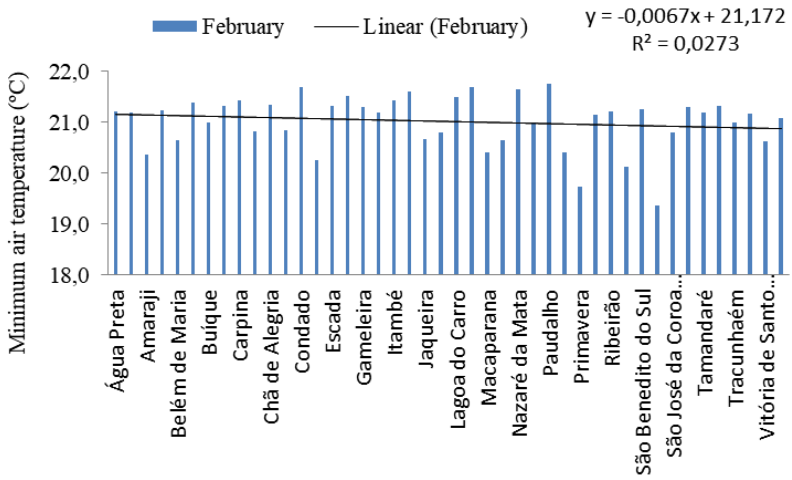
The minimum temperatures in January are shown in Figure 2a, with a negative slope and R^2 of low significance. January has a historical average of 21 °C and its inter-municipal fluctuations range from 22.1 °C to 19.4 °C. The municipalities of Primavera and São Bento do Una registered values below the historical climatological average. The other municipalities recorded minimum temperatures above the historical average. It should be noted that in the last three decades there have been trends in average temperature values above normal. Similar results were presented by França *et al*. (2020).



a

Figure No. 2a: Representativeness of the minimum intermunicipal temperature in the Zona da Mata Pernambucana for January of the 1950-2020 period. Source: Medeiros, (2021).

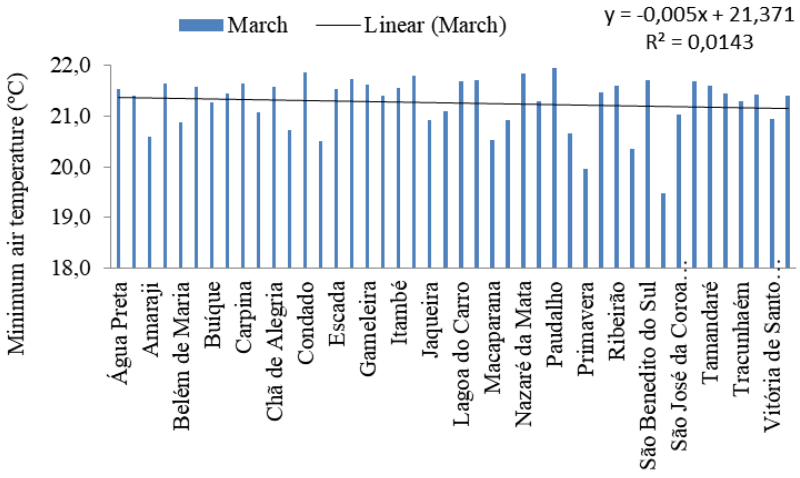
The month of February (Figure 2b) presents an average of 21 ° C, standard deviation of 0.52 °C, and absolute maximum and minimum values of 21.8 °C and 19.4 °C, respectively. In the municipalities of Amaraji, Cortês Primavera and São Bento do Una the minimum temperature was below 20 ° C; the municipalities of Buíque, Condado, Lagoa do Itaem Nazaré da Mata, Paudalho and Primavera recorded minimum temperatures above 21.8 ° C. Similar results were detected by Marengo (2015). Such buoyancy was observed by Brito *et al*, (2015) for the Northeast of Brazil.



b

Figure No. 2b: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for February of the period 1950-2020. Source: Medeiros, (2021).

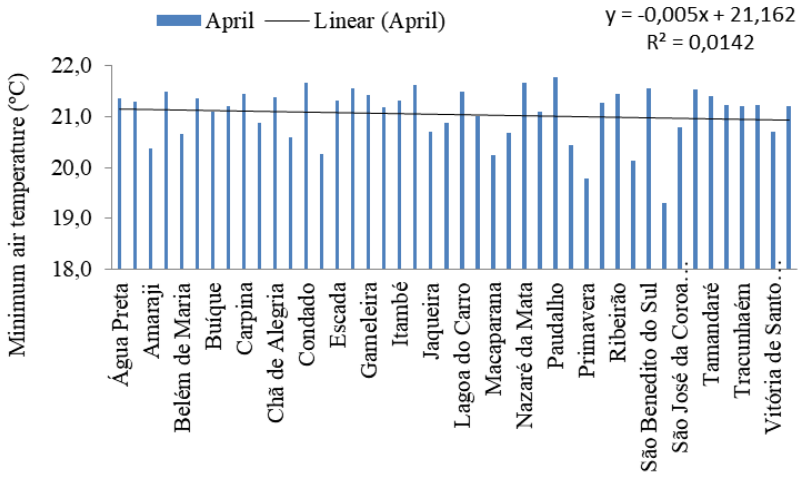
Figure 2c corresponds to the month of March with an average temperature of 21.3 °C, standard deviation of 0.53 °C and coefficient of variance 0.025 °C. The municipalities of Amaraji, Cortês, Primavera and São Bento do Una had a minimum temperature below 20 °C and the municipalities of Água Preta, Barreiros Condado, Nazaré da Mata and Paudalho with a minimum temperature above 21.5 °C. The results of the IPCC (2013) and IPCC (2014) corroborate the discussions in this article.



c

Figure No. 2c: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for March of the 1950-2020 period. Source: Medeiros, (2021).

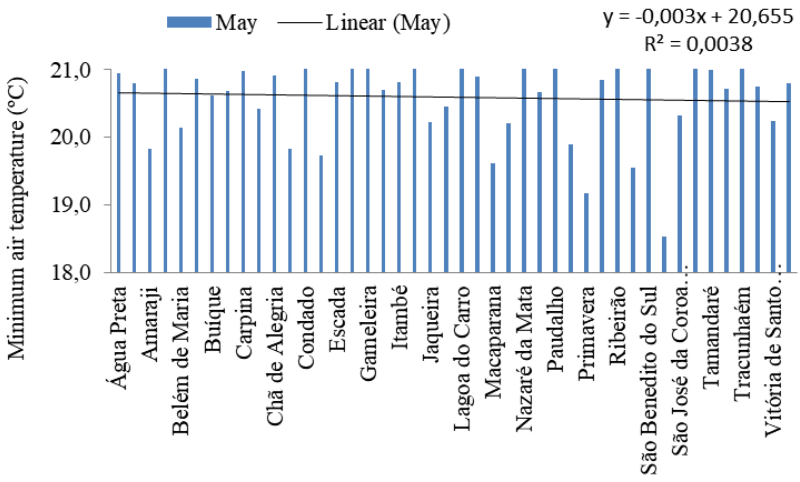
The month of April (Figure 2d) recorded a lower minimum temperature in the municipalities of Amaraji, Cortês, Primavera and São Bento do Una. In the municipalities of Condado, Nazaré da Mata and Paudalho there was a minimum temperature above 21.5 °C. It has an average minimum temperature of 21 °C, standard 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. Such buoyancy was observed by Brito, Becken and Cavalcanti (2015) for the Northeast of Brazil.



d

Figure No. 2d: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for April of the 1950-2020 period. Source: Medeiros, (2021).

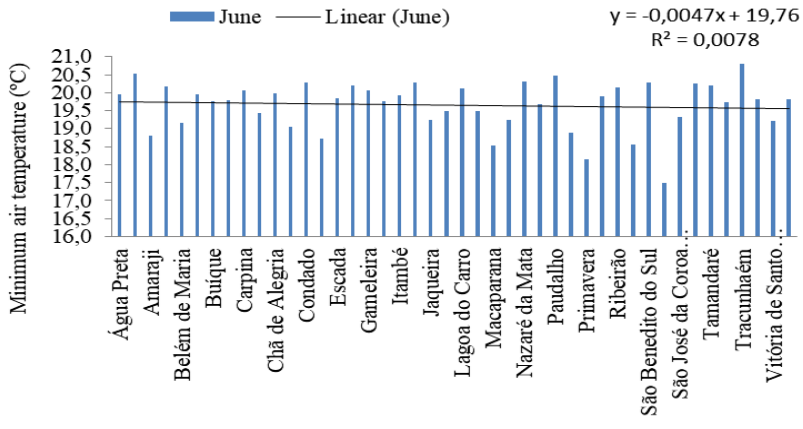
Figure 2e shows the variability of the minimum air temperature in the Zona da Mata of Pernambuco for the month of May for the period 1950-2020. There is an average of 20.6 °C, a standard deviation of 0.62 °C and a coefficient of variance of 0.030 °C and with maximum and minimum absolute temperature fluctuations 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 had a minimum temperature above 21 ° C.



e

Figure No. 2e: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for May of the 1950-2020 period. Source: Medeiros, (2021).

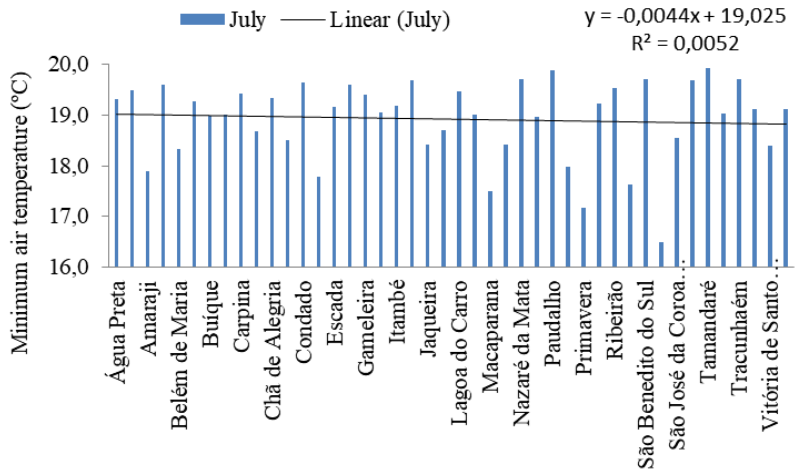
Figure 2f shows the fluctuations in the minimum temperature in the month of June for the period 1950-2020. The municipalities of Primavera and São Bento do Una had a minimum temperature below 18.5°C and the municipality of Tracunhaém with a thermal index of 21°C. The month of June has an average temperature of 19.7°C, standard deviation of 0.68°C, a coefficient of variance of 0.035°C, and the maximum and minimum absolute fluctuations ranging from 18.5°C to 17.5°C. Results of studies by authors Reguero, Losada & Mendez (2019) corroborate those discussed in this article.



f

Figure No. 2f: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for June of the 1950-2020 period. Source: Medeiros, (2021).

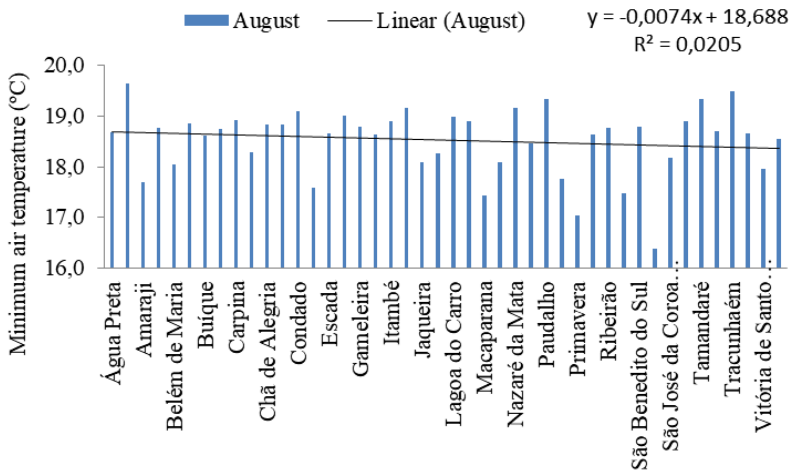
The month of July (Figure 2g) presents an average of 18.9°C, a standard deviation of 0.78°C and a coefficient of variance of 0.041°C. The maximum and minimum absolute temperatures recorded between 1950-2020 were 19.9°C and 16.5°C, respectively. The municipalities of Macaparana, Primavera and São Bento do Una had a minimum temperature of 17.5°C and the municipalities of Paudalho and Tamandaré with a temperature of 20°C. The results found by the authors Lopart *et al*, (2018), corroborate those discussed here in this work.



- g

Figure No. 2g: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for July of the 1950-2020 period. Source: Medeiros, (2021).

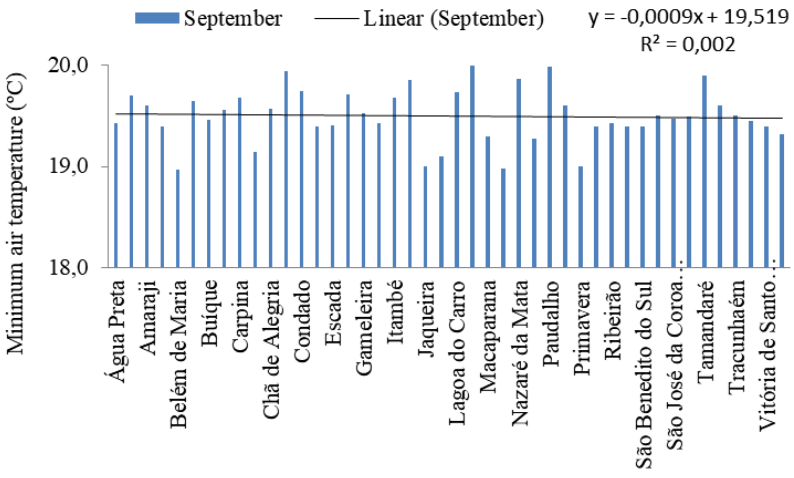
Figure 2h shows the fluctuations in the minimum air temperature in August for the municipalities that make up the Zona da Mata Pernambucana between the years 1950-2020. The municipality of São Bento do Una has a temperature below 17 °C. The municipalities of Aliança, Paudalho and Tracunhaém have a minimum temperature above 19.5 °C. The month of August has a minimum temperature of 18.5 °C, a standard deviation of 9.66 °C, a coefficient of variance of 0.036 and the absolute maximum and minimum extreme temperatures of 19.6 °C and 16.4 °C, respectively. These results can be corroborated with studies by Kayano *et al*, (2017).



h

Figure No. 2h: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for August of the 1950-2020 period. Source: Medeiros, (2021).

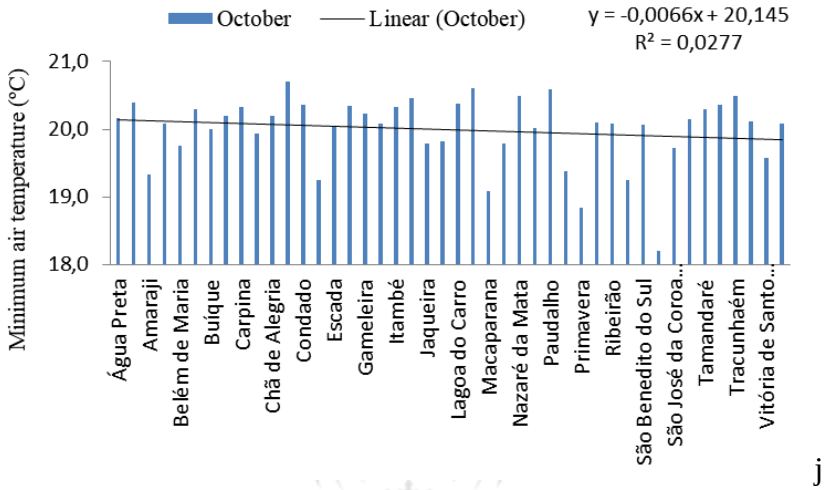
The month of September (Figure 2i) presents a trend line with negative slope and low R^2. The municipalities of Belém de Maria, Catende, Cortês, Escada, Itaquitinga, Jaqueira, Joaquim Nabuco, Macaparana, Marial, Palmares, Primavera, Quipapá, Ribeirão, Rio Formoso, São Benedito do Sul, Vicência and Vitória de Santo Antão show minimum temperature below 19°C. The other municipalities register a minimum temperature between 19°C to 20°C.



i

Figure No. 2i: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for September of the period 1950-2020. Source: Medeiros, (2021).

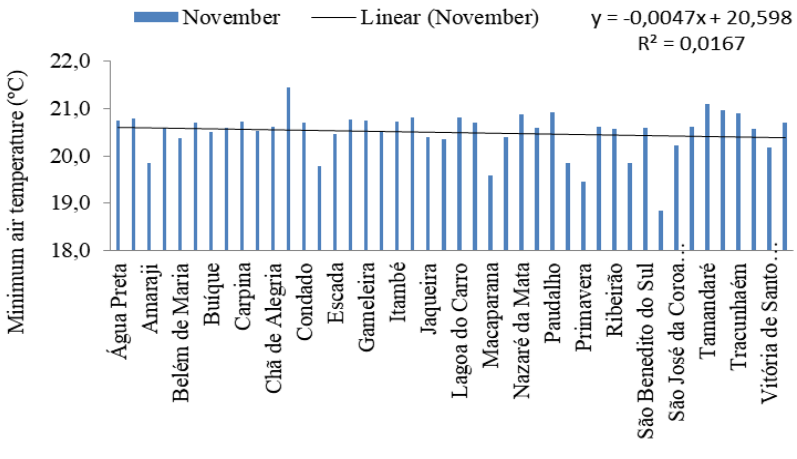
In Figure 2j for the month of October, the municipalities of Amaraji, Belém de Maria, Catende, Cortês, Jaqueira, Joaquim Nabuco, Macaparana, Palmares, Pombos, Primavera, Rio Formoso and São Bento do Una stand out with a minimum temperature below 20°C. In the other municipalities, the minimum temperature flowed between 20°C to 20°C. The trend line has a negative slope and an insignificant R^2. These results are in accordance with the studies by Marengo and Camargo (2008).



j

Figure No. 2j: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for October of the 1950-2020 period. Source: Medeiros, (2021).

In the November (Figure 2k), the municipalities with minimum temperature below 20 °C were Amaraji, Belém de Maria, Cortês, Macaparana, Quipapá, Primavera, São Bento do Una and Vitória de Santo Antão. In the other municipalities, the minimum temperature flowed between 20.1 °C and 21.5 °C. The month of November represented in Figure 2k has a negative trend line and a low R^2.



k

Figure No. 2k: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for November of the 1950-2020 period. Source: Medeiros, (2021).

In Figure 2l there are the fluctuations of the minimum temperatures in the Zona da Mata de Pernambuco, referring to the month of December, oscillating between 20.1 °C and 21.5 °C. The month of December presented a trend line with negative slope and low R^2.

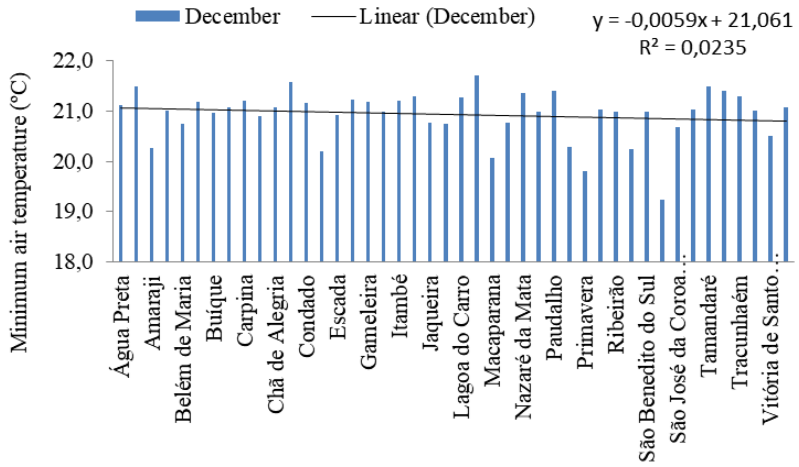


Figure No. 2l: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for December of the 1950-2020 period. Source: Medeiros, (2021).

Figure 2m shows the fluctuations in annual minimum temperatures between 18.5 °C in São Bento do Una and 20.7 °C in Paudalho, with a negative linear equation and R^2 of low significance.

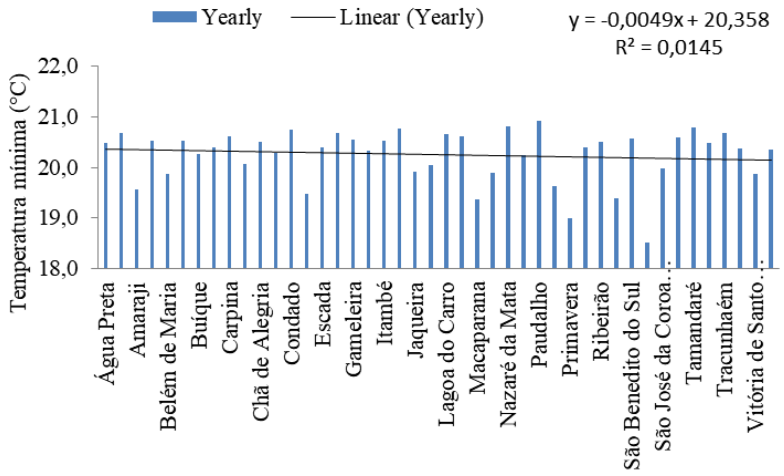


Figure No. 2m: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana for the annual period of 1950-2020. Source: Medeiros, (2021).

Figure 2n shows the variability of the minimum intermunicipal anomalies oscillating between -1.7 °C in the municipality of São Bento do Una and 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. In the other municipalities, positive anomalies occurred.

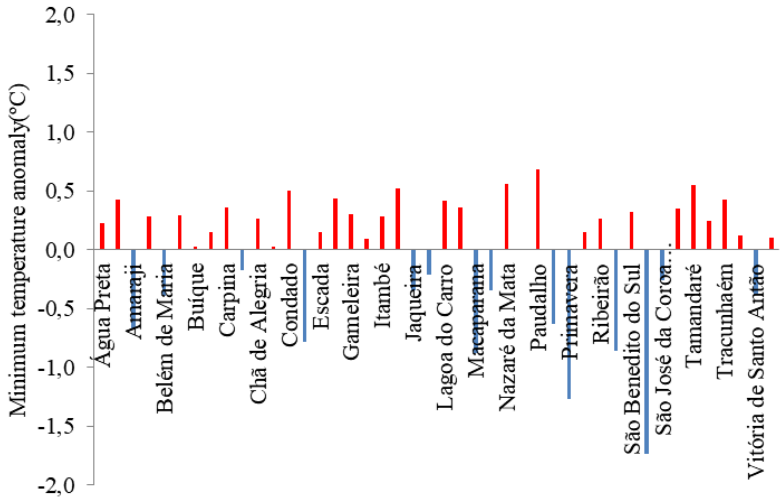
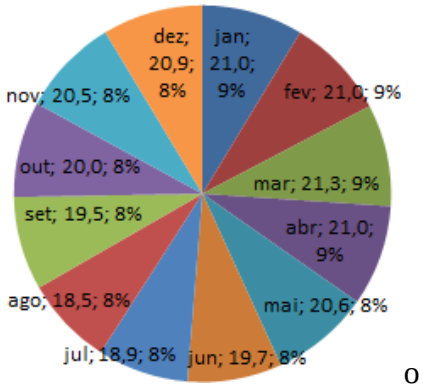


Figure No. 2n: Representativeness of the minimum temperature of the intermunicipal air in the Zona da Mata Pernambucana referring to the temperature anomaly (n) of the period 1950-2020. Source: Medeiros, (2021).

The months of January, February, March and April represent 36% of the annual variability and the months from May to December correspond to 64% of the annual temperature. In the months of May to December, the temperature fluctuations have variable intermunicipal intensities. (Figure 2o). The variability of the minimum temperatures was the one that most presented oscillations. Such variability is in accordance with the study by Rossato (2011) and these fluctuations are in accordance with the (IPCC, 2007; Marengo *et al.* 2006) whose results corroborate with the results of this research.



o

Figure No. 2o: Variability of the average monthly temperatures of the lows and their respective monthly percentages for the period 1950-2020. Source: Medeiros, (2021).

Statistical analysis of the monthly average minimum air temperature for the period 1950 to 2017 for the area of the mata pernambucana área

Table 2 shows the best regression determination coefficients R^2 = 0.0038 (May), R^2 = 0.0078 (June) and R^2 = 0.0052 (July), 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 from the averages.

The average annual minimum temperature is 20.2 °C and its monthly fluctuations range from 18.5 °C in the month of August to 21 °C in the months of January, February and April. Negative linear equations were recorded in all months (Table 2).

Table No. 2: Linear equation, regression determination coefficient (R^2) and monthly average of the minimum air temperature for the period from 1950 to 2020 for the Zona da Mata Pernambucana area. Source: Medeiros, (2021).

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

Table 3 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 between 18.9 °C in the month of August at 21.7°C in March. The annual median is 19.9°C, with monthly fluctuations between 18.1°C in August and 20.9°C in May. The probability of occurrences of the median values occurring is of low insignificance, in view of their dispersion. The average values with the increase or reduction of the standard deviations may be registered or happen in accordance with the authors Katz (1991) and Katz *et al.* (1992), who showed that the relative frequency of extreme events depends on changes in standard deviation and not just on the mean. The variability of Curtose and Asymmetry was negative for all months, including the annual values. The variability of the standard error ranges from 0.2381 in the month of May to 0.3035 in November; the annual standard error is 0.2664 being within the reliability ranges. The values of maximum absolute temperature are likely to occur between 1.2 to 2.3 years; the probability of recurrence for the return values of the absolute minimum values is from 0.88 to 1.2 years.

Table No. 3: Statistical parameters of the minimum air temperature for the period from 1950 to 2020 for the Zona da Mata Pernambucana area. Source: Medeiros, (2021).

Months	Average	Median	standard deviation	Variance coefficient	Kurtosis	Asymmetry	Standard Error	Absolute maximum	absolute minimum
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

According to Galvani (2011) the standard deviation is important for obtaining information on the "degree of dispersion of the values in relation 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 in relation to the average, in percentage."

Extreme events of high magnitude and short time are expected to occur. According to a statement by Marengo *et al*. (2015), these results are in accordance with the present study.

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

Mobile average for 5 and 10 years for minimum temperature

Figure 3 represents the minimum annual, historical temperature, moving averages for 5 and 10 years, from the period 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 the temperatures with reduction of amplitude and flatness between years. Estimates of 10-year moving averages show values with greater significance than for 5 years.

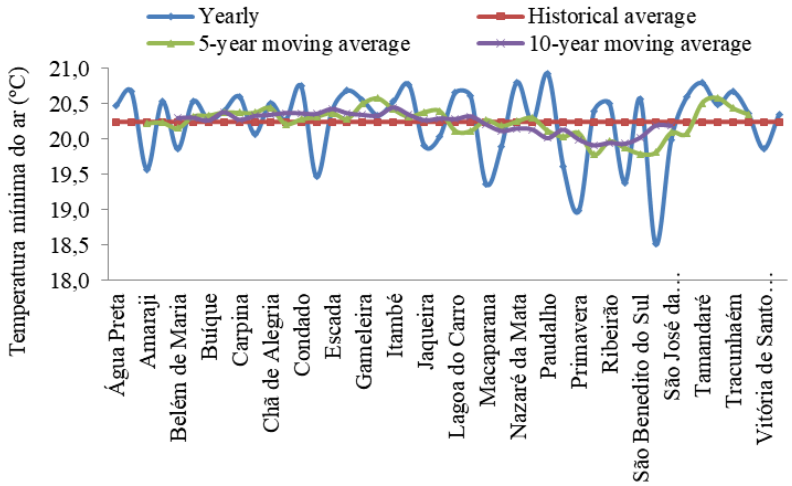


Figure No. 3: Minimum annual, historical temperature, moving averages for 5 and 10 years from the period from 1950 to 2020 for the municipalities of Zona da Mata Pernambucana. Source: Medeiros, (2021).

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

CONCLUSIONS

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

The temperature reductions flow in line 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 the 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 greatest spatial consistency.

Estimates of 10-year moving averages show values of greater significance than for 5 years.

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

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

The air temperature has a significant variation between altimetry and over the years in the Zona da Mata in Pernambuco.

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