TREND OF AIR TEMPERATURE IN THE STATE OF PARANÁ, BRAZIL

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ABSTRACT: Considering the importance of climatologic series and the local temperature variability analyses, this study aimed to evaluate the trend of maximum and minimum air temperature in the State of Paraná, Brazil. It were used daily data for the period 1980 to 2009 of 28 locations. The trend magnitude was obtained through linear regression and statistical significance using the Mann-Kendall non-parametric test. The spatial distribution of changes found was represented in geo-referenced maps elaborated through the ARCGIS v.10.0 with the spline interpolation method. The results revealed that the State of Paraná presents great variability in air temperature changes, with differences between places ranging from reductions of 0.5 reductions to increases of 0.6 °C/decade. These increases occurred mainly during the winter and the spring and reductions in the autumn. It was not possible to define simultaneity between the trends due to different changes found, which may be related to local factors such as relief, vegetation and regional activities.

KEYWORDS: climatic trend, interpolation, mann-kendall.

TENDÊNCIA DA TEMPERATURA DO AR NO ESTADO DO PARANÁ, BRASIL

RESUMO: Considerando a importância da análise de séries climatológicas e da variabilidade das temperaturas locais, este estudo objetivou avaliar a tendência temporal e espacial da temperatura máxima e mínima do ar do estado do Paraná, Brasil. Utilizou-se dados diários correspondentes ao período de 1980 a 2009 de 28 localidades. A magnitude das tendências foi obtida por meio da regressão linear e a significância estatística a partir do teste não paramétrico de Mann-Kendall. A distribuição espacial das alterações encontradas foi representada em mapas georreferenciados elaborados pelo ARCGIS v.10.0 pelo método de interpolação spline. Os resultados encontrados revelam que o estado do Paraná possui uma grande variabilidade nas alterações de temperatura do ar, já que observou-se reduções de 0.5 a aumentos de 0.6 °C/década entre os municípios analisados. Os aumentos ocorreram principalmente durante o inverno e a primavera e as reduções na estação outono. Não foi possível definir uma simultaneidade entre as tendências devido as diferentes alterações encontradas, que podem estar relacionadas a fatores locais como relevo, vegetação e atividades regionais.

Palavras-chave: tendência climática, mann-kendall, interpolação.

1. INTRODUCTION

The climate change issue has been widely debated in society due to its possible environmental, economic and social impacts, which mainly result from its unpredictability. The analysis of climate variability is necessary in studies on climate change identification (TABARI et al., 2011).

Changes in air temperature can point climate change, therefore, the evaluation of that variable tendency becomes essential. However the thermal trend oscillations, as well as their social effects, are distinct in each region of the planet and might differ from the global trend (MINUZZI et al., 2011).

Therefore there is a need to study the variability of temperature in local and regional scales. According El Kenawy et al. (2012) due to the low quantity or poor quality data, the spatial and temporal variability of climate are not well determined in the regional and sub-regional scales. In this sense, the temperature spatial distribution can be better studied with the aid of Geographic Information Systems (GIS), in which different interpolation methods are applied, for example, inverse distance weighting, regression analysis, spline, kriging, polynomial interpolation, etc (DEL RÍO et al., 2011).

The regional and current analysis of air temperature is fundamental in studies that aim, for example, to project future climatic scenarios and predict possible impacts related to climate change. Among other consequences, changes in air temperature, which is a climate variable that influences different biological, physical and chemical processes in the natural ecosystem, might cause changes in the soil water availability. These changes can provoke effects in several sectors associated to the water resources such as agriculture, which is one of the cornerstones of economy in Brazil.

According to Moraes et al. (2011), in the economic sector the agriculture is the activity that presents the highest dependency on the climate conditions, suggesting that any climate change can have some effect in the zoning, yield and management techniques in the sector.

Taking all that into consideration, some research has been developed with the aim to know the current regional climate trend. In these studies, non-parametric analysis statistical tests, for example the Mann-Kendall test, have been used to assess the statistical significance of a trend verified in the climatic data series, for instance the studies carried out by Blain (2010), Santos et al. (2010) and Back et al. (2012) in Brazil, Gocic and Trajkovic (2013) in Serbia and Mandal et al. (2013) in India. The Mann-Kendall test is usually employed to the study of trends as it is more robust and powerful than other statistical tests (NALLEY et al., 2013).

Additionally, aiming to verify the magnitude of changes found in the periods under analysis, linear regression has been applied, in which the angular coefficient values obtained through the straight line fitted to the data represent such magnitude. This method was applied by Minuzzi et al. (2010), Lima et al.

(2010) and Minuzzi et al. (2011). Other studies that employed both methods, linear regression and Mann-Kendall can be referred to: Tabari et al. (2011), Marengo and Camargo (2008), del Río et al. (2011) and Streck et al. (2011).

Studies carried out by Marengo and Camargo (2008) pointed out an elevation of maximum and minimum temperatures in the South of Brazil throughout the year in a seasonal fashion. However, the minimum temperature presented more noticeable increase when compared to the increase in the maximum temperature. Similar results were found by Minuzzi et al. (2011) in the State of Paraná, suggesting a reduction in the region thermal amplitude.

According to Costa et al. (2012) the State of Paraná as it is located in a geographical transition area, presents great climate heterogeneity and complex dynamics of atmospheric phenomena. Due to these particular characteristics and the need to analyze regional climatic series, this study aimed to evaluate the trend of maximum and minimum air temperature in the State of Paraná, Brazil.

2. MATERIALS AND METHODS

The State of Paraná belongs to the southern region of Brazil and is located between the longitudes 741694.12 (54°35’37’’W) and 799877.66 (48°01’24’’W), and latitudes 7509413.11 (22°31’05’’S) and 7044796.94 (-26°43’03’’S).

In order to know the temperature trend in Paraná, minimum and maximum air temperature data collected daily in 28 cities all over the State (Figure 1) was used. Temporal series data obtained from weather stations, represented in Figure 1, comprised the period between 1980 and 2009 and were supplied by the Paraná Agronomic Institute (IAPAR – Brazilian abbreviation).

In the Computational and Applied Statistics Laboratory – LECA (Brazilian abbreviation) at Ponta Grossa State University, Paraná, Brazil, the data was organized monthly in electronic spreadsheets, in which the annual average was calculated and graphically represented in trend diagrams for each month and city. By applying the linear regression technique, it was possible to estimate the trend magnitude, after obtaining the angular coefficient of the straight line fitted to the data.

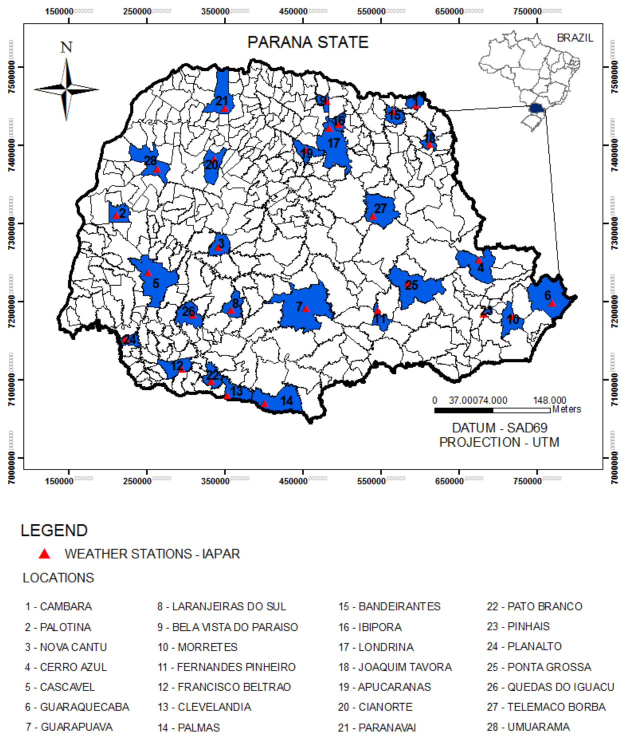

Figure 1 - Cities and IAPAR weather stations distributed throughout the State of Paraná.

For the seasonal analysis, the following months were considered as representative of each season: January to March (summer), April to June (autumn), July to September (winter), and October to December (spring).

The statistical significance of trends found was carried out employing the non-parametric Mann-Kendall test (MANN, 1945; KENDALL, 1975).

Recognizing that the data does not present serial correlation, the tests were applied to the computational environment R (v.3.0.1) for each city and season of the year, and the "Kendall" packet used.

Considering the sequence of values observed both for maximum and minimum temperature along the time (1980-2009), the hypotheses testes were: "H0: data comprise a random variable sample of n independent and identically distributed items", that is, there is no trend in this data set and H1: There is an increasing trend (positive) or decreasing (negative).

The Mann-Kendall test is expressed by the equation:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \qquad (1)$$

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where:

$$sgn\ (x) = \begin{Bmatrix} +1, x > 0 \\ 0,\ \ x = 0 \\ -1, x < 0 \end{Bmatrix}$$

Where the S statistics is the counting of the number of times x_j exceeds its subsequent value x_k , for j>k, more times than x_k exceeds x_j. The D value represents the S maximum possible value and occurs when $x_1 < x_2 < ... < x_n$. (HIPEL and MCLEOD, 2005).

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{p} tj(tj-1)\right]^{0.5} \left[\frac{1}{2}n(n-1)\right]^{0.5}$$

(2)

Kendall's tau statistics (Equation 3) was used to indicate the trend movement, as used in Li, Zhe et al. (2013) and Wagner et al. (2013). A positive tau value means an increasing trend while a negative value represents a decreasing trend.

$$\tau = \frac{S}{D}$$

(3)

For the trend evaluation, the p value obtained through the test to decide the hypothesis was used. Considering a significance level of at least 0.05, that is, when the p-value is below or equal 0.05, H0 is rejected, and H1 is accepted, thus, observing the data trend significance.

Aiming to obtain the spatial distribution of temperature changes for the whole State of Paraná, georeferenced maps were created through the ARCGIS v.10.0, a geographic information system (GIS), in which the spline interpolation method was used. According to Hartkamp et al. (1999), the use of this technique is recommended for climatic variable interpolation, considering error prediction, data assumptions and the computational simplicity. This interpolation method was also used by Sentelhas et al. (2008), Li, Zongxing et al. (2011) and Tabor and Williams (2010). The interpolated values were the angular coefficient values, representing the alteration in °C/year.

3. RESULTS AND DISCUSSION

Table 1 presents the angular coefficient values obtained through the regression method, which represent the magnitude of alterations found in the period under analysis. The State of Paraná presented great variability in temperature changes when comparing the cities under analysis.

Table 1 - Maximum and minimum temperature variable regression angular coefficient values for each city and season of the year

CITIES	ANGULAR COEFFICIENTS							
	SUMMER		AUTUMN		WINTER		SPRING	
	T. Mín.	T.Máx.	T. Mín.	T.Máx.	T. Mín.	T.Máx.	T. Mín.	T.Máx.
APUCARANA	0.005	-0.011	-0.015	0.010	0.002	0.004	-0.001	-0.011
BANDEIRANTES	0.016	0.007	0.003	0.031	0.023	0.034	0.013	0.021
BELA VISTA DO PARAÍSO	0.009	0.004	0.005	0.028	0.029	0.037	0.006	0.022
CAMBARÁ	0.011	-0.010	-0.009	0.016	0.012	0.025	0.013	0.018
CASCAVEL	0.001	-0.002	-0.014	-0.002	-0.001	0.001	0.002	0.008
CERRO AZUL	0.002	-0.013	-0.015	0.007	0.000	-0.004	0.001	-0.002
CIANORTE	0.009	0.005	-0.004	0.009	0.004	0.016	-0.001	-0.001
CLEVELÂNDIA	-0.004	0.018	0.003	0.016	0.019	0.018	0.011	0.028
FERNANDES PINHEIRO	0.008	0.019	0.005	0.030	0.025	0.034	0.013	0.019
FRANCISCO BELTRÃO	-0.007	0.023	-0.005	-0.024	0.000	0.006	0.003	0.027
GUARAPUAVA	0.011	-0.011	-0.010	0.005	0.015	0.012	0.034	0.012
GUARAQUEÇABA	0.001	-0.006	-0.001	0.001	0.033	0.011	0.011	-0.006
IBIPORÃ	0.015	-0.007	0.004	0.026	0.029	0.029	0.011	0.016
JOAQUIM TÁVORA	-0.001	-0.036	-0.027	-0.010	0.013	0.005	0.008	-0.011
LARANJEIRAS DO SUL	0.012	-0.001	0.011	0.003	0.036	0.028	0.013	0.011
LONDRINA	0.018	0.020	0.005	0.040	0.022	0.040	0.024	0.029
MORRETES	0.008	0.008	0.013	0.006	0.034	0.020	0.022	0.004
NOVA CANTÚ	0.007	-0.006	0.005	-0.018	0.032	0.000	0.025	0.020
PALMAS	0.020	-0.014	0.023	-0.001	0.038	0.014	0.035	0.002
PALOTINA	-0.004	0.011	-0.049	0.011	-0.010	0.034	0.015	0.027
PARANAVAÍ	0.012	-0.003	0.008	0.015	0.038	0.029	0.007	0.012
PATO BRANCO	0.010	0.001	0.013	0.003	0.021	0.007	0.032	0.033
PINHAIS	-0.011	-0.001	-0.030	-0.007	-0.007	0.010	-0.012	0.015
PLANALTO	-0.024	-0.004	-0.018	0.001	-0.013	0.005	-0.006	0.014
PONTA GROSSA	-0.010	0.010	-0.046	0.003	-0.009	0.025	-0.014	0.009
QUEDAS DO IGUAÇÚ	-0.004	-0.005	-0.044	-0.011	-0.011	-0.005	-0.009	-0.014
TELÊMACO BORBA	0.019	0.014	0.001	0.027	0.035	0.040	0.025	0.029
UMUARAMA	0.015	0.047	0.018	0.057	0.033	0.061	0.021	0.061

The regression results revealed that, in relation to the minimum temperature, the changes in the period between 1980 and 2009 varied from -0.049°C/year in the city of Palotina in the autumn to 0.038°C/year in the cities of Palmas and Paranavaí in winter. Regarding the maximum temperature, changes varied from -0.036°C/year to 0.061°C/year in the cities of Joaquim Távora (summer) and Umuarama (winter and spring), respectively.

In a general seasonal analysis, it was seen that the changes found for the minimum temperature, varied from -0.024 to 0.020 in the summer, -0.049 to 0.023 in the autumn, from -0.013 to 0.038 in the winter and from -0.014 to 0.035 in the spring. The maximum temperature showed a variation in the change from -0.036 to 0.047 in the summer, from -0.024 to 0.057 in the autumn, from -0.005 to 0.061 in the winter and from -0.014 to 0.061 in the spring.

In general, between the cities under analysis, reduction of 0.5 and increase of 0.6 ºC/ decade were observed, presenting similar variations throughout the seasons of the year. Marengo and Camargo (2008) developing temperature trend studies between 1960 and 2002 in the South of Brazil, in an annual analysis found increase of 0.5°C/decade for the minimum temperature and 0.2°C/decade for the maximum temperature.

The divergence between alterations found in this study might be explained by the fact that the State under analysis, due to its geographical position, is under the influence of factors such as climate, geological formation, relief, altitude and vegetation.

Table 2 shows tau values and the p-values obtained through the Mann-Kendall test for the maximum temperature variable. By analyzing the tau signal, it was seen that 18 cities presented maximum temperature negative trend in at least one of the seasons of the year and 27 cities presented positive trend for the same variable in at least one season of the year.

In general terms, most cities presented maximum temperature positive trend, which was more evident in the winter and spring. The cities that presented significantly positive trend were Londrina in the summer, Telêmaco Borba in the spring and Umuarama in the summer, winter and spring.

Minuzzi et al. (2011) also observed that the city of Umuarama presented significantly positive trend throughout the whole year. According to Junior and Villa (2013) since the second half of the XX century, the city of Umuarama, as well as other cities in the North-west of Paraná, has experienced a disorganized demographic growth. This urban area expansion might be responsible for the increase in the local temperature, thus, explaining the result found in this study.

In relation to the maximum temperature, only the city of Joaquim Távora presented significantly negative trend in the summer. Similar result was observed by Minuzzi et al. (2011), in which the same city presented significantly negative trend also in the summer.

Despite most cities presenting maximum temperature positive trend, it was seen that few cities presented a significantly positive trend. Similar result was observed by Blain (2010) who analyzed climatic trends in eight series of annual average maximum temperatures in the State of São Paulo and found that only the cities of Piracicaba and Campinas presented significant Mann-Kendall test between 1917/2007, indicating an increasing trend.

In general, most cities presented minimum temperature positive trend throughout the seasons of the year, except in autumn, the period in which most cities presented a negative trend (Table 3).

Table 2 - Maximum temperature variable Mann-Kendall test for the cities and seasons of the year

CITIES	MANN-KENDALL TEST- MAXIMUM TEMPERATURE							
	SUMMER		AUTUMN		WINTER		SPRING	
	Tau	p-value	tau	p-value	tau	p-value	tau	p-value
APUCARANA	-0.071	0.592	0.071	0.592	-0.030	0.830	-0.108	0.412
BANDEIRANTES	0.136	0.301	0.186	0.154	0.140	0.284	0.200	0.125
BELA VISTA DO PARAÍSO	0.103	0.432	0.131	0.318	0.145	0.269	0.186	0.154
CAMBARÁ	-0.044	0.748	0.044	0.748	0.136	0.301	0.191	0.143
CASCAVEL	-0.048	0.721	-0.159	0.225	-0.053	0.695	0.053	0.695
CERRO AZUL	-0.058	0.669	0.007	0.972	-0.039	0.775	0.076	0.568
CIANORTE	0.076	0.568	0.016	0.915	0.025	0.858	0.012	0.943
CLEVELÂNDIA	0.182	0.164	0.053	0.695	0.071	0.592	0.218	0.094
FERNANDES PINHEIRO	0.172	0.187	0.159	0.225	0.177	0.175	0.149	0.254
FRANCISCO BELTRÃO	0.237	0.069	-0.218	0.094	0.035	0.803	0.191	0.143
GUARAPUAVA	-0.062	0.643	0.002	1.000	0.058	0.669	0.145	0.269
GUARAQUEÇABA	-0.035	0.803	-0.021	0.887	0.039	0.775	-0.007	0.972
IBIPORÃ	0.090	0.498	0.090	0.498	0.126	0.335	0.177	0.175
JOAQUIM TÁVORA	-0.255	0.050*	-0.122	0.354	0.016	0.915	-0.044	0.748
LARANJEIRAS DO SUL	0.039	0.775	-0.025	0.858	0.168	0.199	0.076	0.568
LONDRINA	0.251	0.054*	0.195	0.134	0.200	0.125	0.237	0.069
MORRETES	0.035	0.803	-0.035	0.803	0.090	0.498	0.039	0.775
NOVA CANTÚ	-0.053	0.695	-0.177	0.175	-0.016	0.915	0.232	0.074
PALMAS	-0.149	0.254	-0.062	0.643	0.103	0.432	0.048	0.721
PALOTINA	0.108	0.412	-0.007	0.972	0.154	0.239	0.218	0.094
PARANAVAÍ	0.030	0.830	0.053	0.695	0.131	0.318	0.149	0.254
PATO BRANCO	0.012	0.943	-0.025	0.858	0.025	0.858	0.246	0.059
PINHAIS	-0.012	0.943	-0.058	0.669	0.058	0.669	0.159	0.225
PLANALTO	-0.016	0.915	-0.048	0.721	0.021	0.887	0.214	0.101
PONTA GROSSA	0.209	0.108	-0.053	0.695	0.122	0.354	0.126	0.335
QUEDAS DO IGUAÇÚ	-0.016	0.915	-0.149	0.254	-0.044	0.748	-0.067	0.617
TELÊMACO BORBA	0.172	0.187	0.154	0.239	0.209	0.108	0.264	0.042*
UMUARAMA	0.384	0.003**	0.232	0.074	0.269	0.038*	0.471	0.000**

** p<0,01; * p<0,05.

Table 3 - Minimum temperature variable Mann-Kendall Test for cities and seasons of the year

CITIES	MANN-KENDALL TEST – MINIMUM TEMPERATURE							
	SUMMER		AUTUMN		WINTER		SPRING	
	tau	p-value	tau	p-value	tau	p-value	tau	p-value
APUCARANA	0.062	0.643	-0.241	0.064	0.021	0.887	-0.002	1.000
BANDEIRANTES	0.260	0.046*	-0.058	0.669	0.195	0.134	0.108	0.412
BELA VISTA DO PARAÍSO	0.159	0.225	0.012	0.943	0.274	0.035*	0.062	0.643
CAMBARÁ	0.182	0.164	-0.090	0.498	0.076	0.568	0.058	0.669
CASCAVEL	0.048	0.721	-0.223	0.087	0.035	0.803	0.062	0.643
CERRO AZUL	-0.002	1.000	-0.154	0.239	0.012	0.943	-0.030	0.830
CIANORTE	0.159	0.225	-0.025	0.858	0.002	1.000	-0.025	0.858
CLEVELÂNDIA	0.025	0.858	-0.016	0.915	0.145	0.269	0.126	0.335
FERNANDES PINHEIRO	0.145	0.269	-0.021	0.887	0.195	0.134	0.140	0.284
FRANCISCO BELTRÃO	-0.067	0.617	-0.071	0.592	0.030	0.830	0.058	0.669
GUARAPUAVA	0.117	0.372	-0.108	0.412	0.103	0.432	0.297	0.022*
GUARAQUEÇABA	0.048	0.721	-0.062	0.643	0.324	0.012*	0.076	0.568
IBIPORÃ	0.223	0.087	-0.021	0.887	0.246	0.059	0.099	0.454
JOAQUIM TÁVORA	-0.007	0.972	-0.232	0.074	0.062	0.643	0.090	0.498
LARANJEIRAS DO SUL	0.145	0.269	0.021	0.887	0.241	0.064	0.140	0.284
LONDRINA	0.274	0.035*	0.025	0.858	0.182	0.164	0.251	0.054*
MORRETES	0.094	0.475	0.053	0.695	0.315	0.015*	0.214	0.101
NOVA CANTÚ	0.159	0.225	-0.058	0.669	0.223	0.087	0.241	0.064
PALMAS	0.232	0.074	0.149	0.254	0.218	0.094	0.283	0.030*
PALOTINA	0.016	0.915	-0.352	0.007**	-0.039	0.775	0.025	0.858
PARANAVAÍ	0.195	0.134	0.007	0.972	0.251	0.054*	0.081	0.544
PATO BRANCO	0.172	0.187	0.030	0.830	0.145	0.269	0.287	0.027*
PINHAIS	-0.205	0.116	-0.329	0.011*	-0.085	0.521	-0.168	0.199
PLANALTO	-0.343	0.008**	-0.200	0.125	-0.071	0.592	0.002	1.000
PONTA GROSSA	-0.177	0.175	-0.343	0.008**	-0.090	0.498	-0.117	0.372
QUEDAS DO IGUAÇÚ	-0.016	0.915	-0.398	0.002**	-0.035	0.803	-0.048	0.721
TELÊMACO BORBA	0.182	0.164	0.021	0.887	0.154	0.239	0.251	0.054*
UMUARAMA	0.218	0.094	0.058	0.669	0.228	0.080	0.223	0.087

** p<0,01; * p<0,05.

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In 19 cities was observed negative trend in the minimum temperature in at least one of the seasons of the year and 25 cities presented positive trend for this variable in at least one of the seasons of the year, and the cities of Pinhais, Ponta Grossa and Quedas do Iguaçu presented negative trends throughout the year.

Regarding minimum temperature, only the city of Planalto presented significantly negative trend in the summer and the cities of Palotina, Pinhais, Ponta Grossa and Quedas do Iguaçu in the autumn.

Cities that presented significantly positive trend were Londrina and Bandeirantes in the summer, Bela Vista do Paraíso, Guaraqueçaba, Morretes and Paranavaí in the winter and Guarapuava, Londrina, Palmas, Pato Branco and Telêmaco Borba in the spring. Blain et al. (2009), found minimum temperature significant trends in three cities in the State of São Paulo (Campinas, Cordeirópolis/Limeira and Ribeirão Preto). The remaining minimum temperature annual series analyzed (Monte Alegre do Sul, Pindorama and Piracicaba) did not present significant increase.

The significant increase in minimum temperature in the cities already mentioned might be a consequence of the deforestation and the occupation with agricultural activities.

More cities were observed to present significantly positive trend for minimum temperature than for maximum temperature. Different results were obtained by Minuzzi et al. (2011), who observed a relatively higher number of maximum temperature significant trends.

Figures 2 and 3 represent the angular coefficient data interpolation for the State of Paraná. In general, changes found varied from -0.06 to 0.12ºC/year, for both the minimum and maximum temperatures.

Most of the State presented a 0.00 to 0.02ºC/year variation of minimum temperature in summer, demonstrating variable stability from 1980 to 2009.

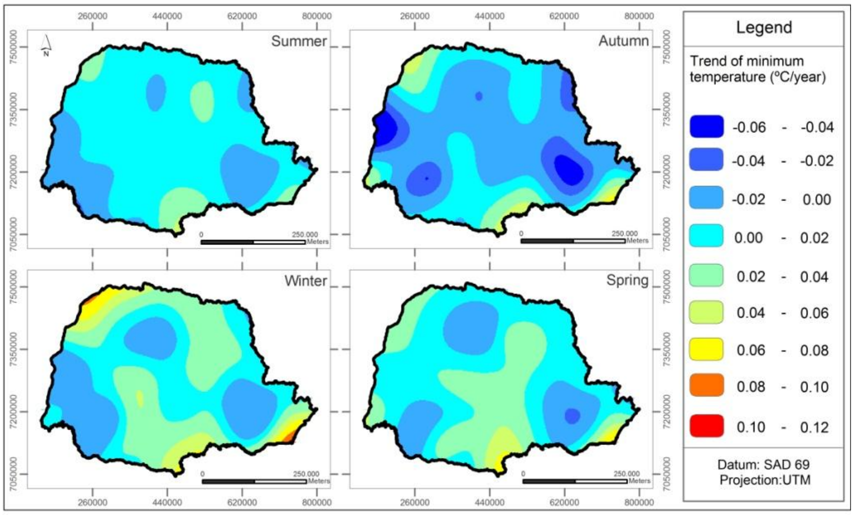

Figure 2 - State of Paraná Map representing minimum temperature changes (ºC/year)

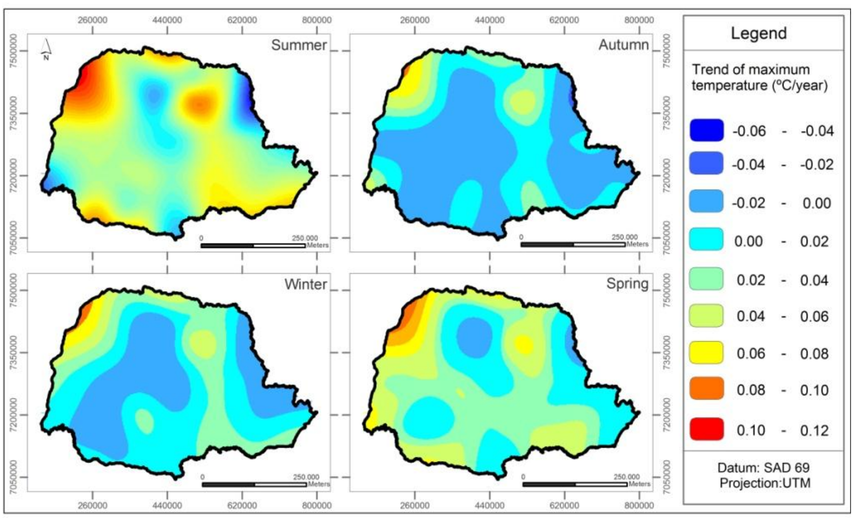

Figure 3 - State of Paraná Map representing maximum temperature (ºC/year)

In the winter and spring, some regions (center and south of the State) were observed to present a discrete increase, from 0.02 to 0.04ºC/year and higher increase in the north-west, extreme south and also on the coast. The autumn also presented reduction in the variable in great part of the State. However, it was seen that in the four seasons of the year some points in the State outstood for presenting noticeable reduction in the minimum temperature.

This fact demonstrates that there are local factors that might be responsible for the reduction in temperature. Blain et al. (2009) suggested an analysis of the local factors, since the temperature stability or even a discrete reduction might be related to places that still have native forests or natural fields, as it is the case in the Campos Gerais region where the cities of Telêmaco Borba and Ponta Grossa are located.

The maximum temperature was observed to present increasing alterations distributed all over the State in the summer. Regarding minimum temperature in the autumn, temperature reduction values were presented in several cities of the State. Similar results were observed by Blain (2009) in the State of São Paulo, where some cities presented negative trend or stability in the data series. Unlike the minimum temperature, the spots indicating temperature reduction were not evidenced; therefore, spots evidencing more accentuated increase in the north-west region of the State were seen, mainly in the summer.

4. CONCLUSIONS

1. The results obtained for each city and also from the interpolation revealed that the minimum temperature presented increase mainly in the winter and spring. Therefore, considerable reduction was noticed in the State of Paraná in the autumn. In relation to the maximum temperature, reductions were also observed in the autumn and increases in the winter and spring. The increase was more evident in the summer, mainly in the north-west region.
2. It was not possible to define simultaneity between the trends, once the alterations varied from reduction to increase in temperature, and few cities revealed significant trend. These different alterations found in temperature are explained by local factors such as relief, vegetation or even activities developed by the local inhabitants, for example, deforestation, which might be responsible for keeping the temperature stable or increasing the air temperature.
3. The several alterations found must be considered in climate change issues, once they indicate the climate vulnerability and suggest some local alteration, either natural or anthropogenic. Therefore, the importance of studying individual series and their relation with local factors is highlighted so that worse consequences of climate changes can be prevented.

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