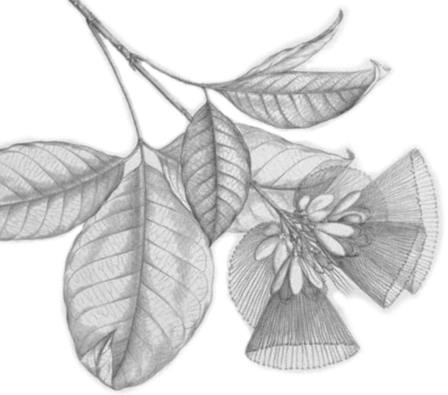

Analysis of average temperatures and trends in Brazil: Applying CUSUM Graphic from 2000 to 2014

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ABSTRACT

In recent decades the temperature trends are being confirmed earlier. To determine the temperature changes in Brazil, analysis of annual trends and seasons was carried out based on daily data from 187 weather stations, covering the period from 2000 to 2014. Trends were confirmed using the Cumulative Sum Chart, a method that notices the changes in series faster than others. The modeling of temperature was obtained by Multiple Regression and using Cluster Analysis, and through this it was possible to group weather stations. The observed trends confirmed oscillations in cooling, heating and, in some cases, cooling followed by heating. These main trends presented during the study period were from -15 to 0 in latitude. The region with the highest confirmation of inversions in temperature was the North, then Northeast. Heights below 500 meters presented higher trends. Regarding the seasons, autumn contributed significantly to the trends.

Keywords: Cumulative Sum Chart; Air Temperature; Temperature Trends; Temperature Modeling.

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A change was noted in global average temperature of 0.6±0.2C in the years 1901-2000, and in another analysis between the years 1906-2005 that estimate was given as 0.74±0.18C IPCC (2007). From the 1880 to 2012 the change of 0.85±0.21C was confirmed on the surface of the planet. When considering two scenarios, changes may occur from 3.7 to 4.8C until the year 2100, thus, the systematic heating term is not wrong due to rising sea levels from the melting of the polar ice caps, warming oceans and atmosphere IPCC (2014).

Changes of temperature have been found in some countries and oceans (Breaker 2007; Gurevech et al. 2011; Toreti & Desiato 2008; Wang et al. 2015). The change in air temperature is associated with the ocean heating which is derived from air currents (Kerr 1992). Several authors report more of a regime change in the temperature series in the years 1925-2004 (Torgovitski 2015; Lorentzen 2015). Regional climate characteristics have local trends which differ in some cases from the global average and in some regions, it was observed cooling trends followed by heating (Bajat et al. 2015; Balling-JR et al. 1998).

Works that covered a large territory as Vincent et al. (2005), Klein-Tank et al. (2002) and Klein-Tank and Konnen (2003) had a challenge to the quality of data because of the numerous Weather Stations and long period studied. To work with lack of data, researchers can delete, accept few gaps or include data from the nearest Weather Station. To identify trends, methods more applied in temperature are the Sum of Least Squares (LSQ), Cumulative Sum Chart (CUSUM), among others.

The process control charts have been tested previously by Roberts (1966), who conducted tests in five models, where the Cumulative Sum chart surpassed the others to categorize small variations and summarize the story. Currently, it has been studied by Zhang et al. (2011) and Torgovitski (2015) and it has been applied by authors like Almazroui et al. (2013) and Fischer et al. (2012) in time series to identify trends in temperatures.

Bajat et al. (2015) conducted a temperature analysis in Serbia applying CUSUM method, as did Lorentzen (2015) who evaluated the coast of Norway. When analyzing temperatures in South America with LSQ method, Vincent et al. (2005) included in his research 19 Brazilian Weather Stations. Thus, this paper applies the methods covered by Bajat et al. (2015) and Lorentzen (2015) and it has a larger scope than studies done by Vincent et al. (2005).

The main purpose of this article is to contribute to the knowledge of the average trend of temperatures that occurred in Brazil from 2000 to 2014. However, the goals extend to: analyze the temperature using the CUSUM control chart; find patterns of trends in average annual and seasons;

perform a temperature analysis due to the geographical position; modeling the temperature to complete the missing data on Weather Stations.

Methods

The study area is Brazil, which is located in the Americas, being positioned in South America, which is composed of 13 countries. The study country has more than 16,000 kilometers of border with its neighbors and occupies an area of 8,547,403.5km2, equivalent to 47.89% of the area of South America.

Factors that may influence the climate are: humidity; temperature; air mass; atmospheric pressure; winds; ocean currents; and others. In Brazil due to the geographical and territorial extension, its climate is variable, being the tropical, equatorial, subtropical and arid the predominated ones.

Dataset

In this article, monthly average temperatures were analyzed during the period 2000-2014 in 187 Weather Stations (WS). The weather stations are shown in Figure 01. The data were provided by Brazilian Institute of Meteorology (INMET). The WS network are spatially distributed; however, the South Atlantic coast has more data collection and gathering. However, it should be noticed that the networks in hilly areas are scarce.

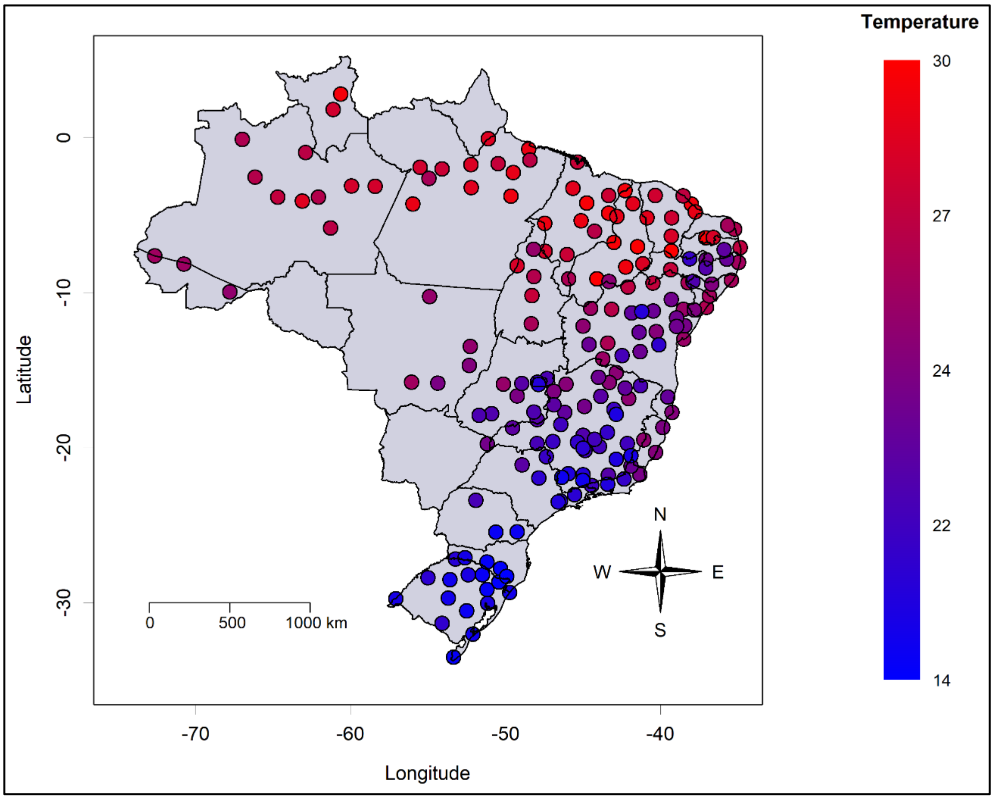
A total of 62.03% of WSs are at altitudes of 0-500 m, about 33.15% represent the data from 500 to 1,000 m, and only 4.82% are from a height exceeding 1,000 m. The data provided is updated hourly and fixed by INMET (2015a).

Trends in time series were studied previously by Bajat et al. (2015) and Breaker (2007). These authors have analyzed trends from the CUSUM chart in Serbia and North Pacific coast. In this article, the CUSUM chart determined the trends and then the new averages were calculated. Data from 266 existing WSs were analyzed to ensure the quality of the research, and 79 WSs were excluded since the data was incomplete. The data are available in INMET (2015b).

Temperature from 2000 to 2014

The annual average temperatures in Brazil are between 17.11 to 29.26°C in locations below 500m. The annual average temperatures were 16.27 to 25.48°C in altitudes between 500-1000m, and locations above 1,000m temperatures were 13.69 to 21.42°C. However, when checking the areas, it is possible to notice that the amplitude of temperature has small changes. Brazil is subdivided into five regions as seen in Table 01.

Figure 01. Location of Weather Stations



Source: National Institute of Meteorology. Elaboration by authors.

Table 01. Analysis of temperatures average in the regions - Brazil - 2000 to 2014. * The North does not have data collection station to altitudes above 1,000 m between 500 to 1000 m, therefore does not have complete data recorded.

REGION	LESS THAN 500 [M]		500 TO 1,000 [M]		MORE THAN 500[M]	
	Min	Max	Min	Max	Min	Max
Midwest	24,46	25.86	22.68	25.48	20.52	21.37
South	17,11	20.79	16.27	22.64	13.69	15.18
Southeast	21,55	25.22	19.12	25.14	18.32	21.42
Northeast	23,91	29.26	20.86	25.14	20.60	21.20
North*	25,28	28,10				

Source: National Institute of Meteorology. Elaboration and adaptation of data by authors.

Due to the distribution of seasons which are considered scarce in some areas of this study, it was not possible to apply some common interpolation methods in order to make an isothermal map. However, the regression model was applied to obtain a map of annual average temperatures for the period 2000-2014. According to Gomez et al. (2008), climatological regressions usually incorporate the height, latitude, and longitude in a climate model. By demonstrating that the altitude compensates latitude, it was obtained a Coefficient of Determination r^2 that explains the majority of the studied data for the period investigated.

TEMPERATURE MODELING

Gomez et al. (2008) analyze the heights and the geographic coordinates as independent variables and the temperature as a dependent. Walpole et al. (2011) show that the regression can be calculated and applied as a model. The regression model can be considered if there is a relationship between two or more variables (Montgomery et al. 2015; Montgomery & Runger 2010). The model suggested by Devore (2015) was adopted in this research as presented in Eq. (1).

$$\hat{Y} = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1^2 + \beta_4 x_2^2 + \varepsilon \quad (1)$$

Where $\hat{Y}$ is equal to the estimated temperature, x_1 is the altitude and x_2 is the latitude. The longitude was not significant.

Pesaran-Pesaran test can be applied to detect the presence of heteroscedasticity in the model. The test is performed by linear regression between ($\hat{Y}$;ϵ^2). If there is no relationship between the homoscedasticity test variables is discarded.

The data were grouped by region and altitude, after this, they were analyzed. The Linear Regression calculation was applied for identifying the averages change trends versus time. The grouping analysis was performed to classify cities and aggregates them based on their characteristics. In this article, the groups were formed by the average connection method. When analyzing the data, the criterion is to compare the distance between the group formed with the pre-existing, prevailing its average.

TREND DETERMINATION

The method of least-squares (LSQ) was used to estimate data trends. The period observed in the annual average temperatures changes its inclination from one WS to another. For this reason, the change detections were applied to the average first before making the estimate of annual trends.

For the changes of detection and determination in the year, the production of CUSUM graph was made. The CUSUM illustration is a graphical method for variation detection. Consider the cumulative sum $C_0; C_1; \dots;\ n$ which is calculated from the data $Xi; \dots; Xn$, which is assumed randomly, as follows ($i = 0; 1; \dots; n$).

As C_i moves in i it forms the CUSUM chart. If the average remains the CUSUM chart displays a steady (constant line), since the data is random (Montgomery 2012; Montgomery & Runger 2010; Devore 2015). Otherwise, a segment of the CUSUM graphic with an upward or downward inclination designates a period in which values tend to be above or below the average, respectively in this order. A sudden change in the CUSUM graphic gradient occurs with a sudden change in the average. The magnitude of sudden change, can be estimated as follows:

$$C_i^+ = \max[0, x_i - k + C_{i-1}^+] \tag{2}$$

$$C_i^- = \max[0, -k - x_i + C_{i-1}^-] \tag{3}$$

Where C_i^+ is the positive inclination and C_i^- is the negative inclination.

Efron and Tibshirani (1991) presented a bootstrap analysis with the reordering of data sampled around the average and with tails smoothing. They reported that with the subtraction of some data it is possible to determine the average within the 95% confidence level, even if there has been a change in the average due to the displacement or change of the sampled site. To determine the change location in CUSUM chart we can use the following expressions:

$$C_i^+ > H \tag{4}$$

$$C_i^- > H \tag{5}$$

$$N^+ = \max[0, (1 + N_{i-1}^+)] \tag{6}$$

$$N^- = \max[0, (1 + N_{i-1}^-)] \tag{7}$$

Where i is the extreme point between 0 and n in CUSUM chart and H represents $n * \sigma$.

The point where i returns a value greater than H in Eq. (4) or (5) confirming the change in the average. The change period is the point C_i^+ or C_i^- subtracted by N^+ or N^-, in that order. If there is a change in average it can be calculated by:

$$\hat{\mu} = \mu_o + K + \frac{C_i^+}{N^+} \tag{8}$$

$$\hat{\mu} = \mu_o - K - \frac{C_i^-}{N^-} \tag{9}$$

Where $\hat{\mu}$ is the new estimated mean; μ_o is the target value; and K corresponds to the reference value.

An important observation in the CUSUM graph is that it sums the differences, and may thus determine when there was a change in the average, thereby ensuring randomness of data around the target value. The autocorrelation function and partial autocorrelation function was calculated to determine if the sample is stationary (Montgomery et al. 2015).

Results and Discussions

In order to identify how modeling the temperature variable would be, we considered how the height above sea level influences average temperature. For this, the Multiple Regression model was used in Brazilian WSs. Data from Multiple Regression are showed in Table 02.

How estimated model it is possible to produce the Isothermal map using the Digital Elevation Model (DEM). Spatial data can be downloaded at the Brazilian Institute of Geography and Statistics (IBGE 2016).

Table 02. Multiple Regression - Brazil - 2000-2014.

β_k	COEFFICIENTS	STANDARD ERROR	STAT T	P-VALUE	95% BELOW	95% HIGHER
β_o	$27{,}20 \times 10^{0}$	$193{,}59 \times 10^{-3}$	140,49	$1{,}61 \times 10^{-187}$	$26{,}81 \times 10^{0}$	$27{,}57 \times 10^{0}$
β_1	$-2{,}33 \times 10^{-3}$	$798{,}08 \times 10^{-6}$	$-2{,}93$	$3{,}87 \times 10^{-3}$	$-3{,}91 \times 10^{-3}$	$-760{,}00 \times 10^{-6}$
β_2	$-92{,}57 \times 10^{-3}$	$37{,}15 \times 10^{-3}$	$-2{,}49$	$13{,}61 \times 10^{-3}$	$-165{,}88 \times 10^{-3}$	$-19{,}26 \times 10^{-3}$
β_3	$-2{,}15 \times 10^{-6}$	$6{,}98 \times 10^{-7}$	$-3{,}08$	$2{,}35 \times 10^{-3}$	$-3{,}5 \times 10^{-6}$	$-7{,}80 \times 10^{-7}$
β_4	$-11{,}35 \times 10^{-3}$	$1{,}11 \times 10^{-3}$	$-10{,}24$	$1{,}03 \times 10^{-19}$	$-13{,}53 \times 10^{-3}$	$-9{,}16 \times 10^{-3}$

Source: Authors.

Gomez et al. (2008) makes a regression line for each month and presents an annual regression with coefficient of determination r^2 exceeding 0.9. Regression presented by him was made in the state of Durango in Mexico. Bajat et al. (2015) presents the regression of Serbia with $r^2 = 0.83$ ($p < 0.001$), he used the height compared with the temperature. Brazil is larger than Serbia and the state of Durango in Mexico, making it difficult to model the dependent variable temperature; however, the independent variables latitude and altitude explain 91.85% of the presented model and has a standard error of 0.93C. The residues analysis resulted in $N(0; \sigma^2)$. The r^2 of residues in Pearson-Pearson test was 0.28% which proves that there is homoscedasticity.

The estimated temperature variation in Brazil when geographical location is kept fixed and the altitude is increased by 01 meter, temperature variation is -0.0023°C. When moves the latitude in 01°C and maintains in static character the altitude change in temperature is 0.13°C. It was concluded that increasing altitude in 56.5 meters the temperature reduces in 0.13°C, equivalent to 01° in latitude.

Table 03. Center of Clusters. *The displayed temperature is the average of the period 2000 to 2014 for 187 Weather Stations.

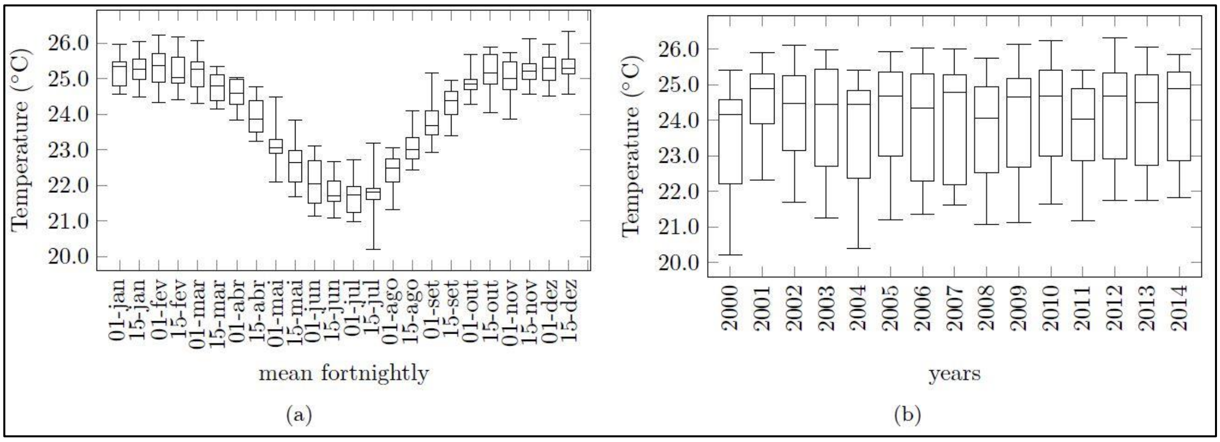
CLUSTER	QUANTITY	ALTITUDE	LATITUDE	LONGITUDE	TEMPERATURE (C)*
1	57	52,18	-8,89	-48,14	25,98
2	37	231,16	-10,80	-47,08	25,87
3	36	472,73	-15,31	-44,40	24,16
4	36	719,80	-18,80	-45,63	21,83
5	20	982,53	-18,98	-45,67	20,08
6	1	1415,00	-28,30	-49,93	13,69

Source: Authors.

The result of cluster analysis was shown in Table 03. There the results are classified into six groups. It can be seen in the groups that as the temperature and latitude decrease, cities are displaced to the next cluster with greater height.

Biweekly and annual temperature average analysis were performed to identify variations in the series from 2000 to 2014. Figure 02a and 02b represents the standard deviation of the average temperature. Figure 02a presents average daily temperatures of 15 days with its standard deviation. Brazil annual temperature in Figure 02b showed higher standard deviation, indicating that the temperature is influenced by local characteristics.

Figure 02. Average temperature - Brazil - 2000 to 2014. (a) Biweekly Average temperature. (b) Annual Average temperature.



Source: Authors.

Subsequently, possible changes in the average annual time series were identified, thereby discovering trends over the years from one WS to another. The analysis results of the data sample series showed significant trends. After calculating the sample correlation LAG-k the sampled data were clarified.

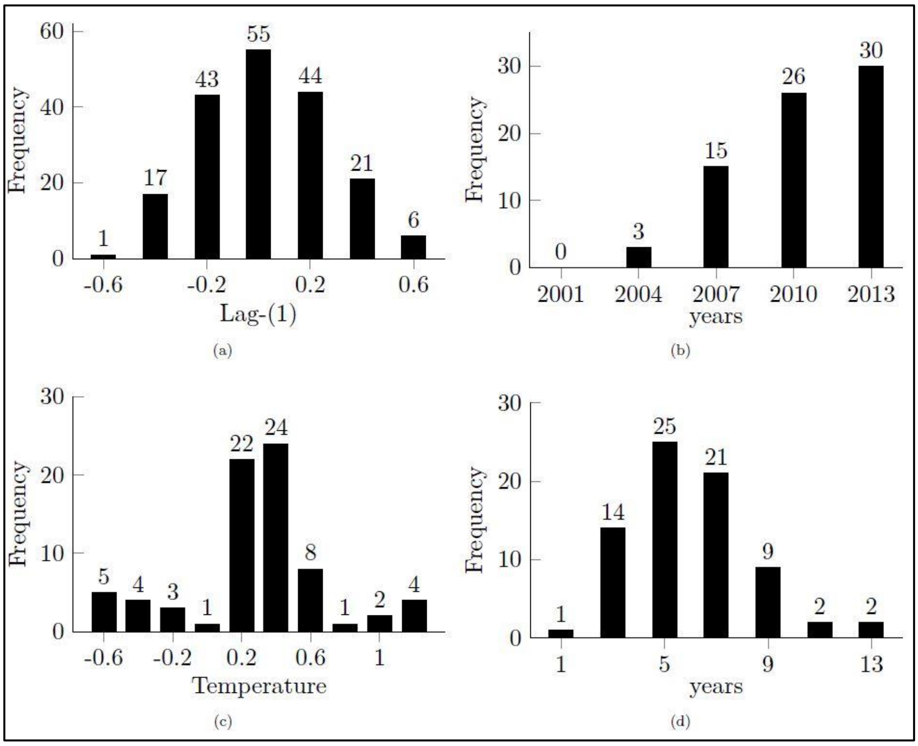
The confidence interval with a 95% significance can be calculated for $N = 15$ and $k = n - 1$. where N is the number of annual averages and k is the number of series lag observed, being necessary to calculate the confidence interval ρ_j for each series considered. The correlation function presented an exponentially decaying confirming that the data were stationary for the Brazilian case. The sample correlation for the average temperature has the standard error of 0.258°C.

The Figure 03a shows the histogram with the sample correlations for each WS. The correlation result can be interpreted as positive or negative correlation, more than 32% of the data below -0.2, and 37.9% of the data are greater than 0.2. The range with a low degree of correlation is between -0.2 to 0.2, but 70.5% of the stations have a serial sample correlation degree. This shows that the series oscillate indefinitely. Bajat et al. (2015) found only positive correlation values for $k = 1$ from 0 to 0.8. On the other hand, Kamruzzaman et al. (2011) conducted studies in Australia, where he presented LAG - [1, 2 and 3] for the temperature and 80% correlated. Lorentzen (2015) analyzes the marine coast of Norway, applies autoregression and verifies that the climatological process is stationary. It was concluded that in Brazil some WS have stationary series and other trends.

CUSUM charts were produced in order to determine the weather changes or reversals in the WSs and the years which showed trends are plotted in Figure 03b, they were determined by Eq's. (6) and (7). In the histogram, from the total of 187 WSs, only 74 present trends. Changes occurred in early 2003 until 2014. The range in which the inversion was more pronounced are from 2009 to 2014, these changes range in the CUSUM chart represents approximately 76% of confirmed trends. Alterations in temperature were plotted in Figure 03c. In this figure, it was observed that more than 62% of the changes in average temperature are between 0.1 and 0.5°C. And the duration of trends is presented in Figure 03d. In this figure, the duration of most of the changes is between 04 to 07 years.

When conducting an analysis in Germany using the CUSUM chart in the period 1901-2012, Torgovitski (2015) reports changes in the years 1956 and 2004, the first one started in the second half of the 20th century with an increase of 1.5°C thus taking 31 years to be proven. In Brazil, in 15 years there was an accumulation of 40% of changes in a short period, which proves that trends are being observed in less time interval. The greater cooling was Luzilândia, the state of Piauí, which has 49 m high with a decrease of -0.63°C, followed by Correntina, state of Bahia, with an altitude of 549.47 m and cooling of 0.62°C. In the areas that heating trends were determined, Taubaté, state of São Paulo, was the first at an altitude of 577 m and an increase of 2.12°C, followed by Bom Jesus, state of Piauí, which is 331.74 m above sea level with heating of 1.82°C in the annual average.

Figure 03. (a) Sample correlation. (b) Annual changes. (c) Changes in averages. (d) Changes Duration.

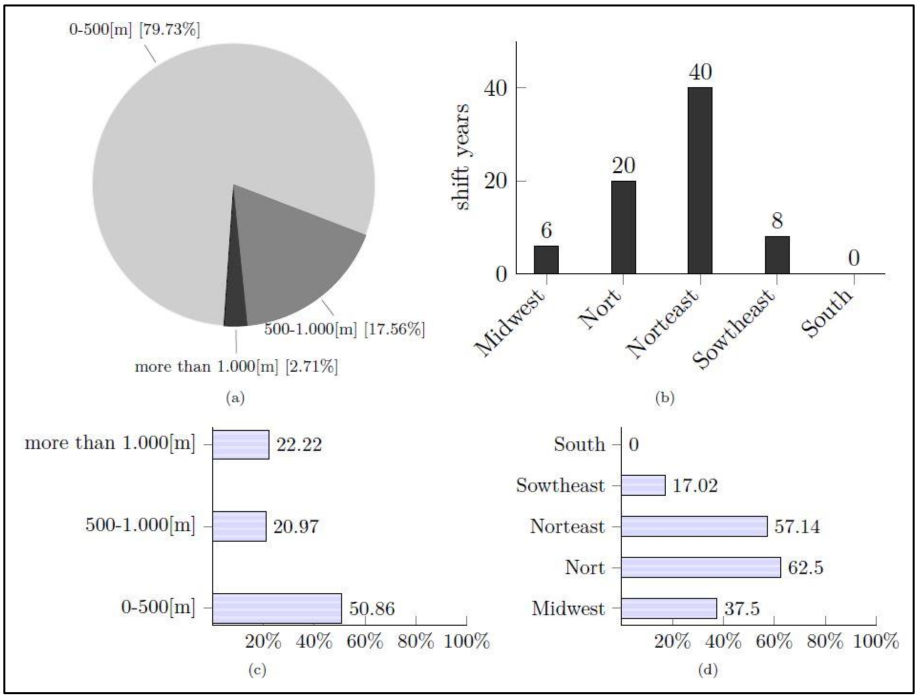


Source: Authors.

By applying the LSQ method, the analysis of monthly average temperature series resulted in some periods in which there have been changes in the averages with a cooling followed by heating. A cooling period was found in Europe in the '70s (Balling-JR et al. 1998; Klein-Tank et al. 2002). Gurevech et al. (2011) discovered alterations in Israel from 1980 to 1990. When analyzing the annual average of Italy, Toreti and Desiato (2008) revealed a cooling period in 1981, followed by a heating period. Breaker (2007) used the CUSUM chart in North Pacific and identified cooling and heating trends. In Brazil, heating trends in 62 WS and cooling trends in 12 WSs was discovered in annual averages. It was also observed that in the cities of Itaberaba, the state of Bahia, Água Branca, state of Alagoas, and Alto do Parnaíba, state of Maranhão, records of changes of cooling followed by heating. In these cities, cooling changes presented were -0.37; -0.26 and -0.23°C followed by heating about 0.13, 0.26 and 0.44°C, respectively.

These results were also observed by Bajat et al. (2015) who conducted an analysis of annual averages and found in Serbia a cooling period of -0.01 to -0.87°C per decade, followed by a heating period from 0.18 to 3.63°C per decade. In a study of annual average temperature series for the period 1948-1973, Brunet et al. (2005) present cooling trend of -0.29°C per decade in Spain and also reported the change to a positive trend of 0.54°C per decade from 1973 to 2003. Klein-Tank and Konnen (2003) estimated a reduction of 0.04°C in Europe per decade from 1946 to 1999, showing a reversal pattern in the periods from 1976 to 1999. Unkasevic et al. (2005) observed an increase of 1.3°C per decade in Belgrade (Serbia) during the period 1975 to 2003.

Figure 04. (a) Height Trends. (b) Regions Trends. (c) Ratio of Trends in altitude. (d) Ratio of Trends in the regions.



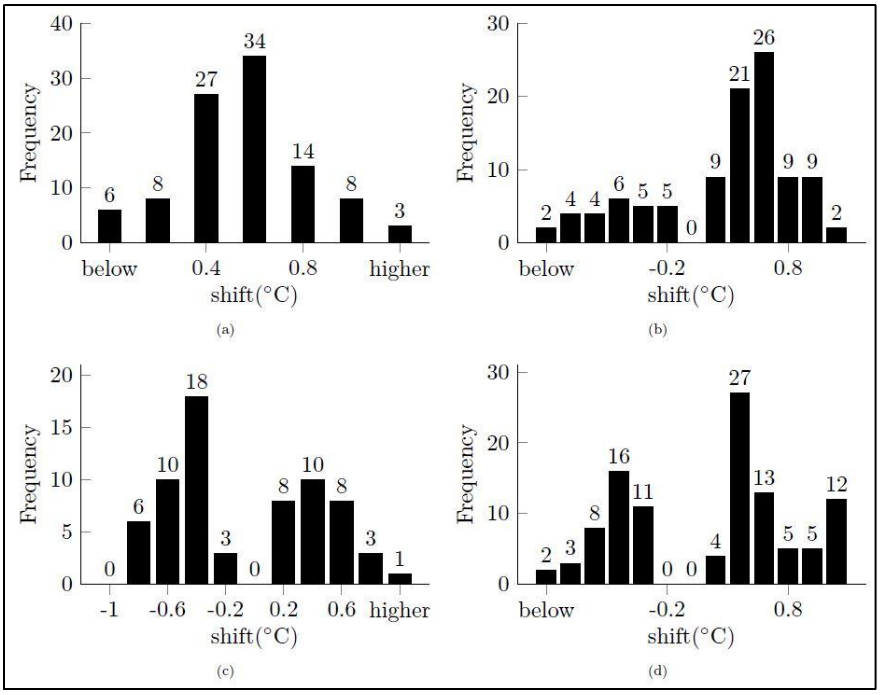
Source: Authors.

The trends were related to altitude regions in order to specify in detail the climatic inversions. Figure 04a is the ratio of the trends confirmed by height. The quantity of WS confirmed below 500m, in altitudes from 500 to 1000m, and over a thousand meters are in Figure 04c. Figure 04b shows the trend in the regions of Brazil. The list of trends by regions is in Figure 04d. The changes identified in the regions were in the South of the country climate change were not identified during the study period; in the Southeast trends were confirmed in 17% of WSs; in the Midwest the changes were 37.5%; the inversions in the Northeast were 57.14%; and the biggest trend was in the North with 62.5% confirmations. The trends in this period concentrated between -15 to 0° in latitude.

Changes were observed within the interval of one year, so the data were divided into a smaller time scale for better understanding. They were classified as summer, autumn, winter and spring. In these seasons three trends were identified: cool, heat and both. The summer, autumn and winter seasons had more heating records, but in the spring, the opposite occurred.

The average temperature analysis in the seasons was studied by Brunet et al. (2007). In this study, they verified the temperature in Spain from 1950 to 1972. They noted that there are cooling trends in the seasons except winter, but from 1973 to 2005 changes for heating have happened. Philandras et al. (2008) conducted studies in 20 WSs spatially distributed in Greece during 1951-2000. They divided the analysis into groups of 25: before 1976 the records were of heating only in the spring, after 1976 prevailed heating in all seasons. Wang et al. (2015) made analysis in the arid region of northwest China selecting 121 air temperature WS in the period from 1960 to 2010. They discovered an increase of records: spring 0.24; summer 0.26; autumn 0.41; and winter 0.39°C per decade. Vincent et al. (2005) analyze the year seasons in South America in 68 WSs between the years 1960 to 2010, finding that 35% of the stations studied showed a trend in minimum temperature during summer and autumn.

Figure 05. (a) Summer. (b) Winter. (c) Autumn. (d) Spring.



Source: Authors.

The summer season is shown in Figure 05a. In this figure, it was observed 6 WSs with cooling trends in 0.98 to 0.22°C, heating trends is from 0.13 to 1.9°C in 94 WSs. It was confirmed 27 trends to the year 2009 and after this date, the records were 72 changes, lasting 8-13 years. The trends concentration that occurred below 500 meters was confirmed in 75% of WSs and above 1,000m, only 02% were confirmed.

In fall, the cooling records were from 1.45 to 0.34°C in 40 WSs and heating from 0.19 to 2.24°C in 66 WSs, as shown in Figure 05c. In this season, after 2010, there were 81 changes in average and prior to 2009 there were in 25 WSs, with periods of 05-12 years. Records observed between 0 to 500 meters were 78.3%, and from 500 to 1,000 m trends were 19.8%. The autumn season showed fewer trends over a thousand meters, with confirmation of 01.9% of change records.

During winter season heating occurred in 75 WSs with variations of 0.13 to 1.35°C and the cooling from 1.17 to 0.16°C in 26 WSs. These trends were 28 WSs by 2009 and 73 after 2010, with a history of 06 to 13 years. The station is shown in Figure 05b. Confirmed trends grouped in 0-500m were 74.3%, for heights of 500-1,000 m 19,8% were found and above 1,000m confirmations were 5.9%.

The results for spring were plotted in Figure 05d. In this figure, it was observed the cooling of 0.21 to 0.87°C with 37 records and heating from 0.15 to 2.26°C, which was confirmed by 30 WSs. The results were divided into two: 23 confirmations by 2009 and 44 after 2010, and duration of 06-13 years. The spring season was the one with higher trend confirmation below 500 meters with 80.6% of trends, between 500 to 1,000m was 16.4% and above 1,000 meters were only 03%.

The analysis of annual data showed fewer change records than the seasons. The station with the highest trend was fall with 106 uncommitted changes, followed by winter with 101. There were fewer records in the spring season with 67 and summer showed a change in 100 WSs. In the studied time, interval change of regimes was confirmed in 86.7% of the cities studied, which is more than double the annual review.

Conclusions

The lack of data from Weather Stations maintenance or other, which are usually discarded, can be used if the gap is small, but it must be cautious in selecting the next season. CUSUM chart provides results equivalent to other methods, confirming the identification of climate trends.

The series of annual average temperature and seasons of 187 WSs was used to calculate the trends in Brazil from 2000 to 2014. The CUSUM charts were produced for each WS in order to detect changes in the years. The results of variance analysis showed that the annual temperature changes can be detected in almost all series. The CUSUM graphics produced by the temperature series indicated variations with a higher incidence between the years 2009-2014. The data series in which cooling trend followed by heating appeared were studied separately. The model estimated a drop in average temperature of -0.43±0.2°C, and heating from 0.09 to 2.12°C for fifteen years. Based on the statistical test results, it is possible to say that a significant heating was found.

The estimation of the average temperature trend in Brazil is in accordance with the one obtained in a global scale, even though the average variation appears to be shifted for some years. The annual temperature series analyzed here confirm heating trends since 2003. Trends have been found considering the average analysis of time series of temperature both in Europe and in South America (Klein-Tank & Konnen 2003; Vincent et al. 2005). According to these authors, there is a heating trend in one season and cooling in another within the same year, therefore, the analysis per station presents more detailed data. It was verified that the fall season is the station with the largest contribution to the yearly trends, followed by winter. The positive trend in high-level significance is recorded in most weather stations.

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Análise da Temperatura Média e Tendências no Brasil: Aplicação do Gráfico CUSUM entre 2000 a 2014

RESUMO

Nas últimas décadas as tendências de temperatura estão se confirmando mais rapidamente. Para determinar as mudanças de temperatura no Brasil foi realizada análise das tendências anuais e por estações do ano tendo por base dados diários de 187 estações meteorológicas, abrangendo o período de 2000 a 2014. As tendências foram confirmadas com a utilização do Gráfico de Soma Acumulativa, este método percebe as alterações em séries mais rápido que outros. A modelagem da temperatura foi obtida por Regressão Múltipla e com a Análise de Cluster foi possível agrupar Estações Meteorológicas. As tendências observadas confirmam oscilações de resfriamento, aquecimento e em alguns casos de resfriamento seguido de aquecimento. As principais tendências apresentadas no período estudado foram a partir de -15 até 0° na latitude. A região com maior confirmação de inversões na temperatura foi o Norte, seguida do Nordeste. Em altitude abaixo de 500 metros é onde apresentou maior tendência. Quanto às estações do ano, o outono contribuiu significativamente com as tendências.

Palavras-Chave: Gráfico de Soma Acumulativa; Temperatura do Ar; Tendência de Temperatura; Modelagem de Temperatura.

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