RESEARCH ARTICLE

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VARIABILITY AND CHANGE ANALYSIS IN TEMPERATURE TIME SERIES AT KOLDA REGION, SENEGAL

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SUMMARY

This paper attempts to analyze spatial variability, temporal trends and identify the discontinuities in the maximum and minimum temperature's time series. This study is based on annual and monthly data from the Kolda Weather Station over a 50-year period. Our approach is essentially structured according to 3 components: first, anomaly index and cumulative sums are calculated and finally, Mann-Kendall statistical test is performed. Considering anomaly index, results highlight four categories of periods both annual and monthly scale: very hot, hot, very cold and cold for the maximums and the minimums. The analysis indicated that minimums increased significantly more than maximums. Regarding the CUSUM, results showed a downward trend for maximums and upwards for minimums on an annual and monthly basis. The dates of these breaks are 2001 and May for maximums and 1975 and February for minimums respectively at annual and monthly scale. Regarding Mann Kendall test, results show a significant downward and upwards trend respectively for maximums and minimums. On a monthly scale, we make the same observations except that the trend is not significant for minimums. It can be concluded that the strong warming experienced by the Kolda region in recent

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years is largely conditioned by the increase in minimum annual temperature.

Keywords*:* Variability**,** Sift, Trend, global warming, Productive water, Greenhouse gases, Regional levels

1. INTRODUCTION

Nowadays, it is increasingly recognized that there is a close association between climate change, environment, ecosystems, water resources availability, its variability and societal sustainable development (Xu et al., 2004; Pai Mazumder and Mölders, 2009; Lanlan et al., 2013). Climate can be basically defined as the average weather conditions of a particular neighborhood observed over a period of together (Traore et al., 2017). According to Diouf et al. (2017), climatic events are mainly a blend of several factors that are natural and/or anthropogenic orders. Pareek (2017*)* stipules that climate change is global phenomenon and occurring continuously since the earth came into existence. According to Fauchereau et al. (2003); Xu-ming et al. (2014), it may cause major changes in climatic variables such as precipitation, air temperature, relative humidity, and solar radiation. Mehan et al. (2017) indicated any change in these variables can result in adverse conditions for the well-being of humans in their environment. For example, the variables such as precipitation, temperature, and atmospheric carbon dioxide concentration influence various hydrological parameters such as stream flow, surface runoff, and evapotranspiration (Watts et al., 2015). Woznicki and Nejadhashemi (2011) said that there is a strong relationship between climate variables and components of the hydrologic cycle. Brouder and Volenec (2008) add that climate changes have significant impacts on alteration in soil moisture conditions and levels, altering of soil water circulation patterns, hydrological drought, destruction of soil minerals, loss of soil fertility and changes in vegetation, plant growth rates, and rates of soil water extraction by plants etc. There is a considerable risk to penalize the projects of agricultural development program and to perturb the efficiency of the irrigation system management and crops (Zhang et al., 2011). According to Pareek (2017), this situation leads to declining in food production; nutritional quality of food may also be reduced raising a concern for nutritional security. Alarmed by the possible impact of the global climate change on the quality of life of human beings, the efforts are being made worldwide to develop strategies to mitigate its negative impacts (Xu et al., 2013). The effect of climate variability and change has been extensively studied in various sectors including human health (Watts et al., 2015); biodiversity (Langdon and Lawler, 2015);

food production (Antle, 2015); economic growth (Moore and Diaz, 2015); water resources (Watts et al., 2015; Palazzoli et al., 2015) and virtually every aspect of human life (Xu et al., 2005). Fulvie et al. (2009); Tossou et al. (2017) bring the precision that poor communities are more vulnerable to extreme climatic phenomena due to their limited adaptation capacities and their great dependence to water resources and rain fed agricultural production systems. In recent years, the collective awareness on climate change implications made that it has becomes a hot topic for researchers, attracting the attention of experts and scholars, as well as the governments of many developing countries (Dai et al., 2010; Shen et al., 2012; Dai and Zhang, 2012). In light of these concerns, the investigations take into account the parameters allowing monitoring and apprehending the essential aspects of climate evolution (Chaouche et al., 2010). Thus, temperature and precipitation, both of which are vital meteorological factors, are usually selected as representative variables to directly reflect and predict global climate change (Lan-lan et al., 2013*).* These parameters influence the soil formation directly by providing biomass and conditions for weathering. They determine values of energy consumption for soil formation and water balances in soil, mechanism of organic mineral interactions, and transformation of organic and mineral substances and flows of soil solutions (Pareek, 2017). The variables of climate change particularly temperature and rainfall dictates various stages of weathering of rocks and minerals (parent material) resulting in chemical and mineralogical changes in soil forming rocks (Shi and Xu, 2008). Changes in temperatures and precipitation will lead to transformation of internal factors (energy, hydrological, biological). From the opinion of Ramírez et al. (2016), among these external factors of climate, the temperature is an integral component of climate variability and change at the regional scale. According to Zhang et al. (2008); Kashaigili et al. (2014) extreme temperature events constitute climate variability and change; hence variations in climate might be an artefact of temperature rise in the area. Rising temperature is expected to strengthen the hydrological cycle because of the ability of warm air to contain and spread more moisture, which causes the change in atmospheric circulation (Wentz et al., 2007; Ye et al., 2013). Despite responding to climate change in different ways, changes in precipitation, runoff, groundwater flow, evapotranspiration, and soil moisture indicate that the hydrological cycle has been intensified along with the rising temperature around the world during the 20th century (Allen and Ingram, 2002; Alan et al., 2003; Gao et al., 2012; Allan et al., 2013). One of the most important and immediate effects of global warming would be the changes in

local and regional water availability, since the climate system is interactive with the hydrologic cycle (Huntington, 2006). Such effects may include the magnitude and timing of runoff, the frequency and intensity of floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of water availability; these changes, in turn, influence the water supply system, power generation, sediment transport and deposition, and ecosystem conservation (Jiang et al., 2007). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013), the global warming trend, which is mainly caused by the increasing amount of greenhouse gas emissions, will continue (Xin and al., 2015). Ram et al. (2015) believe that these increases in temperature may hamper the production of food crops and thus threaten the food security of populations in a large part of the sahelian countries, especially in arid and semi-arid regions. Some of these effects may not necessarily be negative. It has been confirmed in numerous studies according to Xu-ming et al. (2014) that trends in climatic variables vary from place to place. So, the study of temperature evolution is important for a country like Senegal where food security depends on the water supply for *s*ustainable agriculture. The latter has multiple objectives, including efficient use of land to produce nutrients for human consumption, climate resilience, and income for farmers. In this study, we focus on the region of Kolda, in the southern part of Senegal. In this area, *s*ociety relies on rainfed agricultural systems to provide sufficient human energy from food, a range of nutrients required in the human diet, and economic returns for farmers, businesses and others who derive livelihoods from the food system. At the same time, sustainable agricultural systems aim to adapt to climate change and variability, reduce greenhouse gas emissions and environmental impacts of agrochemicals, land use and water efficiently. Unfortunately, in this area, desertification affects soil fertility and food system stability, causing productivity losses, food insecurity, rising social and economic disparity, and poverty; such situation lead to rural migration. Therefore, the objective of the current article is threefold: the determination of the negative and positive anomaly, the detection of linear trend and the determination of change points for temperature series registered at Kolda meteorological station. In this study, we focused on maximum and minimum temperature series. In that respect, we have proceeded through an approach combining Mann-Kendall test to detect linear trend, cumulative sums calculation to locate the sudden change point and anomaly index calculation to categorize the years in terms of heat.

Such information stands as the basic elements for a deeper reflection of climate experts on the phenomena that contribute to the fight against global warming.

2. MATERIALS AND METHODS

2.1. Study area and data

Kolda is a region shaped in 1984. It is located between the middle and high Casamance in the south of Senegal between latitudes 12° 20 and 13° 40 north, and longitudes 13° and 16° West. With an estimated area of 13,718 Km^2, the Kolda region is bounded to the north by the republic of Gambia, to the east by the Tambacounda region, to the west by the Sedhiou region and to the south by the republics of Guinea Bissau and Guinea Conakry (PCC, 2009). After the administrative reform of 2008, it was subdivided into 3 departments, 9 communes, 9 districts, 31 rural communities and 1792 villages. Its population in 46,718 households is estimated at 638,315 inhabitants, a density of 47 hbts / km^2, which represents 5% of the national population. The rate of urbanization is very low, (79% of the population live in rural areas; ANSD, 2012). The population, predominantly composed of women (50.1%), is characterized by its youth, 60% of the population are under 20 years. From the ethnic point of view, the region is composed of Peulhs (75%, Manding and Wolofs (respectively 7.31% and 7.22%), Sarakolés (2.33%), Diolas (1.36%), and Serer (1.10%). 19 other ethnic minorities and nationalities are enumerated for a total of 5.55% (Sylvie, 2011). The most frequent types of dwellings are consisted of huts (56%), mainly in the rural area and of low houses (43%), recorded in urban areas. The economy relies mainly on agricultural activities and mobilizes about 70 to 80% of the region's assets over a period of 3 to 4 months in the year. This activity provides income to producers and plays a predominant role in feeding population. The region also has arable land estimated at 2 million hectares. These natural potentialities favorable to agriculture make this region of Kolda a magnet for producers from other parts of the country in search of new and better lands (Bonhoure et Gauthier, 1997). The types of crops grown in the region are cereal crops (millet, maize, rice, sorghum and fonio ...), cash crops (groundnuts, cotton and sesame, watermelon, beans…), fruits and vegetables (cashew, mango, mad, orange and lemon, bissab, okra, onion, eggplant, cabbage, … (ANSD, 2015). Climatically, the Kolda region is of the Sudano-Guinean type, receiving rainfall from June to October with maximum intensity in August and September, and a dry season during the period from November to May. Average precipitation ranges from 700 to 1300 mm. The lowest monthly mean temperatures are recorded in December and

January and range from 25 to 30°C, with the highest values recorded from March to September varying from 30 to 40°C (Ba et al., 2002). From a topographical point view, the region has a landscape relief consisting of sandy clay sandstone forming plateaus with abundant natural vegetation (savannah or sclerophyll forest), intersected by valleys in which are the rice fields and lowland pastures. On the hydrographic point view, the network is dense and consists of a main stream; the Casamance and its tributaries constituted with brooks and rivelets. Added to this are the Niandouba and confluent dams, which make it possible to dispose of water permanently (ANSD, 2015). In the current article, we have used the temperature data collected from the Kolda weather station over a time span extending from 1960 to 2009. These data were provided by ANACIM (National Agency of Civil Aviation and Meteorology) that guarantees the quality and reliability of data. Maximum and minimum temperature data at yearly and monthly scale are judiciously used for this purpose. Our motivation through this work is to extract necessary information for a valuable theoretical basis to undertake mitigating strategies of extreme weather events' impact on sustainable development and utilization of water resources of rivers for agricultural purpose.

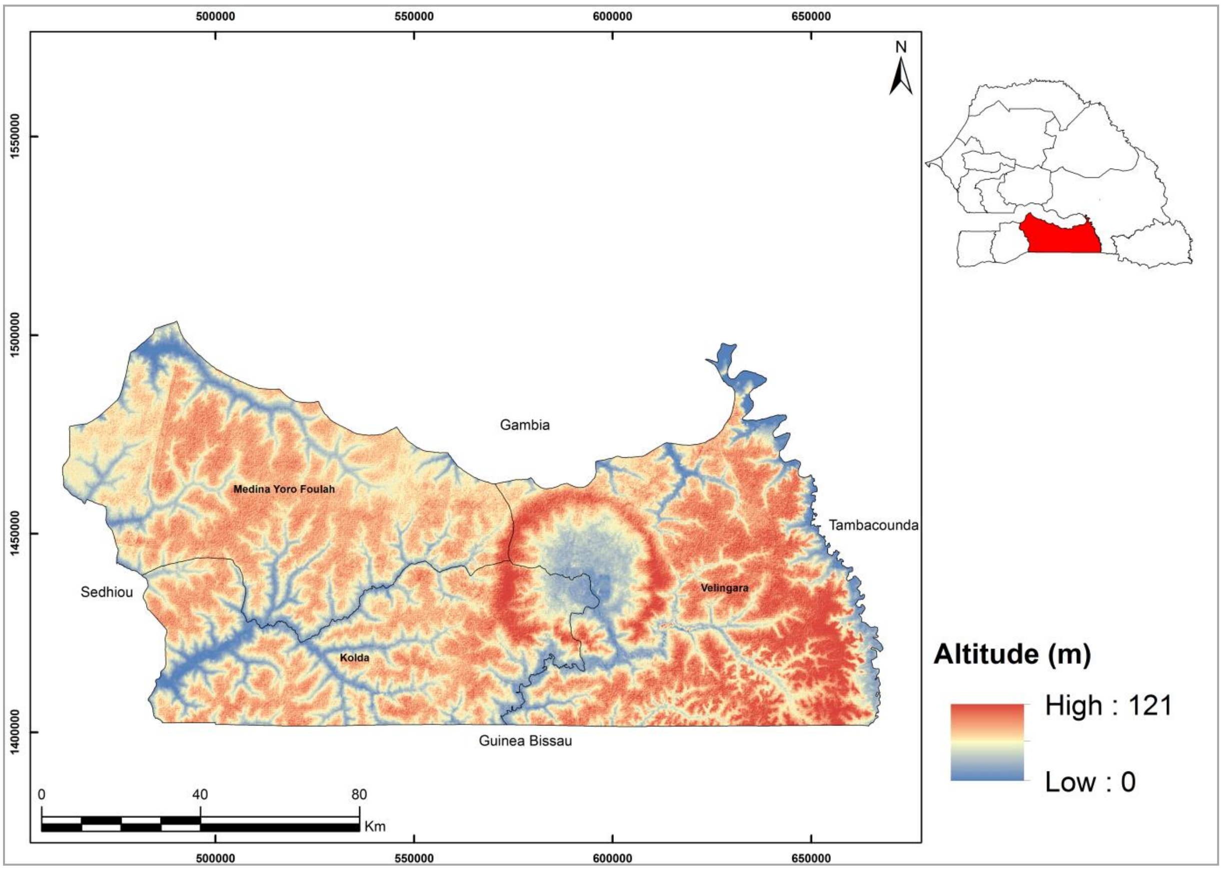

Fig.1. Study area Location

2.2. Variability analysis

Anomaly coefficient were used as descriptors of spatial variability of meteorological data (Bewket and Conway, 2007; Ayalew et al., 2012). It was calculated as the difference between the annual or monthly mean of climatic variable of a particular year and the baseline period mean. This coefficient used to examine the nature of the trends also makes possible the determination of the negative and positive anomaly in the record series. Its formula is given by the equation (1):

$$A_k = X_i - \overline{X} \qquad (1)$$

Where $\overline{X}$ is the baseline period average given by equation (2):

$$\overline{X} = \sum_{i=1}^{n} X_i \qquad (2)$$

The positive anomaly shows the years when the annual or monthly mean (Xi) exceeded the baseline period average (x), i.e. the coefficient value is positive; while the negative anomaly shows the years when the annual or monthly mean (Xi) was less than the baseline period average, i.e. the coefficient value is negative. On a graphic point of view and to facilitate the understanding, negative anomalies are represented below the abscissa and positive anomalies above (Maftei et al., 2009).

2.3. Abrupt change analysis

Cumulative Sum test (CUSUM) is a technique often used to detect the sudden change in meteorological data. They are not the cumulative sums of the values but the cumulative sums of differences between the values and the average (Taylo, 2002). It was commonly used in the climatology as method to detect homogeneities in the meteorological time series (Sahin and Kerem, 2010; Ngongondo et al., 2011). This method tests whether the means of two parts, before and after the unknown change point of time series data are different. The test assumes that the data are normally distributed. This method is developed in 1949 by Litchfied and Wilcom. Let be $Y_{i,}$ i=1, …, n, the registered data. From them, the cumulative sums S0, S_1, …, S_i are calculated following the equation (3) (Raes et al., 2006):

$$S_i = S_{i-1} + (Y_i - \overline{Y}), i = 1, \ldots, n \qquad (3)$$
$$s_0 = 0$$

S_{i-1} is the previous sum, $Y_i - \overline{Y}$ is the difference between current value and the average, $\overline{Y}$ is the average given by equation (4):

$$\overline{Y} = \sum_{i=1}^{n} Y_i \qquad (4)$$

When the series is homogeneous, then the value of S_i will rise and fall around zero; when S_i value shows a maximum or minimum, a sudden change is present. The maximum corresponds to negative shift, while the minimum corresponds to positive shift. From graphical point view, a slope change in the graph of the CUSUM indicates a sudden change

in the average (Maftei et al., 2009). Periods where the graph of the CUSUM follows a relatively straight path indicate a period where the average did not change. For a record Y_i above normal, the S_i increases, while for a record below normal, the S_i decreases. For a homogenous record one may expect that the S_i's fluctuates around zero since there is no systematic pattern in the deviations of the Y_i's from their average value $\overline{Y}$. The significance of this change is evaluated calculating the 'rescaled adjusted range' variable R, which is the difference between the maximum and the minimum of the S_i values scaled by the standard deviation as shown in equation (5) (Kang and Yusof, 2012):

$$R = \frac{\max S_i - \min S_i}{\sigma}, i = 0, \ldots, n \quad (5)$$

The standard deviation σ is evaluated by the equation (6):

$$\sigma = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2 \quad (6)$$

Then, the test statistic R is compared with its critical values R_c given by Buishand (1982) and 5% probability level to make decision on the null hypothesis. If $R > R_c$, the null hypothesis of absence of break points is accepted at 5% probability level if not, it is rejected. And the rescaled adjusted partial sums noted S_i^* are calculated through the S_i by dividing its values by the standard deviation σ as shown in equation (7):

$$S_i^* = \frac{S_i}{\sigma}, i = 0, \ldots, n \quad (7)$$

The point where the maximum jump occurred is defined as change point. Then, a test-statistic *Q* indicating the year corresponding to this point is evaluated according to the equation (8) (Winjngaard et al., 2003):

$$Q = \max\left|S_i^*\right|, o \le i \le n \quad (8)$$

In addition, if the algebraic value of this statistic is positive, then this sudden change is downward and if not, it is upward.

2.3. Trend analysis

Trend is the tendency of a phenomenon over a fixed period; it can vary according to the reference temporal window (Renata et al., 2012). Among the methods to detect (linear) trend in time series the most used statistical and graphical approaches. In this paper we focused on Mann-Kendall test.

- ✓ **Mann-Kendall test (MK)**

Mann-Kendall test is a non-parametric test for identifying and estimating trends in time series data (Traore et al., 2014). This test compares the relative magnitudes of data rather than the data values themselves (Gilbert, 1987). One of the

benefits of this test is that the data need not to confirm to any particular distribution. Moreover, data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data test (Hirsch et al., 1982). This test assumes that there exists only one data value for a time period (Chiew and McMahon, 1993). When multiple data points exist for a single time period, the median value will be used. The data values are evaluated as ordered time series. Each data value is compared to all subsequent data values (Yue et al., 2002). The initial value of the Mann-Kendall statistic S is assumed to be 0. If a data value from a later time period is higher than a data value from an earlier time period, S is increased by 1.On the other hand, if the data value from the later time period is lower than a data valued sampled earlier, is decreased by 1(Zhang et al.,2004). The net result of increments and decrements yields the final value of S (Renata et al., 2012). Let x_1 x_2, x_3,…., x_n represent n data points, then the Mann-Kendall test statistic S is given by the equation (9):

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right) \qquad (9)$$

Where x_j are the sequential data values, n is the length of the data set, and Sgn is the Signe of the difference between x_j and x_i as shown in relation (10):

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} 1 \ if & x_j - x_i > 0 \\ 0 \ if & x_j - x_i = 0 \\ -1 \ if & x_j - x_i < 0 \end{cases} \qquad (10)$$

Mann (1945) and Kendall (1975) have documented that when n>8, the statistic S is approximately normally distributed with the mean and variance as follows (equation 11):

$$\begin{aligned} &E(s) = 0 \\ &Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5)\right] \end{aligned} \qquad (11)$$

Where n is the number of data points, g is the number of tied groups (a tied group is a set of data having the same value), and t_P is the number of data points in the p^{th} group. The standardized test statistic Z is computed by equation (12) (Partal and Kahya, 2006; Yenigun et al., 2008):

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} &, S > 0 \\ 0 \quad if &, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} &, S < 0 \end{cases} \qquad (12)$$

The standardized statistic Z follows the standard normal distribution with mean of zero and variance of one. The absence of a statistically significant trend is evaluated using the Z value. In a two-sided test for trend, the null hypothesis H0 of no trend should be rejected if $|Z| > Z_{1-\alpha/2}$ at a given level of significance. $Z_{1-\alpha/2}$ is the critical value of Z from the standard normal table. For example, for 5% significance level, the value of $Z_{1-\alpha/2}$ is 1.96 (Hadgu et al., 2013). A positive value of Z indicates

an increasing trend while a negative value indicates a decreasing trend (Barry et al., 2017). Mann-Kendall test is commonly employed to detect and estimate monotonic trends in series of environmental data, climate data or hydrological data (Bera, 2017). The magnitude of the trend of the time series is determined using p-value which is estimated in our case by the equation (13):

$$P_{value} = 2\left[1-\phi\left(\left|Z_{MK}\right|\right)\right] \qquad (13)$$

$\phi\left(\left|Z_{MK}\right|\right)$ is its distribution function read in Mann-Kendall standard normal table. Then the trend is said statistically significant at 5% probability level; if the p-value is less than the significance level 0.05.

2.4. Application

This study deals with the region of Kolda in lower Casamance in the southern part of Senegal. It is based on temperature data collected from the Kolda weather station during a period extending from 1960 to 2009.In this study we focus on the series of maximum and minimum temperature because the comparison of the evolution of these two parameters constitutes an interesting element from a climatic point of view. Our procedure is essentially structured in 3 components: a component related to the variability analysis, sudden change analysis and statistical trend processing. At this level, our motivation is to investigate the temporal characteristics of temperature evolution and identify discontinuities in these record series to provide a framework for sustainable resources management in the region of Kolda. The choice of this region is due to the fact that the total cropped area is dependent on uncertainties of monsoon. In this area, rain fed agriculture is important for food security by two ways: it produces the food people eat; and it provides the primary source of livelihood for farmers. Unfortunately, in recent years, climate changes have considerable impacts on food system stability in this region. In this circumstance, the analysis of meteorological time series is more necessary than ever with increased vigilance.

In the first component, we have calculated the anomaly index and then proceeded to its comparison to the reference value (zero), all this to help highlight the negative and positive anomaly in the record series. Afterwards, the index average for the hot years is calculated (noted, Sup) and for the cold years (noted, Inf), the point is to detect the very hot and cold years. The same operation was carried out at monthly scale to visualize the hot, cold, very hot and very colds months. As regards the first component, year is considered as hot when the index is positive and cold when it is negative. A highly hot year is a year of which the index is superior to the average of positive indexes

values and a very cold year is a year of which the index is inferior to the average of positive index values.

In the second component, we have evaluated the cumulative sums for each of the series of temperature and compared them to zero. After, we have identified the maximum and/or minimum value corresponding respectively to negative shift and/or positive shift. This helps to detect the presence of abrupt change. We have evaluated the significance of this change by calculating the 'rescaled adjusted range' variable noted R. The point where the maximum jump occurred is defined as change point. Then, we have calculated a test-statistic Q indicating the year corresponding to this point. If the algebraic value of this statistic is positive, then this sudden change is downward and if not, it is on the upward.

In the third component, we have first conducted the Mann Kendall test to verify the existence or not of a trend in the series. If so, to indicate whether it is going down or up; to confirm or to invalidate the results of the graphical analysis. An objective and rigorous interpretation of the results helps identify possible form of irregularity in the series. The totality of the results is presented in the form of tables and graphs.

3. RESULTS AND DISCUSSION

3.1. Variability analysis

- ✓ **At annual scale**

Analysis of the anomaly index for Kolda weather station is depicted in Figure 2a and Figure 2b, corresponding respectively to Maxima and minima. Considering the maximum temperatures (Fig. 2a), we count 23 hot years including 10 very hot and 26 cold years including 8 very cold. The year 2000 is the hottest and 1979 the coldest year. For the minimum temperatures (Fig. 2b), the analysis shows 26 hot years including 8 very hot and 23 cold years including 10 very cold. 2005 is the hottest year and 1975 is the coldest year. The results obtained from this analysis lead to the conclusion that the thermic regime is modifying in Kolda. Moreover, we find that the minimum temperature have significantly increased than the maximum temperature.

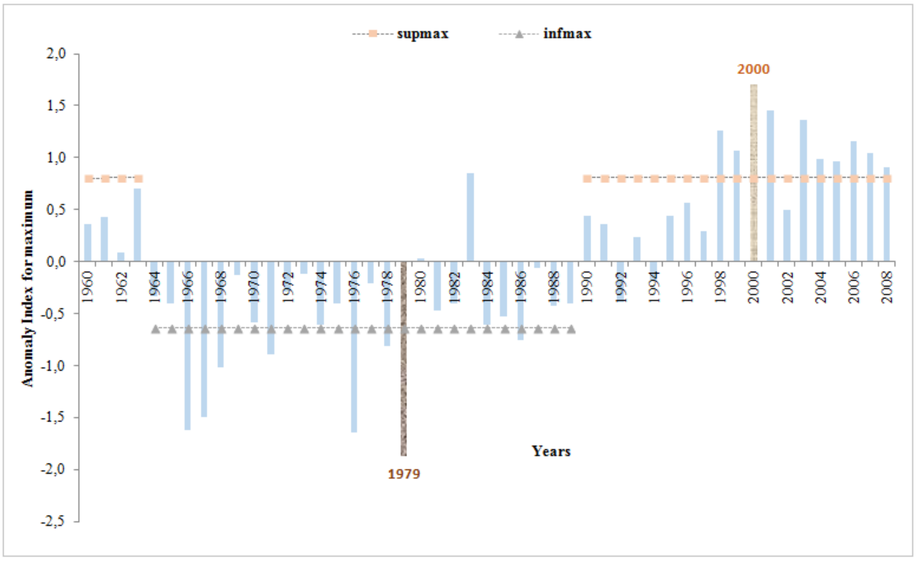

Fig.2a. Annual maximum temperature anomaly chart

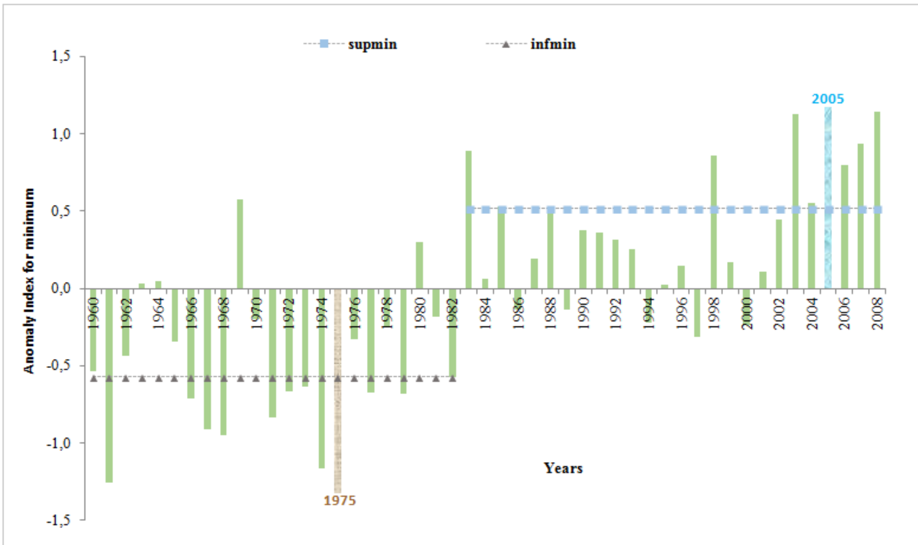

Fig.2b. Annual minimum temperature anomaly chart

- ✓ **at monthly scale**

Figure 3a and Figure 3b illustrate the analysis of the anomaly index for Kolda weather corresponding respectively to maxima and minima. Considering the maximum temperature (Fig. 3a), we count 5 hot months including 3 very hot and 7 cold months including 3 very cold. The month of April is the hottest and August the coldest month. For the minimum temperature (Fig. 3b), the analysis shows 7 hot months including 3 very hot and 5 cold months including 2 very cold. June is the hottest and January is the coldest month. These observations also show that during this period, the minimum temperature continuously increased while the maximum temperature decreased or stagnated.

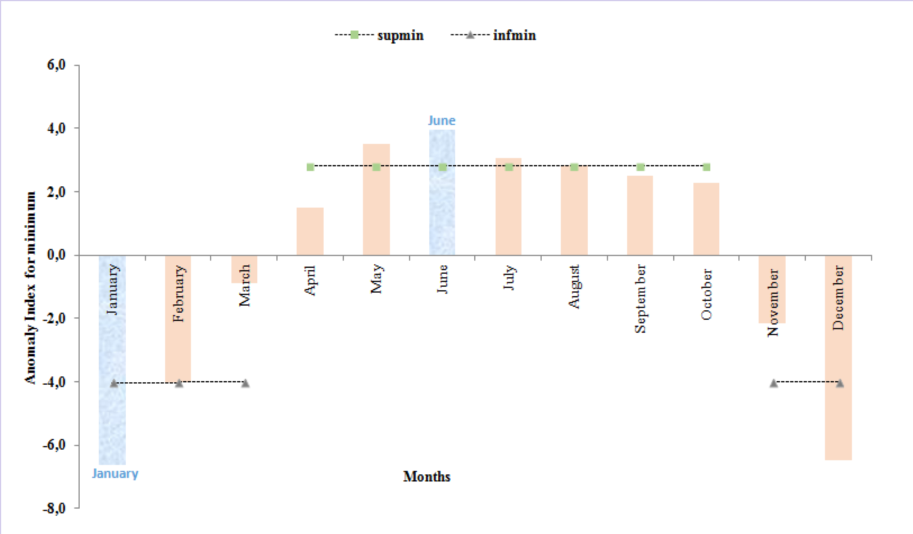

Fig.3a. Monthly maximum temperature anomaly chart

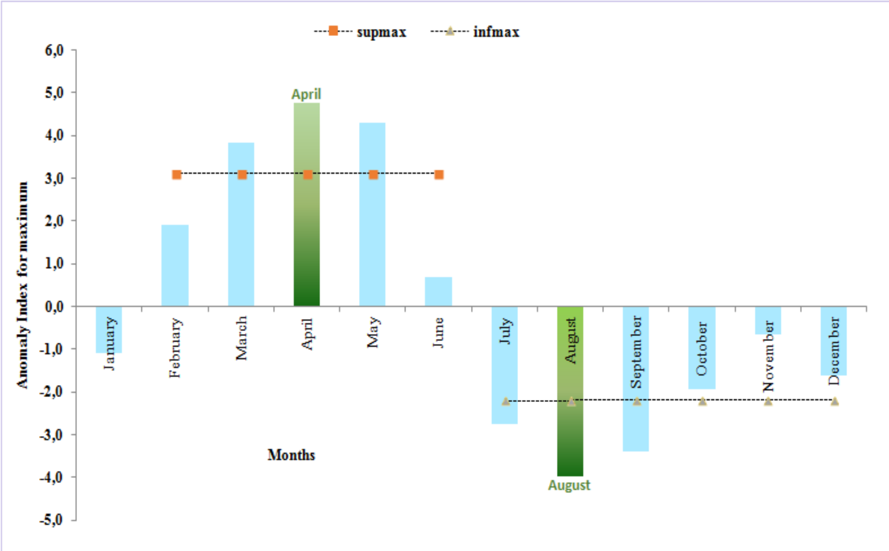

Fig.3b. Monthly minimum temperature anomaly chart

3.2. Sudden change

- ✓ **At annual scale**

We present in Table 1 the results of the sudden change detection tests and CUSUM charts are plotted in Figure 4a and Figure 4b respectively for maxima and minima values of temperature. Analysis shows that for all data of temperature considered, the null hypothesis of «no sudden change» is rejected at 5% probability level. The point where the maximum jump occurred is defined as change point. Then, this point corresponds to 2001 for the maximum temperature and 1975 for minimum temperature as shown in CUSUM charts, where sudden change in direction can be seen around these indicated years. From a climatic point of view, these results show the existence of two inverse tendencies for the maximum and minimum temperature: a period of warming followed by a period of cooling or vice versa. For maximum temperature, there was a

warming between 1960 and 2001 (with an increase of 1.1 ° C), followed by cooling between 2001 and 2009 (with a fall of 0.7°C). For minimum temperature, there is a cooling between 1960 and 1975 (with a drop of 0.5°C), followed by warming between 1975 and 2009 (with a rise of 2°C). It should also be noted that the break is down for the maximum and up for the minimum. It appears from this analysis that the temperature is changing in Kolda area and the warming is more pronounced for minimum than for maximum.

Table 1. Result of sudden change detection

	Value of R	Null hypothesis	Value of Q	Change points	Algebraic value of Q	Direction of change
Tmax	7.4	rejected	3.7	2001	+3.7	downward
Tmin	7.1	rejected	4.2	1975	-4.2	upwards

Null hypothesis: no sudden change

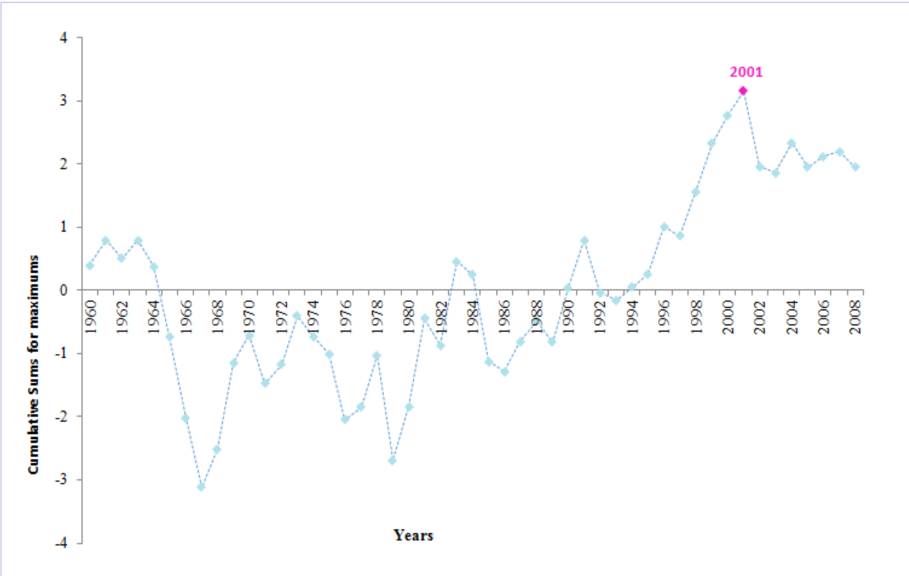

Fig.4a. Annual maximum temperature CUSUM chart

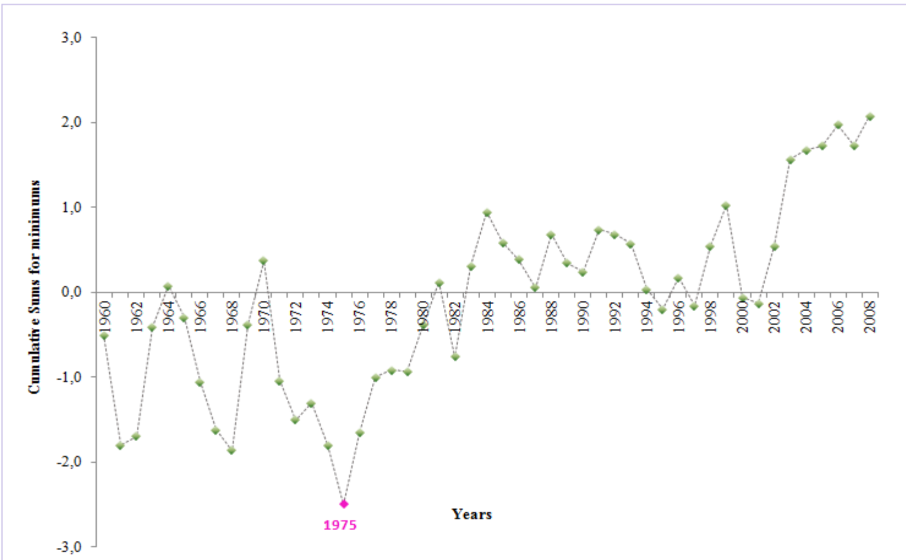

Fig.4b. Annual minimums temperature CUSUM chart

✓ **At monthly scale**

We present in Table 2 the results of the sudden change detection tests and CUSUM charts are plotted in Figure 5a and Figure 5b respectively for maxima and minima temperature. The analysis shows that for all data of temperature considered, the null hypothesis of «no sudden change» is rejected at 5% probability level. The point where the maximum jump occurred is defined as change point. Then, this point corresponds to May for the maximum, February for minimum, as shown in CUSUM charts, where sudden change in direction can be seen around these indicated Months. These results also show that, on a monthly scale, there are two opposite trends: a warm-up period followed by a refreshment period. For maxima, the warm up between January and May followed by refreshment between May and December. For minima, there is refreshment between January and February, then warming between February and December. We have a break down for the maximum temperature and upwards for the minimum one.

Table 2.Result of sudden change detection

	R Value	Null Hypothesis	Q Value	Change points	Algebraic value of Q	Direction of change
Tmax	5.4	rejected	2.9	May	+2.9	downwad
Tmin	4.7	rejected	2.7	February	-2.7	upwards

Null hypothesis: no sudden change

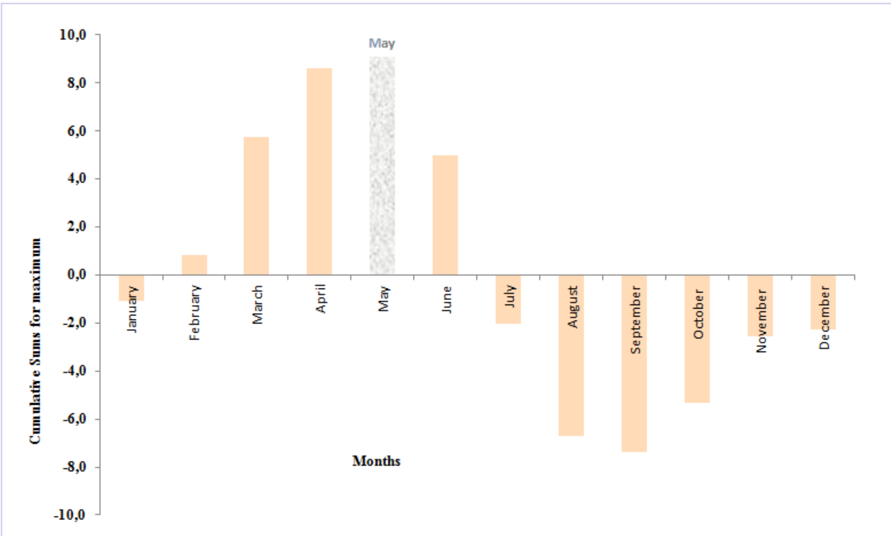

Fig.5a. Monthly maximum temperature CUSUM chart

Fig.5b. Monthly minimum temperature CUSUM chart

3.3. Trend analysis

✓ **at yearly scale**

The results of trend detection test of Mann Kendall are indicated in Table 3. Mann-Kendall trend test rejects the null hypothesis of no trend for all temperature time series at 5% probability level. The statistic value Z of Mann Kendall is negative and positive, implying a decreasing and increasing trend respectively for maxima and minima. According p-values, these trends are significant for the maximum and minimum at yearly scale.

Table 3. Mann Kendall trend tests results

	Z_{MK}	P-value	Null hypothesis	Trend Direction	Trend Magnitude
Tmin	+5.194	$2.052.10^{-7}$	rejected	increase	significant
Tmax	- 4.50	$6.781.10^{-6}$	rejected	increase	significant

Null hypothesis: absence of trend

✓ **At monthly scale**

We present in Table 4 the results of Mann Kendall's trend tests at monthly scale. The analysis shows that the null hypothesis of an absence of trend is rejected at the level of significance of 5% for both maximum and minimum temperature. In addition, Mann-Kendall Z statistic is negative, for maximum implying a decreasing trend and positive for minimum implying an increasing trend. Moreover, the use of p-values (pv < α) watches, this trend is significant for the maximum and no significant for minimum at monthly scale.

Table 4. Mann Kendall trend tests results

	Z_{MK}	P-value	Null hypothesis	Trend Direction	Trend Magnitude
Tmin	+1.978	0.584	rejected	increase	Nosignificant
Tmax	-2.011	0.043	rejected	decrease	significant

Null hypothesis: absence of trend

4. CONCLUSION

In summary, this study analyzed the variations of climate change in region of Kolda, through the change processes of temperature from 1960 to 2009, as well as their frequency and magnitude. So, annually and monthly data of maximum and minimum temperature were explored and examined. The anomaly index is used to analyze temperature variability; the cumulative sums are used to identify sudden change, its position and direction, Mann-Kendall test is used to examine the significance of changes trends in these temperature record series. On the whole, the results obtained are convincing and promising. They allow us to make plosive assumptions about the climatic hazards of this period. Considering the anomaly index, the results showed that the thermic regime is modifying in Kolda. On an annual as well as a monthly scale, the results reveal four categories of periods: very hot, hot, very cold and cold for both the maximums and the minimums. The year 2000 is the hottest and 1979 is the coldest year for maximum temperatures. For minimum temperatures, the year 2005 is the hottest and 1975 the coldest year. On a monthly scale, the month of April is the hottest and August the coldest month for maximum temperature. For minimum temperature, the month of June is the hottest and January the coldest month. The analysis of the results shows that the minimum temperature has increased significantly more than the maximum temperature. Regarding the CUSUM, results showed a break down is for the maxima and upward for the minimum on the annual scale as monthly at 5% probability level. The year of these breaks corresponds to 2001 and 1975 respectively for maxima and minima. On a monthly scale, the months of May and February are identified as break months respectively for the maximum and minimum. It emerges from this analysis that the temperature regime is changing in Kolda area and warming is more pronounced for minima than for maxima. Mann-Kendall trend test rejects the null hypothesis of no trend for all temperature time series at 5% probability level at the annual and monthly scales. There are a decreasing trend for maxima and increasing for minima for both scales. These trends are statistically significant for the maximum and

minimum at yearly scale. However, at the monthly scale, the trend is significant for the maximum and no significant for minimum. These results provide interesting insights for climate scientists. It should be noted that in this study, the temporal characteristics of temperature evolution are studied in order to provide a framework for sustainable resource management in the Kolda region. The analysis shows the risk of penalizing agricultural development projects and disrupting the efficiency of irrigation programs due to the dramatic drop in water tables. In this sense, the fight against global warming is more than a necessity. It should be noted however that our wish was to have a very long and recent chronicle to make our observations more solid. In the near future, we plan to do a simulation with climate models to highlight the spatial structure of temperature. This, in our view, will help build high-performance decision support tools for emergency programs. In addition, the international community, in general and African in particular, must define concrete actions to fight against global warming. It is obvious that global warming is a global phenomenon; it is in cities, which emit greenhouse gases, that solutions are found.

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