TREND IN TEMPERATURE AVERAGE AS A PARAMETER TO QUANTIFY IN CLIMATOLOGY

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Résumé
Les mesures des variations de la température de l’air nous donnent des indications sur les activités quotidiennes humaines. Cette étude montre que les températures moyennes sur plusieurs années sont liées aux modifications climatiques ce qui permet d'introduire les tendances dans les températures moyennes comme paramètre pour les évaluations climatiques. Ce paramètre est d’une grande importance pour la compréhension des origines des changements climatiques afin de réduire leurs impacts. Ce travail s’est concentré sur la détection des tendances dans les données de température de huit stations en Algérie sur la période 1973-2015 en utilisant le test statistique de Mann-Kendall appliqué à un niveau de signification de 5% et l’estimateur de Sen pour connaître la pente d’une éventuelle tendance. Dans la plupart des huit stations l’étude a mis en évidence une hausse dans la température moyenne que ce soit la température moyenne mensuelle; la température moyenne saisonnière ou la température moyenne annuelle.

Abstract
Measurements of air temperature variations give indications for human daily activities. This study shows that seasonal and annual temperature averages along many years are related to climatic modifications. It allows to introduce trends in temperature averages as a parameter for climatic evaluations. This parameter is of importance for the understanding in climatology of origins, prevision, and evolution in order to reduce impact effects. This work has focused on detecting trends of temperature data from eight stations in Algeria from 1973 to 2015 using statistical tests such as Mann-Kendall test applied at a level of 5% of significance (for trend) and Sen’s estimator (for slope of trend). In most of the eight stations the study has brought to light an increase in the temperature average whether monthly average, seasonal average or annual average.

Keywords: climate, parameter, statistical data, trend test, Mann-Kendall, Sen’s estimator.

I. INTRODUCTION

Studies of climate variability are of particular interest in scientific research, water resources, for the economy and for the people themselves.

Most parts of the world has seen a sharp rise in temperatures which we live today its consequences (floods, ice melt, fires, droughts, desertification etc.). These phenomena have caused massive population displacement, economic disruption, and in some cases, famine and even loss of life. It is therefore necessary to explain temperature trend and seek subsequently causes to take precautions to minimize the dangers that can result in order to be in shelter (Anwer., 2015 ; Cécile., 2007-2008 ; Ceppi et al. 2012 ; Domroes and El-Tantawi., 2005 ; Fan et al. 2011; Fossou et al. 2015; GIEC., 2007; Xu et al. 2005).

In order to reach our goal of this work and quantify the evolution of temperature series data the use of mathematical statistic was an indispensable tool. Determination of trend in the temperature series is performed in the mean of Mann-Kendall test and the slope of a possible trend is determined by the Sen’s slope estimator.

II. DATA AND STUDY AREAS

II.1. Area

In Algeria the northern region is characterized by a Mediterranean climate, with hot, dry and mild summers, rainy winters, with annual rainfall between 400 mm and 1000 mm. Summer and winter average temperatures are 25°C and 11°C respectively. Annual precipitation in the highlands and the Saharan Atlas do not exceed 200 mm to 400 mm. The Sahara is a very windy and arid region, where temperature variations are often considerable; these variations can be explained by the total absence of humidity. Across the Algerian desert the height of the annual rains is less than 130 mm.
II.2. Data

Data used are the averages of monthly, seasonal and annual temperatures; they have summers provided by the website (http://meteo-climat-bzh.dyndns.org/mete19-1154-1965-2016.php), table 1.

<table>
<thead>
<tr>
<th>Station</th>
<th>Biskra</th>
<th>Annaba</th>
<th>Alger</th>
<th>Ghardaïa</th>
<th>El Goléa</th>
<th>Tamanrasset</th>
<th>In-Amenas</th>
<th>In-Salah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>05°43′12″E</td>
<td>07°48′36″E</td>
<td>03°15′E</td>
<td>03°47′24″E</td>
<td>02°52′E</td>
<td>05°26′E</td>
<td>09°38′E</td>
<td>02°27′36″E</td>
</tr>
<tr>
<td>Latitude</td>
<td>34°51′N</td>
<td>36°49′12″N</td>
<td>36°43′N</td>
<td>32°22′48″N</td>
<td>30°34′N</td>
<td>22°48′N</td>
<td>28°03′N</td>
<td>27°13′48″N</td>
</tr>
<tr>
<td>Elevation</td>
<td>125m</td>
<td>5m</td>
<td>24m</td>
<td>461m</td>
<td>397m</td>
<td>1362m</td>
<td>561m</td>
<td>269m</td>
</tr>
</tbody>
</table>

III. METHODS

III.1. Mann-Kendall test

Mann-Kendall test is a non parametric test for trend detection. The null hypothesis of the test is $H_0$ (no trend), against the alternative hypothesis $H_a$ (presence of trend) (Esterby., 1993; Goula et al. 2012; Jose and Claudia., 2008 ; Longobardi and Villani., 2010; Mateescu., 2011; Nasri and Modarres., 2009; Qin et al. 2010; Scherrer et al. 2016). Statistic ($Z$) of the test is calculated as follows.

$$ S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) $$

$$ Z = \begin{cases} 
\frac{(S-1)}{\sqrt{\text{var}(S)}} & \text{if } S > 0 \\
0 & \text{if } S = 0 \\
\frac{(S+1)}{\sqrt{\text{var}(S)}} & \text{if } S < 0 
\end{cases} $$

where

$$ \text{var}(S) = N(N-1)(2N+5)/18. $$

For equal values in the series, var(S) was substituted in the above equation by

$$ \text{var}(S) = \frac{(N(N-1)(2N+5)-\sum_{p=1}^{9} t_p(t_p-1)(2t_p+5))}{10} $$

where ($t_p$) denotes the number of equality in the series involving ($p$) values and ($q$) is the number of equalities groups. The null hypothesis is rejected at significance level ($\alpha$) if $|Z| > Z_{(1-\alpha/2)}$ where $Z_{(1-\alpha/2)}$ is $(1-\frac{\alpha}{2})$ quantile of the standard normal distribution.

III.2. Sen estimator of the slope

If a linear trend is present in the time series its slope ($a$) (change per unit time) can be estimated using an non parametric procedure developed by Sen (1968) (Drápeła., Drápelová., 2011; Fossou et al., 2014; Gajbijhye et al., 2015; Ghasemi., 2015; Miro et al., 2006; Partal and Kahya., 2006); this means that the trend may be expressed by a function $f(t)$ such as

$$ f(t) = at + b. $$

In order to obtain the slope ($a$), the slopes of all data pairs are calculated; If there are ($N$) values ($x_j$) in serie we get $n = N(N-1)/2$ slope estimates ($a_j$). Sen estimator of the slope is the median of these values ($a_j$). The ($n$) values ($a_j$) are ranked from smallest to largest and Sen estimator of the slope is.

$$ a = \begin{cases} 
\frac{1}{2} a_{n+1} & \text{if } (n) \text{ is odd} \\
\frac{1}{2} (a_{n} + a_{n+1}) & \text{if } (n) \text{ is even} 
\end{cases} $$

IV. RESULT AND DISCUSSION

Statistical values of the Mann-Kendall test applied at 95% significance level for the eight stations are given in table 2; It showed that an upward trends have existed since 1973 in the monthly average temperatures for all stations except in December and February.
For El-Goléa, Tamanrasset and In-Amenas the upward trend was for 75% of months and the magnitudes of the increase trend varies from 0.02°C/year to 0.09°C/year and the largest slopes are for El-Goléa and In-Amenas; for Biskra, Ghardaïa and In-Salah the increase trend was for 67% of months where the slopes of the upward trends were from 0.04°C/year to 0.09°C/year and the largest slopes are for Ghardaïa and In-Salah; the upward trend detected in monthly average temperatures for the two coastals stations of Annaba and Algiers was in 58% of months and the magnitudes of trend where from 0.03°C/year to 0.07°C/year and the highest are for Algiers.

In seasonal average temperatures it was found that El-Goléa, Tamanrasset and In-Amenas were touched by an increase trend in all seasons with slopes that varied from 0.02°C/year to 0.07°C/year; for the rest of stations the trend was in 75% of seasons and slopes were from 0.03°C/year to 0.06°C/year; the largest slopes were for El-Goléa and Ghardaïa. whereas for average annual temperatures all stations were affected by an upward trends whose slopes were 0.05°C/year for El-Goléa, Ghardaïa, and In-Amenas; 0.04°C/year for Algiers and 0.03°C/year for the rest of stations; generally the upward trends are in almost of 1°C/year to 4°C/year on the study period that spans 43 years. This remarkable temperature increase is related to greenhouse gases; these anthropogenic emissions are mainly due to carbon dioxide (CO₂) coming in first from the consumption of fossil fuels; the biggest of the gas emission sources are traffic (affects most large cities like Algiers, Annaba, Biskra and Guardaia), households, industry (the steel complex of El Hadjjar and asmidal factory that manufactures phosphate and nitrogen fertilizers, oil and natural gas fields in southern Algeria and the in Algerian-Libyan border), services, agriculture, forestry and cattle breeding are an important source of methane production, deforestation caused by land use, energy transformation (Refinery crude, power plants) (Ministère de l’Aménagement du Territoire et de l’Environnement., 2001; Ministère de l’Energie et des Mines.,2007).

For January it’s only in 25% of stations where a trend were observed with 0.04°C/year in El-Goléa and In-Amenas. Regarding seasonal average temperatures upward trends were manifested in 100% of stations for Summer and Autumn, in 87.5% of stations for Spring and in 37.5% of stations for winter. The largest slopes were 0.06°C/year in Summer for Ghardaïa and El-Goléa, 0.07°C/year in Autumn for El-Goléa and In-Amenas and 0.06°C/year in Spring for Ghardaïa and El-Goléa.

For annual average temperature all stations studied were affected with an upward trends. Slopes for these stations were 0.05°C/year in Ghardaïa, El-Goléa and In-Amenas, 0.04°C/year in Algiers and 0.03°C/year in Biskra, Annaba, Tamanrasset and In-Salah.
Figure 1: Largest slopes in the average temperature of March and April
Figure 2: Largest slopes in the average temperature of May, July and August
Figure 3: Largest slopes in the average temperature of September, October and November
Table 2: Trends in average temperature with the values of Mann-Kendall test and Sen’s slope (°C/year).

<table>
<thead>
<tr>
<th>Month</th>
<th>Biskra</th>
<th>Annaba</th>
<th>Alger</th>
<th>Ghardaïa</th>
<th>El-Goléa</th>
<th>Tamanrasset</th>
<th>In-Amenas</th>
<th>In-Salah</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.52 ; 0.04</td>
<td>3.17 ; 0.04</td>
<td>2.60 ; 0.05</td>
<td>2.31 ; 0.05</td>
<td>2.39 ; 0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3.85 ; 0.07</td>
<td>3.63 ; 0.04</td>
<td>3.66 ; 0.06</td>
<td>3.50 ; 0.07</td>
<td>3.94 ; 0.04</td>
<td>2.00 ; 0.03</td>
<td>2.31 ; 0.05</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.62 ; 0.06</td>
<td>2.36 ; 0.03</td>
<td>2.61 ; 0.06</td>
<td>2.35 ; 0.07</td>
<td>3.60 ; 0.05</td>
<td>2.72 ; 0.02</td>
<td>3.92 ; 0.05</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.97 ; 0.04</td>
<td>2.58 ; 0.03</td>
<td>2.80 ; 0.04</td>
<td>3.50 ; 0.05</td>
<td>3.31 ; 0.05</td>
<td>3.65 ; 0.08</td>
<td>2.39 ; 0.05</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2.80 ; 0.04</td>
<td>2.43 ; 0.03</td>
<td>3.33 ; 0.05</td>
<td>4.51 ; 0.09</td>
<td>4.00 ; 0.07</td>
<td>3.82 ; 0.06</td>
<td>3.86 ; 0.05</td>
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<td>8</td>
<td>3.44 ; 0.05</td>
<td>2.73 ; 0.04</td>
<td>3.27 ; 0.05</td>
<td>4.56 ; 0.08</td>
<td>4.03 ; 0.08</td>
<td>3.75 ; 0.04</td>
<td>4.34 ; 0.06</td>
<td>3.73 ; 0.04</td>
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<tr>
<td>9</td>
<td>1.97 ; 0.04</td>
<td>2.58 ; 0.03</td>
<td>3.80 ; 0.05</td>
<td>5.02 ; 0.06</td>
<td>5.05 ; 0.05</td>
<td>4.25 ; 0.07</td>
<td>3.92 ; 0.07</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2.43 ; 0.05</td>
<td>3.22 ; 0.06</td>
<td>3.16 ; 0.07</td>
<td>3.45 ; 0.07</td>
<td>3.60 ; 0.09</td>
<td>3.70 ; 0.04</td>
<td>3.31 ; 0.06</td>
<td>3.52 ; 0.07</td>
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<tr>
<td>11</td>
<td>2.54 ; 0.04</td>
<td>2.37 ; 0.04</td>
<td>3.14 ; 0.06</td>
<td>2.96 ; 0.06</td>
<td>3.61 ; 0.05</td>
<td>3.65 ; 0.08</td>
<td>2.39 ; 0.05</td>
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<tr>
<td>Annual</td>
<td>4.60 ; 0.03</td>
<td>4.25 ; 0.03</td>
<td>4.87 ; 0.04</td>
<td>5.61 ; 0.05</td>
<td>5.39 ; 0.05</td>
<td>5.47 ; 0.03</td>
<td>6.41 ; 0.05</td>
<td>4.69 ; 0.03</td>
</tr>
<tr>
<td>Spring</td>
<td>3.94 ; 0.05</td>
<td>4.14 ; 0.04</td>
<td>5.24 ; 0.05</td>
<td>4.21 ; 0.06</td>
<td>3.78 ; 0.06</td>
<td>3.43 ; 0.04</td>
<td>3.92 ; 0.04</td>
<td>3.03 ; 0.04</td>
</tr>
<tr>
<td>Summer</td>
<td>3.41 ; 0.05</td>
<td>3.22 ; 0.03</td>
<td>3.95 ; 0.05</td>
<td>4.75 ; 0.06</td>
<td>4.86 ; 0.06</td>
<td>4.81 ; 0.03</td>
<td>4.39 ; 0.05</td>
<td>3.59 ; 0.03</td>
</tr>
<tr>
<td>Autumn</td>
<td>3.29 ; 0.04</td>
<td>3.66 ; 0.04</td>
<td>3.04 ; 0.04</td>
<td>4.88 ; 0.06</td>
<td>5.18 ; 0.07</td>
<td>5.96 ; 0.05</td>
<td>5.96 ; 0.07</td>
<td>4.87 ; 0.05</td>
</tr>
<tr>
<td>Winter</td>
<td>2.18 ; 0.03</td>
<td>1.99 ; 0.02</td>
<td>2.62 ; 0.03</td>
<td>2.85 ; 0.05</td>
<td>2.62 ; 0.06</td>
<td>2.32 ; 0.04</td>
<td>2.56 ; 0.06</td>
<td>2.06 ; 0.04</td>
</tr>
</tbody>
</table>

Figure 1, Figure 2 and Figure 3 illustrate the largest slopes highlighted for the average monthly temperatures and table 2 summarizes the results of the application of statistical tests.

V. CONCLUSION

Measurements of the mean values of air temperatures, whether monthly, seasonal or annual for eight stations in Algeria have shown upward trends in the period 1973-2015. This phenomenon could be a result of human activities which are related to industry and agriculture developments. A temperature average is introduced as a parameter for quantifying climatic evaluations. This parameter is of importance for the understanding in climatology of origins, prevision, and evolution in order to reduce impact effects.

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