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Climate change during the last century in Sétif province, Algeria

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Abstract

According to several predictive climate models, Algeria will be exposed to climate change threats over the next decades. The expected annual rainfall will decrease while annual temperatures will have upward trends, which could affect environment and food security. Even though, this finding is actually supported in the literature, it should be demonstrated and checked locally. This paper aims at describing the trend of climate change in Sétif region within and between two periods, 1920-1962 and 1981-2015. Statistical treatment was based on the homogeneity and breaks detection tests for monthly, seasonal and annual time series of rainfall, mean temperature (T_{mean}), maximal temperature (T_{max}) and minimal temperature (T_{min}). The comparison between the control period 1920-1962 and the recent period 1981-2015 reveal a drop of 55 mm in the annual rainfall. Meanwhile, the annual averages of temperatures show upward trends, where the annual T_{mean} increases by 0.48°C, also the annual T_{max} raises by 0.49°C and the annual T_{min} records the highest raise of 1.38°C. Furthermore, it should be noted that, the increase of temperature is more exacerbated within 1981-2015 period compared to 1920-1962 period, especially for the annual T_{min}, which suggests a warming trend and a shifting to arid bioclimatic stages.

Key words: Climate change; Rainfall; Temperature; Semi-arid; Sétif; Algeria.

INTRODUCTION

Nowadays, climate change is the most prominent developmental issues and becomes a subject of intense debate. As a result, large amounts of capital are being made available to strengthen resilience and adaptive capacity of people. Global climate models predicted for the Mediterranean region temperature rises of 2 °C to 3°C by 2050 and from 3°C to 5°C by 2100 (IPCC, 2007). Seasonally, the largest warming is likely to be in the Mediterranean area in summer (Christensen et al., 2007). Globally, the spatial and temporal distributions of precipitations is expected to change (Dorsouma and Requier-Desjardins, 2008), the rain events will be less frequent but more intense. In winter the strongest drying is projected around the eastern Mediterranean and North Africa (Lelieveld et al., 2012). Algeria is among the most vulnerable countries to climate change (Boudjadja et al., 2003). In last decades, Algeria suffered from a severe and persistent water shortage, induced by rainfall deficit estimated to 30% (FAO, 2008). Regional models with the IPCC scenarios applied to Algeria forecast an increase in average temperature of 0.8°C to 1.1°C and 10% reduction of precipitation (Sahnoune et al., 2013) and the drought episodes will be more common and longer. Semi-arid climate is very restrictive and unpredictable from year to year. Annually, areas receiving more than 400 mm of rainfall are considered semi-arid, sub-humid or humid (Emberger, 1930). However, areas receiving less than 100 mm of precipitation are classified as desert or Saharan (Emberger, 1930; Le Houérou, 1959). Sétif region is characterized by a typical semi-arid climate, where the majority of staple crops are rainfed and the population livelihood is based on. Therefore, climate studies should be of a particular interest in this region. Therefore, the main aim of the present study is to assess the temporal trends of rainfall and temperatures of Sétif region, based on a comparison of historical datasets of temperatures and rainfall at different time scales (monthly, seasonally and annually).

MATERIAL AND METHODS

1. Regional context

The province of Sétif covers 6,549 km²; it is situated in the Eastern part of Algeria, between 35.0°-36.5° of latitude north and between 5° - 6° of longitude east. The region is crossed by many mountains; the high plains occupy more than 50% with an altitude comprised between 900m and 1200m. The mountains, which are mainly oriented west east, reduce the Mediterranean influences. Therefore, the region has a continental semi-arid climate with cold and wet winter and dry and hot summer. The region is traditionally subdivided in three agro-ecological zones. The North has black and deep vertic soils, with a clay to clay-loamy texture (Lahmar, 1993) and an annual rainfall of 600 mm. In the central and the southern parts of the region, annual rainfall does not exceed 300 mm (Baldy, 1974) and soils are brown calcareous. In the South, stony soils are common and some saline soils are found in the depressions.

Annual crops represent 92.1% of the cultivated area, with 88% under rainfed conditions (Abbas et al., 2005). The main crops are durum wheat (104 258 ha), barley (47 297 ha), bread wheat (22 919 ha), oat (6 286 ha) (MARD, 2012). Locally, the insufficiency and irregularity of rainfall, mainly falls between October and April, coincides with the vegetative cycle of crops and hence governs crop potentials.

2. Sources of collected climatic data

Worldwide, the lack of climate data and the weakness of the observation network are the main obstacles that face climatic studies (Plummer et al., 2003). We used in the present study monthly, seasonal and annual series that are more relevant than daily records, which considerably vary in space. The data collected for the purpose of this study cover two main periods, 1920-1962 and 1981-2015. The lack of climate data between 1963 and 1980 was due to the cessation of the climatic monitoring after the independence of Algeria. The information concerning the period 1920-1962 was extracted from the archives of the Central Library of the National Oceanic and Atmospheric Administration (NOAA) USA (http://docs.lib.noaa.gov/rescue/data_rescue_algeria.html) while the climatic data of 1981-2015 period were provided by the National Office of Meteorology of Algeria.

Hubbard (1994) found that one station every 60 km is adequate to capture 90% of the spatial variability in daily temperature while IPCC (2001) considered that one station per 2.5° latitude by 3.5° longitude grid is sufficient, this density being also consistent with General Climate Models (GCM) resolutions and gridded climatic fields. The observation site used during the period 1920-1962 was a military airport located at 6 km far from Sétif city (36 ° 10 '35 "N - 5 ° 19' 51" E, 1030 m a.s.l.). For the period 1981-2015, the observation site was situated at the southern border of Sétif city (36° 10'32" N - 5° 23' 50’’ E, 1033 m a.s.l.).

3. Digitalization of the collected data and management of missing data

The data of the first period 1920-1962 were transferred into Excel files. This period however presented some gaps related to the absence of data or the difficulty to read the information on documents often deteriorated. To fill this gap and correct aberrant values, we used the simple linear regression method (Glasson-Cicognani and Berchtold, 2010). In the years: 1941, 1942 and 1945, however, datasets had more than 5% of missing data, preventing an accurate application of this method (Garcia-Acosta and Clavel-Chaplon, 1999). We consequently used the simple linear regression model basing on the full series of Constantine city, which presented a correlation coefficient (r) with those of Sétif superior to 0.95 for the period 1938-1962.

4. Analysis of the climatic variability

By suppressing transient interannual fluctuations, graphic representations of the moving average (slippery) carried out on rainfall, T_{mean}, T_{max} and T_{min} with a 5 year step, allowed identify long-term trends. The study of homogeneity was performed on the monthly, seasonal and annual series, using the test of autocorrelogram (WMO 1966; Chatfield 1989), the test of correlation on the rank (Kendall and Stuart 1943; WMO, 1966) and the test of Buishand. The methods of detection of breaks included the Standard Normal Homogeneity Test (SNHT) (Alexandersson, 1986), Pettitt test (Pettitt 1979; Ceresta 1986) and Hubert test (Hubert et al., 1989). A break was considered significant if validated by at least two tests at 95% confidence level.

The software SPSS V18 (Statistical Package for Social Sciences) was used to analyze the descriptive statistics and the comparison of means (Student test). We used the software KHRONOSTAT to analyze the random character of data sets through the test of correlation on the rank using the test of autocorrelogram. In case the series was declared nonrandom, the software ran the test of Pettitt, the test of Buishand, and the segmentation procedure of Hubert to characterize the breaks in the chronologic set. However, SNHT test was run by EXCELSTAT, this test is more robust in detecting the breaks at the beginning and at the end of the series (Kang and Yusof, 2012).

To characterize the local climate and its variations during the two periods we used two climatic indexes, the pluviothermic quotient from Emberger (1930) and the ombrothermic diagram of Bagnouls and Gaussen. The pluviothermic quotient (Q_2), frequently used in North Africa to classify and characterize climates (Benabadji and Bouazza, 2000) and used also to separate the bio-climatic stages. It was calculated as: $Q_2 = \frac{2000P}{M^2-m^2}$, where (P) was the annual rainfall (mm), (M) the monthly T_{max} of the hottest month and (m) the monthly T_{min} of the coolest month, both measured in Kelvin degrees (°K). On the ombrothermic diagram which presents the evolution, over a year, of T_{mean} and total rainfall, the area between the intersections of the rainfall and T_{mean} curves reflects both duration and intensity of the dry season, dry month occurred when rainfall (mm) is less than or equal to the double of T_{mean} (°C). (Bagnouls and Gaussen, 1953).

RESULTS

1. Climate evolution

1.1. Control period 1920-1962

During the period 1920-1962, annual rainfall was stationary with an annual average value of 456.2 mm without any break, oscillating between 299 mm (in 1926) and 623 mm (in 1944). The highest variability of rainfall was observed during summer. A random pattern was noted in all months excepted for April series, where the test of Pettitt indicated a significant break in 1935 with an increase of 23.13 mm. However, the seasonal and annual rainfall series were stationary (Table A1).

Monthly mean temperatures series showed a random pattern for the majority of months with a highest variability in February and January. A non-random pattern was noted for April series, with a significant downward break of 2.17°C, detected by Pettit, SNHT and Hubert tests in 1951. Annual mean temperature series showed a non-random pattern with a downward break of 0.88°C in 1951, detected by Pettit and Hubert tests (Table A2). Annual mean temperature was 14.44°C before the break and 13.65°C after the break (Fig. 1a). Similarly, monthly T_{max} showed the highest variation in February and January. A random pattern was noted in most months, except April and August series. A downward rupture of 2.44°C was noted in 1951 by Pettit, Hubert and SNHT tests for April. An upward break of 1.09°C was recorded in 1940 for August. The analysis showed stationary patterns for the majority of the annual and the seasonal T_{max} series, except for the summer series, which exhibited an upward break of 1.04°C in 1940 (Table A3). The monthly T_{min} series showed a very high variability in January and February. Significant breaks were noted in 1951 for April and October T_{min} series, with respective downward breaks of 1.90°C and 2.17°C. In 1950, downward breaks of 1.86°C, 1.10°C and 1.70°C were noted in July, August and September, respectively. The annual and the seasonal T_{min} showed several breaks. Seasonal series of spring and autumn showed downward breaks of 1.40°C and 1.49°C, respectively in 1951 and 1950 (Table A4). The annual series registered in 1951 a downward break of 1.42°C, with a mean of 8.80°C during the 1920-1951 period and 7.38°C for the post-break period (Fig. 1b).

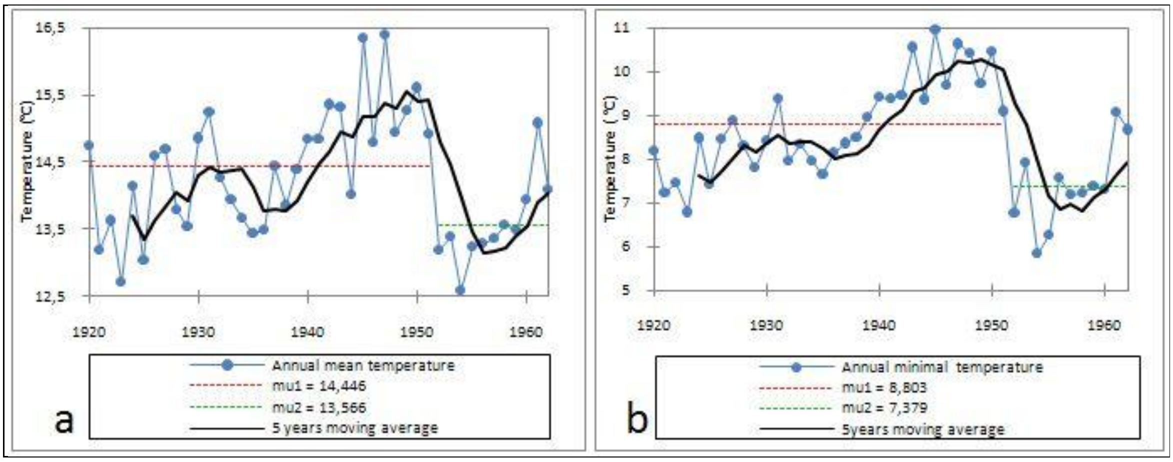

Figure 1. Evolution of the climate patterns: (a) Annual T_{mean}, (b) Annual T_{min} and relative breaks during 1920-1962 time series

1.2. Recent period 1981-2015

During the period 1981-2015, annual rainfall was stationary with an average of 401.37 mm, oscillating between 200 mm (in 1983) and 585 mm (in 2003). As the first period, the highest variability was noted during summer. The Monthly and seasonal series were also stationary (Table A5).The annual T_{mean} was 14.70°C, oscillating between 13.27°C (in 1991) and 15.63°C (in 2001). All monthly series showed a stationary pattern except April series, with an upward break of 1.46°C in 1996, also spring T_{mean} series showed a significant break of 1.23°C at the same date (Table A6). Whereas, the annual mean temperature recorded a non-random pattern with an upward break of 0.72°C in 1996, with a mean of 14.30°C before the break and 15.02°C afterwards (Fig. 2a). Monthly T_{max} series showed a homogeneous pattern for all months. The annual average of T_{max} was 20.49°C; an upward rupture of 0.79°C was recorded in 1998 (Fig. 2b). The seasonal T_{max} series exhibited significant upwards breaks for spring and autumn in 1996 and 2011, respectively (Table A7).The monthly T_{min} series showed a very high variability in December and January. However, no significant breaks were recorded for them. The annual and the seasonal T_{min} series both showed upwards breaks in 1996. The annual T_{min} series exhibited an upward break of 0.81°C (Fig. 2c) while the seasonal temperature of spring and summer registered positive shifts of 1.13°C and 1.04°C, respectively (Table A8).

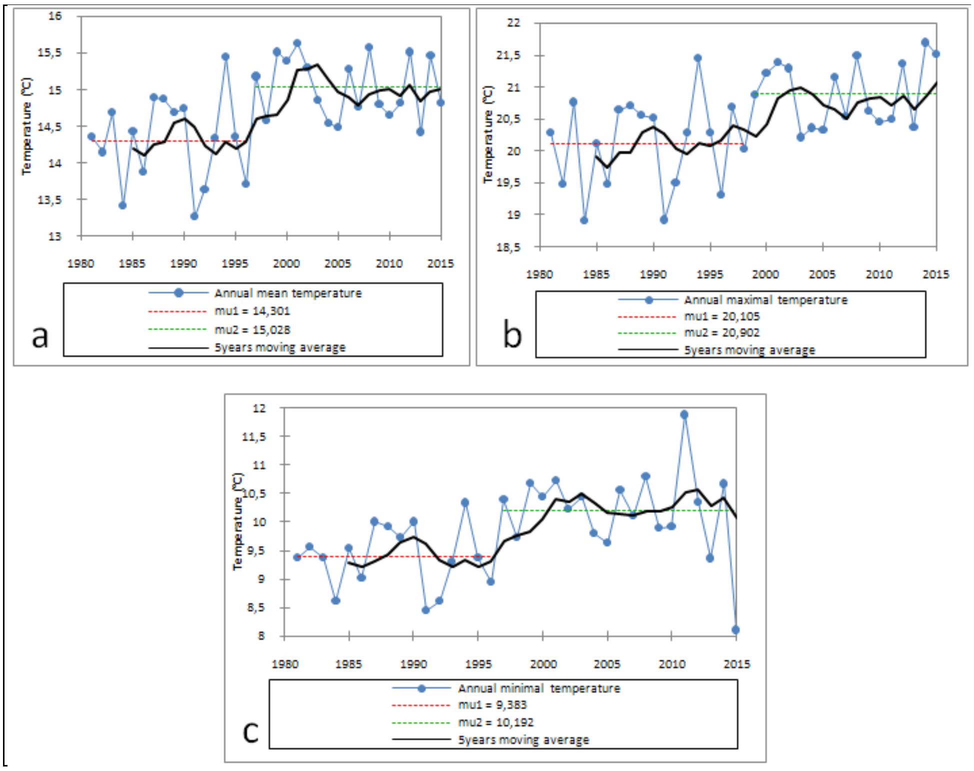

Figure 2. Evolution of the climate patterns: (a) Annual T_{mean}, (b) Annual T_{max}, (c) Annual T_{min} and relative breaks during 1981-2015 time series

Paired Student tests showed significant differences between the control period 1920-1962and the recent period 1981-2015. For the rainfall series, the average monthly rainfall decreased from 38.02mm to 33.45mm but the difference was not enough significant (P>0.05), However, T_{mean}, T_{max} and T_{min} series recorded significant increases of 0.48°C, 0.49°C and 1.38°C, respectively (Table 1).

Table 1. T test for paired observations of the rainfall and T_{mean}, T_{max} and T_{min} series

	Rainfall		**T_{mean}**		**T_{max}**		**T_{min}**	
	1920-1962	*1981-2015*	*1920-1962*	*1981-2015*	*1920-1962*	*1981-2015*	*1920-1962*	*1981-2015*
Mean±SEM	38.02±4.33	33.45±3.25	14.22±2.10	14.70±2.22	20.00±2.42	20.49±2.52	8.44±1.78	9.82±1.91
Difference	-4.57mm		0.48°C		0.49°C		1.38°C	
t-value	2.71		-2.68		-2.60		-8.33	
P value	0.02**		0.02**		0.02**		0.00***	

**: p<0.05 ; ***: p<0.01

The extent of the dry season was similar in both periods, starting from the end of May and continuing until mid-September. The control period 1920-1962 was however characterized by more intense dry season and wet season compared to the recent period 1981-2015 (Fig. 3). During the summer of the recent period, an earlier decrease of rainfall was noted.

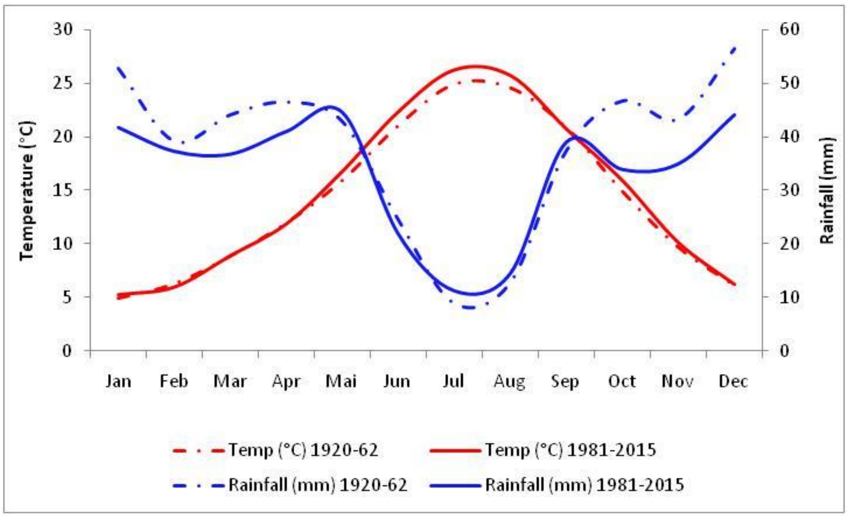

Figure 3. Ombrothermic diagrams for 1920-1962 and 1981-2015 periods

Globally, temperatures tend to increase between the two periods. The T_{max} of the warmest month rise 0.95°C, while the T_{min} of the coldest month recorded an increase of 0.73 °C. Despite the decrease of the pluviothermic quotient (Q_2) value from 49.60 to 43.22 between the two periods (Table 3), Sétif station remained positioned in the semi-arid bioclimatic stage with fresh winter (Fig. 1A).

Table 3. Evolution of the pluviothermic quotient between the 1920-1962 and 1981-2015

Periods	P (mm)	T_{min} of the coldest month (m)	T_{max} of the hottest month (M)	Q_2	Bioclimatic stage
1920-1962	456.18	0.89 (°C)	32.63 (°C)	**49.60**	Semi-arid with fresh winter
1981-2015	401.37	1.62 (°C)	33.58(°C)	**43.22**	Semi-arid with fresh winter

DISCUSSIONS

A clear modification of climatic characteristics was noted between the two studied periods, with a reduction of 55 mm of the annual rainfall. Gsell (1913) pointed that at the beginning of the 20th century, the North of Sétif had a very high rainfall, exceeding one meter close to the *Babor* chain of mountains. This information, together with our results suggests a constant decrease of rainfall in Sétif region during the last century. During the period 1920-1962, a downward trend was noted for temperatures with significant breaks in 1950 and 1951. Spring and particularly April series were the most affected by temperature breaks during this period, what is in good agreement with the global cooling trend reported since the 40's by Peterson et al., (2008). According to Salinger et al., (2005) the northern hemisphere has undergone two periods of temperature rise: one between 1910 and 1945, the other was from 1976 to1999. However, the period 1946-1975 was characterized by a cooling trend. Joos and Bruno (1998) considered that cooling trend between 1940 and1960, was due to the increase of the greenhouse gases. The direct and indirect effect of sulphate aerosols though had a rapidly increasing trend (Roeckner et al., 1999), which partly compensated the increase of greenhouse forcing during the 1940-1960 period (Bengtsson et al., 2003). Conversely, during 1981- 2015 period, temperatures significantly increased, compared to the 1920-1962 period, with a drastic shift observed in 1996. In the 20th century, warming was the largest during the last 1000 years. Globally the 1990's was the warmest decade and 1998 was the warmest year since 1860 (Salinger et al., 2005) before it was dethroned in 2016 where the global temperature reached

a peak in February 2016 around 1.5°C higher than at the start of the Industrial Revolution. In both periods, the temperature rise affected more particularly the April series. The changes of temperatures in April affected the spring seasonal pattern, which in turn affected the annual trend. The sensitivity of spring series to climate change has been previously reported by Wang et al., (2011) in some regions worldwide during the recent years. These changes are expected to affect vegetation growing in mid to high latitudes of the Northern hemisphere, known to be very sensitive to modification of temperature, particularly in spring (Menzel et al., 2006; Schwartz et al., 2006). Upward trends of temperature could attenuate the negative risks of frost on crops, which severely affect crop production, particularly when they coincide with flowering stage (Gu et al., 2008). As carbon release from organic matter decomposition is also enhanced by the rising temperature, net carbon exchange between terrestrial ecosystems and the atmosphere does not necessarily benefit from this warming trend (Piao, 2008). During 1981-2015 period, the dry season was longer, because of the drop of rainfall at the beginning of autumn. These changes during the first months of autumn are expected to affect negatively the soil water balance, which is an important element for managing the availability of water in soil that would be needed to mitigate the effects of climatic change and reduce the risks faced by the crop (Gate et al., 1996).
The climagram of Emberger showed that Sétif Station moved towards the arid bioclimatic stage, although remaining in the semi-arid stage. This change is likely to be due to the decline of rainfall and is expected to be more exacerbated in the southern part of the Sétif province, as reported by Fenni et al., (1991) who considered that climate change moved the southern regions of the Sétifian High Plains from the semi-arid to the arid bioclimatic stage.

CONCLUSIONS

The main goal of this study was the assessment of the temporal evolution of the rainfall an temperatures at different timescales, which can represent a valuable support of information for local population and decision makers as well. Climate change with its global apprehension could concern the planning processes for several sectors in the region such as environment, agriculture and human health, so planning is the back bone of adaptation and mitigating the effects of climate change. Results showed a significant shifting of the local semi-arid climate to a novel stage of climate more severe, dryer and warmer. The observed upwards in annual temperatures particularly during the period 1981-2015 were +0.72°C, +0.79°C and +0.81°C for T_{mean}, T_{max} and T_{min} respectively. This finding is very preoccupying and the warming is too exacerbated in the region. Indeed the scientific community worldwide has drawn in Paris Climate Agreement objective of keeping global warming well below 2°C during the first half of the 21st century compared to the pre-industrial temperature. In the study area, if the rate of warming will continue in this way, certainly the 2 degrees bar would be exceeded by far in 2050. So it’s time for action at the holistic scale to manage the global temperature rise.

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APPENDIX

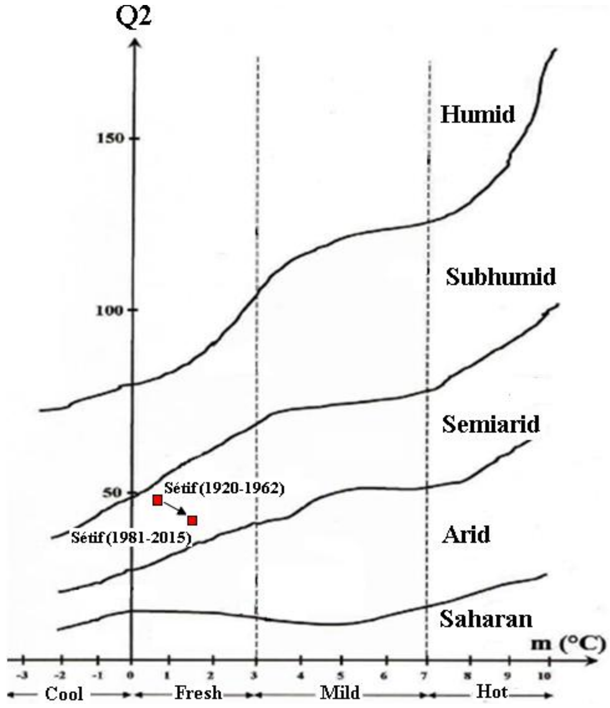

Figure A1. Emberger Climagram representing Sétif station during the periods 1920-1962 and 1981-2015

Table A1. Results of statistical tests conducted on monthly, seasonal and annual rainfall series during the period 1920-62

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	52.88	39.24	44.18	46.58	42.92	24.50	8.86	12.81	37.50	46.78	43.38	56.56	148.68	133.68	46.17	127.66	456.18
Coefficient of variation (cv)	66.57%	57.69%	59.12%	68.66%	65.45%	88.25%	145.09%	94.13%	85.24%	83.0%	53.64%	64.68%	33.62%	41.39%	62.09%	46.15%	19.97%
Tests of homogeneity																	
Autocorrelogram	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Rank correlation test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Buishand test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Break tests																	
Pettitt test	ns	ns	ns	sig	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Segmentation of Hubert	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SNHT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Conclusion	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A2.Results of statistical tests conducted on the monthly, seasonal and annual mean temperature series during the period 1920-62

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	5.00	6.34	8.93	12.01	15.98	21.08	24.94	24.59	20.90	14.95	9.74	6.18	5.84	12.31	23.54	15.20	14.22
Coefficient of variation (cv)	29.22%	32.73%	19.66%	14.43%	11.90%	8.97%	5.01%	4.87%	6.25%	11.53 %	16.44%	21.91%	19.83%	10.99%	5.07%	7.24%	6.37%
Tests of homogeneity																	
Autocorrelogram	ns	ns	ns	**	ns	**	**	**	**	**	ns	**	*	*	**	**	***
Rank correlation test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Buishand test	ns	ns	ns	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
Break tests																	
Pettitt test	ns	ns	ns	1951**	ns	ns	ns	ns	ns	1950*	ns	ns	ns	ns	1936*	ns	1951**
Segmentation of Hubert	ns	ns	ns	1951***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1951***
SNHT	ns	ns	ns	1951	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1951*
Conclusion	**ns**	**ns**	**ns**	**1951 (-2.17°C)**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1951 (-0.88°C)**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A3. Results of statistical tests conducted on the monthly, seasonal and annual maximum temperature series during the period 1920-62

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	9.11	11.31	14.46	17.9	22.53	27.99	32.63	31.94	27.24	20.08	14.29	10.47	10.29	18.32	30.86	20.54	20.00
Coefficient of variation (cv)	23.31%	23.76%	14.85%	11.29%	11.84%	7.86%	4.32%	4.40%	6.15%	12.58%	14.82%	17.69%	12.87%	9.14%	4.14%	6.78%	4.38%
Tests of homogeneity																	
Autocorrelogram	ns	ns	ns	*	*	*	**	**	***	ns	ns	**	**	**	***	**	**
Rank correlation test	ns	ns	ns	*	ns	ns	ns	**	ns	ns	ns	Ns	ns	ns	***	ns	ns
Buishand test	ns	ns	ns	*	ns	*	ns	*	ns	ns	norm	Ns	ns	ns	**	ns	ns
Break tests																	
Pettitt test	ns	ns	ns	1951**	ns	Ns	Ns	1940*	ns	ns	ns	Ns	ns	ns	1940**	ns	ns
Segmentation of Hubert	ns	ns	ns	1951 ***	ns	ns	ns	1940***	ns	ns	ns	ns	ns	ns	1940***	ns	ns
SNHT	ns	ns	ns	1951***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Conclusion	**ns**	**ns**	**ns**	**1951 (-2.44°C)**	**ns**	**ns**	**ns**	**1940 (+1.09°C)**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1940 (+1.04°C)**	**ns**	**ns**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A4. Results of statistical tests conducted on the monthly, seasonal and annual minimum temperature series during the period 1920-62

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	0.89	1.38	3.40	6.06	9.43	14.17	17.25	17.25	14.56	9.82	5.19	1.89	1.39	6.29	16.22	9.85	8.44
Coefficient of variation (cv)	215%	149%	54%	31%	18%	14%	10%	9%	12%	18%	31%	76%	107%	22%	9%	14%	14%
Tests of homogeneity																	
Autocorrelogram	***	ns	**	**	ns	**	***	**	**	***	ns	**	***	***	**	***	***
Rank correlation test	***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Buishand test	***	ns	ns	ns	ns	*	*	*	ns	*	ns	**	--	ns	*	**	**
Break tests																	
Pettitt test	1934***	ns	ns	ns	ns	ns	1950**	1950*	1950*	1951**	ns	ns	1937*	1951*	1951*	1950**	1951**
Segmentation of Hubert	ns	ns	ns	1951***	ns	1926***	1950***	1950***	1949*	1950***	ns	1951***	1938***	1951***	1950***	1950***	1951***
SNHT	ns	ns	ns	1951**	ns	1923*	1950**	ns	1950**	1951***	ns	ns	ns	1951**	1951*	1951***	1951***
Conclusion	**ns**	**ns**	**ns**	**1951 (-1.90°C)**	**ns**	**ns**	**1950 (-1.86°C)**	**1950 (-1.01°C)**	**1950 (-1.70°C)**	**1951 (-2.17°C)**	**ns**	**ns**	**ns**	**1951 (-1.40°C)**	**ns**	**1950 (-1.49°C)**	**1951 (-1.42°C)**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A5. Results of statistical tests conducted on monthly, seasonal and annual rainfall series during the period 1981-2015

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	41.76	37.31	36.79	41.02	44.56	21.89	11.33	14.59	39.06	33.94	34.99	44.12	120.87	122.37	47.823	107.99	401.37
Coefficient of variation (cv)	67.96%	71.78%	63.34%	57.95%	65.24%	83.88%	119.42%	74.58%	70.96%	70.20%	65.05%	69.08%	39.42%	40.46%	48.65%	33.71%	19.86%
Tests of homogeneity																	
Autocorrelogram	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	***	ns	***	ns	ns
Rank correlation test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Buishand test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Break tests																	
Pettitt test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Segmentation of Hubert	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SNHT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Conclusion	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	ns	ns	ns	ns	ns

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A6. Results of statistical tests conducted on the monthly, seasonal and annual mean temperature series during the period 1981-2015

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	5.27	5.99	8.92	11.89	16.80	22.37	26.28	25.75	20.75	15.95	10.14	6.24	5.83	12.54	24.80	15.61	14.70
Coefficient of variation (cv)	22.50%	31.92%	16.54%	12.68%	12.36%	7.72%	5.15%	5.16%	5.58%	10.99%	12.69%	20.93%	15.15%	9.25%	4.40%	5.44%	4.16%
Tests of homogeneity																	
Autocorrelogram	ns	ns	ns	ns	**	**	***	***	*	*	**	ns	**	**	***	***	***
Rank correlation test	ns	ns	ns	**	ns	ns	ns	**	ns	*	ns	ns	**	**	ns	**	***
Buishand test	ns	ns	*	**	ns	ns	*	ns	ns	*	ns	ns	*	**	*	**	***
Break tests																	
Pettitt test	ns	ns	ns	1997**	ns	ns	ns	ns	ns	ns	ns	ns	ns	1996**	ns	ns	1996***
Segmentation of Hubert	ns	ns	ns	1996***	ns	ns	ns	ns	ns	ns	ns	ns	2012***	1996***	1996***	2011***	1996***
SNHT	ns	ns	ns	1996**	ns	ns	ns	ns	ns	ns	ns	ns	ns	1996**	ns	ns	1996***
Conclusion	**ns**	**ns**	**ns**	**1996 (+1.46°C)**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1996 (+1.23°C)**	**ns**	**ns**	**1996 (+0.72°C)**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A7. Results of statistical tests conducted on the monthly, seasonal and annual maximal temperature series during the period 1981-2015

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	9.74	10.89	14.23	17.65	23.12	29.39	33.59	32.93	27.24	21.58	14.91	10.62	10.42	18.34	31.97	21.24	20.49
Coefficient of variation (cv)	15.50%	23.59%	12.52%	10.89%	10.91%	6.31%	4.14%	4.17%	4.90%	10.02%	11.04%	16.56%	11.03%	8.05%	3.41%	4.86%	3.49%
Tests of homogeneity																	
Autocorrelogram	*	ns	***	ns	***	**	***	***	**	ns	*	**	**	**	***	***	***
Rank correlation test	*	ns	***	*	ns	ns	*	**	ns	ns	ns	ns	ns	**	**	**	***
Buishand test	*	ns	***	*	ns	ns	**	ns	ns	ns	ns	ns	ns	**	**	**	***
Break tests																	
Pettitt test	ns	ns	1996**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1998**	ns	ns	1998**
Segmentation of Hubert	2006***	ns	2012***	ns	ns	ns	ns	ns	ns	ns	2007***	ns	ns	1996***	1998***	2011***	1998**
SNHT	2006*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1996**	ns	2011**	1998***
Conclusion	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1996 (+1.38°C)**	**ns**	**2011 (+1.64°C)**	**1998 (+0.79°C)**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*

Table A8. Results of statistical tests conducted on the monthly, seasonal and annual minimal temperature series during the period 1981-2015

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean (°C)	1.62	1.99	4.42	6.91	11.13	15.99	19.53	19.52	15.53	11.51	6.34	3.37	2.33	7.49	18.35	11.13	9.82
Coefficient of variation (cv)	75.96%	74.42%	29.41%	18.92%	16.45%	10.56%	7.04%	6.61%	7.15%	13.94%	20.54%	126.50%	69.06%	13.21%	6.25%	8.20%	7.77%
Tests of homogeneity																	
Autocorrelogram	ns	ns	*	***	ns	*	**	***	ns	*	**	*	ns	**	**	*	***
Rank correlation test	ns	ns	*	**	ns	ns	ns	*	ns	ns	ns	ns	ns	**	ns	**	***
Buishand test	ns	ns	*	**	ns	ns	*	ns	ns	*	ns	ns	ns	***	*	*	**
Break tests																	
Pettitt test	ns	ns	ns	1998**	ns	ns	ns	ns	ns	ns	ns	ns	ns	1996***	1996**	ns	1996***
Segmentation of Hubert	ns	ns	ns	1995***	ns	ns	ns	ns	ns	1998***	ns	ns	ns	1996***	1996***	ns	1996***
SNHT	ns	ns		1997**	ns	ns	ns	ns	ns	ns	ns	ns	ns	1996***	1996*	ns	1996**
Conclusion	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	ns	**1996 (+1.13°C)**	**1996 (+1.04°C)**	**ns**	**1996 (+0.81°C)**

*level of significance: *: (p<0.1), ** :(p<0.05), *** :(p<0.01), ns: not significant*