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Observed Changes in Minimum and Maximum Temperatures in Nile Delta, Egypt in the 20th Century

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Abstract. This study examines changes in annual mean minimum and maximum temperatures (AMMIT and AMMXT) variations in Nile Delta (Egypt) during the 20th century. The analyses focus on two time series records (1900-1947 and 1957-2010) at the Alexandria, Port Said and Cairo Meteorological Stations. The climate trend coefficient, Rxt, value compared with t-test table and represent that there is no significant linear climate trend in all annual time series for all stations under investigations. The occurrence of abrupt changes and trends were examined using cumulative sum charts (CUSUM) and bootstrapping and the Mann-Kendall rank test. Statistically significant abrupt changes and trends have been detected. Major change points in the AMMIT and AMMXTT occurred in different years with different significant levels during the two periods. The significant warming trend slope between; (1900-1947), AMMIT has increased by rate of (0.031, 0.021 and 0.027 °C/year) and during the period between; (1957-2010), AMMIT has increased by rate of (0.014, 0.021 and 0.034 °C/year) for Alexandria, Port Said and Cairo respectively. The significant warming trend slope between; (1900-1947), AMMXT has increased by rate of (0.011, 0.023 and 0.057 °C/year). The significant warming trend slope between; (1957-2010) for Cairo, AMMXT has increased by rate of 0.008 °C/year, while significant cooling slope trend for Alexandra and Port Said by rate of -0.004 and -0.007 °C/year respectively. Negative diurnal temperature range (DTR) trend in Alexandria (1901-1947) was mainly due to night temperature increasing faster than during the day. Positive DTR trends in Port Said and Cairo (1900-1947) caused by opposite minimum and maximum temperature situation than in Alexandria. Negative DTR results for the three stations during (1957-2010) mainly due to high urbanization development inside the three cities.

Keywords: Egypt, maximum & minimum temperature, trends, Nile Delta, DTR

Introduction

"Global warming" and "climate change" are major keywords in the present-day global change discussion. Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere commonly recognized to affect the climate. The concentration of carbon dioxide in the atmosphere has increased by more than 30 percent since 1750. These developments have the potential of raising global surface temperatures and in consequence they impact other parts of the climate system (Schaefer and Domroes, 2008). Human-induced climate change and changes in climatic variability continue to be major global change issues not only for the present generation but also for future generations. On the basis of the latest scientific assessment of the Earth's climate system, (Hasanean and Abdel Basset, 2006) have revealed that the average global surface temperature has increased by about 0.6 +/- 0.2 °C since the late nineteenth century. The Northern Hemisphere experienced cooling during the period from 1946 to 1975. They pointed out that the recent 1976–2000 warming was largely globally synchronous, but was more pronounced in the continents of the northern Hemisphere during winter and spring (Hasanean and Abdel Basset, 2006).

One aspect of climate change is change in variability of weather elements, such as temperature. Adaptation to climate change and efforts to mitigate the impacts of climate change need to emphasize not only changes in long-term mean weather attributes but also trends in the variability of climatic variables (Bryant *et al*., 2000). According to Giorgi (2002), the impact of climatic variability on human and natural systems is more important than that of mean changes in climate.

Many studies have been devoted to global, hemispherical, or regional long-term temperature variations. On a global scale, climatological studies indicate an increase of 0.3–0.6°C of the surface air temperature (0.5–0.7°C for the Northern Hemisphere) since 1865 (Jones *et al.,* 1986; Jones *et al.,* 1999 and Maftei and Barbulescu, 2008). Climate scientists have concluded that: (1) The earth's surface air temperature increased by about 0.6°C during the 20th century, and (2) the temperature augmentation was highest during the 1990s (IPCC, 2001).

World-wide interest in global warming and climate change has led to numerous trend detection studies. A study using average reconstruction of land surface air temperature (LST) by Smith and Reynold (2005), indicated warming through the twentieth century and indicates warming of about 0.6°C over the twentieth century with an uncertainty estimate for the warming ±0.3°C, also the study indicates that there was a gradual LST warming until about 1940, cooling (1940-1970) and a second warming trend began about 1970. The successive periods of global warming, cooling and warming in the 20th century show distinctive patterns of temperature change suggestive of roles for both climate forcing and dynamical variability (Hansen *et al*., 2001).

Various studies showed that the observed warming trend during past decades occurred mainly due to the increase in the minimum (night-time) temperatures rather than the maximum (day-time) temperatures. The increase in the minimum temperatures appeared mainly in USA, former USSR, China and Australia (Smadi, 2006). This has been related to several factors such as global warming, increased concentrations of anthropogenic green house gases (GHG), aerosols which exert cooling effects on the climate, increased cloud cover and urbanization (Smadi, 2006).

In the Middle East, investigations of long-term variations and trends in temperature data are not receiving enough attention even though, these countries suffer serious environmental, agricultural and water resources problems. Aesawy and Hasanean (1998) studied the Variations of surface temperature at six southern Mediterranean stations: Marakesh (1910±1991), Algeria (1823±1991), Tripoli (1944±1991), Alexandria (1942±1991), Amman (1923±1991), and Beirut (1863±1991). They concluded that by examining the annual temperature times series it was shown that a significant abrupt climatic change was observed at all stations except for Tripoli. Warming episodes occur at Marakesh in 1922, and in 1976, at Algeria in 1865, and in 1967, and at Beirut in 1910. On the other hand, changes towards cooling took place at Alexandria in 1962 and at Amman in 1955.

The objectives of this study are to characterize: (1) The occurrence of abrupt changes and trends in annual minimum and maximum time series temperatures in Nile Delta, Egypt; (2) the changes of mean annual diurnal temperature range (DTR).

Study Area

Nile Delta is one of the most important regions in the economy of Egypt and northeastern Africa. With an extension of approximately 20000 Km^2, this region is highly dependent on agricultural activities and contributes about 85% to the national agricultural production. This activity has proven to be sensitive to extreme weather and climate events. The extreme events, such as sea level rise, salt intrusion water logging, drought, and rainfall decreasing may have negative economic impacts in the region.

Climate in Egypt is commonly described as arid and semi-arid, characterized by hot, dry summers, moderate winters and erratic rainfall. According to Koeppen's climate classification (Griffiths, 1968 and Domoroes and Tantawi, 2005), Egypt experiences the 'hot desert climate type' (BWh) in the southern and central parts of the country and the 'hot steppes climate type' (BSh) along the coast. Most parts of Egypt are occupied by the Sahara desert, which represents the most extensive area of severe aridity on globe. For at least 4000 years, Egypt has been facing climate change, which has impact on agricultural production. In the future it is expected that climate change will affect Egypt in many ways, in particular with regard to water resources and agricultural production (David and Kenneth, 1998).

The coastal zone of Egypt is distinctly vulnerable to climate change because of the impact of sea-level rise, predicted as between 0.5 and 1 m over the 21st century (El-Raey, 1996). If no action against sea-level rise is taken, an area of about 30% of Alexandria city will be lost due to inundation. Port Said is another vulnerable city affected by the predicted sea-level rise (El-Raey, 1996). Clearly indicating the impact of sea-level rise on society, a sea-level rise of 0.5 m would cause in the governorate of Alexandria alone a displacement of almost 1.5 million people and the loss of about (200,000) jobs by the middle of the 21st century (El-Raey, 1996). Therefore, substantial reductions of heat-trapping gas emissions in developed countries and adaptation strategies are in great demand (Desanker, 2001).

Materials and Methods

Climatic data were available more or less than 100 year period from 1900 until 2010 (8 years are missed from 1948-1956) at three stations:

Alexandria and Port Said in northern Egypt, and Cairo as shown in Table 1 and Fig. 1. The daily mean temperature data series (1900-2010) under study were provided by the Egyptian Meteorological Authority, Cairo.

Table 1. Stations used in this study, location, elevation and periods.

Location	Latitude	Longitude	Altitude	Period	Weather station
Alexandria	31.22	29.95	-2	1900-1947	623180 (HEAX)
				1957-2010	
Port said	31.26	32.29	6	1900-1947	623330 (HEPS)
				1957-2010	
Cairo	30.13	31.4	64	1900-1947	623660 (HECA)
				1957-2010	

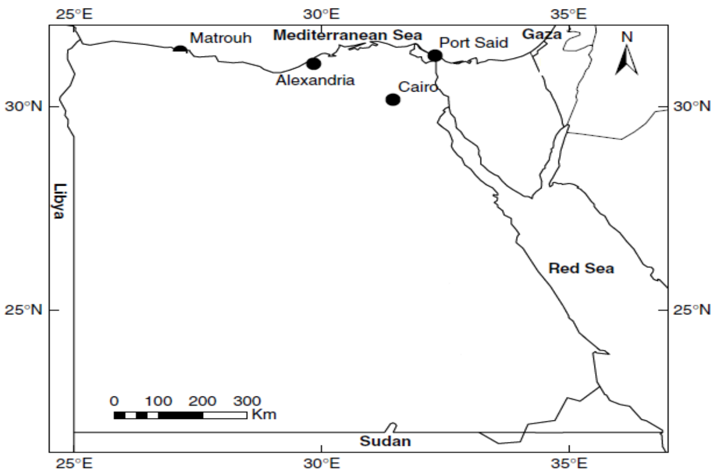


Fig. 1. Location of Meteorological stations used in this study

The mean annual maximum and minimum temperatures are derived from an average of the monthly maximum and minimum temperatures. The mean monthly diurnal temperature range (DTR) is defined as the difference between the mean annually maximum and minimum temperatures. The first indication that there might be important large-scale characteristics related to changes of the mean daily maximum and minimum temperatures was reported by (Karl *et al.*, 1984; Karl *et al.*, 1993 and Marengo and Camargo, 2008).

Homogeneity of Time Series

The homogeneity of long-term observations of temperature, widely used for instance in analyses of climate change, should be carefully tested as these series of observations could be adversely affected by changes in instrumentation, station moves, environmental changes (urban growth) or changes in observing practices (different observation times, new observers) (Serra *et al*., 2001). A detailed revision of procedures aimed at verifying the homogeneity of a series can be found in (Peterson *et al*., 1998). A homogeneous climate time series is defined as one where the variations are caused only by variations in climate (Aguilar *et al*., 2003). Non-climatic factors may hide the true climatic signals and patterns, and thus potentially bias the conclusions of climate and hydrological studies. Frequent factors are monitoring stations relocations, changes in instrumentation, changes of the surroundings, instrumental inaccuracies, and changes of observational and calculation procedures. Unfortunately, few long term climate time series are free of irregularities (Auer *et al*., 2005).

Test of Randomness

A classical procedure such as the von Neumann ratio test was chosen to reveal a possible lack of randomness in the temperature records owing to a variety of factors such as time trends, sharp changes, instrumental problems (Serra *et al*., 2001). Starting from the daily series of maximum and minimum temperatures, it is straightforward to obtain the average monthly and annual temperatures and their standardized values. According to (Mitchell *et al*., 1966; Serra *et al*., 2001 and Ramos and Casasnovas, 2006), the von Neumann ratio (VNR) *V* is defined as the quotient of the mean square successive difference to the variance:

$$V = \frac{N\sum_{i=1}^{N-1}(T_i - T_{i+1})^2}{(N-1)\left\{\sum_{i=1}^{N} T_i^2 - \left[\sum_{i=1}^{N} T_i\right]^2 / N\right\}} \qquad (1)$$

For a large number *N* of observations, under conditions of randomness, *V* is Gaussian distributed with an expected value of $2N/(N-1)$ and a variance given approximately by $4(N-2)/(N-1)^2$, T_i being the consecutive maximum or minimum temperatures at the different time-scales. As a general feature, if the value of the von Neumann ratio is greater than the parameter (Serra *et al*., 2001):

$$V_t = \frac{2N \pm 2t_g\sqrt{N-2}}{N-1} \qquad (2)$$

with t_g being equal to 1.645, equivalent to considering the one-tailed test at the 0.05 significance level for the Gaussian distribution, the hypothesis that the time series analyzed is random should be accepted. It should be noted that parameter V_t tends to be 2 for a large number N.

Von Neumann, (1941) proposed a nonparametric test where the statistic is defined as the ratio of the mean square successive (year-to-year) difference to the variance. The null hypothesis is that the data are independent, identically distributed random quantities and the alternative is that the time series is not randomly distributed. Under the null hypothesis of a constant mean, the expected value of the test statistic is equal to two (Buishand, 1982). The von Neumann ratio test is not location specific, which means that it gives no information about the date of the break.

Tests of Randomness Results

The parameter V_t, given by Equation (2), reaches values of 2.517 and 1.567, depending on the sign considered, for the yearly case for period 1900-1947 and 2.485 and 1.590 for period 1957-2010 for all three stations under investigation. Therefore, these quantities can be compared with the evolution of the empirical von Neumann ratio depicted in Table 2 and Fig. 2. All Von Neumann Ratio (VNR) values for all stations and periods are less than minimum threshold value deduced by equation (2), this mean that all period's data are not randomly distributed and if there are any changes appearing, will be due to actual change in maximum or minimum temperature and not for random chance.

Table 2. Time evolution of the Von Neuman Ratio for annual maximum and minimum temperature (Vt values represent threshold values deduced from Equation (2)) and climate trend coefficient (Rxt).

Periods	Vt (max)	Vt (min)	VNR&Rxt	Alexandria	Port Said	Cairo
1900-1947	2.51731629	1.567790093	VNR (Tmax)	0.832269	0.831822	0.6613272
			VNR (Tmin)	1.2722424	0.9118171	1.0001325
			Rxt (Tmax)	-0.066071	0.1916706	0.3543246
			Rxt (Tmin)	0.5945405	0.3224324	0.3063139
1957-2010	2.485368441	1.590103257	VNR (Tmax)	1.1946212	0.6068547	1.4738738
			VNR (Tmin)	0.7429464	0.8217743	0.413842
			Rxt (Tmax)	-0.106148	-0.060504	0.1126546
			Rxt (Tmin)	0.3846648	0.2459552	0.342145

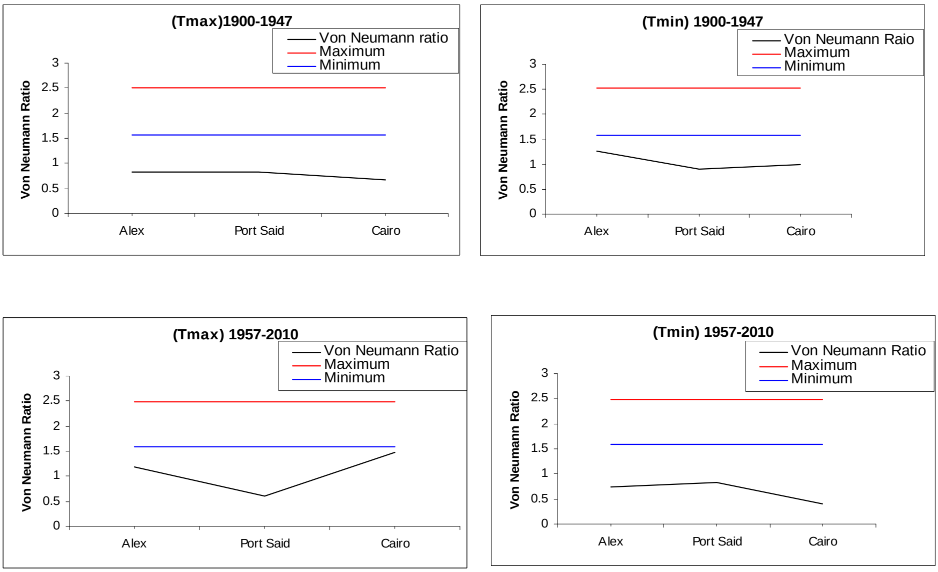


Fig. 2. Time evolution of the Von Neuman Ratio for annual maximum and minimum temperature, colored lines represent threshold values deduced from Equation (2).

1. Climate Trend Coefficient

The climate trend coefficient, R_{xt}, can be used to assess whether there is a significant linear climate trend in time series (Lin *et al.*, 2001).This coefficient is defined as the correlation coefficient between the time series $\{X_i\}$, and nature numbers {i}, i=1,2,3,...,n. In this study (n) is the total span of years of the data. The coefficient is computed from:

$$R_{xt} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(i - \bar{t})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(i - \bar{t})^2}} \qquad (3)$$

Where, $\bar{t} = (n+1)/2$. Its significant level is determined from the student t-test. The positive/negative value of R_{xt} indicates that the time series, $\{X_i\}$, has a linear positive/negative trend.

2. Mann Kendall Rank Test

The non parametric Mann-Kendall rank statistic was used to determine the possible existence of a significant trend in the collected data over a period of time. This test was found to be useful and widely used for detecting trends in climate and environmental sciences (Smadi, 2006). Whether or not a constant increasing or decreasing trend was occurring, the non-parametric Mann–Kendall test for trend was applied; a positive (negative) *Z* value indicates an upward (downward) trend. Significance levels are 0.001, 0.01, 0.05 and 0.1 (Salmi *et al*., 2002). Excel program was used to analyze temporal and spatial temperature changes in Egypt. The Excel template MAKESENS (Salmi *et al.,* 2002) was also used to detect trends in the annual values of temperature by the Mann–Kendall test.

3. Cumulative Sum Charts (CUSUM) and Bootstrapping

This procedure was used by (Taylor, 2000a; Smadi, 2006; and Maftei and Barbulescu, 2008) devised a procedure for performing change point analysis using cumulative sum charts (CUSUM) and bootstrapping. Let X_1 ,X_2 ,...,X_n represent the n data points. The cumulative sums S_0 ,S_1 ,...,S_n are calculated iteratively as follows:

1. Calculate the average

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \dots + X_n}{n} \quad (4)$$

2. Let $S_0 = 0$.

3. Calculate S_i recursively:

$$S_i = S_{i-1} + (X_i - \overline{X}), \quad i = 1, 2, \dots n \quad (5)$$

A segment of the CUSUM chart with an increasing slope indicates a period where the values tend to be above the overall average. Likewise, a segment with a decreasing slope indicates a period of time where the values tend to be below the overall average. A sudden change in direction of the CUSUM indicates a sudden shift in the average. A period where the CUSUM chart follows a relatively horizontal path indicates a period where there is no change in the average. The confidence level can be determined by performing bootstrap analysis (Smadi, 2006 and Abu-Taleb *et al.,* 2007).

The above-mentioned control chart and the change point analysis are based on the assumption of independent errors around a possibly changing mean. When such techniques are applied to autoregressive data, erroneous conclusions can be obtained. However, shifts in the mean create autocorrelation between the observations which makes it difficult to distinguish the mean-shift data from the autoregressive data. A pattern test has been devised which can detect a violation of independent errors assumption and thus can reliably distinguish between these two important cases (Taylor, 2000b and Smadi, 2006). In this work, the software Change Point Analyzer was used and performs this test any time when analyzing any set of time ordered data (Taylor, 2000c and Smadi, 2006).

Results and Discussion

Analyses of fluctuations in long term AMMIT and AMMXT temperatures are presented for all reference stations. The following asterisks will be frequently used in the result tables to denote statistical significance at different levels (α): + for α = 0.1, * for α = 0.05, ** for α = 0.01, *** for α = 0.001 and if the cell is blank, the significant level is >0.1 (Salmi *et al.,* 2002 and Smadi, 2006). The climate trend coefficient, R_{xt}, value Table 2 compares with t-test table and represent that there is no significant linear climate trend in all annual time series for all stations under investigations.

Annual Mean Minimum Temperatures (AMMIT)

The time series plots of the annual mean minimum temperature for all stations are shown in Fig. 3. No statistical outliers were detected. The Figure shows generally steady rise in minimum temperature since the beginning of the record from 1900 to 2010. Although, the minimum temperature during the second period (1957-2010) has slightly increased than the first period

Table 3 displays the regression slope estimates and Mann-Kendall (M-K) test statistics for the AMMIT for entire two periods (1900-1947 and 1957-2010). A warming trend is noted in the mean minimum temperatures for all stations also, it is statistically significant at α= 0.001 for all stations during the two periods except at Alexandria during the period (1957-2010) it was significance at α = 0.01.

Table 3. Summary statistics and M-K statistics of AMMIT for all stations.

		1900-1947				1957-2010			
	Annual	Mean	Slope	M-K	signific.	Mean	Slope	M-K	signific.
Alexandria		17.129	0.031	4.427	***	15.963	0.014	2.664	**
Port Said		17.708	0.021	4.498	***	18.550	0.021	3.917	***
Cairo		15.063	0.027	4.764	***	16.191	0.034	5.275	***

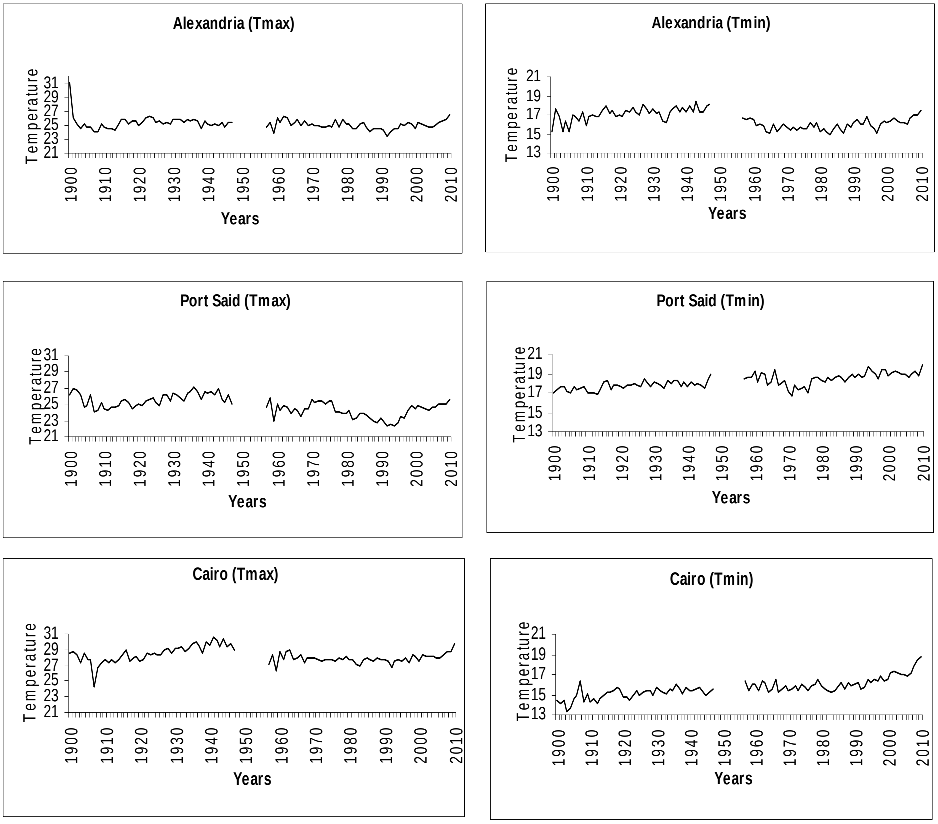


Fig. 3. Time series of Alexandria, Port Said and Cairo AMMXT & AMMIT.

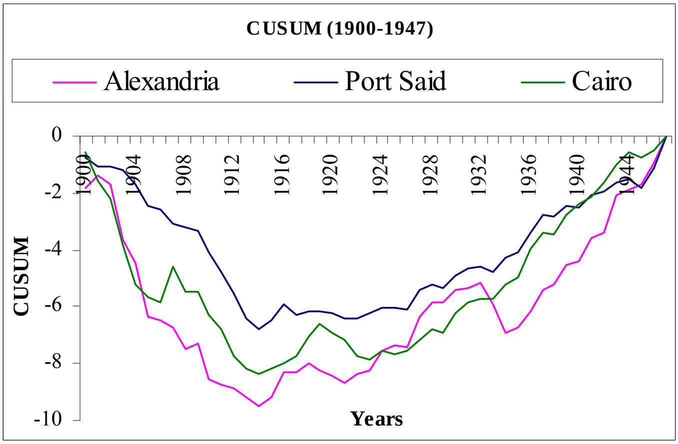
Table 4 illustrates the results of a change-point analysis for AMMIT of all stations during the first period. The table gives the level associated with each change. This level is an indication of the importance of change. Applying the test gives no departure from the independent error structure and no outlier's assumptions were found. The CUSUM chart is shown in Fig. 4. This analysis detects change in the years 1915, 1914 and 1914 for Alexandria, Port Said and Cairo respectively. The most important change is estimated to have occurred around these years with 100% confidence level. Table 4 also indicates that prior to the three changes in (1915, 1914 and 1914), the average AMMIT were (16.49, 14.47 and 14.87 °C), respectively, while after these changes, the temperatures were, (17.41, 15.3 and 15.3 °C), respectively.

Table 4. Results of change point analysis on AMMIT of Alexandria, Port Said and Cairo stations during (1900-1947).

Year	Confidence Interval	Conf. Level	From	To	Level
1915	(1907, 1918)	100%	16.495	17.417	2

Year	Confidence Interval	Conf. Level	From	To	Level
1914	(1908, 1916)	100%	14.478	15.303	4

Year	Confidence Interval	Conf. Level	From	To	Level
1914	(1908, 1916)	100%	14.478	15.303	4



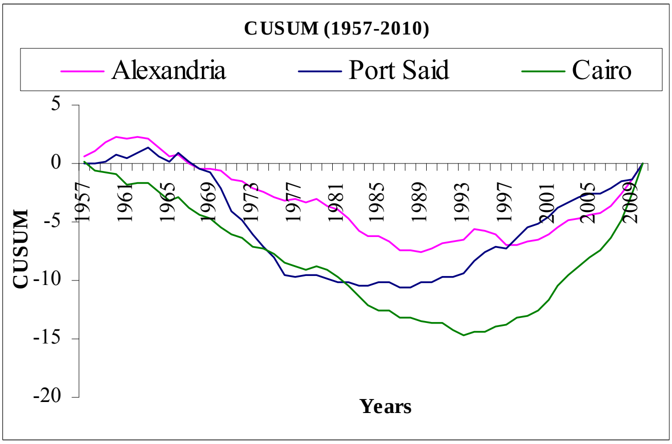


Fig. 4. CUSUM chart for the AMMIT of Alexandria, Port Said and Cairo during (1900-1947) and (1957-2010).

The results revealed significant warming trends in the period between; (1900-1947) for Alexandria, Port Said and Cairo respectively. The rate of increase in AMMIT is 0.031, 0.021 and 0.027 °C/year respectively as shown in Table 2.

Table 5 shows the results of a change-point analysis for the annual mean minimum temperature for all stations during (1957-2010). The CUSUM chart of the period (1957-2010) is shown in Fig. 4. In Alexandria, the analysis detects five changes which occurred in the years 1961, 1990, 1995, 1998 and 2008 with different confidence level.

Table 5. Results of change point analysis on AMMIT of Alexandria, Port Said and Cairo stations during (1957-2010).

Year	Confidence Interval	Conf. Level	From	To	Level
1961	(1961, 1963)	98%	16.529	15.623	2
1990	(1986, 1990)	98%	15.623	16.352	3
1995	(1995, 1995)	94%	16.352	15.517	4
1998	(1998, 1998)	98%	15.517	16.303	1
2008	(2007, 2008)	95%	16.303	17.167	2

Year	Confidence Interval	Conf. Level	From	To	Level
1967	(1964, 1968)	100%	18.648	17.504	4
1977	(1975, 1977)	100%	17.504	18.538	3
1993	(1991, 1999)	100%	18.538	19.088	1

Year	Confidence Interval	Conf. Level	From	To	Level
1994	(1993, 1995)	100%	15.792	16.791	2
2008	(2008, 2008)	96%	16.791	18.303	4

Prior to these five changes, the average AMMIT were 16.52, 15.62, 16.35, 15.51 and 16.3 °C, respectively, while after these changes, the temperatures were, 15.62, 16.35, 15.51, 16.3 and 17.16 °C, respectively Table 5. In Port Said, the analysis detects three changes which occurred around the years 1967, 1977 and 1993 with 100% confidence level.

Prior to these three changes, the AMMIT were 18.64, 17.5 and 18.53 °C, respectively, while after these changes, the temperatures were, 17.5, 18.53 and 19.08 °C, respectively Table 5. In Cairo, the analysis detects two changes which occurred around the years 1994 with 100% confidence level and 2008. Prior to these two changes, AMMIT were 15.79 and 16.79 °C, respectively, while after these changes, the temperatures were 16.79 and 18.3 °C, respectively Table 5. The results revealed significant warming trends between; (1957-2010) for all three stations. The rate of increase in AMMIT is 0.014, 0.021 and 0.034 °C/year is shown in Table 3.

Annual Mean Maximum Temperature (AMMXT)

The time series plots of AMMXT for all stations are shown in Fig. 3. It shows that AMMXT trend in Port Said are increasing in the first period (1900-1947) and vice verse in second one (1957-2010), but in Alexandria there is decreasing in both periods and in Cairo there is increasing in both periods.

Table 6 displays the regression slope estimates and Mann Kendall (M-K) test statistics for the AMMXT for the entire periods.

Table 6. Summary statistics and M-K of AMMXT for the entire periods for Alexandria, Port Said and Cairo.

		1900-1947				1957-2010			
	Annual	Mean	Slope	M-K	signific.	Mean	Slope	M-K	signific.
Alexandria		25.39911	-0.0048	1.048913		25.03991	-0.0041	-0.85049	
Port Said		25.61437	0.0227	3.217598	**	24.2033	-0.007	-0.99226	
Cairo		28.5303	0.0573	6.017679	***	27.88562	0.0082	1.544432	

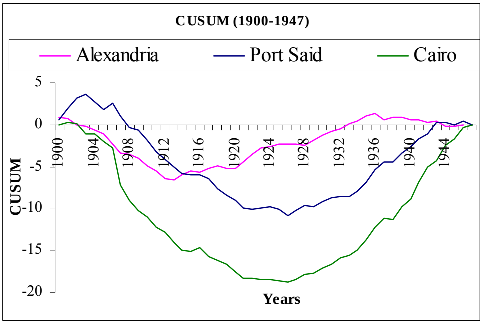
Table 7 shows the results of a change point analysis for the AMMXT for all stations during (1900-1947). The CUSUM chart is shown in Fig. 5. The analysis of Alexandria data detects two changes which occurred in 1915 and 1938. The first and most important change point is estimated to have occurred around 1915 with 100% confidence level. Prior to 1915 average annual mean maximum temperature was found 24.8 °C while after the first change it was 25.62 °C. The change point occurred 1915 with confidence level agrees with the detected change point in the AMMIT which was also in 1915. The analysis of Port Said data detects three changes which occurred in 1904, 1927 and 1944. The first and most important change point is estimated to have occurred around 1927 with 100% confidence level. Prior to 1927 AMMXT was found 24.48 °C while after the first change it was 26.26 °C. The three changes detected of Cairo data occurred in 1915, 1927 and 1935. The most important change point is estimated to have occurred around 1927 with 100% confidence level. Prior to 1927 AMMXT was found 28.21 °C while after the first change it was 29.0 °C.

Table 7. Results of change point analysis on AMMXT of Alexandria, Port Said and Cairo stations during (1900-1947).

Year	Confidence Interval	Conf. Level	From	To	Level
1915	(1910, 1917)	100%	24.804	25.623	1
1938	(1932, 1944)	96%	25.623	25.136	2

Year	Confidence Interval	Conf. Level	From	To	Level
1904	(1904, 1906)	98%	26.539	24.982	2
1927	(1925, 1929)	100%	24.982	26.267	4
1944	(1935, 1946)	97%	26.267	25.554	2

Year	Confidence Interval	Conf. Level	From	To	Level
1915	(1901, 1918)	100%	27.533	28.211	2
1927	(1923, 1928)	100%	28.211	29.005	1
1935	(1935, 1943)	97%	29.005	29.683	2



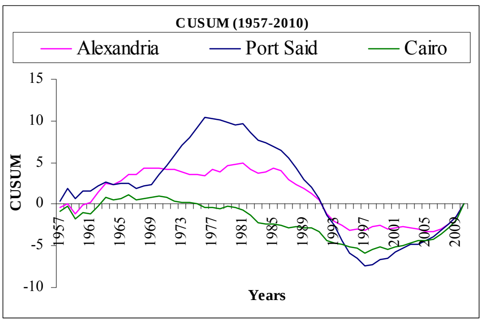


Fig. 5. CUSUM chart for the AMMXT of Alexandria, Port Said and Cairo during (1900-1947) and (1957-2010).

The results revealed significant warming trends between; (1900-1947) for all stations, the rate of change in AMMXT is 0.011, 0.023 and 0.057 °C/year for Alexandria, Port Said and Cairo respectively as shown in Table 6.

Table 8 shows the results of a change-point analysis for the AMMXT for all stations during (1957-2010). The CUSUM chart is shown in Fig. 5. In Alexandria, the analysis detected four changes which occurred in the years 1960, 1986, 1996 and 2008 with 100% confidence level around 1986 and 1996. Prior to these two changes (1986 and 1996), the AMMXT were 25.25°C and 24.28 °C, respectively, while after these changes, the temperatures were, 24.28°C and 25.05 °C, respectively. The change point occurred in 2008 with confidence level agreed with the detected change point in the AMMIT which was also in 2008. In Port Said, the analysis detected five changes which occurred around the years 1970, 1977, 1988, 1998 and 2007, with 100% confidence level around 1977, 1988 and 1998. Prior to these three changes, the AMMXT were 25.36°C, 23.375°C and 22.88 °C, respectively, while after these changes, the temperatures were, 23.71, 22.88 and 24.58 °C, respectively. The change point occurred in 1977 with confidence level agreed with the detected change point in the AMMIT which was also in 1977. In Cairo, the analysis detected three changes which occurred around the years 1971, 1998 with different confidence level and during 2010 with 100% confidence level. Prior to last year change (2010), the AMMXT was 28.2 °C, while after this change; the temperature was 29.8 °C.

The results revealed significant warming trend in the period 1957-2010 for Cairo, by rate of 0.008 °C/year, while significant cooling slope trend for Alexandria and Port Said by rate -0.004 and -0.007 °C/year respectively as shown in Table 6.

Linear trends for annual DTR are typically used to assess changes in the behavior of climate variables during relatively two long periods' equal to 48 and 54 years. The annual DTR trends for the two periods are represented in Fig. 6. Table 9 shows the decadal trends of annual DTR, minimum and maximum temperature during (1900-1947) and (1957-2010).

Table 8. Results of change point analysis on AMMXT of Alexandria, Port Said and Cairo stations during (1957-2010).

Year	Confidence Interval	Conf. Level	From	To	Level
1960	(1958, 1984)	90%	24.675	25.25	4
1986	(1982, 1986)	100%	25.25	24.289	7
1996	(1996, 1998)	100%	24.289	25.056	3
2008	(2008, 2008)	94%	25.056	26.025	1

Year	Confidence Interval	Conf. Level	From	To	Level
1970	(1964, 1970)	100%	24.385	25.363	2
1977	(1977, 1977)	100%	25.363	23.771	1
1988	(1986, 1990)	100%	23.771	22.886	3
1998	(1998, 1998)	100%	22.886	24.589	5
2007	(2005, 2007)	93%	24.589	25.196	4

Year	Confidence Interval	Conf. Level	From	To	Level
1971	(1958, 1985)	90%	27.952	27.636	3
1998	(1996, 2001)	94%	27.636	28.209	4
2010	(2010, 2010)	100%	28.209	29.817	1

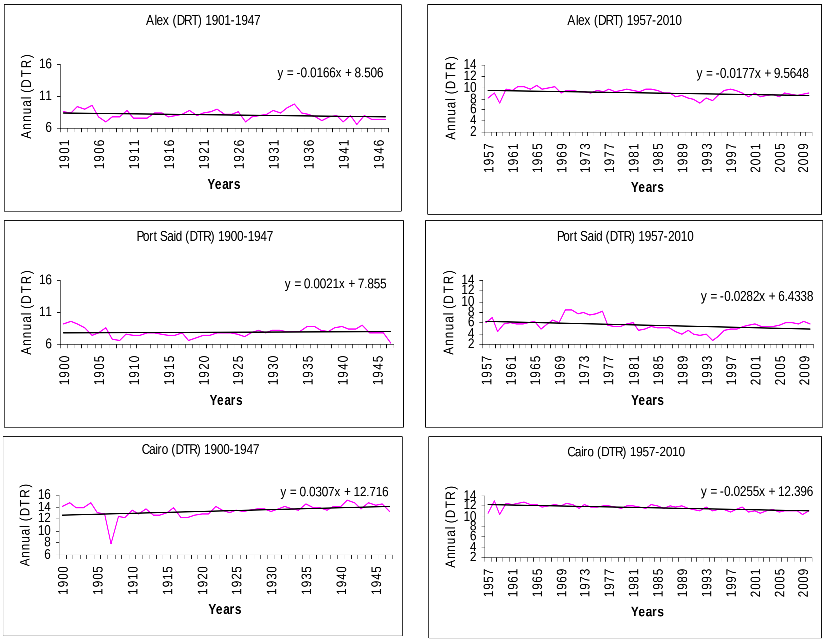


Fig. 6. Annual (DTR) trend during (1900-1947) and (1957-2010).

Table 9. Decadal trend of annual diurnal temperature range (DTR) for the entire periods for Alexandria, Port Said and Cairo.

		Alexandria	Port Said	Cairo
1900-1947	DTR	-0.166	0.021	0.307
	Minimum	0.307	0.206	0.266
	Maximum	0.111	0.227	0.573
1957-2010	DTR	-0.177	-0.282	-0.255
	Minimum	0.136	0.213	0.337
	Maximum	-0.041	-0.07	0.082

At decadal level, all the stations that exhibit positive and significant trends for minimum temperature show rates of warming trend ranging between +0.21 and +0.31 °C per decade during (1900-1947) and between +0.14 and +0.34 °C per decade during (1957-2010), while the maximum temperature show trends of warming ranging between +0.11 °C and +0.57 °C per decade for (1900–1947) and cooling trend ranging between -0.07 and -0.04 in Port Said and Alexandria respectively and warming trend (+0.08°C) in Cairo per decade during (1957-2010).

Possible variations in DTR in Nile Delta are partially related to land use changes and may be due to agriculture and urbanization activity. Negative DTR trend in Alexandria (1901-1947), it is caused by temperature increasing faster at night than the day. While positive DTR trends in Port Said and Cairo (1900-1947) caused by opposite minimum and maximum situation than in Alexandria. Makowski *et al.* (2008) showed that DTR decreased on a global scale during the second half of the twentieth century. Marengo and Camargo, (2008) showed a decrease in DTR in eastern USA since 1950 mainly due to urbanization. Zhou *et al.* (2004) showed the decrease of DTR is greatest in the Yangtze and Pearl River deltas and generally is larger at coastal stations, they also mentioned that areas with the greatest increase in percentage urban have the largest reduction in DTR. Dahech and Beltrando (2012) showed the heat absorbed by massive hard surfaces during daytime are re-emitted at night. This is the reason why higher temperatures are observed in these areas during the night survey. The emission of heat by human activities such as transport and air conditioning of buildings contribute to some urban heat islands. In addition, the diminution of vegetation cover can reduce moisture availability. This can increase the sensible heat and reduce the fraction of solar energy converted into latent heat. There is an agreement between above mentioned results and our present negative

DTR results for the three stations during (1957-2010) Table 9. The tendency of the DTR trends is mainly explained by the steep positive minimum temperature trends for all stations and periods as compared to moderately weak positive trends in maximum temperatures except in Cairo with high trend (1900-1947) and negative trend in Alexandria and Port Said (1957-2010).

Conclusion

The climate trend coefficient, R_{xt}, value compares with t-test table and represent that there are no significant linear climate trends in all annual time series for all stations under investigations. These results agree with the phenomena that the climate change behavior as sinusoidal curve, increase in some interval and decrease in others and represented as cycles.

Statistically significant change points in the mean minimum (night-time) temperature during 1900-1947 occurred in 1915, 1914 and 1914 for Alexandria, Port Said and Cairo respectively. The most important change is estimated to have occurred around these years with 100% confidence level. The significant change points during 1957-2010 occurred in different years with different significant levels, 1961, 1998 and 2008 for Alexandria (98% confidence level), 1967, 1977 and 1993 for Port Said and 1994 for Cairo (100% confidence level). The significant warming trend slope between; (1900-1947), the mean annual minimum temperature has increased by rate of (0.031, 0.021 and 0.027 °C/year) and during the period between; (1957-2010), the mean annual minimum temperature has increased by rate of (0.014, 0.021 and 0.034 °C/year) for Alexandria, Port Said and Cairo respectively.

Statistically significant change points in the mean maximum (day-time) temperature during 1900-1947 occurred with 100% confidence level in 1915 for Alexandria, 1927 for Port Said and 1915 and 1927 for Cairo. The significant change points during 1957-2010 occurred in different years with different significant levels. Significant change points with 100% confidence level occurred in 1986 and 1996 for Alexandria, 1970, 1977, 1988 and 1998 for Port Said and 2010 for Cairo. The significant warming trend slope between; (1900-1947), the mean annual maximum temperature has increased by rate of (0.011, 0.023 and 0.057

°C/year) for Alexandria, Port Said and Cairo respectively. The significant warming trend slope between; (1957-2010) for Cairo, the annual mean maximum temperature has increased by rate of 0.008 °C/year, while significant cooling slope trend for Alexandra and Port Said by rate -0.004 and -0.007 °C/year respectively.

Possible variations in DTR in Nile Delta are partially related to land use changes, agriculture and urbanization activity. Negative DTR trend in Alexandria (1901-1947) was mainly due to night temperature increasing faster than during the day. Positive DTR trends in Port Said and Cairo (1900-1947) caused by opposite minimum and maximum situation than in Alexandria. Negative DTR results for the three stations during (1957-2010) mainly due to urbanization development inside Cairo, Alexandria and Port Said.

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التغيرات في درجات الحرارة الصغرى والكبرى بدلتا النيل (مصر – القرن العشرون)

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المستخلص. تبحث هذه الدراسة التغيرات في المتوسط السنوي لدرجات الحرارة الصغرى والكبرى في دلتا النيل (مصر) خلال القرن الماضي ،لذلك تم اختيار سلسلتين زمنيتين (1900–1947) و(1957–2010) لكل محطة أرصاد جوية بالإسكندرية وبورسعيد والقاهرة للدراسة والتحليل. استخدم عدد من التحليلات الإحصائية لاختبار ظهور أي تغيرات مفاجئة بالبيانات قيد الدراسة ومن ثم تحديد اتجاه هذه التغيرات (هبوطًا أو صعودًا). نتائج التحليلات الإحصائية أثبتت بأن التغيرات واتجاهها والتي تم اكتشافها بالبيانات هي ذات دلالة إحصائية فهناك نقاط تحول رئيسية للمتوسطات الصغرى والكبرى لدرجات الحرارة خلال فترة الدراسة. لوحظ ارتفاع في متوسط درجات الحرارة الصغرى (للمحطات الثلاث) للفترتين وسجلت الإسكندرية أعلى قيمة (1900–1947) والقاهرة (1957–2010). أيضًا هناك ارتفاع في متوسط درجات الحرارة الكبرى (1900–1947) وسجلت القاهرة أعلى قيمة. أما خلال (1957–2010) فسجلت القاهرة ارتفاعًا طفيفًا بالمقارنة مع الفترة الأولى، وعلى النقيض هناك انخفاض في متوسط درجات الحرارة الكبرى في كل من الإسكندرية وبورسعيد (1957–2010). بدراسة نطاق التغير النهاري لفرق درجات الحرارة الصغرى والكبرى اتضح أن القيمة السالبة لهذه الكمية (الاتجاه) بالإسكندرية (1901–1947) تعبر عن أن معدل ارتفاع درجة الحرارة الصغرى بالليل أسرع من ارتفاع درجة

الحرارة الكبرى بالنهار. وعلى النقيض فإن القيمة الموجبة للاتجاه بكل من القاهرة وبورسعيد تعبر عن أن معدل ارتفاع درجات الحرارة الكبرى بالنهار أسرع من معدل ارتفاع درجات الحرارة الصغرى بالليل. أما فى الفترة (1957–2010) فإن الهبوط الملحوظ (الاتجاه) في المدن الثلاث يمكن تفسيره بأنه نتيجة للزيادة العمرانية الكبيرة التي حدثت بهذه المدن خلال تلك الفترة.