USING GIS AND STATISTICAL METHODS TO DETECT THE MULTI-DECADAL VARIABILITY FOR TEMPERATURE TRENDS ON EGYPT: 1960-2000

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ABSTRACT:
Times series of Egypt for 24 stations were investigated for multi-decadal variability for temperature trends over the period 1960-2000. One-Way ANOVA analysis was applied to assess whether there is any statistically significant differences between the means of temperature at the decadal scales. Annual trends are assessed by means of the linear trend analysis by calculating the least squares fit for a line multiplied by 10 gives the change per decade and the non-parametric Mann-Kendall test for trend was applied to detect the trends. The spatial interpolation by universal kriging method was applied by ArcGIS software to generate the temperature surface for each decade to show the spatial variability between the decades and the spatial variability to temperature trends were detected by symbology process in ArcGIS software. For the observation period (1960-2000) upward trends were shown for mean and minimum temperature and downward trends for maximum temperature, and Egypt showed relatively disparate between the means of decades, and the first decade was the coolest and the fourth decade was the warmest for all temperature variables. The southern part has clear upward trend than the other parts of Egypt in all variables of temperature.

Keywords: *Time series, Egypt, temperature trends, ArcGIS.*

1. INTRODUCTION

Surface air temperature change is a primary indicator of global climate change. (*Hansen et al, 1999*).Numerous studies have indicated direction and significance of temporal trends of temperature at various spatial scales from the global to local (e.g., *Jones et al. 1999; Domroes and El- Tantawi, 2005; Hansen et al, 2006; Michaels, Balling, 2009*). Since the late 1950s (the period of adequate observations from weather balloons), the overall global temperature increases in the lowest 8 km of the atmosphere and in surface temperature have been similar at 0.1°C per decade and since the beginning of the satellite record in 1979 the global average temperature of the lowest 8 km of the atmosphere has changed by $+0.05 \pm 0.10$°C per decade (*IPCC, 2001*). The global mean annual temperature trend was 0.17 °C/decade for the 1971–2000 period, the mean minimum temperature trend was 0.20 °C/decade and the mean maximum temperature trend was 0.10°C/decade (*Jones et al. 1999*). The overall global trend for the maximum temperature during 1950 to 1993 is approximately 0.1°C/decade and the trend for the minimum temperature is about 0.2°C/decade (*IPCC, 2001*). Between the mid-1970s and the late 1990s global temperature increased by about 0.5°C, i.e., about 0.2°C/decade, about twice the rate of warming that occurred early in the century (*Hansen et al, 1999*). The global surface temperature has increased by 0.2°C per decade in the past 30 years (*Hansen et al, 2006*). According to the latest estimates by (*IPCC, 2007*) Earth's linearly averaged surface temperature has increased by 0.74°C during the period 1901-2005, and Michaels and Balling stated that in the last three decades ending in 2005, the warming rate was (0.178°C - 0.021°C) per decade

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(*Michaels and Balling, 2009*). On continental scale the temperature trend for Africa, climate change scenarios indicate future warming ranging from 0.20°C/decade (low scenario) to more than 0.50°C/decade (high scenario) (*IPCC, 2001*). The five warmest years in Africa have all occurred since 1988, with 1995 and 1998 being the two warmest years (*UNFCCC, 2006*).

Temperatures of Egypt vary widely in the inland desert areas (*Robaa, 2008*). According to the study of Domroes and El- Tantawi Temperature trends of Egypt over the period 1941-2000 showed different behaviour. Decreasing trends of the mean annual temperature were observed in northern Egypt and (weakly) increasing trends in southern Egypt but for the recent period, 1971–2000, positive trends were computed for the mean annual and mean minimum temperatures, the mean maximum temperature trends were, however, negative in most stations (*Domroes, El- Tantawi, 2005*). The main contributor to rising air temperature comes from the increase in night time temperature, this rise in night time temperature may be due to the effect of greenhouse gases and increasing water vapor in the boundary layer (*EEAA, 1999*) .

2. DATA AND METHODLOGY

2.1 Study area

Egypt which lies between latitudes of 22°N and 31º 37`N and longitudes of 25°E and 35°E was selected as the study area. Egypt is located in northeastern Africa; occupying an area of approximately 1,001,450 sq. km. Egypt is bounded by the Mediterranean Sea in the north, the Red Sea, Israel and the Palestinian Authority in the east, the Sudan in the south, and from the west by Libya (**Fig. 1**). The study area is vast plateau divided by the River Nile to Western and eastern desert and most of Egypt land is a plane except for the Red Sea Mountains and South Sinai where the peaks of mountains are close to 2500m, the lowest point is Qattara Depression (-133m below sea level) and the highest point is the Catherine mountain (2629m).
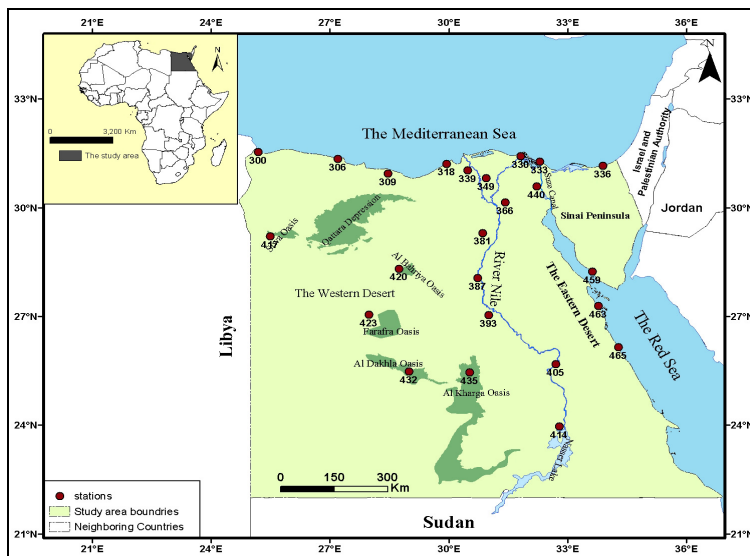

Fig. 1 Location of the study area

2.2 Data description and quality control

The Egyptian Meteorological Authority (EMA) data employed in this study comprise mean, minimum, and maximum monthly temperature for 24 selected stations to trace changes in decadal temperature trends see (**Fig. 1**) and (**Table 1**). The data series for three stations (El Arish, El Tor and Ismalia) have missing data so; data was manipulated by fitting interpolation model in Mathematica software version 7. The current study is based on temperature records spanning the period from January 1960 to January 2000. The length of the data records is satisfactory to capture long-term temperature variations where the WMO suggested a minimum of 30 years to trace reliable trends in climate data series. Data was checked for identical values (i.e. same value is repeated more 3 months). Also, the data was checked for presence of outliers in the series: i.e. values that vary too much from the average values. This was principally done by checking each value against values of the neighboring stations. This can be considered as a preliminary indication of possible inhomogenities in the data. The monthly time series are tested for their homogeneity using the Standard Normal Homogeneity test (SNHT) developed by Alexandersson and Moberg, (1997). And then apply adjustments if necessary, the test applied by using AnClim software ver. 5.023 (*Stepanek, P., 2008*). After that the means were calculated of each year for each station to extract the general mean of the base period 1960-2000 in the study area then calculating the means for each decade. One-Way ANOVA analysis was applied to assess whether there is any statistically significant differences between the means of temperature at the decadal scales. Analysis of variance is used to test the hypothesis that several means are equal and the significance levels tested are 0.05 (∗). Minitab software version 16 was used to apply the test. The spatial interpolation by universal kriging method was applied by ArcGIS software to generate the temperature surface for each decade to show the spatial variability between the decades.

A *trend* is defined as the slope of a line that has been least-squares fit to the data, (*Douglass et al, 2007*). For this study annual trends are assessed by means of the linear trend analysis by calculating the least squares fit for a line represented by the following equation (1) which is called a linear equation:

$$Y = mx + b \tag{1}$$

For this study annual and decadal trends were calculated for each station and were then averaged over all the stations to obtain the regional-average of temperature trend per year and the slope (m) in equation (1) multiplied by 10 gives the change per decade, the trend was expressed in ºC per decade. To identify whether the trend increases, decreases or is stable, the non-parametric Mann-Kendall test for trend was applied by a positive/ negative Z value which indicates upward or downward trend, the formula (2) is:

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i-1} sign\left(x_i - x_j\right) \tag{2}$$

Where sign $(x_i - x_j)$ is $\begin{cases} -1 \text{ for } x_i - x_j < 0 \\ 0 \text{ for } x_i - x_j = 0 \\ +1 \text{ for } x_i - x_j > 0 \end{cases}$

Table 1. *Temperature observatories selected for this study*

	Station Name	WMO code	Lat.	Long.	Elev. (m)	Start. date	Status quo	Data Status from 1960-2000	Stations description
1	Alexandria	62318	31.12	29.57	-3.4	1942	IWO	Complete	Coastal
2	Aswan	62414	23.58	32.47	200	1901	IWO	Complete	Inland (Valley)
3	Asyout	62393	27.03	31.01	234.7	1901	IWO	Complete	Inland (Valley)
4	Bahariya	62420	28.20	28.54	128	1931	IWO	Complete	Inland (Desert)
5	Cairo	62366	30.08	31.24	111.5	1947	IWO	Complete	Inland (Valley)
6	Dakhla	62432	25.29	29.00	106.2	1905	IWO	Complete	Inland (Desert)
7	Damanhour	62339	31.02	30.28	2.4	1931	IWO	Complete	Inland (valley)
8	Damietta	62330	31.25	31.49	1.9	1915	IWO	Complete	Coastal
9	**El Arish**	**62336**	**31.16**	**33.45**	**15**	1936	**IWS**	**Missing data (32%)**	**Coastal**
10	El Dabaa	62309	30.56	28.28	17	1948	IWW	Complete	Coastal
11	**El Tor**	**62459**	**28.14**	**33.37**	**2.7**	1919	**IWS**	**Missing data (32%)**	**Coastal**
12	Farafra	62423	27.03	27.58	90	1955	IWO	Complete	Inland (Desert)
13	Fayoum	62381	29.18	30.51	22	1931	IWO	Complete	Inland (Valley)
14	Hurghada	62463	27.17	33.46	1	1928	IWW	Complete	Coastal
15	**Ismalia**	**62440**	**30.35**	**32.14**	**12.5**	**1946**	**IWW**	**Missing data (32%)**	**inland**
16	Kharga	62435	25.27	30.32	77.8	1926	IWO	Complete	Inland (Desert)
17	Luxor	62405	25.40	32.42	93.3	1936	IWO	Complete	Inland (Valley)
18	Mersa Matruh	-62306	31.20	27.13	28.3	1920	IWO	Complete	Coastal
19	Minya	62387	28.05	30.44	39	1907	IWO	Complete	Inland (Valley)
20	Port Said	62333	31.16	32.17	1	1900	IWO	Complete	Coastal
21	Quseir	62465	26.08	34.18	8.7	1931	IWO	Complete	Coastal
22	Sallum	62300	31.32	25.11	4	1927	IWO	Complete	Coastal
23	Siwa	62417	29.12	25.29	-15	1912	IWO	Complete	Inland (Desert)
24	Tanta	62349	30.49	30.56	8.6	1927	IWW	Complete	Inland (Delta)

Note: IWO refers to those stations still in work without any site change, IWW (In work with site change), and IWS (In work but stopped in some period). Sources: Depending on EMA data

And the significance levels tested are 0.001 (***), 0.01 (**), 0.05 (*) and 0.1 (+). If the cell is blank, the significance level is >0.1 and the Mann-Kendall macro in Minitab software version 16 was used to apply the Mann-Kendal test to detect the trends for each station and for all the study area. The spatial variability to temperature trends were detected by symbology process in ArcGIS software.

3. ANALYSIS AND RESULTS

3.1 Mean temperature

An alternative hypothesis involves detecting the multi-decadal mean temperature variability, One-Way ANOVA was applied to detect the mean temperature variability between the decades by comparison of the means of decades see (**Table 2**) and (**Fig. 2**) which show the variation between the means of decades and the standard error that indicates that all the variations between the decades are relatively disparate but not significant. The variation between the first decade (1960-1969) and the other three decades (1970-1979), (1980-1989), (1990-2000) is (-0.09°C, -0.15°C, -0.01°C) respectively, this indicates a decreasing in decadal mean temperature but not significantly. The third decade (1980-1989) was the coolest decade and the fourth decade (1990-2000) tending to the warming.

Table 2. *The variability of multi-decades.*

Multi-decadal Mean Temperature	
Decades	**Temperature**
D1 (1960-1969)	**22.02±0.15**
D2(1970-1979)	**21.92±0.06**
D3 (1980-1989)	**21.86±0.07**
D4 (1990-2000)	**22.00±0.09**

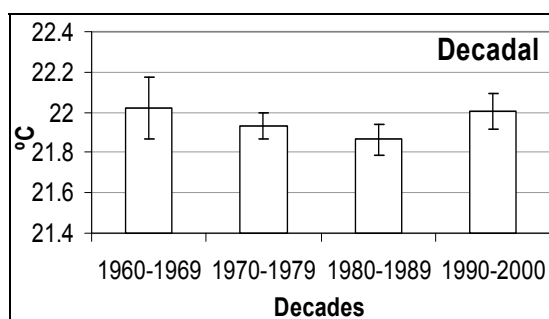Values are given as Mean± Standard Error * Significant (p< 0.05)

Fig. 2 The variation between the means of decades by Error Bars.

Fig. 3, shows the spatial interpolation of multi-decadal mean temperature for the four decades and refers to the relative homogeneity between the decades and the increasing in mean temperature in the stations which lie in southern parts and the decreasing in the northern parts from the first decade to the fourth decade but it is roughly and that may be attribute to the climatic conditions in the regional scale.
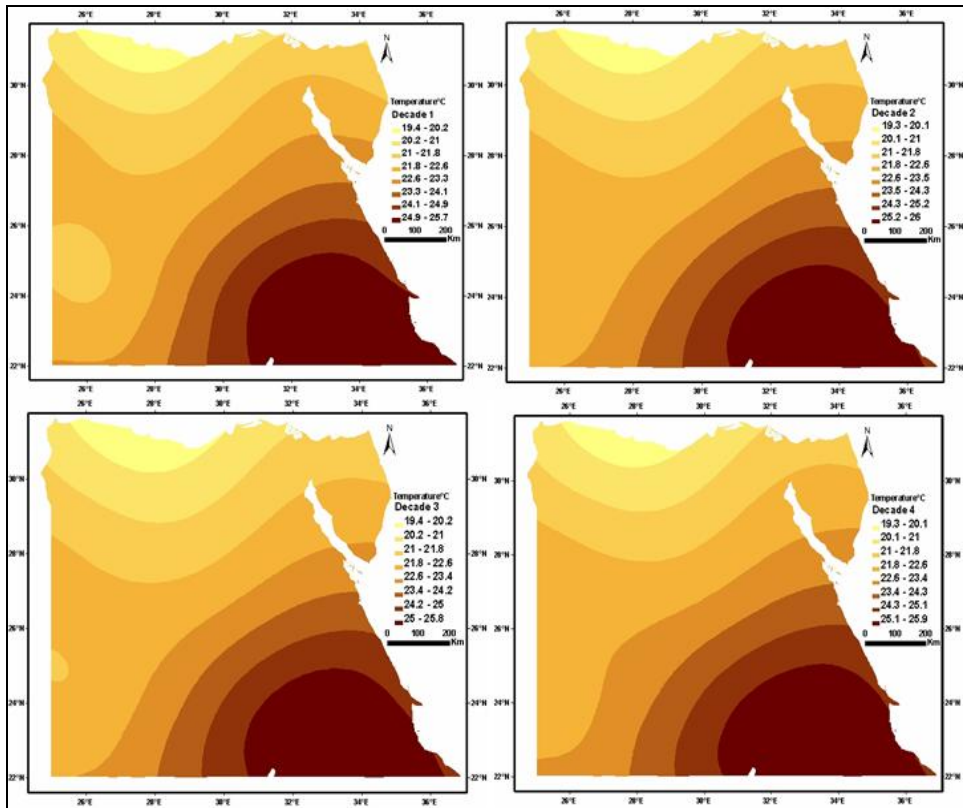
Fig. 3 Spatial interpolation for multi-decadal mean temperature in the study area from 1960 to 2000 using universal kriging method.

3.2 Multi-decadal mean temperature trends

The nonparametric Mann-Kendall test is used for detecting the trend between the decades where multi-decadal mean temperature for Egypt shows upward trend by +0.005°C/decade and shows upward trend in all decades except for the first decade (1960-1969) which shows downward trend by slope values (-0.03°C, +0.03°C, +0.01°C and +0.05°C) respectively and only the fourth decade (1990-1999) shows a significant trend at (0.05) level and the significant level for other decades is less than (0.1) as shown in (**Table 3**). Regarding the stations, disparity between the decades is shown in positive or negative values for the trend in the first three decades (1960-1696, 1970-1979, and 1980-1989) but the fourth decade, all the stations show positive values except Alexandria and El Tor which shows a negative value, see (**Table 3**) and that may be attribute to the effect of greenhouse gases.

The spatial variability of multi-decadal mean temperature trends in Egypt shows disparity for all parts where in the first decade(1960-1969) all parts of Egypt represented downward trend except for few stations which showed upward trend, in the second decade (1970-1979) all parts of Egypt represented upward trend except for few stations in the northern parts which showed downward trend, but in the third decade (1980-1989) the picture was different where the northern parts represented upward trend and the remaining

parts represented downward trend except for few stations in the southern parts which showed upward trend, and in the fourth decade (1990-1999) all parts of Egypt represented upward trend except Alexandria station in the north which showed downward trend but generally the spatial variability for mean temperature trend for Egypt showed clear upward trend in the fourth decade (1990-1999) may be due to the increase of greenhouse gases concentration which lead to the increase in global temperature which confirmed it the scenarios by IPCC, see (**Fig. 4**).

Table 3. *Slope values (ºC/decade) and Mann-Kendall test (Z) results for multi-decadal mean temperature for all Egypt from 1960 to 2000*

Time series and stations	Index Number station No.		Slope	Z	Significance	Slop values for Decades			
						Decade1 (1960-1969)	Decade2 (1970-1979)	Decade3 (1980-1989)	Decade4 (1990-1999)
Alexandria	62	318	-0.1	-1.72	+	-0.07	0.02	0.019	-0.001
Aswan	62	414	0.06	0.71		-0.04	0.05	0.05	0.03
Asyout	62	393	-0.2	-2.67	**	-0.07	-0.06	0.11	0.06
Bahariya	62	420	0.04	0.74		0.02	0.05	-0.02	0.09
Cairo	62	366	0.01	-0.08		-0.05	0.05	0.009	0.03
Dakhla	62	432	0.06	1.18		-0.02	0.09	-0.04	0.14
Damanhour	62	339	0.04	1.16		-0.003	-0.04	0.03	0.02
Damietta	62	330	0.01	0.22		0.002	-0.005	0.03	0.04
ElDabaa	62	309	0.02	0.50		-0.03	-0.02	0.03	0.05
Farafra	62	423	0.12	1.46		-0.03	0.11	-0.007	0.02
Fayoum	62	381	-0.1	-1.34		-0.1	0.06	-0.006	0.01
Hurghada	62	463	0.05	0.83		-0.03	0.06	0.03	0.01
Kharga	62	435	0.09	1.43		-0.03	0.1	-0.01	0.06
Luxor	62	405	0.05	0.82		-0.008	0.02	0.02	0.06
Mersa Matruh	62	306	-0.02	-0.55		-0.04	-0.02	0	0.08
Minya	62	387	0.04	1.01		-0.07	0.05	-0.001	0.06
Portsaid	62	333	-0.01	-0.38		-0.07	0.03	0.03	0.02
Quseir	62	465	0	0.80		-0.08	0.04	-0.006	0.01
Sallum	62	300	-0.01	-0.34		-0.03	0.03	0.02	0.04
Siwa	62	417	0.003	0.36		-0.004	0.03	0.01	0.04
Tanta	62	349	-0.14	-1.15		-0.04	0.08	-0.09	0.1
El Arish	62	336	0.01	0.19		-0.03	-0.01	-0.04	0.004
El Tor	62	459	0.01	0.22		-0.02	-0.04	-0.02	-0.004
Ismalia	62	440	0.05	0.80	*	0.02	-0.04	-0.06	0.04
Egypt			+0.005	0.50					
Decade1			-0.03	-0.72					
Decade2			+0.03	0.72					
Decade3			+0.01	0.00					
Decade4			+0.05	2.15	*				

The significance levels tested are 0.001 (***), 0.01 (**), 0.05 (*) and 0.1 (+). If the cell is blank, the significance level is >0.1
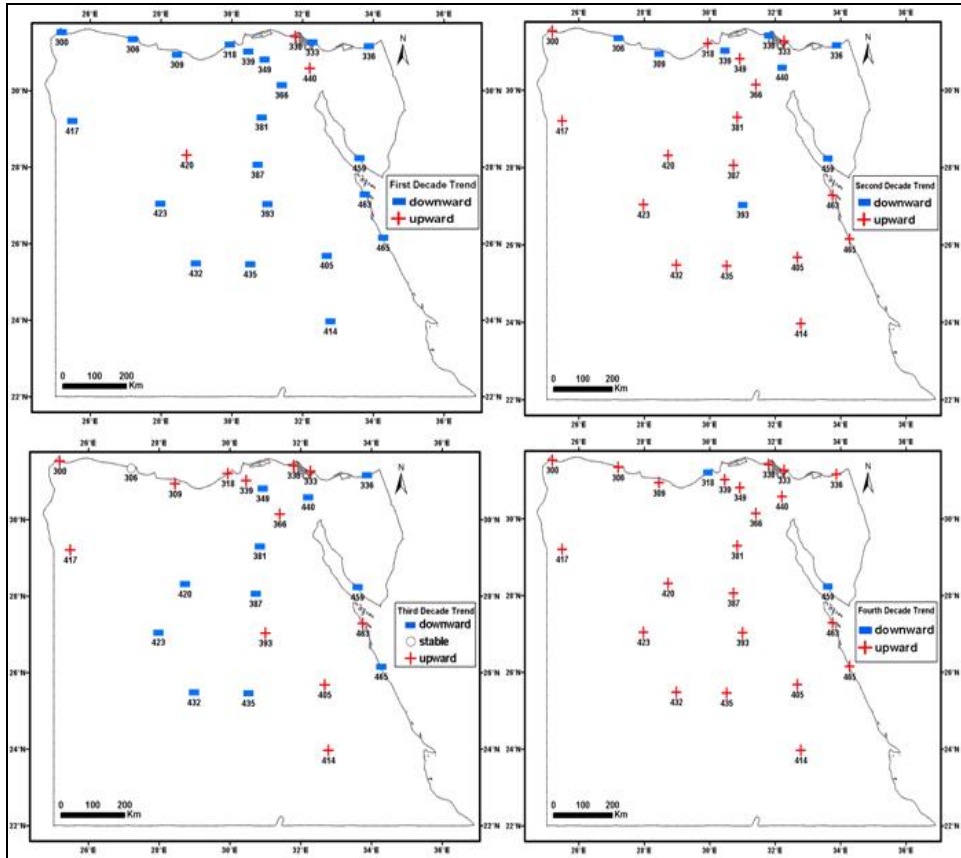
Fig. 4 The spatial variability of multi-decadal mean temperature trends at the study area relative to 1960-2000 reference period. The numbers on the maps refer to the stations number.

3.3 Minimum temperature

The variation between the first decade (1960-1969) and the other three decades (1970-1979), (1980-1989), (1990-2000) is (-0.06ºC, -0.10ºC, +0.08ºC) respectively, this shows the decrease in annual mean minimum temperature between the three decades but not significantly and the increase in the fourth decade but also not significantly as shown in see (**Table 4**) and (**Fig. 5**).

Table 4. *The variability of multi-decades*

Multi-decadal Mean Minimum Temperature	
Decades	Temperature
D1 (1960-1969)	15.48±0.14
D2(1970-1979)	15.41±0.07
D3 (1980-1989)	15.38±0.08
D4 (1990-2000)	15.57±0.08

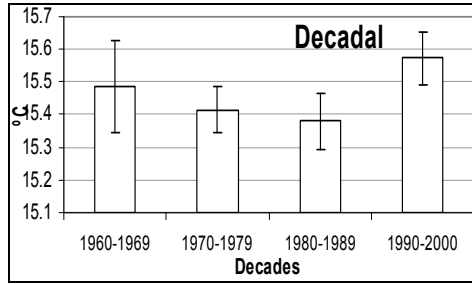Values are given as Mean± Standard Error * Significant (p< 0.05)

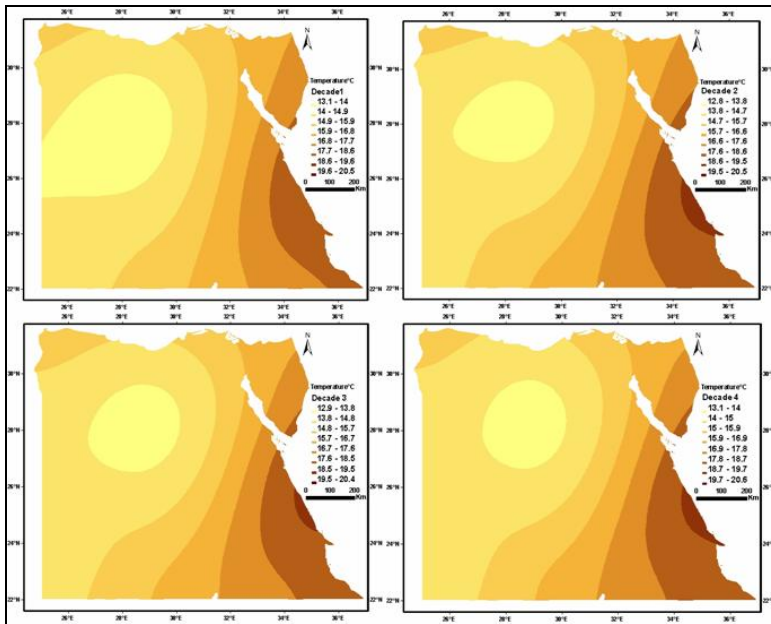**Fig. 5** The variation between the means of decades by Error Bars.

Fig. 6 Spatial interpolation for multi-decadal mean minimum temperature in the study area from 1960 to 2000 using universal kriging method.

Fig. 6 shows the spatial interpolation of multi-decadal mean minimum temperature for the four decades and indicates the relative increase in mean minimum temperature for the third and fourth decades, and that may be attributed to the increase in greenhouse gases concentrations**.**

3.4 Multi-decadal minimum temperature trends

Multi-decadal mean minimum temperature for Egypt shows upward trend by +0.03ºC/decade and shows downward trends for the first and third decades (1960-1969, 1980-1989) by slope values (-0.02ºC and -0.01ºC) respectively, and shows upward trends in the second and fourth decades (1970-1979, 1990-1999) by (+0.05ºC) for both decades and the significant level is less than (0.1) except for the fourth decade significant at (0.05) as shown in (**Table 5**) and the stations show disparity in minimum temperature trends between the decades through the positive or negative values and not constantly as shown in (**Table 5**).

The picture is completely different for the spatial variability of multi-decadal mean minimum temperature from the mean temperature which in the first decade (1960-1969) shows downward trends in all parts of Egypt except for few stations in the delta area and the southern parts with tendency to upward trends, in the second decade (1970-1979) upward trends appear in all parts of Egypt except for few stations in the northern coast for the western side with tendency to downward trends, the third decade (1980-1989) shows downward trends in all Egypt except for the northern coast and few stations in the inland areas close to the south where show upward trends, and the fourth decade (1990-1999) shows clearer upward tendency in comparison with other decades in all parts of Egypt except for few stations in the north and inland areas where show downward trends as explained in (**Fig. 7**). It is obvious from the previous results and discussion for minimum temperature that the fourth decade (1990-1999) was the warmest, may be due to the effect of greenhouse gases.

Table 5. *Slope values (ºC/decade) and Mann-Kendall Test (Z) result for multi-decadal mean minimum temperature for all Egypt from 1960 to 2000.*

Time series and stations	Index Number station No.		Slope	Z	Significance	Slop values for Decades			
						Decade1 (1960-1969)	Decade2 (1970-1979)	Decade3 (1980-1989)	Decade4 (1990-1999)
Alexandria	62	318	-0.12	-2.34	*	-0.06	-0.001	0.04	-0.02
Aswan	62	414	0.22	2.65	**	-0.02	0.09	-0.02	0.04
Asyout	62	393	-0.25	-3.30	***	-0.06	-0.1	0.08	0.06
Bahariya	62	420	0.09	1.53		0.05	0.02	-0.04	0.11
Cairo	62	366	0.05	1.04		-0.02	0.07	-0.04	0.03
Dakhla	62	432	0.07	1.27		0.02	0.06	-0.05	0.11
Damanhour	62	339	0.03	1.10		0.003	-0.04	0.018	0.01
Damietta	62	330	0.008	0.06		0.02	0.05	0.01	-0.03
ElDabaa	62	309	-0.004	0.21		0.001	-0.04	0.02	-0.03
Farafra	62	423	0.18	2.32	*	-0.03	0.12	-0.02	0.03
Fayoum	62	381	-0.19	-1.34		-0.14	0.03	-0.03	0.1
Hurghada	62	463	0.29	3.28	**	-0.02	0.17	-0.05	0.08
Kharga	62	435	0.23	2.41	*	0.11	0.14	0.02	0.005
Luxor	62	405	0.02	0.53		0.03	0.06	-0.04	0.06
Mersa Matruh	62	306	0.1	2.16	*	-0.03	-0.001	-0.001	0.09
Minya	62	387	-0.02	-0.48		-0.08	0.02	0.02	-0.02
Portsaid	62	333	-0.06	-0.52		-0.08	0.18	-0.09	0.11
Quseir	62	465	0.04	1.49		-0.07	0.05	-0.014	0.06
Sallum	62	300	-0.03	-0.78		-0.04	0.01	0.02	0.04
Siwa	62	417	0.12	2.06	*	0.025	0.07	-0.06	0.05
Tanta	62	349	-0.1	-0.93		0.008	0.09	-0.16	-0.18
El Arish	62	336	0	0.003		-0.01	0.02	0.02	0.06
El Tor	62	459	-0.01	-0.11		-0.05	0.005	0.05	0.06
Ismalia	62	440	-0.004	-0.26		-0.001	0.03	-0.002	-0.002
Egypt			+0.03	1.29					
Decade1			-0.02	-0.36					
Decade2			+0.05	1.61					
Decade3			-0.01	-1.07					
Decade4			+0.05	2.15	*				

The significance levels tested are 0.001 (***), 0.01 (**), 0.05 (*) and 0.1 (+). If the cell is blank, the significance level is >0.1
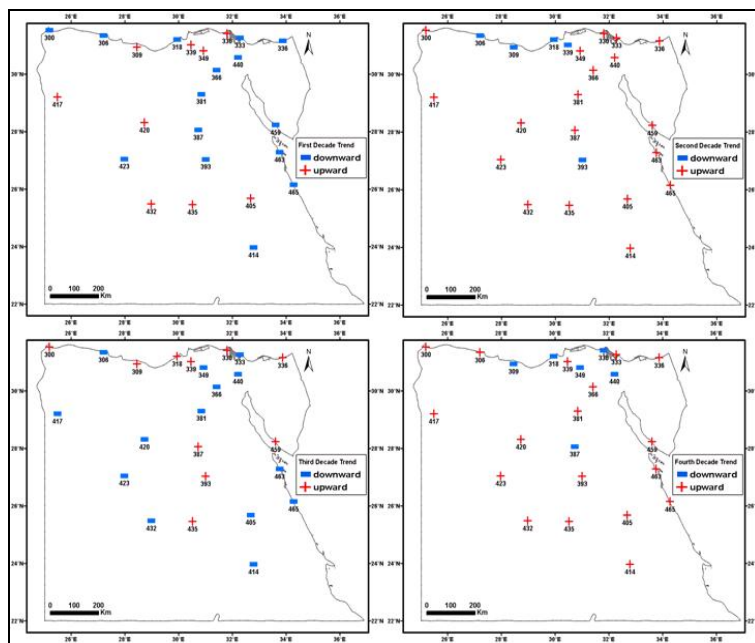
Fig. 7 The spatial variability of multi-decadal mean minimum temperature trends at the study area relative to 1960-2000 reference period. The numbers on the maps refer to the stations number.

3.5 Maximum temperature

The variation between the first decade (1960-1969) and the other three decades (1970-1979), (1980-1989), (1990-2000) is (-0.11 ºC, -0.17 ºC, -0.09ºC) respectively, this shows the decrease in the mean maximum temperature in the last three decades than the first decade but in the last three decades there is tendency to increase but not significantly. The third decade was the coolest decade and the fourth decade was the warmest decade as shown in see (**Table 6**) and (**Fig. 8**).

Fig. 9 shows the spatial interpolation of multi-decadal mean maximum temperature for the four decades and indicates the relative homogeneity between the decades and tendency to increase in the fourth decade particularly in the southern parts and that may be due to the effect of greenhouse gases.

Table 6. *The variability of multi-decades*

Multi-decadal Mean Maximum Temperature	
Decades	Temperature
D1 (1960-1969)	28.55±0.15
D2(1970-1979)	28.44±0.07
D3 (1980-1989)	28.38±0.07
D4 (1990-2000)	28.46±0.09

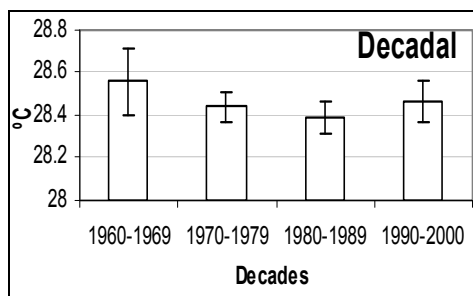Values are given as Mean± Standard Error
* Significant (p< 0.05)

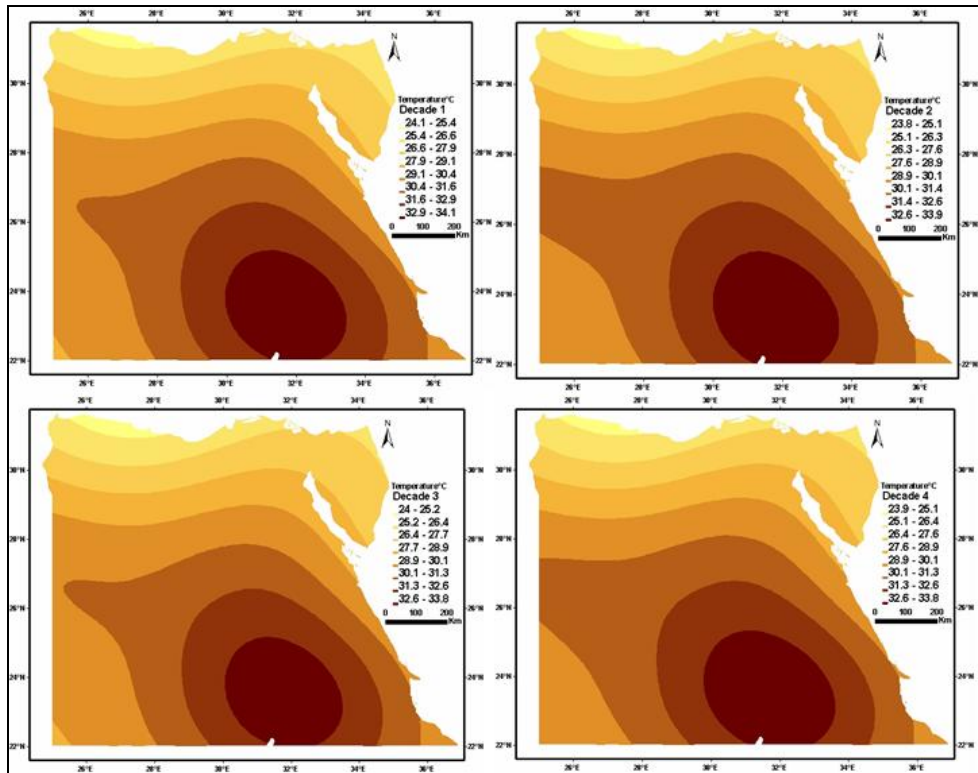**Fig. 8** The variation between the means of decades by Error Bars

Fig. 9. Spatial interpolation for multi-decadal mean maximum temperature in the study area from 1960 to 2000 using universal kriging method.

3.6 Multi-decadal maximum temperature trends

Multi-decadal mean maximum temperature for Egypt shows downward trend by -0.02ºC/decade, and shows upward trends in all decades except for the first decade (1960-1969) which shows downward trend by slope value (-0.04ºC) and the other decades (1970-1979, 1980-1989, 1990-1999) by slope values (+0.02ºC, +0.01ºC and +0.05ºC) respectively, and shows a significant level less than (0.1) as shown in (**Table 7**) may be due to the increase in greenhouse gases concentrations. Regarding the stations, they show disparity between the decades in positive or negative values for the trend as shown in (**Table 7**) where in the first decade (1960-1969) all the stations show negative values except for (Damnhour, Damietta, Kharga, Luxor, Tanta and El Arish) which show positive values, in the second decade (1970-1979) all the stations show positive values except for (Asyout, Damnhour, Damietta, Luxor, Mersa Matruh, Port Said, El Tor and Ismalia) which show negative values, in the third decade (1980-1989) twelve stations show negative values and twelve stations show positive values and for the fourth decade (1990-1999) all the stations show positive values except for (Asyout, El Dabaa, Hurghada, and Port Said) which show negative values.

The spatial variability of multi-decadal mean maximum temperature trends for Egypt shows in the first decade (1960-1969) that the downward trend prevailed in all parts of Egypt except for few stations in the Delta area and in the south upward trends appear, the

second decade (1970-1979) shows clear upward trend for all parts of Egypt except for few stations in the north and in the south where show downward trends, in the third decade (1980-1989) disparity appears between all parts of Egypt but the extreme south continues to show the upward trend, and in the fourth decade (1990-1999) the upward trend returns to cover all Egypt land except for few stations in the north and Asyout in the south as shown in (**Fig. 10**).

Table 7. *Slope values (ºC/decade) and Mann-Kendall Test (Z) results for multi-decadal mean maximum temperature for all Egypt, 1960-2000.*

Time series and stations	Index Number station No.	Slope	Z	Significance	Slop values for Decades			
					Decade1 (1960–1969)	Decade2 (1970–1979)	Decade3 (1980–1989)	Decade4 (1990–1999)
Alexandria	62 318	-0.1	-1.69	+	-0.06	0.07	-0.001	0.02
Aswan	62 414	-0.08	-0.79		-0.04	0.03	0.08	0.02
Asyout	62 393	-0.2	-2.04	*	-0.05	-0.03	0.1	-0.01
Bahariya	62 420	-0.04	-0.36		-0.01	0.04	-0.01	0.04
Cairo	62 366	-0.04	-0.20		-0.05	0.03	-0.01	0.03
Dakhla	62 432	-0.01	0.34		-0.06	0.12	-0.04	0.11
Damanhour	62 339	0	-0.19		0.02	-0.04	0.02	0.038
Damietta	62 330	-0.01	-0.05		0.01	-0.06	0.04	0.06
ElDabaa	62 309	0.06	-0.04		-0.03	0.007	-0.005	-0.005
Farafra	62 423	0.1	1.39		-0.06	0.13	-0.01	0.01
Fayoum	62 381	0.07	0.78		-0.002	0.04	0.03	0.03
Hurghada	62 463	-0.1	-1.83	+	-0.04	0.01	0.09	-0.009
Kharga	62 435	0	0.74		0.12	0.11	-0.07	0.13
Luxor	62 405	0.07	0.27		0.003	-0.002	0.04	0.07
Mersa Matruh	62 306	-0.1	-2.02	*	-0.06	-0.04	0.02	0.13
Minya	62 387	0.08	1.12		-0.08	0.06	-0.01	0.09
Portsaid	62 333	0.04	0.52		-0.039	-0.16	0.17	-0.05
Quseir	62 465	0	0.52		-0.07	0.09	-0.04	0.07
Sallum	62 300	0.03	0.80		-0.01	0.05	0.003	0.07
Siwa	62 417	-0.07	-1.35		-0.04	0.01	0.08	0.03
Tanta	62 349	-0.05	-0.34		0.09	0.07	-0.11	0.17
El Arish	62 336	0.03	0.91		0.013	0.019	0.011	0.06
El Tor	62 459	0.01	0.25		0	-0.01	-0.04	0.03
Ismalia	62 440	0.03	0.85		-0.006	-0.01	-0.03	0.03
Egypt		**-0.02**	**-0.64**					
Decade1		**-0.04**	**-0.89**					
Decade2		**+0.02**	**0.72**					
Decade3		**+0.01**	**0.18**					
Decade4		**+0.05**	**1.61**					

The significance levels tested are 0.001 (***), 0.01 (**), 0.05 (*) and 0.1 (+). If the cell is blank, the significance level is >0.1
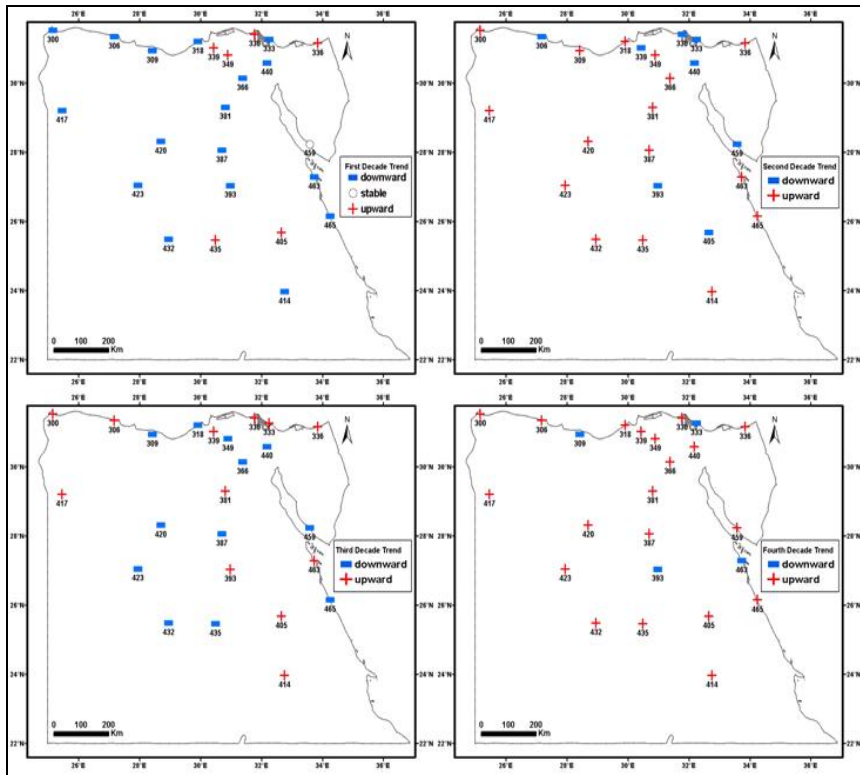
Fig. 10 The spatial variability of multi-decadal mean maximum temperature trends at the study area relative to 1960-2000 reference period. The numbers on the maps refer to the stations number.

4. CONCLUSION

The study of the multi-decadal variability for temperature trends on Egypt indicates remarkably different decadal trends over a long observation period (1960-2000), and the variation between the means of decades and the standard error that indicates that all the variations between the decades are relatively disparate but not significant. Egypt has upward trend in some variables of temperature in phase with the global trend and the previous studies on Egypt but with lower rates. There were weakly upward trends for the mean temperature over the period 1960-2000 and the fourth decade (1990-1999) was the warmest and the first decade (1960-1969) was the coolest. The minimum temperature showed upward trends over Egypt, and also the fourth decade was the warmest and that may be attributed to the increase in greenhouse gases emissions throughout the fourth decade. The maximum temperature showed downward trends but tends to be increase in the last three decades (1970-1979; 1980-1989; 1990-1999) and also the fourth decade was the warmest and the first decade was the coolest. The spatial variability showed that the southern stations have increase trend more than the northern parts and the eastern coast warmer than the northern coast for all the decades and the inland stations are not showing a regular trend which varied between positive and negative trend. The increase in temperature trends can have both direct and indirect impacts on the various activities in Egypt, so Egypt must be ready to face the likely threats.

R E F E R E N C E S

Alexandersson H., Moberg A., (1997), *Homogenization of Swedish temperature data. Part I: a homogeneity test for linear trends*. International Journal Climatology, Vol. 17 pp.25–34

Domroes Manfred, EL-Tantawi Attia, (2005), *Recent Temporal and Spatial Temperature Changes in Egypt*, International Journal of Climatology 25, Royal Meteorological Society, 51–63pp.

Douglass David, Christy H., John R., Pearsona Benjamin D., Singerc Fred S., (2007), *A comparison of tropical temperature trends with model predictions*, International Journal of Climatology, Vol. 28, Issue 13, pp.1693-1701 DOI: 10.1002/joc. Published online in Wiley InterScience (www.interscience.wiley.com)

Egyptian Environmental Affairs Agency (EEAA), (1999), *The Arab Republic of Egypt: Initial National Communication on Climate Change*, Prepared for the United Nations Framework Convention on Climate Change UNFCCC, June 1999, pp.119

Hansen J., Ruedy R., Glascoe J., Sato M., (1999), *GISS analysis of surface temperature change*. NASA Goddard Institute for Space Studies, New York, Published by the American Geophysical Union, Paper Number 1999JD900835

Hansen J., Sato M, Ruedy R., Lo K, Lea D.W., Medina-Elizade M., (2006), *Global temperature change*. PNAS 103, no. 39, pp.14288–14293 available at: http://www.pnas.org/content/103/39/14288.full.pdf

IPCC, (2001), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 83pp.   Available at URL: http://www.ipcc.ch

IPCC, (2007), *Climate Change 2007: The Physical Science Basis. Contribution of Working GroupI to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available at URL: http://www.ipcc.ch/ipccreports/ar4-wg1.htm

Jones P.D., Parker D.E., Osborn T.J., and Briffa K.R., (1999), *Global and hemispheric temperature anomalies land and marine instrument records. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center*, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, TN, USA.

Michaels Patrick J., Balling Robert C. Jr., (2009): *Climate of extremes: global warming science they don't want you to know*, Cato Institute, Washington, D.C., USA, pp.267.

Robaa S.M., (2008), *Evaluation of sunshine duration from cloud data in Egypt*, Energy 33, PP. 785–795 available at www.elsevier.com/locate/energy

Stepanek P., (2008): *AnClim - software for time series analysis*. Department of Geography, Faculty of Natural Sciences, Masaryk University, Brno. **Available at** http://www.climahom.eu/ACDownload.html

UNFCCC, (2006), *Background paper on Impacts, vulnerability and adaptation to climate change in Africa*, for the African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention, Accra, Ghana, 54pp.

http://www.climate.org/CI/africa.shtml