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Analysis of Summer Temperature Anomalies in Egypt during the 20th Century

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Abstract: Summer surface air temperature anomalies over Egypt have been studied using data obtained from 13 different monitoring stations during different periods of time starting from 1870's till 2007. Three groups are constructed. The groups are; North Group (NG), South Group (SG), Desert Group (DG), in addition to Cairo station. Two phase analysis are applied to all monitoring stations. One deals with each station separately and the other with stations groups. Trend analysis is performed using both data segmentation as well as whole record concept. Our results show that, the temperature at North of Egypt is raised with a value of 1.05°C during summer season in the last century. Meanwhile, at South a nonsignificant, very low warming trend is observed during the same period. Cross-correlation analysis is applied between sunspot number and temperature anomalies for each group. Negative correlations are found and the effect of 11 year cycle appears in all correlation panels. Power spectral analysis is performed to the anomalies. This analysis declares short and long period oscillations as well as Gleissberg period.

Key words: Climate changes, cooling, warming, oscillations, cross correlation sunspots

INTRODUCTION

Climatic changes have been identified as the cause of several long-term alterations of ecological processes (Walther *et al*., 2002). Near surface, air temperature changes have been the subject of research for many years. Temperature distribution in Africa which lies largely within the tropics is determined mainly by altitude. Qun (2001) examined the abrupt change of summer climate occurring in east China. He concluded that the change in climate is mainly due to the pollution resulting in the accelerating industrialization through mainly using coal in East China. Oliver (2002) described a simple method for calculating circulation indices by using gridded data of mean sea level pressure in Estonia. Feidas *et al*. (2004) studied trends of annual and seasonal surface air temperature time series for 20 stations in Greece. They also studied the relationship between temperature variability and atmospheric circulation using correlation analysis. Jones *et al*. (2006) investigated the global and hemispheric temperature anomalies-land and marine instrumental records. They discussed different data trends through the period of investigation from 1856 till 2005.

The correlation between sunspots and temperature is always regarded as negative relationship. Also, the sign of the correlation depends on the period studied and not on the location. According to recent publications, solar activity forcing may share from one third to half of the observed global heating, (Lean *et al*., 1995; Ring *et al*., 2002; Cliver *et al*., 1998). Throughout their researches, they had found that the decadal averages of surface temperature are highly correlated with solar activity from 1881 to 1990. Javaraiah *et al*. (2005) studied the long-term variations in solar differential rotation with the strength and length of the sunspot activity cycles and found two Gleissberg cycles with different strengths.

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The aim of this study is to investigate the temperature anomalies in Egypt during the last century for summer season. Trends as well as temperature behaviour are examined and calculated. Moreover, both spectral analysis and cross correlation techniques are applied to investigate the influence of the solar activity on temperature. We deem it is essential to conduct such analysis on the Egyptian temperature because of its paramount importance in the follow-up protection necessary to archaeological treasures, investigating the dependence of the global warming on the changes in local climate and also for humans to adapt with the new climatic conditions.

MATERIALS AND METHODS

Map of Egypt and Data Used

Figure 1 shows the locations of stations. The climatic conditions of the stations are totally different from each other due to the diversity of the neighborhoods of the Egyptian boarders. The boarders' nature varies among the Mediterranean sea at North, Red sea at East and the desert at both West and South. Stations' information are shown in Table 1.

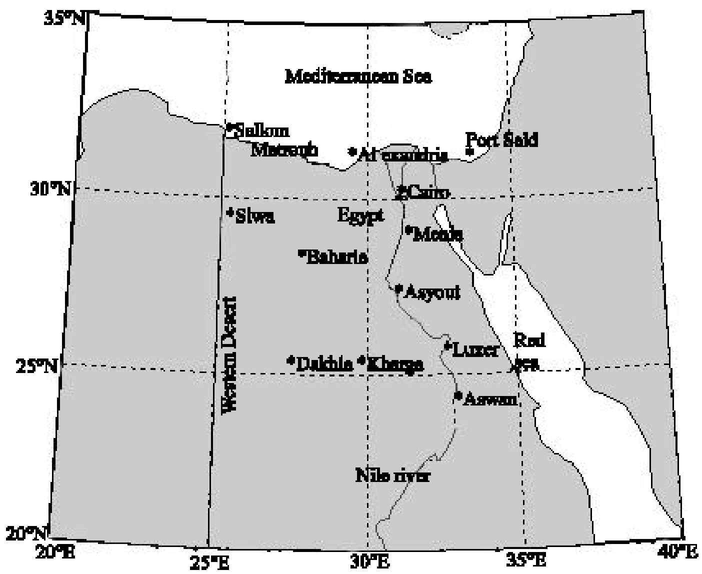

Fig. 1: Map of Egypt showing location of monitoring stations

Table 1: Data of monitoring stations

Station	Period	Latitude	Longitude
Cairo	1904-1995	30.01 N	31.14 E
Alexandria (Alex)	1870-2005	31.13 N	29.58 E
Matrouh	1950-2006	31.19 N	27.09 E
Port Said	1945-1980	31.16 N	32.18 E
Sallom	1951-1976	31.32 N	25.90 E
Menia	1945-1980	28.07 N	30.33 E
Asyout	1902-1978	27.11 N	31.04 E
Luxor	1941-1974	25.41 N	32.38 E
Aswan	1951-2006	24.04 N	32.57 E
Kharga	1951-1980	25.30 N	30.33 E
Dakhla	1951-1991	25.30 N	28.50 E
Baharia	1951-1980	28.30 N	28.90 E
Siwa	1951-1980	29.11 N	25.31 E

Summer average (June-August) has been obtained for each of the 13 stations and their temperature anomalies have been calculated referenced to the period (1951-1980). Here, we decided to classify the 13 considered stations according to their locations. As a result, three groups are produced, rather than Cairo, based on the nature of the areas they are located in. The first group is the North Group (NG) conducted through taking the average of four stations located at North Alexandria, Port Said, Marsa Matroh and Sallom. These stations have mediterranean climate. The second group is the South Group (SG) that located at south including Menia, Asyout, Luxor and Aswan. This group is also known to lie in Upper Egypt which represents the hottest area on the Nile river sides in Egypt. The third group named Desert Group (DG) containing Dakhla, Kharga, Baharia and Siwa, located in the Western desert. Some gaps, which are always short, are found in the data. To minimize errors resulting in such gaps, an interpolation program applying series mean interval process is applied to replace the missing readings with interpolated ones.

RESULTS AND DISCUSSION

North

Figure 2a-d show patterns of surface air temperature time series anomalies for the North stations. The data available from these stations cover periods of time ranging from 30 years period in Sallom, 40 years for Port Said, 60 years for Matrouh and finally 125 years in Alexandria. This range at North of Egypt can supply us with an excellent view about the temperature changes during the last century. Examining data of Alexandria (Alex), it's found that before the start of the 20th century data stability was noticed below the average value. In the start of the 20th century, 1903, sudden cooling of -1.93°C

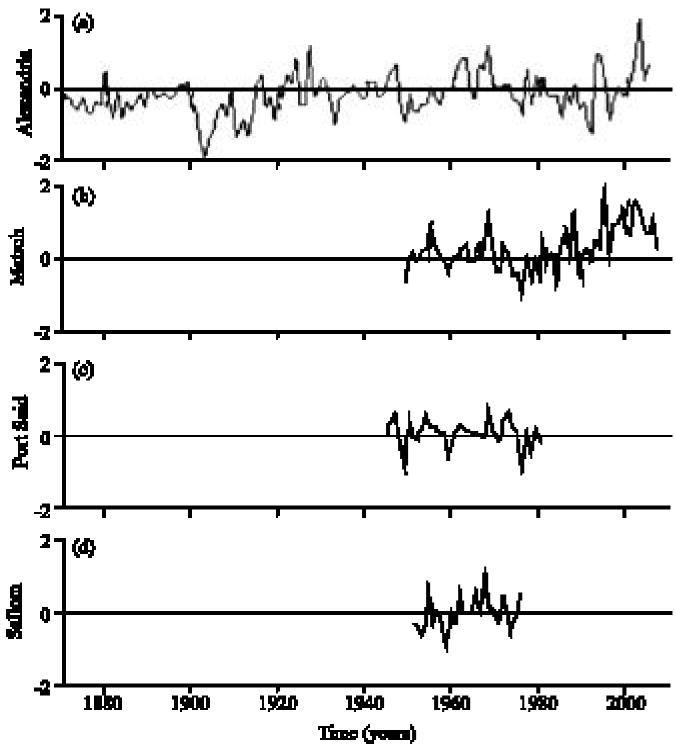

Fig. 2: (a-d) Surface air temperature anomalies for separate stations at North of Egypt

Table 2: Warming and cooling events for Alexandria station, North group and South group

Variables	Trend type	Trend period	Trend coefficient in °C/10 years	Significance
Alexandria	Warming	1904-1959	0.10	0.020
	Cooling	1960-1989	-0.31	0.001
	Warming	1990-2005	0.89	0.030
North group	Warming	1904-1927	0.64	0.000
	Cooling	1927-1949	-0.10	0.400
	Warming	1949-1968	0.39	0.004
	Cooling	1968-1989	-0.14	0.300
	Warming	1990-2007	0.66	0.005
South group	Cooling	1924-1943	-0.35	0.040
	Warming	1943-1956	0.76	0.016
	Cooling	1956-1984	-0.29	0.010
	Warming	1984-2007	0.69	0.001

below the average occurs. After that, a trend follow up was disposed for the temperature readings and successive prominent ones are detected and registered in Table 2.

Turning to Matrouh station we found a significant cooling event of -0.18/10 years in the period 1950-1980 followed by high significant warming event from 1981 till 2007 having a value of 0.38/10 years. When the whole data was treated as one segment from 1950 to 2007, a very high significant warming trend having a value of 0.16°C /10 years is traced. The observatory at Port Said supplied the following 2 sudden cooling events which were shown during 1949 and 1976 reaching values of -0.92 and -0.95°C, respectively below the average. Also, non significant cooling having a value of -0.04°C/10 years is shown when the whole period is considered. Finally, Sallom station shows a low, significant warming event of 0.21°C/10 years. Figure 3 shows the change in surface air temperature anomalies for North group. From 1903 till 2007, when the data is regarded as one segment, a highly significant warming trend of coefficient 0.10/10 years is detected. The trend measurements during this period show that during the last century the temperature at north has been raisin by 1.05°C. In this, our opinion, may be interpreted due to the human activities which contributed to a great extent in this temperature rise at civilized north. This result is in consistence with those obtained by Colin *et al*. (1999) during their analysis for Cyprus climate. When data is segmented, a series of warming and cooling trends are traced and recorded in Table 2.

South

Figure 4a-d show panels of surface air temperature anomalies for stations at South. All stations display significant cooling trends with different rates from early 50's till late 70's. Luxer and Asyout have coefficient values of -0.44°C/10 years and -0.26°C/10 years, respectively. Menia shows a stable temperature profile during the whole period of record. At Aswan, an obvious cooling is traced during the period 1951-1984 with 0.34°C/10 years followed by reversal warming trend of 0.58°C/10 years through 1985-2007 showing the presence of cyclic influence in the temperature readings. Figure 5 shows surface air temperature anomalies for South group. A series of warming and cooling events are traced and registered in Table 2.

Desert

Figure 6a-d represent surface air temperature anomalies for desert stations. Dakhla shows high significant cooling trend of -0.47/10 years during the period 1951-1980 while, Siwa shows high significant cooling trend having coefficient of -0.3/10 years for the same period of time. Kharga and Baharia show warming events of 0.36°C/10 years and 0.15°C/10 years, respectively for the period 1951-1979. Figure 7 shows surface air temperature anomalies for desert group. A significant cooling

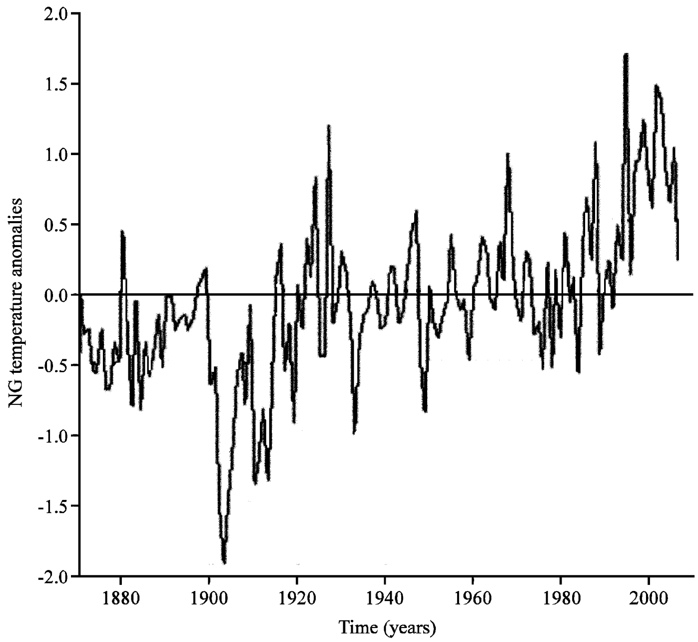

Fig. 3: Surface air temperature anomalies for North group

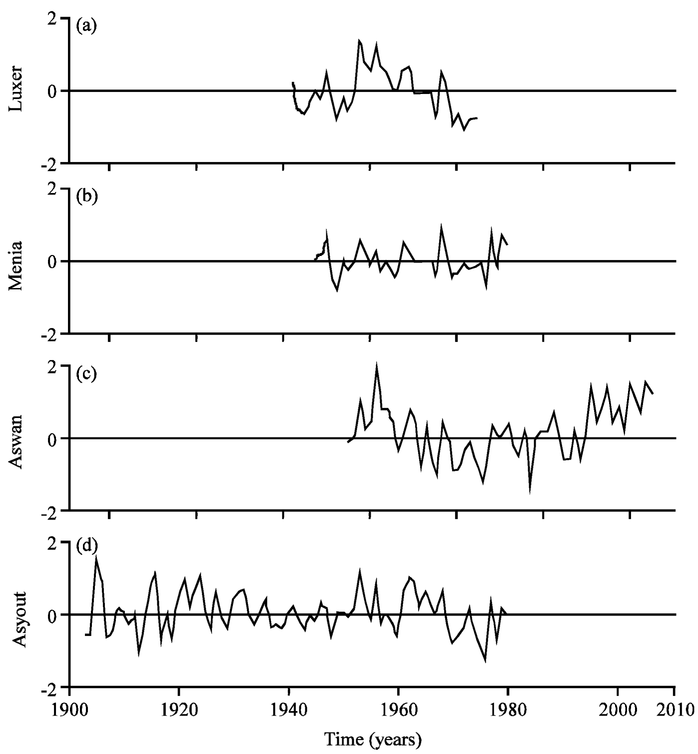

Fig. 4: (a-d) Surface air temperature anomalies for separate stations at South of Egypt

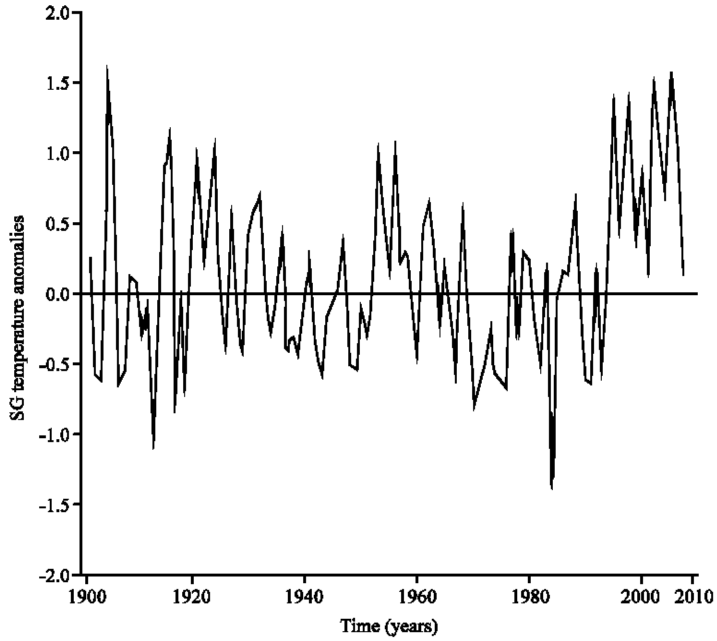

Fig. 5: Surface air temperature anomalies for South group

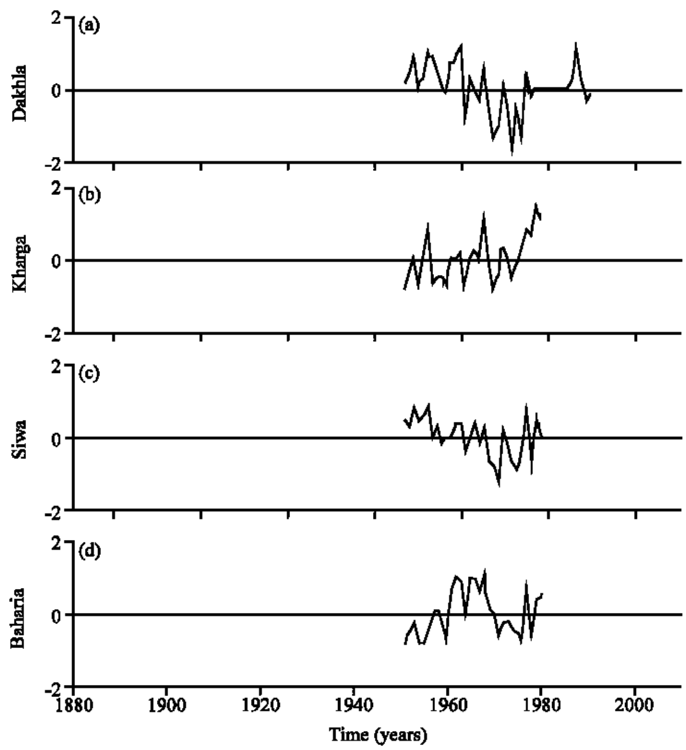

Fig. 6: (a-d) Surface air temperature anomalies for separate station at desert of Egypt

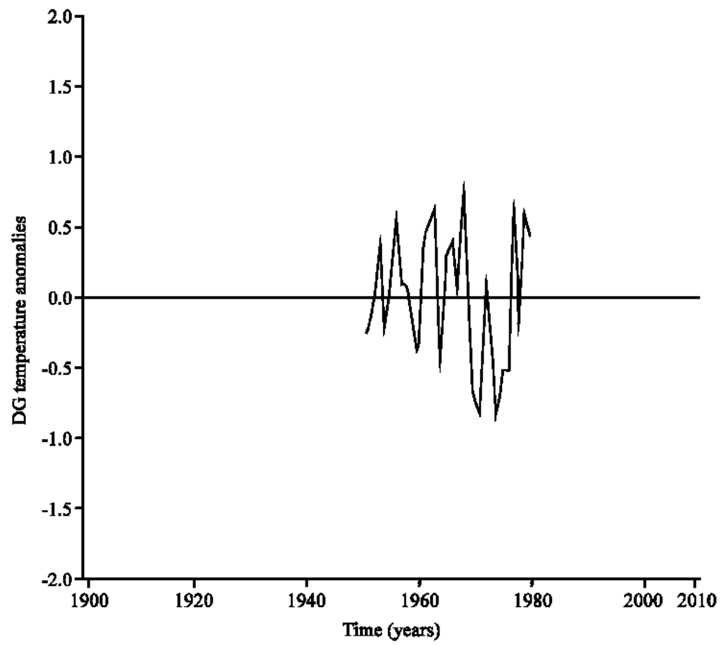

Fig. 7: Surface air temperature anomalies for desert group

having a value of -0.23°C/10 years for the period 1951-1976 followed by non-significant warming of 0.17°C/10 years during the time interval 1977-1991 are detected.

Cairo

Figure 8 shows surface air temperature anomalies pattern for Cairo. A reversal significant warming followed with cooling trend having values of 0.33°C/10 years and -0.09°C/10 years for the periods 1904-1930 and 1931-1984, respectively are detected. This is followed by rapid warming till the temperature reaches a value of 1.59°C above the average in 1988 which is considered the highest temperature recorded then.

Spectral Analysis

Spectral analysis of the data is carried out. Oscillations with different periods are identified. Short period variations with periods ranging from 2 to 7 years are detected as well as long period oscillations which range from 10 to 30 or 80 years. All data series were filtered and detrended in order to detect the effect of solar signals with them.

Figure 9a-d show spectral analysis results for surface air temperature anomalies for North, South, desert groups and Cairo, respectively. Analyzing the spectrum resulting from North group panel, (Fig. 9a) we found peaks of long period oscillations having lengths of 77.0 and 25.0 years. The long term peak of 77.0 years can be interpreted as originating from changing conditions on the sun. More specifically, it can be assigned to the Gleissberg period (Gleissberg, 1944; Reichel *et al*., 2001). The peaks at 2.5, 2.3, 2.2, 2.1 and 2.0 years can be related to the Quazi Binal Oscillations (QBO) (Maravilla *et al*., 2004) and the peak at 4.0 years is associated to the magnetic flux emergence, interplanetary shocks and cosmic ray flux. Peaks at 9.1, 7.9 and 5.0 years could be harmonics of the 11 years sunspot cycle. For South group, (Fig. 9b) a long term peak of 33 years is detected as well as short term peaks of 7.5, 3.8, 2.9, 2.8, 2.2 and 2.1 years. The peak of 7.5 years may be considered

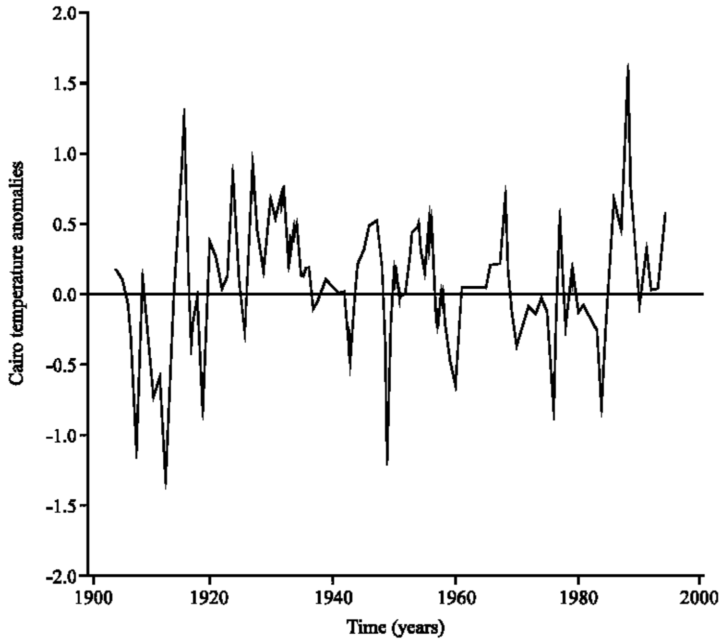

Fig. 8: Surface air temperature anomalies for Cairo

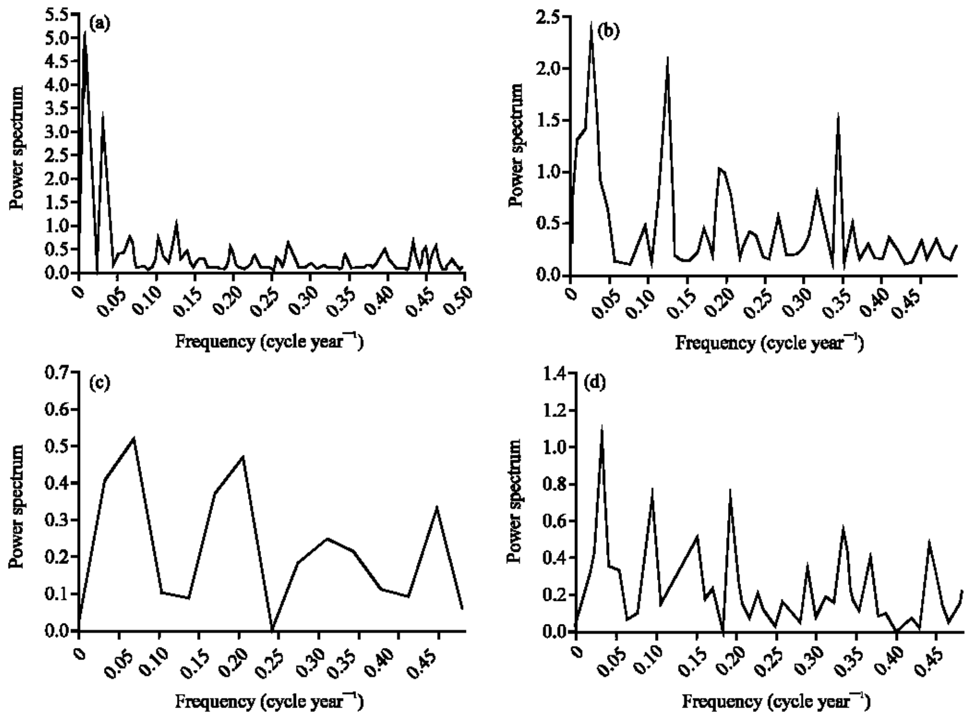

Fig. 9: Spectral analysis for surface air temperature anomalies, (a) North, (b) South, (c) desert group and (d) Cairo

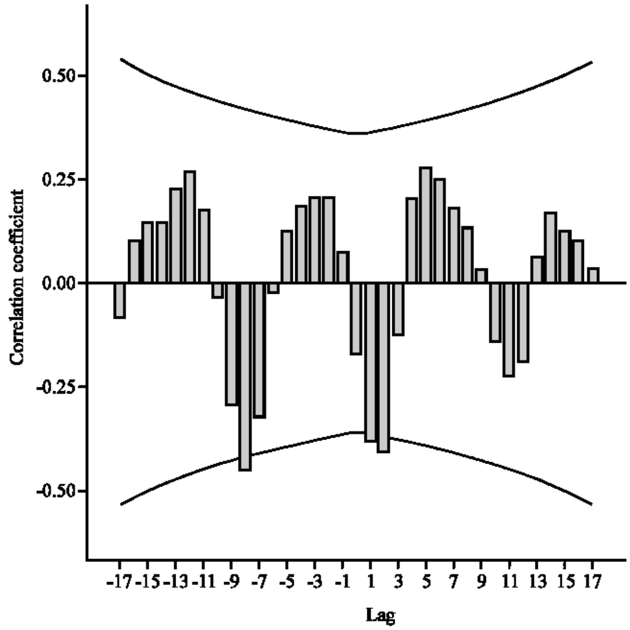

Fig. 10: Cross correlation diagram between sun spot No. and surface air temperature anomalies at North during the period 1935-1965

as a harmonic of the 11 years sunspot cycle. Peaks obtained at 2.5, 2.3, 2.2, 2.1 and 2.0 years can be linked to the QBO. At desert group, (Fig. 9c) peaks of 14.2, 5 and 2.2 years are detected. The first peak can be assigned to the 22 solar cycle and the 5.0 years peak can be a harmonic of the 11 years sunspot cycle and finally, the 2.2 peak may be related to QBO. Figure 9d shows a cycle of length 33.3 years well as a series of short oscillations having ranges of 11, 6.7, 5.0, 4.3, 3.3, 2.9, 2.7 and 2.2 years for Cairo station.

Cross Correlation between Sunspot Number and Temperature at Different Groups

Cross correlation analysis between sunspot number and surface air temperature anomalies are performed. Segmentation process took place during cross correlation calculations to search for the best correlations among data with its corresponding sunspots. It is well known that the sign of the correlation depends on the period studied (Georgieva *et al*., 2005). The time series for groups were splitted into different periods of time so the highest impact for the solar sunspots on temperature would be obtained.

Figure 10 shows cross correlation pattern between sunspot number and surface air temperature anomalies for North group. A negative correlation to sunspot number is detected during the period from 1935 till 1965 with coefficient r = - 0.4 at lag 2 years. Figure 11a and b show cross correlation patterns between sunspot number and surface air temperature anomalies during the shown periods for South group. As shown in Fig. 11a, negative correlation for the period 1935-1965 is detected for one lag. Figure 11b shows negative correlation during the period 1966-2007 with coefficient r = 0.3 for two lags. Figure 12 shows cross correlation pattern between sunspot number and surface air temperature anomalies for desert group. A positive correlation is found between the sun spots and the temperature anomalies during the period 1950 till 1981 with coefficient r = 0.36 for a delay of 3 years. Figure 13a and b show cross correlation patterns between sun spots and surface air temperature anomalies for Cairo station. Figure 13a, shows a negative correlation for the period 1935-1965 with coefficient

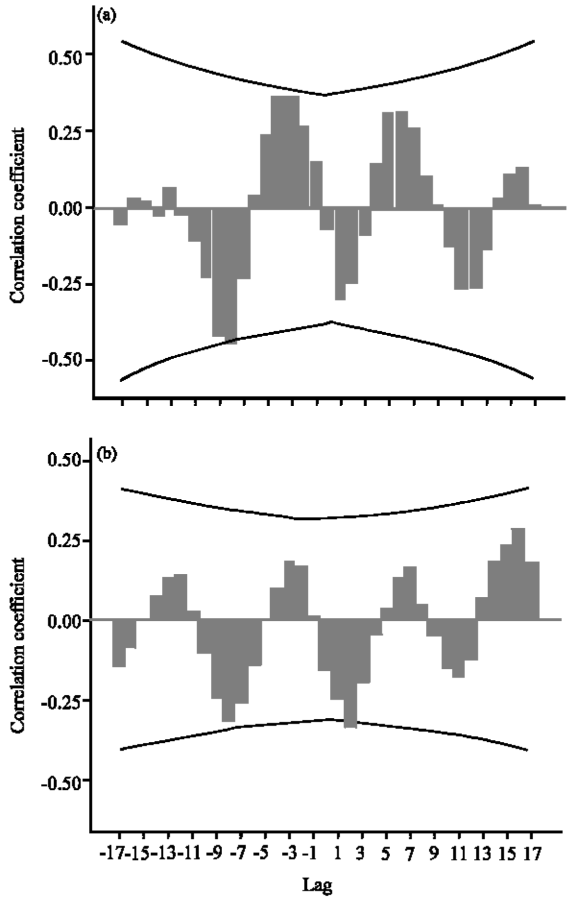

Fig. 11: Cross correlation between sun spot No. and air temperature anomalies at South during the period: (a) 1935-1965 and (b) 1966-2007

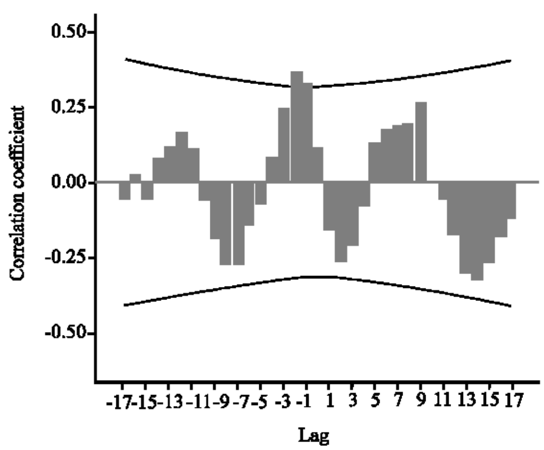

Fig. 12: Cross correlation diagram between sunspot No. and surface air temperature anomalies for desert during the period 1951-1981

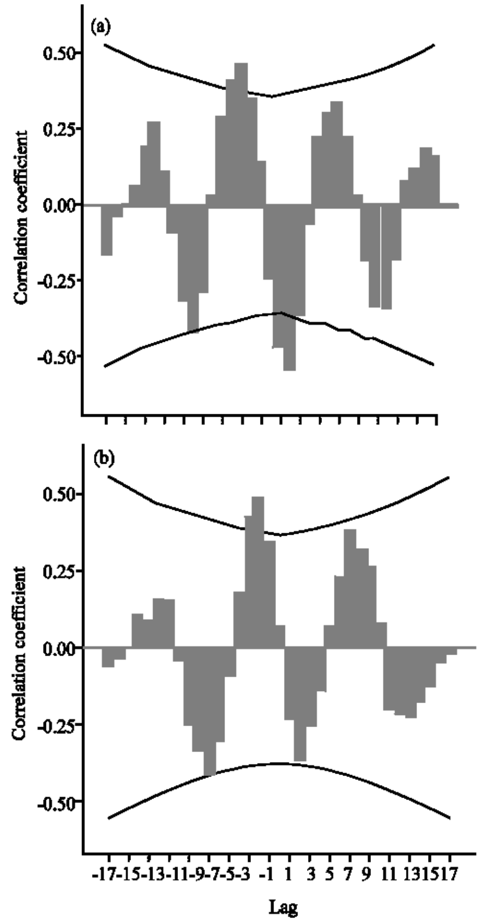

Fig. 13: Cross correlation between sunspot No. and surface air temperature anomalies of Cairo during the period (a) 1935-1965 and (b) 1966-1995

r = -0.56 for two lags. Also, Fig. 13b shows a positive correlation for the period 1966-1995 with coefficient of r = 0.47 for a delay of 2 years. The effect of 11 year cycle appears almost in all groups. Almost all correlation coefficients are negative indicating that maximum temperatures occur at minimum sunspots during the period under study.

Generally, the cross correlation study has shown that the correlation between the sun spot with surface air temperature anomalies is negative at North and South groups as well as at Cairo. Also, the correlation depends on the elected period of time. This result is in consistence with the results obtained by many researchers all over the world (Mendoza *et al*., 2001; Georgieva *et al*., 2005; Dimitar, 2006).

CONCLUSION

Climate in Egypt has been investigated using long term time series surface air temperature anomalies. Present results show that, the temperature at North of Egypt is raised with a value of 1.05°C during the last century. Meanwhile, at south a nonsignificant, very low warming trend is observed during the same period, retrieving the temperature level to the value registered at 1900's. Same sequential cyclic patterns of warming and cooling at almost same periods of time are observed at both North and South showing the effect of solar activity. Spectral analysis is performed on the data leading to the discovery of the influence of short and long period oscillations as well as Gleissberg period. Cross correlation study is performed between sun spot number and temperature anomalies showing that the effect of solar activity on temperature anomalies is negative. Also, the correlation depends on the period of time elected from the whole record of data available. The effect of 11 year cycle appears in all correlation panels especially that of Cairo where its coefficient reaches a value of 0.56. We deem that the Egyptian climate must be always put under investigation and consideration due to many facts: firstly, the supreme location of this country in both North Africa and its partial location Asia. Secondly, the paramount archeological treasures on its land as well as the effect of the climatic changes on life style and development processes taken by officials.

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