Influence of circulation indices upon winter temperature variability in Egypt

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ABSTRACT

Trends of winter surface air temperature anomalies, WSATA, are investigated using data obtained from 13 monitoring stations. The analysis is performed in two steps; one deals with separate stations independently and the other deals with stations’ groups. Groups’ anomalies are correlated to circulation indices showing negative correlation between temperature with North Atlantic Oscillations and positive one with Mediterranean Oscillation Index. Both power analysis and frequency distribution analysis are applied. The results show existence of Schwabe, Hale and Gleissberg cycles and declare that there are no critical thermal changes of climate in Egypt. It is concluded that the temperature changes during the past three decades are not only because of the human activity but the extraterrestrial impacts as well.

1. Introduction

Climate changes have been given a great attention by different countries and governments all over the world. They are thought to be as a result of natural processes and human interference as well. Of all climatic elements, temperature plays a major role in detecting climatic changes brought about by urbanization and industrialization. Therefore, monitoring needs to be taken regularly so that naturally different climatic cycles as well as long term trends are to be recorded and identified. Many circulation indices such as North Atlantic Oscillation, NAO; ELNino, Southern Oscillation Index, SOI and the Mediterranean Oscillation Index, MOI are expected to play a major role in explaining the variability of surface air temperature. Also, they are believed to be related to the distinct climatic and geographic characteristics of the place of investigation. Regarding NAO in its positive phase for the northern European coast, both the low pressure zone over Iceland and high pressure over the Azores are intensified, resulting in changes in the strength, incidence, and pathway of winter storms crossing the Atlantic. In a negative phase for the Mediterranean coast, a weak subtropical high and weak Icelandic low results in fewer and weaker winter storms crossing in more west–east pathway. Over local and regional scales, the recent patterns of temperature changes have been shown to be linked to various phases of atmospheric–oceanic oscillations. MOI is defined as the standardized geo-potential height difference between north-eastern Atlantic and central Mediterranean and is highly correlated with the salinity in the Adriatic Sea (Suplic et al., 2004). In our work we used the MOI data based on the difference in pressure between Algiers and Cairo. Valcav (2002) examined the causes leading to global mean sea surface temperature, GT, variability with variations of the global circulation including NAO and ElNino, EN. He showed that both EN as well as NAO events can be identified in the variability of GT. Kay et al. (2007) investigated the relation of sea surface height, SHH, in the Mediterranean Sea with numerous atmospheric circulation indices. They found a negative correlation between NAO and SHH in the western part of the Mediterranean Sea. Ryan and Sethu (2003) showed that the temperature patterns in north Carolina are in phase with NAO and the temperature during the last 10 years are warmer than average. Grbce et al. (2007) showed that two long-scale atmospheric indices NAO and MOI are correlated to the Adriatic climate. Hatzaki et al. (2006a, b) made attempts to investigate the existence of the Eastern Mediterranean teleconnection pattern, EMP, as a component of the low frequency atmospheric circulation at the upper levels in the future climate. Their results helped to redefine the index for future scenarios and to further capture the intensity of pattern changes. Hansen et al. (2006) estimated temperature analysis for seasonal and longer time scales at middle and high latitudes. They found out, using the teleconnection approach that, 2005 is to be the warmest year. Also, they concluded that, the global warming is a real climate signal and not an artifact due to measurements in urban areas. Atsamon and Joaquim (2008) examined surface air temperature during the period 1951–2003 to determine the dominant patterns of inter annual and longer period variability and illustrated their connection to large-scale climate variability.

Our objectives throughout this work are to investigate the inter-decadal variability and trends of winter surface air temperature anomalies, WSATA. Also, to recognize the leading periodicities that are hidden within the data and their probable origin as well, and
finally establishing circulation indices-time series correlations referenced to the adopted periods.

2. Nature of climate in Egypt

In the north of Egypt, the Mediterranean Sea is located while the Red Sea lies to east. Western Sahara is in the west and the Nile River flows penetrating it from south till it ends in north where it joins the Mediterranean Sea. The main differences between seasons in Egypt are the variations in daytime temperature and changes in prevailing winds. In coastal regions at north, the Mediterranean climate prevails and the temperature has a maximum value of 18 °C and a minimum value of 8 °C. In the south of Egypt, the temperature has a maximum value of 23 °C and a minimum value of 7 °C. The temperature in the desert has a minimum of 2 °C and a maximum of 30 °C. Throughout the Delta and the northern Nile Valley, there are occasional winter cold spells accompanied by light frost.

3. Materials and method

3.1. Map of Egypt and data used

As shown in Fig. 1, Egypt lies in the south of the Mediterranean basin, between longitude 20°E:35′E and Latitude 20°N:32′N. The climatic conditions of the stations are totally different due to the diversity of the neighborhoods of the Egyptian borders, where the Mediterranean Sea is in the north, Red Sea is in east and the Desert in west. The data used for NAO, SOI and MOI in this study are taken from NOAA data base archive at the following sites: http://www.cpc.ncep.noaa.gov/wd52dg/data/indices/, http://www.bom.gov.au/clim/ and www.cru.uea.ac.uk/data/moi, respectively.

Throughout this study, temperature data for 13 different monitoring stations distributed all over Egypt have been used. These data are obtained from Global Climate Observing System, national climatic data center, NCDC and are presented on the site http://www1.ncdc.noaa.gov/pub/orders/CDO9582701319562.html. The specifications of monitoring stations are listed in Table 1. The time series represented by the temperature data extends from 1870 for Alexandria station and lasts till 2005 forming a 135 years time series. For other stations, the time series range from 4 to 8 decades. The normal definition for winter time at the longitude and latitude considered here starts on December till February and the average of those three months is calculated. The data trends are calculated as temperature changes in degrees Celsius per decade. A temperature anomaly could be expressed as the difference between low or high temperature measured at one station on one date and an average temperature recorded by the same station for a certain period of years. Such period is called ‘reference period’, which is chosen such that it almost contains equal positive and negative temperature fluctuations. This, in turn, leads to minimum linear trend, which is almost zero making this period an ideal one to represent a reference period. Therefore, following this principle, we calculated the temperature anomalies for each station with reference to the period 1951–1980.

3.2. Description of the observing stations

Land based observation stations using mercury-in-glass thermometer having a scale markings with an increment of 0.2 °C. A support keeps it in a vertical position with its cylindrical shaped bulb at the lower end. The thermometer is placed in a standard wooden shelter at a height ranging between 1.5 and 2.0 m above ground level to ensure its position is at true air temperature. This sheltering protects the thermometer from precipitation while allowing the free circulation of air around it and also prevents accidental damage. The observed air temperature is representative for the free air surrounding the station’s site. This is guaranteed since the thermometer is freely exposed to sunshine, wind and not

<table>
<thead>
<tr>
<th>Station</th>
<th>Period</th>
<th>Latitude (°N)</th>
<th>Longitude (°E)</th>
<th>Elevation (m)</th>
</tr>
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<tbody>
<tr>
<td>1 Cairo</td>
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<td>30.01</td>
<td>31.14</td>
<td>33</td>
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<tr>
<td>2 Alexandria (Alex)</td>
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<td>29.58</td>
<td>7</td>
</tr>
<tr>
<td>3 Matroh</td>
<td>1949–2007</td>
<td>31.19</td>
<td>27.09</td>
<td>28</td>
</tr>
<tr>
<td>4 Port Said</td>
<td>1945–1980</td>
<td>31.16</td>
<td>32.18</td>
<td>6</td>
</tr>
<tr>
<td>5 Sallom</td>
<td>1951–1976</td>
<td>31.32</td>
<td>25.9</td>
<td>6</td>
</tr>
<tr>
<td>6 Menia</td>
<td>1945–1980</td>
<td>28.07</td>
<td>30.33</td>
<td>40</td>
</tr>
<tr>
<td>7 Asyout</td>
<td>1902–1978</td>
<td>27.11</td>
<td>31.04</td>
<td>52</td>
</tr>
<tr>
<td>8 Luxor</td>
<td>1941–1974</td>
<td>25.41</td>
<td>32.38</td>
<td>99</td>
</tr>
<tr>
<td>9 Aswan</td>
<td>1951–2006</td>
<td>24.04</td>
<td>32.57</td>
<td>100</td>
</tr>
<tr>
<td>10 Kharga</td>
<td>1951–1980</td>
<td>25.30</td>
<td>30.33</td>
<td>73</td>
</tr>
<tr>
<td>12 Baharia</td>
<td>1951–1980</td>
<td>28.3</td>
<td>28.9</td>
<td>130</td>
</tr>
<tr>
<td>13 Siwa</td>
<td>1951–1980</td>
<td>29.11</td>
<td>25.31</td>
<td>14</td>
</tr>
</tbody>
</table>

Fig. 1. World map showing the location of Egypt (left), and monitoring stations location in Egypt (right).
shielded by, or close to, trees, buildings and other obstructions over a circle having a diameter of 40 m.

3.3. Method

The data averaging over 3 months for a whole series length is calculated as follows:

\[ x_{jk} = a_{ik} \]  

where \[ x_{jk} \] is the average value for seasonal temperature \( j \) and \( a_{ik} \) is the temperature at month \( i \) corresponding to station \( k \).

The average value of the temperature reference period over 29 years is given by

\[ x_k = \frac{1}{s} \sum_{j} x_{jk} \]  

where \( x_k \) is the temperature value of the reference period.

Therefore, the temperature anomalies, \( \eta_{jk} \), for station \( k \) can be calculated as follows:

\[ \eta_{jk} = x_{jk} - x_k \]  

We decided to classify the stations into three groups according to their locations, so we can have three combined locations with longer time series for each location than if we take each station individually. This idea enables us to overcome the shortage in temperature data for some stations and gives us three long time series representing three hypothetical stations instead. As a result, the first group is given the name ‘north group’, NG, and conducted throughout taking the average of four stations: Alexandria, Marsa Matrouh, Port Said and Sallom. These stations have Mediterranean climate. The second group is named ‘south group’, SG, including Luxor, Menia, Aswan and Asyout. This group is also known to lie in the Upper Egypt region, which is a hot area on the Nile river side. The third group named ‘desert group’, DG, containing Dakhla, Kharga, Siwa and Baharia located in the desert and having continental climate.

The average anomalies for group \( l \), \( \bar{\zeta}_l \), is calculated as follows:

\[ \bar{\zeta}_l = \frac{1}{s} \sum_{k} \eta_{jk} \]  

Finally, Cairo station is treated separately for its special nature and characteristics such as overpopulation, traffic congestion, industrial pollution, since it is the capital of Egypt. Some short gaps are found in the temperature data; therefore, an interpolation program applying series mean interval process is used to replace these gaps with the interpolated data.

4. Results and discussion

4.1. North

4.1.1. Stations

Fig. 2 shows WSATA diagrams for north stations. The diagram obtained for Alexandria time series shows normal fluctuating behavior and a non-significant warming trend having a value of 0.02 °C/10 years is obtained for the whole period. Sequences of warming and cooling events are detected. Warming trend is noticed during the period 1920–1950 as well as during the last three decades. A sudden cooling event having a value of −1.37 °C at 1905 is observed recording maximum drop in temperature during winter seasons. Also, the diagram shows a cycle of 100 years length starting from 1905 and ending in 2005. This cycle may be referenced to Gleissberg cycle, which will be checked in Section 4.7 in this paper. During the last three decades the temperature records were above the average and maximum rise in temperature was recorded in 2001. The time series diagram for Matrouh station shows high significant warming trend having a value of 0.12 °C/10 years with normal fluctuations for the whole record. During the period 1950–1980, the anomalies are hovering around the average value with peaks at 1952, 1964 and 1976. Starting from 1983 the values show a warming behavior till 2007. Minimum and maximum temperature values of −1.28 °C and 1.44 °C are registered in 1983 and 1986, respectively. Port Said diagram shows fluctuations with peaks in 1950 and 1960. The diagram for Sallom time series shows significant warming trend having a value of 0.35 °C/10 years for the whole record 1951–1976 giving a percentage of 0.049% as a temperature rise during this period. A very low temperature
anomaly is registered in 1950 followed by a maximum value in 1955. Also, we can notice that the fluctuations in the amplitudes are getting higher from Alexandria to Sallom. This, in our opinion, may be due the effect of the desert climate upon the climate of the Mediterranean.

4.1.2. Group

Fig. 3a–c shows WSATA diagrams for NG overlapped with different circulation indices. Different trends for temperature anomalies are detected and registered in Table 2. In Fig. 3, during the period 1870–1948, the anomalies lie above the average value recording positive behavior. Post 1948–1983 the anomalies vary around the average value registering lower temperature than prior 1948. Post 1983 till 2007, the temperature retrieves its early behavior as before 1948 and records values above the average. Maximum anomalies are registered in 1879, 1881, 1956 and 2001. Observations during the last three decades show that there were a temperature warming that we expect to continue for the next decade based on the temperature warming shown during the period 1904–1936. This warming trend may be due to the effect of solar activity upon the temperature here. The cyclic behavior of temperature can be observed easily either on the temperature diagram or from Table 2, where successive cooling and warming events appear. This behavior may be assigned to the existence of Gleissberg cycle. This observation is in coincidence with De Castro et al., 2009, who, at local scale, described two consecutive cooling-warming cycles in the Bay of Biscay waters during the period 1854–2007. When considering the whole time series, a non-significant trend is observed. The overlapping between temperature anomalies and the circulation indices shown in Fig. 3a–c gives an idea about the extent and type of correlation between them, which will be discussed later in Section 4.6 in this paper.

![Fig. 3. (a)–(c) Surface air temperature anomalies for NG with circulation indices.](image)

4.2. South

4.2.1. Stations

Fig. 4 shows WSATA diagrams for south stations. Luxor panel shows negative fluctuations during 1940–1955 followed by fluctuations about the average value and finally smaller amplitude fluctuations post 1960. The lowest temperature anomaly registered was in 1949 having a value of $-1.9\,^\circ{}C$ while the highest anomaly was registered in 1960 with a value of $1.7\,^\circ{}C$. Warming trend of $0.22\,^\circ{}C/10\text{ years}$ is observed for the whole record 1941–1971. At Menia, Stable behavior is observed on the diagram representing the whole record, 1945–1980, and there is no sign for any abnormal thermal behavior. High anomaly was recorded in 1960 as in Luxor. The diagram representing Aswan time series shows that most of the anomalies are negative and have values below the average except for the period prior to 1962 and post 1994. The temperature fluctuations are similar for all stations; this can be explained as a result of the prevailing nature of climate for the south stations. Asyout diagram shows warming and cooling trends having coefficient values of $0.24\,^\circ{}C/10\text{ years}$ during 1904–1950 and $-0.57\,^\circ{}C/10\text{ years}$ between early 1960s and 1980, respectively, both trends are significant.

4.2.2. Group

Fig. 5a–c shows WSATA diagram for SG overlapped with circulation indices. Most of the time series record obtained for the SG shows fluctuations about the average value. The behavior was found positive during the period 1930–1964. Minimal anomalies were detected in both 1983 and 1992 with values of $-3.26$ and $-3.86\,^\circ{}C$, respectively, showing a ratio of about 21.7% below the average value while maximal readings were recorded in 1994, 1999 and 2006 with values of $1.87$, $1.64$ and $2.03\,^\circ{}C$, respectively, showing that the average rise in temperature is about 14.5% above the average value in those years. The embracing of both the temperature anomalies

<table>
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<th>Period</th>
<th>SG</th>
<th>Degree of freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.15$</td>
<td>0.17</td>
<td>Cooling</td>
</tr>
<tr>
<td>0.41</td>
<td>0.001</td>
<td>Warming</td>
</tr>
<tr>
<td>$-0.23$</td>
<td>0.2</td>
<td>Cooling</td>
</tr>
</tbody>
</table>

Table 2

Trend analysis for NG and SG.

Fig. 3. (a)–(c) Surface air temperature anomalies for NG with circulation indices.
with the circulation indices is clear on the diagrams. This type of diagrams give us, at first glance, an idea about the docking between the two time series from which we can conclude the influence and the extent of positivity and negativity between them. SG shows the same sequences of warming and cooling events as NG, but with different trends values, as shown in Table 2.

### 4.3. Desert

#### 4.3.1. Stations

Fig. 6 shows WSATA diagrams for DG stations. Dakhla record shows a cyclic shape of 28 years length during the period 1957–1985. The highest anomalies recorded here are 2.98, 1.92 and 1.88°C in 1956, 1960 and 1987, respectively. The diagram obtained for Kharga describes fluctuations around the mean value. Negative anomaly values were recorded in 1956, 1959 and 1973 and a highest value was detected in 1960. No maximal or minimal values are found in Siwa. Baharia record displays trend of warming followed by cooling. The lowest temperature anomaly recorded was in 1954 with a value of −1.76°C, and the highest was in 1961 with a value of 1.7°C. Non-significant warming trends having values 0.26°C/10 years, 0.18°C/10 years and 0.06°C/10 years are detected for Dakhla, Kharga and Baharia, respectively.

#### 4.3.2. Group

Fig. 7a–c shows WSATA diagrams for DG with circulation indices. It is clear from the group record that there was no change in temperature during the period studied. This is because the length of the reference period in this group is almost as the same as that of the time series and there will not be any noticeable thermal change due to the shortage in data. The only extreme anomaly recorded was in 1987 with a value of 1.88°C.
4.4. Cairo

Fig. 8a–c shows WSATA diagram for Cairo with circulation indices. The anomalies change in Cairo shows negative behavior during the period 1904–1948 after which its values increase to reach the average value. The time series is continued till 1994 with peaks of minimal and maximal in 1905 and 1986 having coefficients of $-2.87$ and $1.27^\circ C$, respectively. Regarding the whole period, 1904–1995, a high significant warming of $0.13^\circ C/10$ years is observed. This warming trend indicates that the temperature in Cairo is increased with about $1.18^\circ C$ during the last century. This result agrees with that obtained by Colin et al. (1999), where they found a warming event of approximately $1–1.5^\circ C$ over the last century in Cyprus, which shares Egypt in the Mediterranean climate properties.

4.5. Frequency distribution

The frequency distribution is a routine used to investigate time series record and to obtain some statistical interpretation that may contribute to the addendum of interpretations for the natural phenomena.

Fig. 9a and b shows the frequency distribution histograms for NG during the periods 1904–1979 and 1980–2006, respectively. No phenomenal events were noticed when the data are clustered during the period 1904–1979. The normal distribution curve is clear on the histogram with slight shift towards warming and confirms the analysis performed with segmentation process during this work. The clusters’ size is small showing uniform temperature transition from cooling to warming. Ranging between warming and cooling there are 51 counts with positive values and 25 counts with...
Fig. 8. (a)–(c) Surface air temperature anomalies for Cairo with circulation indices.

Fig. 9. Temperature anomalies diagram patterns for NG (a) and (b), SG (c) and (d), DG (e) and Cairo (f).
negative ones. For the period 1980–2006, Fig. 9b, the warming shift is very clear and the clusters show a change in temperature between 0 and 1.5 °C. From the panel, 24 counts for positive behavior in return for 3 counts for negative ones. There are 9 counts in the range 0 and 0.5 °C, 8 counts in the field 0.5–1 °C and 6 counts for rise with values between 1–1.5 °C. On the contrary, for the negative behavior, there are only 3 values within the field 0–1 °C. The average change in temperature is 0.59 °C.

Fig. 9c and d represents the frequency distribution histograms for SG during the periods 1904–1979 and 1980–2006, respectively. Fig. 9c, 1904–1979, shows a perfect normal distribution curve for temperature anomalies. During this period, 36 positive counts in return for 40 negative ones are detected. Fig. 9d shows that, the smoothing curve is directed very slightly towards cooling with a value of −0.02 °C. Also, a slight cooling behavior is clear on the chart and the standard deviation of the curve is very high.

Fig. 9e shows the frequency distribution histogram for DG, where 24 positive counts against 17 negative counts are clustered showing tendency towards warming during the whole period.

Fig. 9f shows the frequency distribution histogram for Cairo. A slight negative tendency is detected for anomalies with 21 positive counts in return for 26 negative ones.

From all histograms we can observe that the intervals between anomalies are very small and this leads us to the fact that the Egyptian climate has no severe thermal changes.

4.6. Cross correlation technique

4.6.1. Cross correlation between circulation indices and temperature anomalies

Cross Correlation technique is applied with two tailed T test, 95% significance and (n – 1) degree of freedom to investigate the relation between each of MOI, NAO and SOI with WSATA. The time series for each group is segmented into periods so the highest impact for the indices upon temperature is obtained.

Table 3 shows the cross correlation coefficients, periods selected, types of correlation and lags for all groups correlated to MOI, NAO as well as SOI. Positive correlations are found between temperature anomalies and MOI for all Egypt; NG shows almost same quantitative and qualitative values for the two chosen periods at different lags. SG shows a higher value for the correlation during the last two decades. DG as well as Cairo show lower coefficient values than the other groups but same type of positivity. According to these results, we can explain the relation as follows: the pressure on Algiers is higher than that on Cairo, which gives rise to MOI index and causes the hot wind to blow towards east rising up the temperature in Egypt. Negative correlations are found between all groups and NAO. It is obvious, from Table 3 that, the highest correlation coefficients appeared for NAO with both NG and SG are −0.63 and −0.6 during the periods 1870–1904 and 1904–1942, respectively. This, in our opinion can be explained as follows, in the negative phase of NAO index, the relatively warm and moist air moves towards lower latitudes and lays over the Mediterranean Sea causing the winter temperature in Egypt to increase and in positive phase, it happens vice versa and the winter gets colder. This result coincides with those obtained by Hatzaki et al. (2006a, b), where they found same type of correlation for the temperature and NAO at the Mediterranean coasts.

SOI index declares positive correlation when related to SG with high coefficient value during the last three decades. No other correlations are found for NG, DG as well as Cairo. This is most likely resulting from the indices that have centers of actions above or close to Mediterranean region (NAO and MOI), perform better than those whose centers of actions were distant (SOI).
4.6.2 Cross correlation between solar activity and regional temperature anomalies

Cross correlation analysis between sunspot number and surface air temperature anomalies is performed with two tailed T test, 95% significance and \((n - 1)\) degree of freedom. The periods were chosen to give the highest impact for correlations between sun spots and temperature. It is well known that the sign of the correlation depends on the period studied (Georgieva et al., 2005). When the time series are investigated, no significant correlations were found prior to 1980. Table 4 shows the correlation coefficients obtained for all groups and Cairo with sunspot number. These results declare the signature of solar activity upon local temperature and this will be further investigated throughout data spectral analysis in the next section. Mouel et al. (2008) showed that the solar activity modulates major features of climate in total solar irradiance in the 1 – 11 year range.

### Table 4

<table>
<thead>
<tr>
<th>Sunspot number</th>
<th>Period</th>
<th>Coefficient</th>
<th>Lag (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>1980–2006</td>
<td>–0.33</td>
<td>1</td>
</tr>
<tr>
<td>SG</td>
<td>1980–2006</td>
<td>–0.49</td>
<td>1</td>
</tr>
<tr>
<td>DG</td>
<td>1980–1991</td>
<td>–0.45</td>
<td>1</td>
</tr>
<tr>
<td>Cairo</td>
<td>1980–1995</td>
<td>–0.44</td>
<td>1</td>
</tr>
</tbody>
</table>

4.7. Spectral analysis

Spectral analysis technique is carried out using the chi-square function with significance level of 95%. All data series are detrended in order to detect the effect of signals within them. Oscillations with different periods are identified. Short period oscillations with lengths ranging from 2 to 7 years are detected as well as long period oscillations ranging from 25 to 100 years (Nuzhdina, 2002). Fig. 10a–d shows spectral analysis results obtained for NG, SG, DG and Cairo, respectively. Analyzing the spectrum resulting from NG panel, Fig. 10a, peaks of short periods of 7.7, 4.2, 2.9, 2.7, 2.3 and 2 years as well as long periods of 25 and 100 years are found. The long term peak of 100 years can be interpreted as originating from changing conditions on the sun. More specifically, it can be assigned to the Gleissberg period (Gleissberg, 1944). The 25-year peak can be referenced to Hale cycle. The short peaks can be related to the Quasi-Biennial Oscillations, QBO (Maravilla et al., 2004, 2008). For SG, Fig. 10b, a long term peak of 102 and 34 years are detected as well as short term peaks of 7.9, 5, 4.3, 4, 3, 2.85, 2.5 and 2.4 years. The short peaks can be linked to the QBO and long peak of 102 y is referenced to Gleissberg cycle. At DG, Fig. 10c, peaks of 20, 8.3, 4.5, 3.7, 2.9 and 2.4 years are detected. The first peak can be associated to the Hale cycle and the 8.3y peak can be related to the Schwabe cycle. The other short period cycles can be related to QBO. At Cairo, Fig. 10d shows cycles of lengths 16.7, 7.7, 4.3, 2.5 and 2.2 years. The first peak may be referenced to the Hale cycle, the second one can be related to the Schwabe cycle and the rest of the peaks may be related to QBO.

Fig. 10. Power spectra for surface air temperature anomalies at (a) NG, (b) SG, (c) DG and (d) Cairo.
5. Conclusion

Surface air temperature anomalies in Egypt during winter time have been examined throughout this work. The data examination showed that the Egyptian winter climate represented a stable environment during the last century. Data segmentation procedure has proven its efficiency in the extraction of warming and cooling events. Also, the rise in temperature shown at NG during the last three decades may not be referenced to the human activities alone as a major cause, but the impact of extraterrestrial activities must be taken into consideration as well. The effect of MOI index on the temperature in Egypt is positive while the effect of NAO index is confirmed negative for all groups. The only group that is affected by the SOI index is SG. Spectral analysis technique had proven its efficiency in detecting the signature of extraterrestrial events hidden within the data such as Gleissberg, Hale and Schwabe cycles. Based on the assurance of the signature of the sun upon temperature variability throughout the different cycles detected within the temperature data here, this research predicts that the warming phenomena in the climate of Egypt will continue for almost the next decade which is similar to that happened during 1904–1936. The frequency distribution technique confirmed warm winter at north while cold one at south.

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