Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 5 (4): 316-328, 2011
ISSN 1819-3412 / DOI: 10.3923/rjes.2011.316.328

Regional Climate Interaction with the Solar and Geomagnetic Activities

E. Shafik Elmallah
Department of Basic and Applied Sciences, College of Engineering and Technology, Arab Academy for Sciences, Technology and Maritime Transport, Abo Kir, Alexandria, Egypt

ABSTRACT

In this study, we investigate the effects of solar-geomagnetic activity on the annual surface air temperature anomalies recorded in Egypt. The temperature of Egypt is divided into two main zones, north of Egypt NE (Mediterranean coastal) and south of Egypt SE (Upper Egypt) on the Nile river. Linear trends are calculated for each zone as an entire record and after segmented into different periods. Cross correlation as well as partial correlation between each solar-geomagnetic index and both NE and SE are applied. Finally spectral and coherency analysis are employed to know the periodicities and the variation that have similar spectra properties. Present results reveal a slight warming trend for the whole record on both NE and SE, but sequences of warming and cooling with different trends have been observed. Significant higher warming trend are detected on SE than NE at the last three decades. Negative correlations between solar-geomagnetic activity indices and SE at lag (1-3 years) were observed. In addition it was found that the solar indices are more effective on the relation (geomagnetic activity-NE), while geomagnetic indices have small effect on the correlation between solar activity and both NE and SE. Regarding the periodicities of the series, several cycles have been identified, with periods of about 50, (20-25), 10 year and (2-3) years. These may indicate that there is solar activity effect on local temperature.

Key words: Climate change, solar activity, geomagnetic activity, temperature anomalies

INTRODUCTION

Possible influence of the solar variability on the climate change have been the subject of research for many years e.g., (Lockwood and Frohlich, 2007; Karner, 2009; Georgieva *et al*., 2007). Many studies have revealed a good correlation up the last decades, between century-scale changes in global surface temperature and solar activity, through the mechanism is still controversial, (Kirov and Georgieva, 2002; Bucha, 2002). Scafetta and West (2005) observed that the climate sensitivity to solar changes is a multiscale phenomenon because the frequency-amplitude-dependent damping effect of the ocean and atmosphere thermal inertia should make the climate more sensitive to slower solar variations.

El-Borie and Al-Thoyaib (2006) found that about 40% of the variance in global temperature could be accommodated by concurrent alterations in geomagnetic and solar activity. Scafetta and West (2006) studied the role of solar forcing on global surface temperature during the four periods of the industrial era (1900-2000, 1900-1950, 1950-2000 and 1980-2000) by using a sun-climate coupling model. They concluded that the Sun contributed as much as 45-50% of the 1900-2000 global warming and 25-35% of the 1980-2000 global warming.

High positive correlation was found between the geomagnetic activity and the surface air temperature in Middle and Southern Europe (Georgieva, 1998). Kilcik *et al.* (2008) investigated the effects of solar activity on the surface air temperature of Turkey. They considered the parameters temperature and flare index data for the period (1976-2006), which cover almost three solar activity cycles, 21st, 22nd and 23rd. They found a significant correlation between solar activity and surface air temperature of Turkey for only cycle 23.

Rigozo *et al.* (2007) have found evidence for the presence of the solar activity long-term periods (~11, 22, 80 and 208 years) by examining the tree ring time series extended over a period of 400 years. One key element that is very often taken as evidence of a response, is the similarity of periodicities between several solar activity indices and different meteorological parameters (Tsiropoula, 2002).

Usoskin *et al.* (2006) reported that Sun's intensity over the first half of the 20th century was higher than at any time over the last ~4000-8000 years found ${}_6C^{14}$ proxy data reconstruction. Therefore the warming trend that occurred in the second half of 20th century may be raised from that high solar activity.

Le-Mouel *et al.* (2008) analyzed temperature data from meteorological stations in the USA (six climatic regions, 153 stations), Europe (44 stations) and Australia (five stations) indicating that significant solar forcing is present in temperature disturbances in these areas and conjecture that this should be a global feature. Le-Mouel *et al.* (2009) identified a strong correlation between the long-term (decadal to centennial) evolutions of winter time temperature and pressure disturbances in Europe and solar activity.

Valev (2006) found statistically significant correlations between the global and hemispheric temperature anomalies with solar -geomagnetic indices for the period (1856-2000). The correlation between the temperature anomalies and the geomagnetic indices is about two times higher than the correlation between the temperature anomalies and the solar indices. These results support the suggestion that the geomagnetic forcing predominates over the solar activity forcing on the global and hemispheric surface air temperature.

The surface temperature anomaly and sunspot number (Rz) time series in the period 1880-2000 were studied with wave let multi-resolution analysis by Souza Echer *et al.* (2008). They found a very low correlation of 0.11 between surface temperature anomaly and Rz in the 11-year- solar cycle band. A higher correlation of 0.66 was found in the ~22-year-band at zero lag. Palus and Novotna, 2009. Demonstrate detection of oscillatory modes with period of about 96 months (7-8 years) in the long-term records of geomagnetic activity aa index as well as in the records of surface air temperature from several mid-latitude European locations.

The aim of this study is to examine the regional climate in Egypt (North and South stations) and its possible dependence on the solar and geomagnetic activity.

MATERIALS AND METHODS

To investigate the Sun-climate relationship on local scale we have used annual surface air temperature anomalies data of Egypt and global solar-geomagnetic activity indices. Temperature data set used in this study cover 24-31° latitudinal and 25-33° longitudinal regions which separated into two regions according to their locations. North of Egypt (NE) is considered the average of four stations, Alexandria (31.13N, 29.58E), Matrouh (31.19N, 27.09E), PortSaid (31.16N, 32.18E) and Sallom (31.32N, 25.9E). This region is considered as Mediterranean climate. The second region is South of Egypt (SE) including Menia (28.07N, 30.33E), Asyout (27.11N, 31.04E), Luxer (25.41N, 32.38E) and Aswan (24.04N, 32.57E). This region represents hot areas on the Nile river sides. The

Table 1: Time series analyzed and their duration

Time series	Duration
North of Egypt(NE)	1881-2006
South of Egypt (SE)	1904-2005
aa (nT)	1881-2005
kp (nT)	1932-2005
Nv^2 (nPascal)	1967-2007
Rz	1880-2005

temperature data used in this study were taken from (http://www. ncdc.noaa.gov). The anomalies of these temperatures are calculated by subtracting the 1950-1980 mean from the data sets. Some gaps were found in the data, an interpolation program applying series mean interval process to replace the missing readings with interpolated ones. Table 1 shows the examined periods of surface air temperature (north and south of Egypt) and solar-geomagnetic parameters.

Solar changes are today easily traced through many activity indicators such as sunspot number, coronal mass ejection (CME), solar flare, solar dynamic pressure (nv^2), etc. These indicators show cycle behaviors from days to thousands of years. We have used in this study annual sunspot number (Rz) and annual solar dynamic pressure data sets (nv^2) as solar activity indicators as well as (aa), (Kp) as geomagnetic activity indicators.

Sunspot number is one of the longest solar data set available which exhibit long-term cyclic variations of 11 years (Schwabe), 22 years (Hale) and 80-90 years (Gleissberg) and also some other periods such as those of 35 years (Kilcik, 2005), or even longer 210-year Suess cycle (Braun *et al.*, 2005). The sunspots have been obtained via (http:// ftp.ngdc.noaa.gov/STP/SOLAR DATA/ SUNSPOT NUMBERS/MONTHLY). The most geoeffective solar wind parameters are the flow speed v and the proton density n. One can construct proxy for the dynamical pressure P. The pressure P exerted on the Earth's magnetosphere is best represented by nv^2. Dynamic pressure increased by velocity or density of the solar wind that can result in the production of energy within the Earth's magnetic field that can affect the troposphere. Maintained small increases in dynamic pressure in the order of NanoPascal from the solar wind due to the expansion of the solar magnetic corona may be sufficient to produce the energy that has resulted in the increase of surface temperatures on the Earth. A 1 nPa increase in dynamic pressure is equivalent to the increase of about 16 nT in the geomagnetic activity index aa values observed over the last 100 years (Michael, 2009). For ion density and ion speed, data were obtained from (http://omniweb.gsfc.nasa.gov/cgi/nx1.cgi).

The aa index is defined as the average of each 3-hour period, of the maximum of magnetic elements from two near -antipodal mid-latitude stations in Australia (Melbourne) and England (Greenwich). The aa index exhibits a dual structure related to the two components of the magnetic solar field: the sunspot solar component and the dipolar solar component, (Ouattara and Mazaudier, 2008). A widely used measure of the overall geomagnetic activity is the planetary magnetospheric Kp index. The Kp index is evaluated using the amplitude of the variation of the horizontal magnetic components X and Y at the Earth's surface at geomagnetic latitudes between 48° and 63° (Fredrik and Henrik, 2002). Aa and Kp data have been obtained from (http://www.wdcb.rssiru/stp/data/geomagni ind/).

The statistical analysis of the examined data series involves, cross correlation, partial correlation, spectral density and squared coherency. Cross-correlation is applied between solar-geomagnetic indices and both NE and SE for the common period (1967-2005). Partial correlation analysis is aimed to finding correlation between two variables after removing the effects of other variables. This type of analysis helps spot spurious correlation (i.e., correlations explained by the effect of other variables) as well as to reveal hidden correlations, i.e., correlations masked by the effect of other variables. Coherence analysis, or cross-spectral was used to identify variations that have similar spectral properties (high power in the same spectral frequency bands). Coherence between a pair of signals indicates that changes in one signal are related to changes in the other signal.

RESULTS AND DISCUSSION

Trend analysis: To explain some parts of temperature behaviors on Egypt, the whole period of temperature record was segmented to some sequences and calculated the trend of each segment as well as the trend of the entire record (Table 2). Figure 1a, b and 2a-d show the annual time series of air temperature anomalies on both regions of Egypt and the global solar-geomagnetic indices. In Fig. 1, one can see that both regions display three main periods. Two with a sharp rise from the beginnings of 20th century to around 1940 and the second is between 1981 till 2006. This is interrupted by cooling period from 1940 to the late 1970s. It is obvious that both are fluctuate about 1°C above and below the reference period. Fall in temperature on SE reach -2.3°C at 1983 followed by another drop to reach (-1.8°C) at 1992, the maximum temperature reach 1.46°C at 1998. On

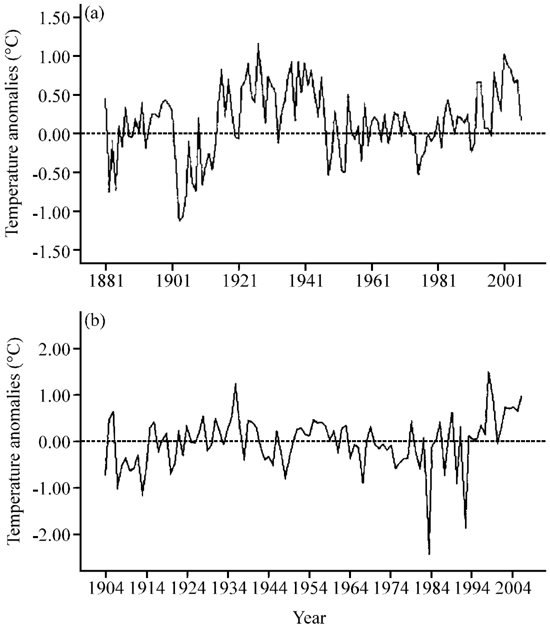

Fig. 1: Time series of annual surface air temperature (a) NE and (b) SE

Table 2: Trend analysis of NE and SE at different periods

Period	Type	Trend of (NE)	Trend of (SE)
1904-1940	Warming	1.3°C (0.037°C year^{-1})	0.8°C (0.023°C year^{-1})
1941-1980	Cooling	-0.46°C (-0.012°C year^{-1})	-0.15°C (-0.004°C year^{-1})
1981-2006	Warming	0.6°C (0.024°C year^{-1})	1.6°C (0.06°C year^{-1})
1904-2006 (whole record)	Warming	0.2°C (0.002°C year^{-1})	0.3°C (0.003°C year^{-1})

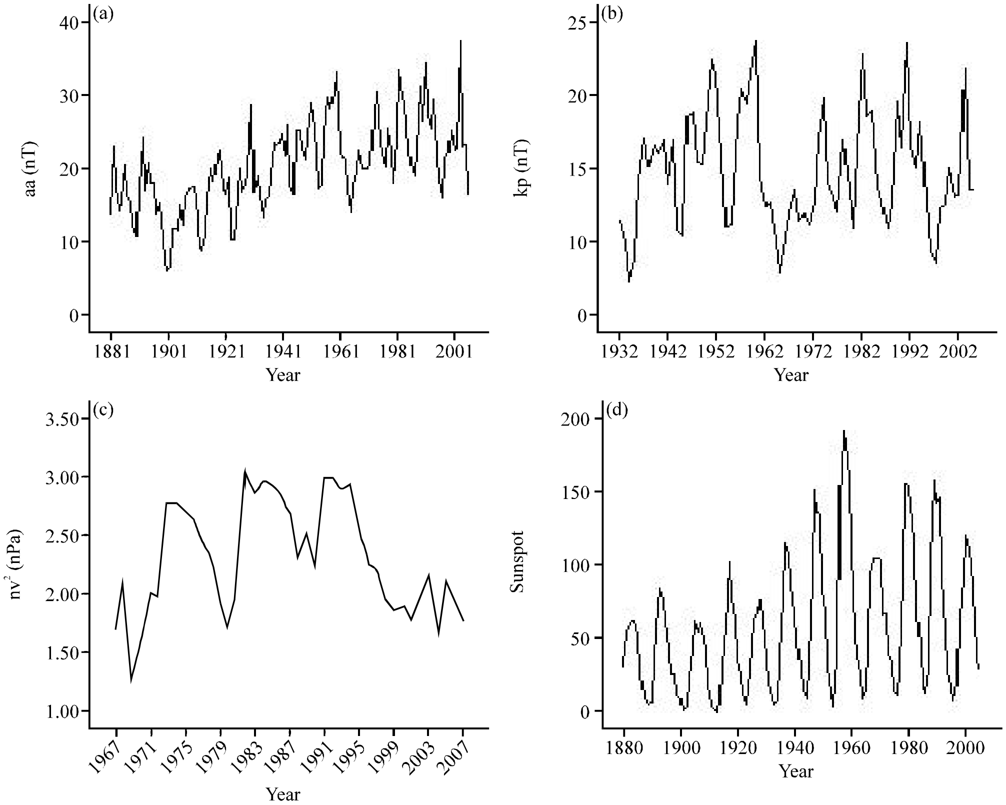

Fig. 2: Time series of annual (a) aa, (b) kp, (c) nv^2 and (d) Rz

NE the minimum temperature is (-1.12°C) at 1903 and the maximum reaches 1.12°C at 1921 and 1.02°C at 2001 above the reference period.

Table 2 shows the trend values for each period as well as the whole record for both regions, it is obvious to regard that the first warming period (1904-1940) rose sharply on NE (1.3°C) more than SE (0.8°C). In contrary, on the second warming period, SE rose sharply (1.6°C) more than NE (0.6°C). This trend value for NE is close to the ~0.2°C per decade in the past 30 years that obtained for the global surface air temperature by Hansen *et al.* (2006). Although the cooling period is appear in both SE and NE, its highly significant trend on NE than on SE. Non significant slight warming is observed on both regions for the entire record (1904-2006), this is contradicted with Lugina *et al.* (2008) who showed that the northern hemisphere has warmed at a rate of 0.71°C/100 years and the southern hemisphere at rate of about 0.56°C/100 years. The warming rate for the globe is 0.64°C/100 years. In conclusion, it is obvious that for recent years the climate of SE stations is more sensitive by three times than these of NE.

Cross correlation and partial cross correlation: Figure 3 and 4 show the cross correlation coefficients between solar-geomagnetic indices and both NE and SE. The two solid horizontal lines show 95% confidence limit interval. Linear trend was removed from the data before it is cross-correlated. Figure 4a-d show negative significant correlation between SE and geomagnetic activity indices (aa, Kp) at lag 1. These correlations appear more significant than the correlations between NE and these indices at lag 6 year (Fig. 3a-d). Cyclic of 11 year appear in the correlation between sunspot number (Rz) and both NE and SE. Correlation coefficients are reported in Table 3,

Table 3: Cross correlation coefficients between NE and SE with solar-geomagnetic indices for the period (1967-2005)

Solar-Geomagnetic Indices	NE	lag	SE	lag
aa	-0.3	6	-0.46	1
kp	-0.32	6	-0.5	1
nv^2	-0.334	1	-0.38	1
Rz	0.2	2	-0.3	3

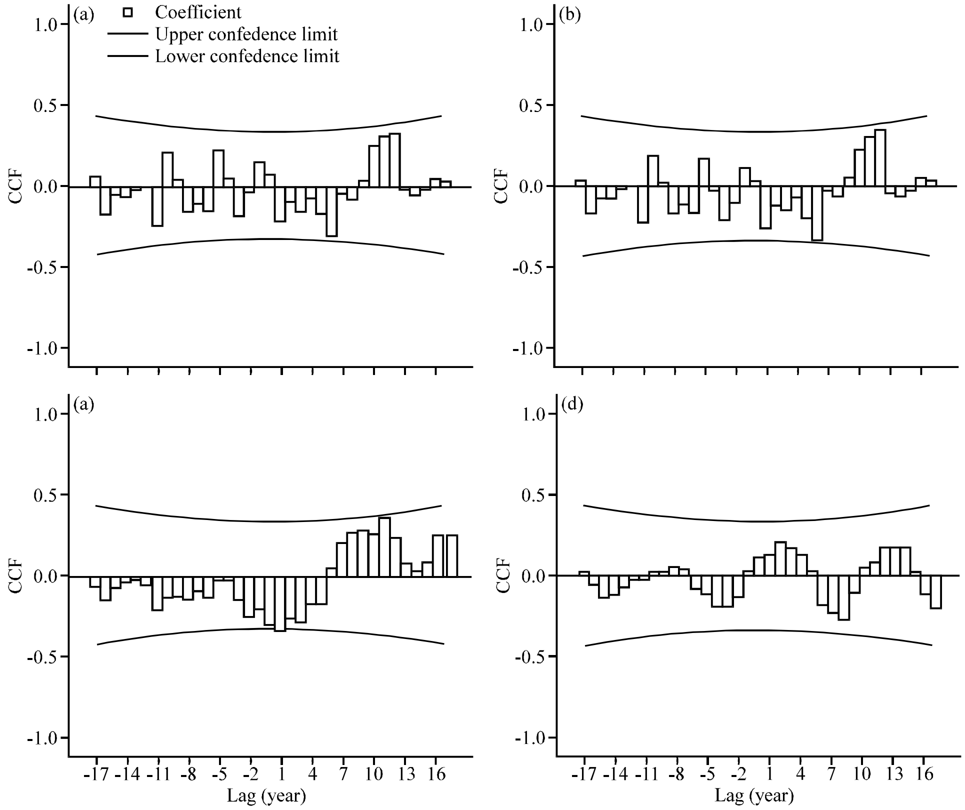

Fig. 3: Cross correlation between NE and (a) aa, (b) kp, (c) nv^2 and (d) Rz

negative moderate correlations between the solar-geomagnetic activity indices and both (NE) and (SE) at different lags have been observed, except (Rz) has positive correlation (0.2) with NE at lag 2. High significant correlation between geomagnetic indices (aa,Kp) and SE at lag1 (-0.46, -0.5) and non significant moderate correlation between (aa,Kp) and NE at lag6 (-0.3, -.32). Solar dynamic pressure (nv^2) has negative moderate correlation with both NE and SE at lag1. These results are not consistent with (Valev, 2006), who analyze the data series from 1856 to 2000 for the annual global and hemispheric surface air temperature anomalies and found that no statistically significant global temperature lag behind the sunspots as well as behind aa-indices. Dobrica *et al.* (2009) analyze 100-150 years-long temperature and precipitation records from 14 meteorological stations in Romania, in connection with long-term trends in solar and geomagnetic activities. The correlation of climatic parameters seems to be stronger for geomagnetic activity than for solar activity. The study indicates that solar and geomagnetic activity effects are present on the 22-year Hale cycle timescale. The temperature variation on this timescale lags the solar/geomagnetic ones by 5-9 years. This result is consistent with our results.

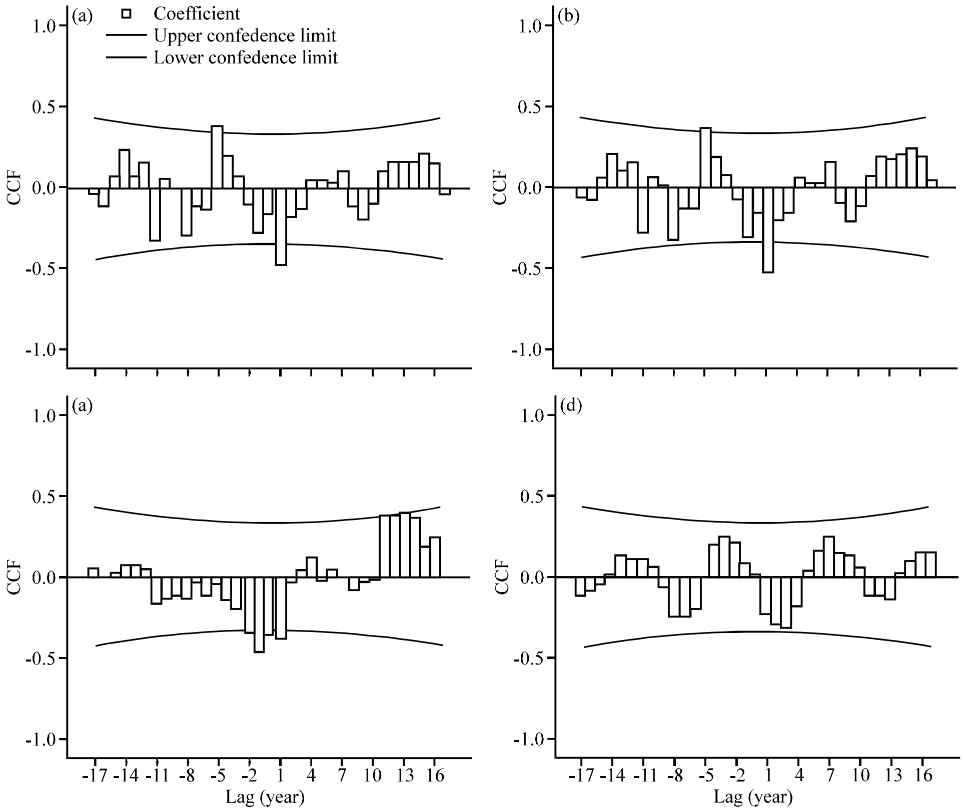

Fig. 4: Cross correlation between SE (a) aa, (b) Kp, (c) nv^2 and (d) Rz

Table 4: Partial correlation coefficients between temperature anomalies at NE, SE and solar-geomagnetic indices for the period (1967-2005)

	Control factors	NE	Significance (2-tailed)	SE	Significance (2-tailed)
kp	none	0.03	>0.1	-0.15	>0.1
	Rz,nv^2	0.30	0.06	0.14	>0.1
aa	none	0.068	>0.1	-0.158	>0.1
	Rz,nv^2	0.317	0.05	0.114	>0.1
nv^2	none	-0.30	0.06	-0.35	0.02
	aa,kp	-0.37	0.02	-0.32	0.05
Rz	none	0.115	>0.1	0.02	>0.1
	aa,kp	0.166	>0.1	0.07	>0.1

A partial correlation analysis was applied to check whether these indices have direct influence on the temperature or only reflect the effects of other indices. For this analysis it has been used the periods between 1967 and 2006, since nv^2 data were not available before this time. We have studied the correlation between surface air temperature anomalies on NE and SE with solar activity indices (Rz, nv^2) after controlling the effects of geomagnetic activity indices (aa, Kp). In contrast, the correlations between NE and SE with the geomagnetic activity indices after controlling the effect of solar activity indices have been added. Table 4 shows the correlation coefficients before (none) and after controlling the effects of other variables, the statistical significance is determined by the paired-sample t-test. Non significant positive correlation are seen between both Kp and aa with NE (0.03, 0.068) before controlling the effects of Rz and nv^2 (zero order). These correlations became strengthened after removing the effects of Rz and nv^2 (0.3, 0.317), implying that these correlations are largely resulting the effect of solar activity indices. In contrast, non significant negative correlation between both Kp and aa with SE were found (-0.15, -0.158), but after remove the effect of nv^2 and Rz, non significant opposite sign was appear (0.14, 0.11). This mean that with controlling the effect of solar activity indices, the correlation between Kp and aa with SE are positive. On other hand, significant negative correlation between nv^2 and both NE and SE (-0.3, -0.35) did not change much when the effect of aa and Kp was removed (-0.37, -0.32). Removal of geomagnetic activity indices (aa, Kp) also did not change the positive correlation between Rz and both NE and SE implying that aa and Kp only reflects the effects of nv^2 and Rz and does not have a direct influence on these regions.

Spectral analysis and coherency: To assess the solar-climate link it is important to know the periodicities involved and their interactions with climatic phenomena. The available whole record for each of the data set was used in both spectral and coherency analysis. The data was smoothed before these analyses by using Tukey-Hamming filter with span (3). Our spectral analysis results (Fig. 5a-f) show that all the data sets have about the same periodicity, albeit showing small

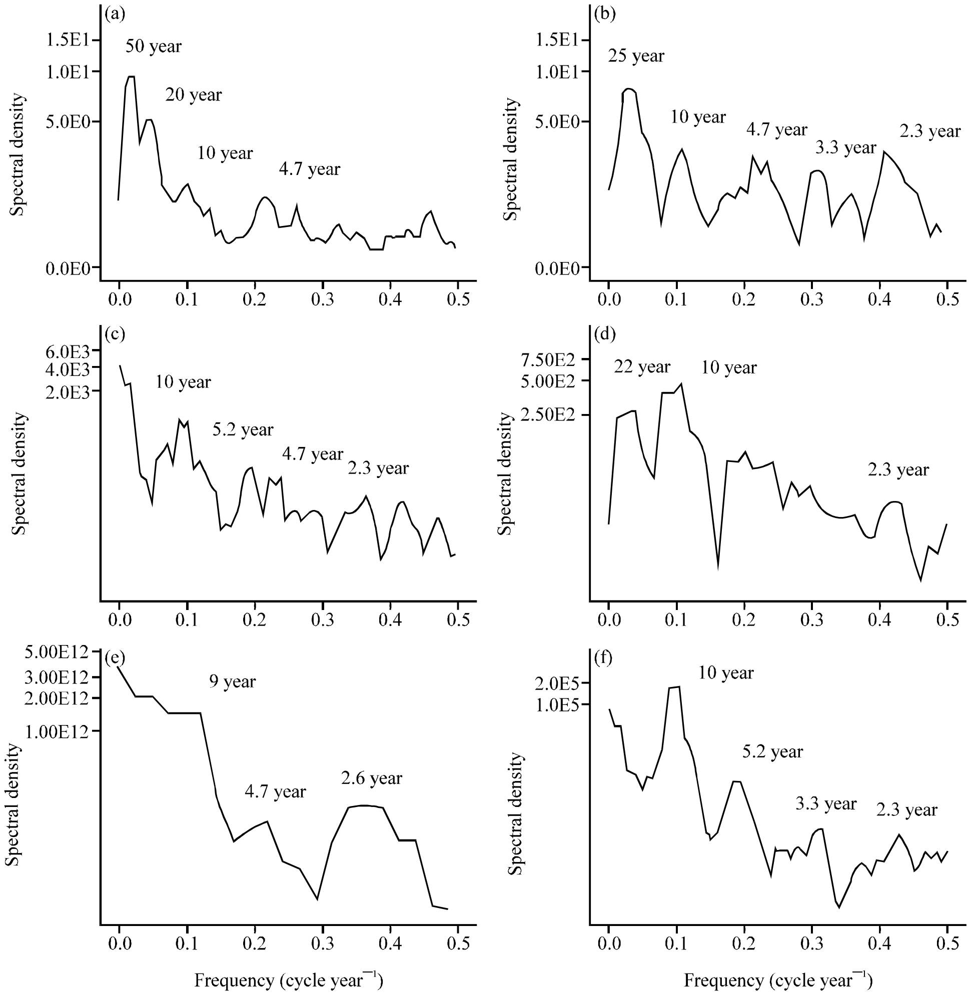

Fig. 5: Power spectra of (a) NE, (b) SE, (c) aa, (d) Kp, (e) nv^2 and (f) Rz

differences. The climatic oscillations with periods 20-25 years and 10 years have been revealed for both NE and SE (Fig. 5a,b). It may be related to Shwabe cycle (~11 year) 10 year period appear with large amplitude on SE than on NE. Other modes of 4.7, 3.3 and 2.3 years are also appear on SE. Significant peak of 50 year appear in NE spectra. The spectra of aa (Fig. 5c), have wavelengths of annual, semi- annual, 5, 2, 10-11 years. These results coincident with that obtained by Prestes *et al.* (2006) who applied the multiple-taper spectral analysis to aa, Ap and Rz annual and monthly average series (1868- 2001) and showed that the significant periods at 95% confidence level for annual averages are 11.1 and 10.2 years for Rz and 11.1, 5.3, 4.3, 2.7 and 2.1 years for aa. The significant modes in the Kp (Fig. 5d) are located at 22 and 11 years. These cycles could be related to the solar magnetic cycle or (Hale cycle~22 year) and solar activity. Another mode with the period of (2-3) years was observed in both solar-geomagnetic indices and in the temperature records. This frequency lies within the range of the Quasi-Biennial Oscillations (QBO) and it may be corresponding to ion density variation. Significant peak at 10 year cycle was detected on all data series with different amplitudes. This peak is the most prominent on the Rz series (Fig. 5f). These results are agreement with those of Palus and Novotna (2007) who applied the Monte Carlo singular system analysis (MCSSA) to records of monthly average near surface air temperature from several European locations, to the monthly North Atlantic Oscillation (NAO) index, as well as to the monthly aa index and the monthly sunspot numbers. They found several significant oscillatory modes in all the source data, the QBO 27-month (2.3 year) mode is shared by the atmospheric data. The 136 months (11.3 years), related to the solar activity cycle is shared by the sunspot data and the aa index, the mode with the period of 64 months, or approximately 5.5 year has been detected in the aa index and in the temperature records. In this study the mode of period 5.5 year is observed only in the aa index.

Table 5 summarizes the results of coherency analysis; the values of frequencies shown in terms of its inverse, the entries in the table indicate the frequency bands where coherence in a pair of variables is given. It should be read as pairs of values (frequency, square coherency).

Table 5: Squared coherencies of solargeomagnetic activity with NE and SE

Solar-Geomagnetic Index		NE	SE
nv^2	Frequency(cycle/year), Squared coherency	$(3\text{-}3.5)^{-1}$, 0.8	$(20\text{-}25)^{-1}$, 0.98
		$(2\text{-}2.5)^{-1}$, 0.7	$(2\text{-}2.5)^{-1}$, 0.8
		$(20\text{-}25)^{-1}$, 0.6	$(3\text{-}3.5)^{-1}$, 0.4
Rz	Frequency(cycle/year), Squared coherency	$(3.5\text{-}4)^{-1}$, 0.85	$(12\text{-}14)^{-1}$, 0.9
		$(2\text{-}2.5)^{-1}$, 0.8	$(2\text{-}25)^{-1}$, 0.75
		$(20\text{-}25)^{-1}$, 0.8	$(3\text{-}4)^{-1}$, 0.7
		$(5\text{-}6)^{-1}$, 0.7	$(20\text{-}25)^{-1}$, 0.6
		$(9\text{-}12)^{-1}$, 0.5	$(9\text{-}12)^{-1}$, 0.4
Aa	Frequency(cycle/year), Squared coherency	$(3\text{-}4)^{-1}$, 0.98	$(20\text{-}25)^{-1}$, 0.8
		$(9\text{-}12)^{-1}$, 0.8	$(2\text{-}2.5)^{-1}$, 0.75
		$(2\text{-}2.5)^{-1}$, 0.65	$(9\text{-}12)^{-1}$, 0.65
		$(20\text{-}22)^{-1}$, 0.6	$(3\text{-}4)^{-1}$, 0.6
kp	Frequency(cycle/year), Squared coherency	$(3\text{-}4)^{-1}$, 0.95	$(2\text{-}2.5)^{-1}$, 0.9
		$(5\text{-}6)^{-1}$, 0.7	$(3\text{-}4)^{-1}$, 0.8
		$(2\text{-}2.5)^{-1}$, 0.6	$(9\text{-}12)^{-1}$, 0.7
		$(20\text{-}25)^{-1}$, 0.6	$(20\text{-}25)^{-1}$, 0.3
		$(9\text{-}12)^{-1}$, 0.45	

Frequency is given as a range (cycle year^{-1}) and squared coherency is given by the maximum value in the frequency range. Figure 6a-d and 7a-d represent the value of squared coherency as function of frequency (cycle/year) for NE and SE with solar-geomagnetic activity indices. Observing

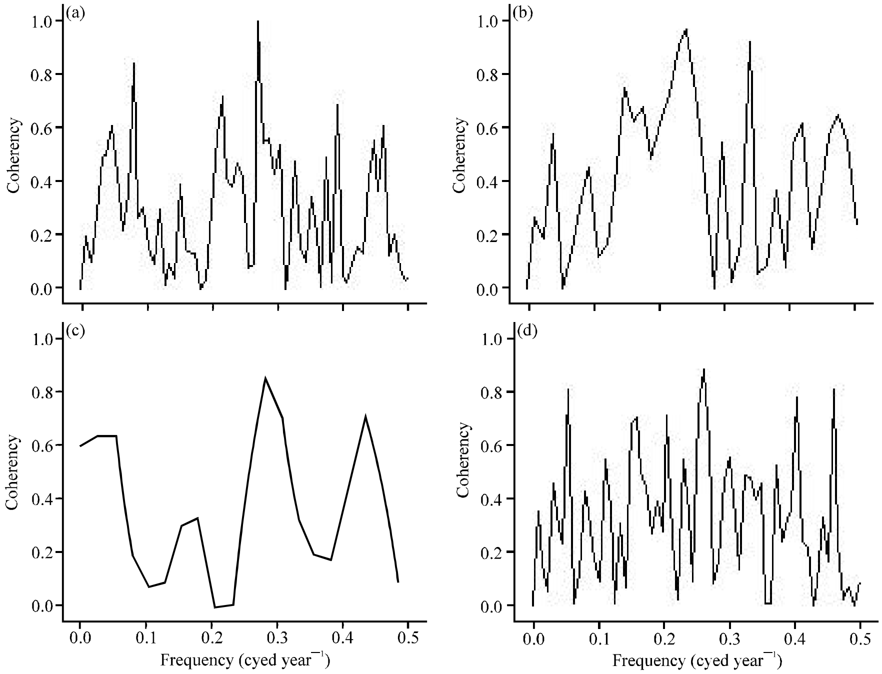

Fig. 6: Squared coherency of NE with (a) aa, (b) Kp, (c) nv^2 and (d) Rz

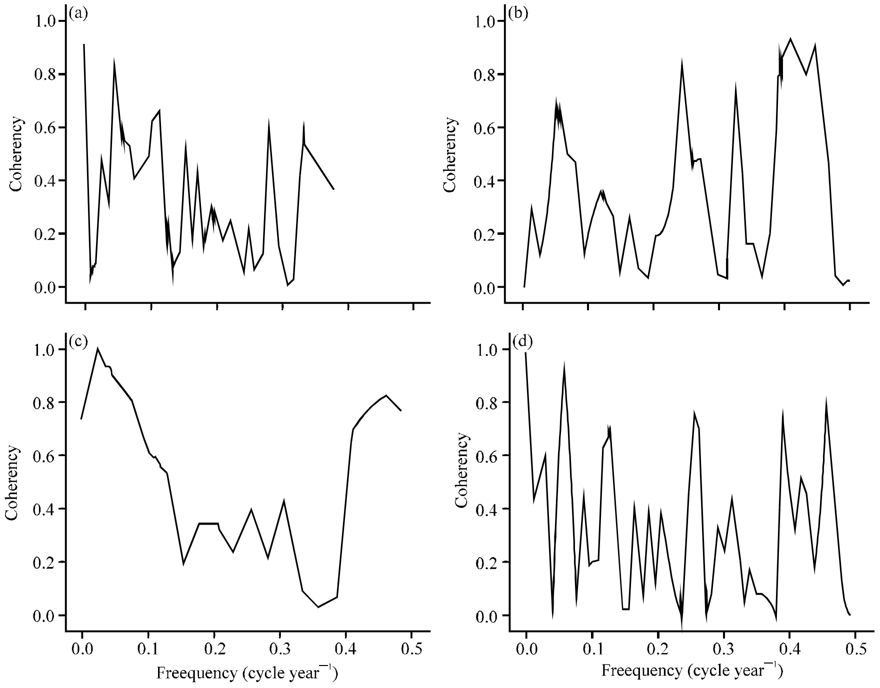

Fig. 7: Squared coherencies of SE with (a) aa, (b) Kp, (c) nv^2 and (d) Rz

Table 5, the most prominent feature is mainly four periods that appear almost in all spectra with maxima coherencies. The four periods are (20-25), (9-12), (3-4) and (2-2.5) years, except at the period (9-11) years the coherencies for (NE-nv^2) and (SE-nv^2) are not observed. Thus suggest that there is no relation of nv^2 with both NE and SE at 11 year cycle. The second noticeable feature is that maxima coherencies (~0.98) occur on NE-aa and NE- Kp at (3-4) years period and of SE-nv^2 at (20-25) years period. Thus suggest a close relation on NE with both aa and Kp at this period and on the relation of SE with nv^2 at ~22 year cycle. Another maximum coherency (0.9) is observed on SE-Kp for (2-2.5) years period. The (20-25) years period is appeared on SE-aa with maximum 0.8, but diminishes on the relation between NE-aa (0.6), while in contrary, the same period appear in the relation of both Rz, Kp with NE and then diminishes with SE. (5-6) years period is only observed with coherency (0.7) on the relation between NE and both Rz and Kp.

CONCLUSION

Based on the annual surface air temperature of north and south of Egypt it was found that:

- Both north and south of Egypt temperatures have stable climate through 20th century with same sequences of warming and cooling periods. Following by significant warming trend in the last three decades till 2006 on the south of Egypt reached three times more than on the north. This periodicity makes a cycle of around ~90 years, it may be related to Gliessberg cycle
- The cross-correlation analysis for the period from 1967 to 2005 shows a negative correlation between solar-geomagnetic parameters and the temperature in Egypt at different lags. Non significant correlation is found between sunspot number and the temperature on north Egypt. High significant negative correlation between geomagnetic activity indices and the temperature on south Egypt at lag one year. Also no significant correlation were seen between geomagnetic activity and the temperature on north of Egypt at lag 6 year. Cyclycity of 11 year appear also on the correlation between Rz and both the temperature on north and south of Egypt
- From partial correlation analysis, we found that the solar activity indices are more effective on the relation between geomagnetic activity and the temperature on north Egypt. Thus implying that the correlations between geomagnetic activity indices and the temperature in this region are largely a result of solar activity. While geomagnetic activity indices have small effect on the correlation between solar activity and the temperature on both north and south of Egypt. Thus indicating that geomagnetic activity indices only reflect the effect of solar indices and does not have a direct influence on the temperature on Egypt
- Our spectral analysis revealed periodicities of (2-3) years, 10 year on solar-geomagnetic indices as well as both NE and SE. These may indicate that there is solar activity effect on local temperature. Maxima coherencies (~0.98) occur on NE-aa and NE- Kp at (3-4) years period and on SE-nv^2 at (20-25) years period. Thus suggest a close relation on NE with both aa and Kp at this period and on the relation on SE with nv^2 at ~22 year cycle.

ACKNOWLEDGMENT

I wish to thank Prof. M.A. El-Borie, Head of Physics Department, University of Alexandria, for his help and effort.

REFERENCES

Braun, C.M., S. Rahmstorf, A.M. Ganopolski, C. Kubatzki, K. Roth and B. Kromer, 2005. Possible solar origin of the 1,470-year glacial climate cycle demonstrated in a coupled model. Nature, 438: 209-211.

Bucha, V., 2002. Long-term trends in geomagnetic and climatic variability. Phys. Chem. Earth, 27: 427-431.

Dobrica, V., C. Demetrescu, C. Boroneant and G. Maris, 2009. Solar and geomagnetic activity effects on climate at regional and global scales: Case study-Romania. J. Atmos. Solar-Terrestrial Phys., 71: 1727-1735.

El-Borie, M.A. and S.S. Al-Thoyaib, 2006. Can we use the aa geomagnetic activity index to predict partially the variability in global mean temperatures. Int. J. Phys. Sci., 1: 67-74.

Fredrik, B. and L. Henrik, 2002. Solar wind variations related to fluctuations of the North Atlantic Oscillation. Geophys. Res. Let., 29: 1718-1724.

Georgieva, K., 1998. A relation between solar activity and temperature in Northern hemisphere in the period 1881-1988. Bulg. Geophys. J., 3: 114-119.

Georgieva, K., B. Kirov, P. Tonev, V. Guineva and D. Atanasov, 2007. Long-term variations in the correlation between NAO and solar activity: The importance of north-south solar activity asymmetry for atmospheric circulation. Adv. Space Res., 40: 1152-1166.

Hansen, J., M. Sato, R. Ruedy, K. Lo, D. Lea and M. Elizade, 2006. Global temperature change. Natl. Acad. Sci. USA., 103: 14288-14293.

Karner, O., 2009. ARIMA representation for daily solar irradiance and surface air temperature time series. J. Atmos. Terr. Phys., 17: 841-847.

Kilcik, A., 2005. Regional Sun-climate interaction. J. Atmos. Terr. Phys., 67: 1573-1579.

Kilcik, A., J.P. Rozelet and S. Yesilyurt, 2008. Possible traces of solar activity effect on the surface air temperature of Turkey. J. Atmos. Terr. Phys., 70: 1669-1677.

Kirov, B. and K. Georgieva, 2002. Long term variations and interrelations of ENSO, NAO and solar activity. Phys. Chem. Earth, 27: 441-448.

Le Mouel, J.L., V. Courtillot, B. Blanter and M. Shnirman, 2008. Evidence for solar signature in the 20th century temperature data from the USA and Europe. C.R. Geoscience, 340: 421-430.

Le Mouel, J.L., V. Courtillot, E. Blanter and M. Shnirman, 2009. Evidence for solar forcing in variability of temperatures and pressures in Europe. J. Atmos. Terr. Phys., 71: 1309-1321.

Lockwood, D. and C. Frohlich, 2007. Recent oppositely directed trends in solar-climate forcings and the global mean surface air temperature. Proc. Royal Soc., 463: 2447-2460.

Lugina, K.M., P.Y. Groisman, K.Y. Vinnikov, V.V. Koknaeva and N.A. Speranskaya, 2008. Monthly Surface Air Temperature Time Series Area-Averaged Over the 30-Degree Latitudinal Belts of the Globe. CDIA Center, Oak Ridge, USA.

Michael, A.P., 2009. The possible role of dynamic pressure from the interplanetary magnetic field on global warming. Int. J. Phys. Sci., 4: 44-46.

Ouattara, F. and C.A. Mazaudier, 2008. Solar-geomagnetic activity and Aa indices toward a standard classification. J. Atmos. Terr. Phys., 71: 1736-1748.

Palus, M. and D. Novotna, 2007. Common oscillatory modes in geomagnetic activity, NAO index and surface air temperature records. J. Atmos. Solar-Terrestrial Phys., 69: 2405-2415.

Palus, M. and D. Novotna, 2009. Phase-coherent oscillatory modes in solar and geomagnetic activity and climate variability. J. Atmos. Terr. Phys., 71: 923-930.

Prestes, A., N.R. Rigozo, E. Echer and A. Vieira, 2006. Spectral analysis of sunspot number and geomagnetic indices (1868-2001). J. Atmos. Terr. Phys., 68: 182-190.

Rigozo, N.R., D.J.R. Nordemann, M.P. Souza Echer, E. Echer, H.E. Silva and F.L. Guarnieri, 2007. Solar activity imprints in tree ring width from Chili (1610-1991). J. Atmos. Terr. Phys., 69: 1049-1056.

Scafetta, N. and B.J. West, 2005. Estimated solar contribution to the global surface warming using the ACRIM TSI satellite composite. Geophys. Res. Lett., 32: L18713-L18713.

Scafetta, N. and B.J. West, 2006. Phenomenological solar contribution to the 1900-2000 global surface warming. Geophys. Res. Let., 33: L05708-L05714.

Souza Echer, M.P., E. Echer, D.J.R. Nordemann and N.R. Rigozo, 2008. Multi-resolution analysis of global surface air temperature and solar activity relationship. J. Atmos. Terr. Phys., 71: 41-44.

Tsiropoula, G., 2002. Signatures of solar activity variability in meteorological parameters. J. Atmos. Terr. Phys., 65: 469-482.

Usoskin, I.G., S.K. Solanki and M. Korte, 2006. Solar activity reconstructed over the last 7000 years: The influence of geomagnetic field changes. Geophys. Res. Let., 33: L08103-L08104.

Valev, D., 2006. Statistical relationships between the surface air temperature anomalies and the solar and geomagnetic activity indices. Phys. Chem. Earth, 31: 109-112.