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GIZA MONUMENTS AND LOCAL CLIMATE CHANGE

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ABSTRACT

Detailed studies on the effects of urbanization and industrialization processes on various microclimatological parameters and climatic variabilities over Giza have been investigated. The study revealed the occurrence of 8 distinctly dangerous changes. Effects of various atmospheric pollutants and other environmental parameters like air temperature, relative humidity and wind speed on Giza monuments have been explained. The study revealed that climatic variabilities over Giza induced by urbanization processes are important factors for deterioration of Giza monuments.

1. INTRODUCTION

The process of urbanization involves the construction of building, roads, underground drainage system, traffic, factories which radically transforms the radiative, thermal, moisture and aerodynamic characteristics of the pre-existing landscape and thus creates a climate of its own (Oke, 1987). As a result, more energy is received and retained, greenhouse elements such as carbon monoxide, nitrogen oxides, hydrocarbons beside high levels of concentration of suspended dust and other pollutants are increased. In general, growth of cities introduces a profound modification of climate by urbanization and human activities, which is not fount in many places else. Studies show that many large cities have experienced significant changes in cloudiness, precipitation, radiation and energy balance, temperature, air quality and visibility. The extent of urban climate change varies from city to city, according to the site and size of a city, land use pattern, structure and density of buildings, traffic, industry and other urban activities (Taesler, 1991).

Greater Cairo is considered one of the highly polluted cities in the world due to the increase of urbanization and industrialization processes in and around it. The existed pollutants are very harmful to human health and his comfort in addition, historical places and important monuments suffer from environmental deterioration, (Mossad, 1996 and Robaa, 1998).

Giza is a very important part of Greater Cairo region where the most important Egyptian monuments and historical places exists. The present study has been directed towards induced impacts of urbanization on local climatic variabilities and on the monuments and historical places of Giza City.

2. GEOGRAPHY AND DESCRIPTION OF THE STUDY AREA

River Nile runs through Cairo City from south to north. A narrow strip of Giza Governorate lies on the West Bank of the river, opposite to the city of Cairo. The sector of Giza has two mains, but small, industrial centers one in the northern part of the strip and another in the southern. Residential districts lie between both industrial centers. Mokatam hills lie about 8 km east of Giza on the east bank of the river. Shoubra El-Khema, about 10 km to the north of Giza City, is a big industrial activity area. The main industries are textiles, engineering constructions, chemical fertilizers and petroleum and industries power stations. Helwan is a big industrial castle lies 20-km south west of Giza. Its industrial activities are iron and steel manufacture, cook, cement, textile, car factories and power stations. Emissions from all these industries directly and indirectly affect the air quality of Giza area. Urbanization processes and the increased concentration of population and their activities in Giza area are the important reasons to contaminate it's atmosphere by high concentration of pollutants such as carbon and nitrogen oxides, hydrocarbons and high levels of load in the suspended dust. Giza station and other meteorological stations in Greater Cairo region are illustrated in fig. (1).

3. MATERIAL AND METHOD

Data of Giza station has been used to investigate variabilities of local climatic norms. Variations attributed to solar cycles have been excluded from climatological norms. Records represent stages of growth and development of Giza area give an evidence of the presence of three periods. The old period (1901 to 1930) represent pre-urbanized period, middle period (1931 to 1975) represent moderate urbanized period and the recent period (1989 to 1995) represent heavy urbanized period. The last period is chosen to distinctly explain the effect of the recently concentrated urbanization processes. Several meteorological elements have been used in this study. These are the monthly mean daily values of maximum, minimum and daily temperatures (Tmax, Tmin and T), relative humidity (RH%), wind speed (kt), cloud amount (oktas), evaporation (mm per day), rainfall (mm) and percentage of possible sunshine duration (%). The values of all these data were found from records of the Egyptian Meteorological Authority. Sunspot activities were obtained from the world data center for sunspot index at Zurich observatory.

4. CLIMATIC VARIABILITIES

4.1. Maximum, minimum and mean temperatures

Monthly and annual mean values of anomalies of minimum temperature (Tmin ^oC), maximum temperature (Tmax ^oC) and mean temperature (T ^oC) of Giza agrometeorological station during the study periods have been examined in relation to the rapid increased population concentration. The anomaly values of Tmin ^oC, Tmax ^oC and T ^oC are given in table (1) and illustrated by figs. (3.a, b and c).

Table (1): Normal values of meteorological elements and its corresponding anomalies during the three distinguished periods (1901-1930, 1931-1975 and 1989-1995) at Giza station.

Elements	Normal 1901-95	Anomalies		
		1901-30	1931-75	1989-95
Minimum temperature (^oC)	14.20	- 1.30	- 0.40	+ 1.70
Mean temperature (^oC)	20.86	- 0.98	+ 0.12	+ 0.84
Maximum temperature (^oC)	28.41	- 0.13	+ 0.08	+ 0.05
Atmospheric turbidity factor	5.03*1	- 0.82*2	- 0.16*3	+ 0.98*4
Sunshine duration (%)	78.67	+ 1.08	- 0.42	- 0.83
Wind speed (kt)	4.47	+ 0.23	+ 0.13	- 0.37
Evaporation (mm per day)	5.93	- 0.06	+ 0.70	- 0.64
Relative humidity (%)	62.67	+ 5.33	- 3.67	- 1.67
Cloud amount (oktas)	1.90	+ 0.30	+ 0.10	- 0.40
Rainfall amount (mm)	19.90	+ 0.34	+ 0.12	- 0.47
Sunspots number	67.25	- 25.1	+ 0.50	+ 24.5

*1 Normal values of turbidity factor (t) have been calculated using mean of t in the periods 1962-1963, 1975-1979 and 1989.
*2 The anomaly of the period 1962-1963, *3 The anomaly of the period 1975-1979.
*4 The anomaly of the year 1989.

The annual mean values of anomalies of Tmin increased gradually from -1.30^o C in the first period (1901-1930) to –0.40^o C in the middle period (1931-1975), and again increased to +1.70^o C in the recent period (1989-1995), (Fig.3.a). The annual mean anomalies of T have similar behavior to Tmin, whereas T mean values have been increased from –0.98^o C in the first period (1901-1930) to +0.12^o C in the middle period (1931-1975), thereafter its values increased to +0.84^o C in the recent period (1989-1995), (Fig.3.c). The annual mean anomalies of Tmax increased gradually from -0.13^o C in the first period to +0.08^o C in the middle period (1931-1975), thereafter its values very slightly decreased to +0.05^o C in the recent period (1989-1995), (Fig.3.b).

The above gradual increase in surface air temperature points to the recent increased intensity of air pollution and green house gases over Giza. These are induced by the very rapid growth of population in addition to the increase in density of buildings and pollution sources. Fig. (2) illustrates the rapid increase of population density in Greater Cairo (Central Agency For Egypt Statistics). The estimated mean rate of percentage of population density in Greater Cairo is about 3.9% each year. This is followed by rapid increase in traffic density and the necessary industrial activities.

The strong increase in Tmin, slightly increase in T and decrease in Tmax that occurred through the recent period (1989-1995) explains that effect of urbanization processes is more significant on Tmin than on both T and Tmax. This result confirms the findings of Katsoulis and Theoharatos, 1985 and Katsoulis, 1987.

2.3^{o} C, 1.5^{o} C and 0.6^{o} C departures from the normal of Tmin, T and Tmax respectively occurred in April month of the recent period. This could be attributed to the recent increase of intensity of sandstorm and Khamsin hot waves prevailing during April month perhaps as a local impact of the global warming (Robaa, 1998).

The second two peaks occurred in September and October months of the recent period (1989-1995) could be attributed to large values of atmospheric turbidity in these months during the recent period (See fig.3.d). The above result agree with the result of Robaa, 1995 who found that the significant increase of atmospheric heating over urban areas occurred resulting from sharp increase of aerosols in its atmosphere from both natural and industrial sources.

The variabilities of anomalies of Tmax shown in fig.3.b are irregular, however distinct increase occurred in most months of the recent period (1989-1995). During May month, the anomaly values of Tmax during the three understudy periods have approximately values around zero. This may be attributed to the occurrence of Khamsin depressions, which causes similarity active weather disturbances over all Egypt in spring season (March to May) periodically every year.

4.2. Atmospheric turbidity

Studies on monthly and annual mean values of anomalies of atmospheric turbidity (Linke factor) in two periods (1962-1963), (1975-1979) in addition to the year (1989) at Abbasiya station (the nearest station to Giza) revealed gradual increase from –0.82 in the old period to –0.16 in the middle period up to +0.98 in the year (1989), (Table 1 and fig.3.d). This could be correlated to the increased air pollution values whereas, this increase in atmospheric turbidity was found parallel to the distinctly increase in aerosol concentrations over Abbasiya area from 98 $\mu g/m^3$ in the period 1962-1963 to 214 $\mu g/m^3$ in the period 1992-1993. These values of aerosol concentrations are previously obtained by the present author (Robaa, 1998). It is clear that the aerosol concentrations have increased more double from 1962 to 1993. Furthermore, according to the classification of aerosol concentration levels (Table 2) proposed by the New Tersely State Department Of Health (1958), the aerosol concentration increase and translate from both light and moderate levels in the period 1962-1963 to both heavy and very heavy levels in the last period 1992-1993.

Table (2): Relationship between aerosol concentration $\mu g/m^3$ and adjective ratings.

Adjective rating	Aerosol concentrations range $\mu g/m^3$
Light	<74
Moderate	75-149
Heavy	150-224
Very heavy	225-299
Extremely Heavy	>300

This serious increasing in aerosol concentration in Abbsiya indicates that on the average the air over Greater Cairo region and in turn Giza City is mostly very polluted.

4.3. Sunshine duration

At urban sites, high aerosol concentration reduces the total incident energy and alters the direct-diffuse ratio. Peterson and Stoffeel, (1980), indicated that under cloudless sky conditions the differences between urban and rural irradiation were about 4.5% during winter and 2.0% in summer.

The instrumental and other difficulties have been encountered in measuring solar radiation components, except sunshine duration, at Giza station. Therefore, values of sunshine duration have been used to represent the solar radiation parameter. This parameter is of real benefit especially for evaluating the amount of pollutants in the atmosphere.

Studies on monthly and annual mean anomalies of percentage of possible sunshine duration (%) of the three selected periods revealed that the annual mean anomalies of sunshine duration (%) distinctly decreased from +1.08% in the old period (1901-1930) to -0.42% in the middle period (1931-

1975), then continuously decreased to -0.83% in the recent period (1989-1995). This is ascribed to the effect of increased atmospheric pollution associated with very rapidly growing of urbanization in and around Giza City.

The monthly mean anomalies of percentage of sunshine duration for the recent period (1989-1995) show fairly opposite behavior compared to eldest period (1901-1930), while the values of the middle period (1931-1975) indicates that the percentage of sunshine duration has slightly monthly variation (Table 1 and fig.4.a). This is clearly attributed to the graduate of the effect of urbanization processes that rapidly growth from eldest to recent period.

4.4. Wind speed

The annual mean anomalies of wind speed decreased from +0.23 kt in the old period (1901-1930) to +0.13 kt in the middle period (1931-1975), and again distinctly decreased to -0.37 kt in the recent period (1989-1995), (Table 1 and fig. 4.b). The decreased values of wind speed are attributed to the increased number of buildings and growing up of high establishments results in an increase of the roughness parameter (assumed to be grown from 0.01 m to 0.20 m). Therefore, wind velocity has been decreased in recent years compared to old periods.

Higher velocity and turbulence of the surface wind increases ventilation condition. This increased ventilation causes greater mixing of the highly polluted low-level air with cleaner air flowing above the urban canopy. Otherwise, the lower wind velocity decreases ventilation condition. The decreased ventilation assists increasing concentration of suspended dust and other pollutants over Giza. Wind speed decreased from old period to recent period occurred at Giza area increases the concentration of pollutants and greenhouse gases (Water vapor, HO, Carbon dioxide, CO2, carbon monoxide, CO, Ozone, O3, Methane, CH, Nitrous oxide, NO, hydrocarbons and Chlorofluorocarbons, CFCs). The great amount of pollutants coming from adjacent industrial area of Shubra El-Kheima and surrounding urban areas increase the concentration of these pollutants over Giza more and more. As mentioned above, these pollutants are very harmful to the historical places and important monuments inside Giza area, (Mossad, 1996 and Robaa, 1998).

4.5. Evaporation

The annual mean anomalies of evaporation (mm per day) increased gradually from – 0.06 (mm per day) in the eldest period (1901-1930) to +0.70 (mm per day) in the middle period (1931-1975), thereafter it has been sharply decreased to –0.64 (mm per day) in recent period (1989-1995), (Table 1 and fig. 4.c). The increase in evaporation during the months of the middle period (1931-1975) could be attributed to the increase of heat island effect resulting from rapidly increasing in population and urbanization processes. This artificial heat favors and causes increase of the rate of evaporation process.

The lesser values of evaporation during the recent period (1989-1995) is attributed to the distinctly decrease in both sunshine duration and wind speed during the same period (See figs.4.a and 4.b). The above result agrees well with the findings of Padmanabhamurty and Bahl, (1982).

4.6. Relative humidity

Statistical studies on relative humidity (RH%) values revealed that the annual mean anomalies of relative humidity decreased gradually from +5.33% in the eldest period (1901-1930) to -3.67% in the middle period (1931-1975), thereafter it has been increased to –1.67% in recent period (1989-1995), (Table 1 and fig. 4.d). The decrease in RH% during the months of the middle period (1931-1975) could be attributed to the increase of heat island effect resulting from rapidly increasing in population and urbanization.

The slightly increase in RH% from the middle period (1931-1975) up to the recent period (1989-1995) could be attributed to the increase in concentration of aerosols and condensation nuclei liberated recently from the industries. These artificial nuclei are greedy to pick up humidity from the atmosphere assisting an increase in relative humidity near earth's surface. Also, condensation of water droplets in the form of mist, haze or fog near the ground level has been increased (Higazy, 1973 and Rizk, 1975).

4.7. Cloud amount

The annual mean anomalies of cloud amount (oktas) decreased gradually from +0.30 in the eldest period (1901-1930) to +0.10 in the middle period (1931-1975), then to -0.40 in the recent period (1989-1995), (Table 1 and fig. 5.a). This goes along with the decrease of relative humidity except in the recent period (1989-1995) which is characterized by slight increase in RH% values, (See fig.4.d). This may be due to the increase in concentration of hygroscopic nuclei liberated recently from the industries. These artificial nuclei are greedy to pick up water vapor from the atmosphere and condense it as water drops forming mist, haze or fog near the ground level. This process assists increase in relative humidity near earth's surface and decrease the cloud amount, (Higazy, 1973 and Rizk, 1975).

4.8. Rainfall amount

A decrease from +0.34 mm in the eldest period to +0.12 mm in the middle period then -0.47 mm during the recent period was found in the annual mean anomalies of rainfall amount (mm), (Table 1 and fig. 5.b). This decrease in rainfall amount was found parallel to the decrease in cloud amounts, (See fig.5.a), due to the distinctly effect of urbanization processes occurred at Giza as mentioned above. .

Also, it has been found that the anomalies in rainy months of the middle period (1931-1975) are subjected to fluctuations from positive to negative values. This is attributed to weakening of urbanization processes occurred at Giza in (1931-1975) period. Therefore, its effects on cloud amounts and in turn the amount of rainfall was very weak compared to the recent period (1989-1995) which is characterized by heavy urbanization processes.

5. ASTRONOMICAL VARIABILITIES

Values of the annual mean anomalies of sunspot number have been increased gradually from –25.1 in the eldest period to +0.5 (around normal) in the middle period, and again increased to the highest value +24.5 during recent period, (Table 1 and fig. 6). It was found that the surface air temperature in Giza has been subjected to decrease in its value while the number of sunspot increases.

Studies on the correlation between sunspots number (S) and mean surface air temperature (T) over Giza, (Fig. 7), revealed that the monthly mean values of S and T for the pre-urbanized period (1901-1930) are correlated as follows;

$$\mathbf{T = 21.03 - 0.03\ S, \qquad (C=0.89,\ E=0.01)}$$

Where C is the correlation coefficient and E is standard mean error.

6. EFFECTS OF SOME METEOROLOGICAL ELEMENTS ON GIZA MONUMENTS

In this section we explain the adverse effects of three effective meteorological elements namely, air temperature, relative humidity and wind speed in addition to atmospheric pollutants induced by urbanization and industrialization processes over Giza on monuments lie in the study area.

6.1. Air temperature effects

The increased air temperature over Giza during recent years due to the urbanization processes causes various harmful effects on its historical places and important monuments. The high temperature rapidly heats the monument surface. A great difference between the surface temperature of monument and its internal layers has been occurred due to the nonconductor of the stones. This process leads to difference of stretching and retraction of the surface and its followed layers and in turn secession and falling of the surface parts in the form of peels (Saleh, 1987). Also, the increased air temperature causes severe dryness of monument stones that leads to some changes of its chemical composition such as transformation of the gypsum to anhydrite as follows;

$$\mathbf{CaSO_4\ .2H_2O \longrightarrow CaSO_4 + H_2\ O}$$

This transformation cause in losing two water molecules that combined with calcium sulfate. This process leads to retraction in dimensions of cells and finally causes dangerous irregular fissions in monument's layers (Torraco, 1982).

6.2. Relative humidity effects

Relative humidity is considered more dangerous than other factors in deterioration of monuments. There are at least three clear methods for deterioration of stone monuments by inappropriate levels of relative humidity such as formal transformations, corroding and mechanical failure (Arnold, 1978). High humid conditions favor the growth of organism while low humid conditions make the paintings, papers, textiles, leather etc., brittle and fragile (Kamalakar and Pandit, 1995).

In our case the increased relative humidity over Giza during recent years due to urbanization processes, as mentioned above, causes various harmful effects on its historical places and important monuments whereas the mineral composition of stone monuments has been changed due to hydration processes. For example, Feldspar mineral turned to Kaolinite minerals group that is faster affected and dissolved by water. Furthermore, the stone monuments absorb humidity leading to dissolution of salts existent in stones and move it to the surface through the stone pores by the capillarity. Thereafter, these salts crystallize on the stone surface and between its pores in the form of treelike, needle and very whitish spots. These processes cause weakness of the internal structure of stones and losing of sculptured materials on the stone (Arnold, 1978 and Dahi, 1999). Also, the increased relative humidity causes some changes of its chemical composition such as transformation of the anhydrite to gypsum as follows;

$$\mathbf{CaSO_4 + H_2O \longrightarrow CaSO_4 .2H_2O}$$

The two gained water molecules cause increase in cell volume. This process leads to stretching in dimensions of the cells and finally causes serious deterioration in monument's layers (Torraco, 1982).

In case of low humidity, the gypsum transforms to anhydrite. This transformation leads to retraction in dimensions of cells and finally causes irregular thin fissions in monument's layers (Dahi, 1999).

6.3. Wind speed effects

The Wind speed is considered an important factor in deterioration of monuments. The wind carries large hard sand particles that make as mobile saws and erodes the monuments surface by different degrees depend upon both gross and detail building morphology, the nature of the building material and its finish. The scratches that occur in the surface of the monuments when the loaded particles clash with it leads to corrosion the external surface and in turn gradually leads to corrosion and decay the monument (Shoulikidis, 1991).

Furthermore, when the high wind speed passes on the surface of monuments, the salt solutions have been evaporated and released the salts flowering on the surface, (Amoroso and Fassina, 1983).

Although the urbanization processes over Giza area cause decrease in wind speed during recent years as shown earlier (Fig.4.b), the harmful effect of wind on Giza monuments is still existent whereas these monuments lie in exposed sandy area far from the inhabited area (See fig.1).

7. EFFECT OF SOME AIR POLLUTIONS IN MONUMENTS

As a result of the processes of urbanization, more energy is received and retained, greenhouse elements such as carbon dioxide, nitrogen oxides, hydrocarbons beside high levels of concentration of suspended dust and other pollutants are increased. The effects of these pollutants on the monuments and historical places are very harmful (Jimenez, 1991).

Industrialization has been increasing very rapidly in and around Giza City, in the last 50 years. The urbanization in Giza leads to pollution of its atmosphere causing costly problem. In Egypt, many studies have been performed to investigate the nature and magnitude of the air pollution problem in Greater Cairo region and Giza City.

Traffic air pollution is a major nuisance in Giza. As the number of cars is still growing rapidly, it must be expected that this problem will become more important in the future. El-Abssawy, (1995), has estimated the minimum overall emissions from the registered motor vehicles in Greater Cairo area during the year 1993. He has been found these quantities were 53 tons/day. As the climate during a large part of the year, in Giza, is sunny; it must be expected that photochemical smog be formed, resulting in large concentration of oxidants. These oxidants constitute a public nuisance and can inflict considerable damage on human health, plants and Giza monuments, so that traffic air pollution may result in economic losses too.

El-Ghandour et al., (1983), studied the amount and composition of dust deposits in Helwan area, about 14 km south-east of Giza, Egypt, during the period from June 1976 to May 1978 over 24 different sites covering the various activities in the studied area. They found that the deposition values over the dusty industrial districts are more than 10-12 times those deposited over the residential which dust-fall concentration were 26.81±5.92 tons Km^{-2} $month^{-1}$ during the first year and 25.30 ± 9.64 tons Km^{-2} $month^{-1}$ during the second year. This reflects the magnitude of the role played by industry in polluting the air of Helwan. They also found values of 3,310.95 tons Km^{-2} $month^{-1}$ and 2,787.92 tons Km^{-2} $month^{-1}$ as the averages over the two years. While the rural areas (south Helwan) have dust deposition 59.56 ± 12.99 tons Km^{-2} $month^{-1}$ and 67.62 ± 17.37 tons Km^{-2} $month^{-1}$ annual averages during the two years. They also compared the amounts of deposition over the area of Helwan with standards set up in other countries of the world, whereas, the annual mean rate of deposition of inert dusts over industrial sections in the United States of America is 19 tons Km^{-2} $month^{-1}$ but in Canada, this value is 7 tons Km^{-2} $month^{-1}$ for residential areas.

Abdel Salam et al., (1981), studied smoke content of the atmosphere over the Greater Cairo area during the period from June 1977 to May 1978. Daily and yearly cycles of smoke concentration were also studied and discussed in terms of man-made source activities and meteorological conditions. They found that the study area was considerably higher in smoke contamination and man-made activity is the principal source of smoke in the Cairo atmosphere.

From the above review it is clear that Greater Cairo area and in turn Giza City could be considered one of the heavy polluted areas due to rapid urbanization and industrialization processes in and around. These processes cause not only an increase of pollutants which are threaten the national wealth of Giza monuments and harmful to human health but also create several environmental problems. Some harmful effects of pollutants on Giza monuments have been explained in the following section.

7.1. Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) effects

SO_2 and NO_2 are formed when fossil fuels such as coal, gas and oil are being burned for power generation, in mobile sources and in industries. Sulfur dioxide transforms in existence water vapor to sulfur trioxide (SO_3) which in turn transforms to Sulfuric acid ($H_2 SO_4$). The formed Sulfuric acid attacks the fundamental component of stones (Calcareous materials) and transforms some of these components to Calcium Sulfate. The later component deposits on the monument surface and between its pores and gradually leads to decay of the monument (Camuffo, 1991).

Nitrogen dioxide transforms in existence water vapor to Nitric acid (HNO_3). The formed Nitric acid attacks one of the fundamental components of stone, Calcium Carbonate, and transforms it to Calcium Nitrate. The later component causes brittleness and fragile of the monument (Mill, 1992).

7.2. Carbon dioxide (CO_2) effects

Carbon dioxide plays an important role in deterioration of stone monuments built. It transforms in presence water vapor to Carbonic acid (H_2CO_3). The later component interacts with the fundamental components of stone and transforms it to soluble salts. This process represents great damage for the monument, (Ramy, 1970).

7.3. Ammonia (NH_3) effects

Ammonia gases arise by large amounts in atmosphere of industrial cities as a result of urbanization and industrial processes. These gases contribute the pollutant gases such as Sulfur dioxide and others to oxidation and transformation to acids attack the different components of stone and cause great damage for the monuments, as mentioned above, (Zezza, 1991).

7.4. Artificial aerosols

Artificial aerosols arise by large amounts in atmosphere of industrial and urbanized cities as a result of urbanization and industrial processes. These aerosols consist of fine carbonate particulate, organic compounds such as aldehyds, hydrocarbons and tars. These aerosols deposit on monument surfaces and deform its external appearance by black layers in addition to its important role in help of different pollutant gases to transform into damager acids (Meetham, 1961).

7.5. Acid rain effects

Some gases react with rain to form acid solutions. The major concern of acid rain is with the acidity produced as a result of the various oxides of sulfur and nitrogen that are placed in the atmosphere as effluent from industrial and urbanized processes, especially from electricity generating plants and from traffic. Sulfur dioxide, once oxidised, may be dissolved to give $H_2 SO_4$ (Sulfuric acid). The acidity is often enhanced by the presence of HNO3 formed as the result of large emissions of various of the oxides of nitrogen (NO_X). The consequence of this is that the acidity of the precipitation is increased, (Henderson and Robinson, 1989).

The great harmful effect of acid rain distinctly show when these acid rains react with the metals component of stone (Feldspar) and transforms to soluble salts such as Potassium, Sodium and Calcium in addition to Kaolinite metals. This process leads to smash the internal structure of limestone and losing of the force tenacity of its particulate and leads finally to powdered stone (Lehmann, 1970 and Dahi, 1999).

On the other hand, the various atmospheric elements and environmental pollutants induced by industrialization and urbanization processes threaten the Egyptian monuments in other historical places in Egypt by damage and brittleness of its components. Such as Kayetbay fort in Alexandria (Yassin, 1993), Heebes temple in Kharga Oasis (Tarik, 1997) and El-Hawawish and El-Salamuni tombs in Sohag, (Dahi, 1999).

It becomes clear that the national wealth of Egyptian and Giza monuments exposed to real danger and decay if the people's activities are continued by the same rate of growth.

8. CONCLUSION

Detailed studies on the effect of urbanization and industrialization on meteorology parameters over Giza have been performed. Different meteorological elements throughout the different periods, 1901-1930, 1931-1975 and 1989-1995 have been used. The three periods have been selected to represent stages of growth and development of Giza area. Among the main goal was to study different effects of urbanization and industrialization on climatic variabilities, air quality in addition to their effects on monuments and historical places over Giza. Final results and conclusions could be summarized in the following:

(1) Values of minimum temperature mean temperature and sunspots number have distinctly increased during all year months from old periods passing to recent period. Maximum air temperature values have irregular fluctuations.

(2) Atmospheric turbidity values have been gradually increased until they reach maximum values during recent years while sunshine duration attained inverse behavior.

(3) Relative humidity values have been decreased from old period to middle period, then they increased during recent period, while evaporation values have inverse behavior.

(4) Wind speed, cloud and rainfall amounts have been decreased gradually from the old period to attained minimum values during recent period.

Effects of various atmospheric elements and pollutants on Giza monuments have been explained. The study revealed that these pollutants and their local induced climatic variabilities over Giza threaten the national wealth of Giza monuments by damage and brittleness of its components. Therefore, the given recommendations in this paper should be taken seriously into consideration.

9. RECOMMENDATIONS

It becomes clear that the urbanization and industrialization processes over urban area of Giza cause stone decay of Giza monuments. Therefore, the following recommendations should be taken seriously into consideration:

1- No further consents be given into commission for any extensions to existing industries or any new industries into urban area in Greater Cairo.

2- All extensions to exiting industries and all new industries should be subjected to an Environmental Impact Analysis at an early stage of the design and development phase of the project.

3- In order to limit the air pollutant concentration near the ground, it is preferable either to let the top of the stacks reach above the surface inversions or to use filter in the chimneys to purify the exhauster, or both.

4- in city planning, the direction of the main roads should be decided upon taking in consideration the direction of the prevailing wind.

5- To discourage excessive disposal of wastes in deserts so that they would not be a source of pollution if blown by wind.

6- An efficient exhaust ventilation should be installed in factories where the concentration of suspended dust particulates have been found higher than the threshold limit value.

7- environmental monitoring should be done regularly by the factory personal. The results should be logged and kept for future comparison.

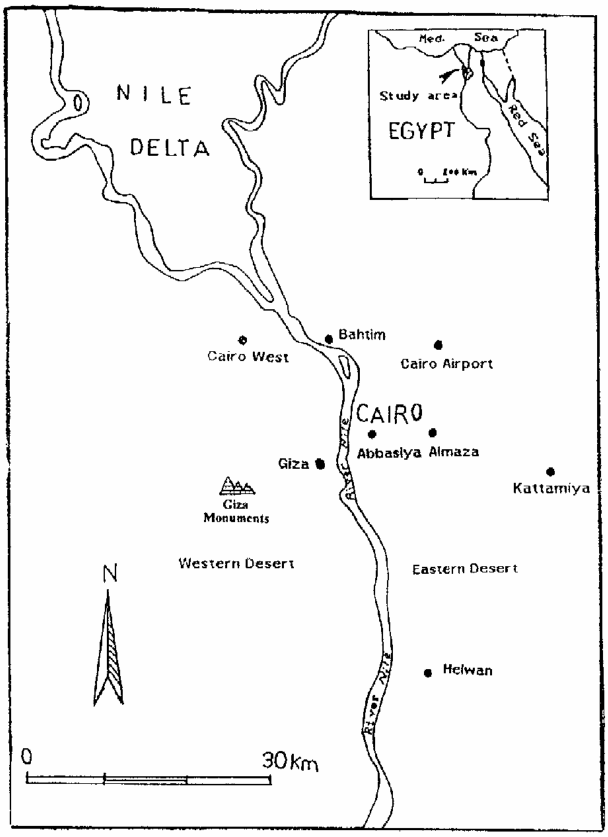

Fig.(1): Map of stations of Greater Cairo area, Egypt, (Study area)

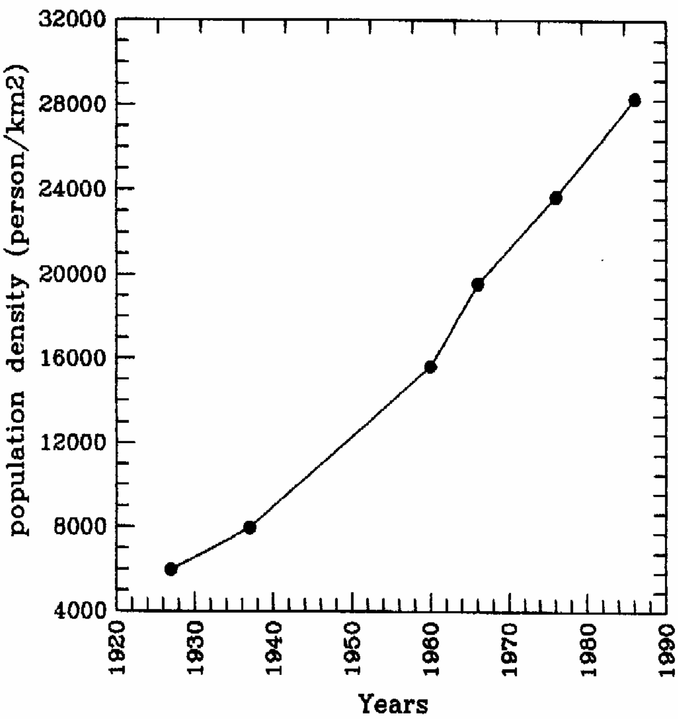

Fig.(2): The Greater Cairo's growth of population density from 1927 to 1986.

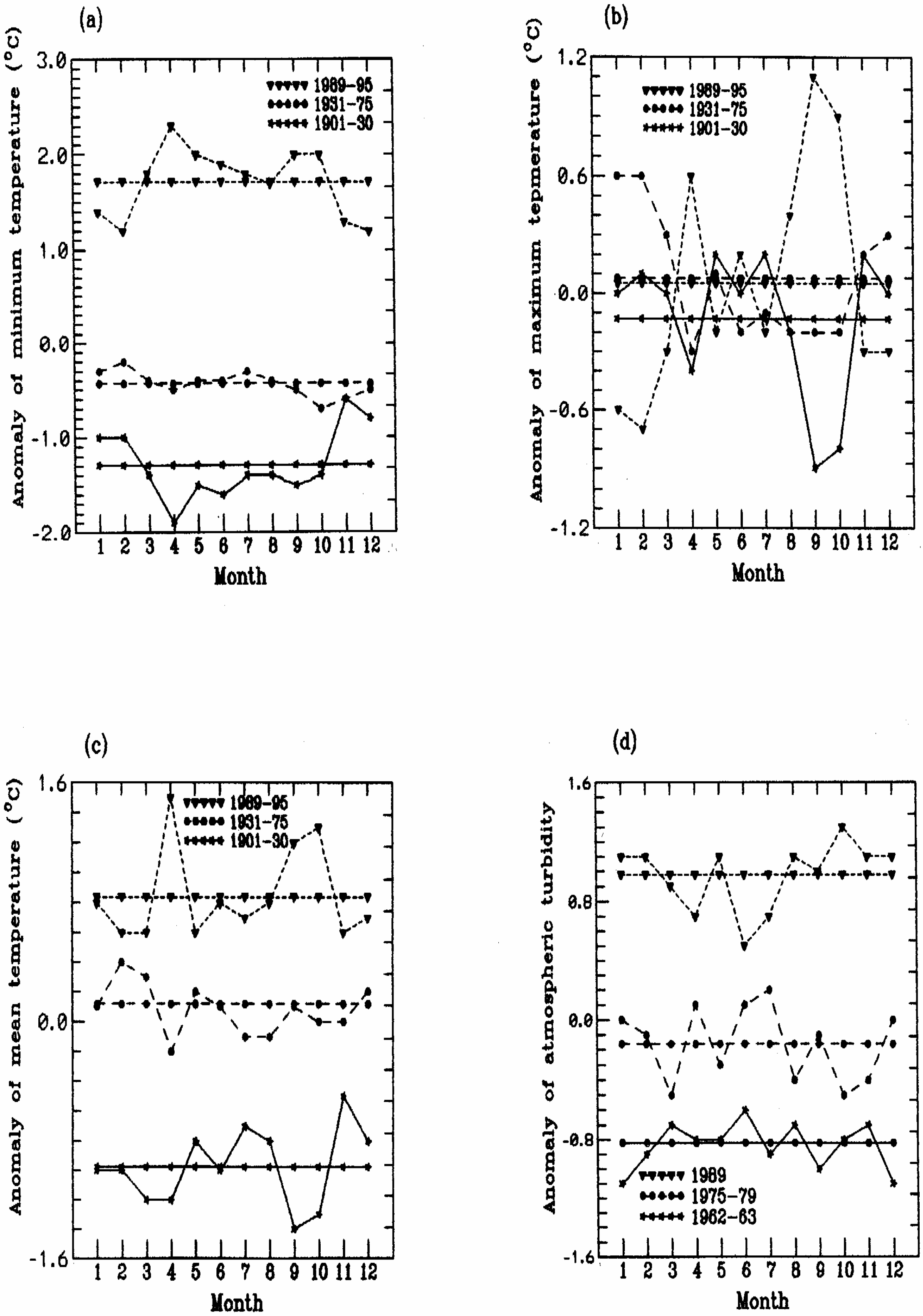

Fig.(3) Variation of monthly mean anomalies in different periods at Giza for:
(a) Minimum temperature (b) Maximum temperature
(c) Mean temperature (d) Atmospheric turbidity

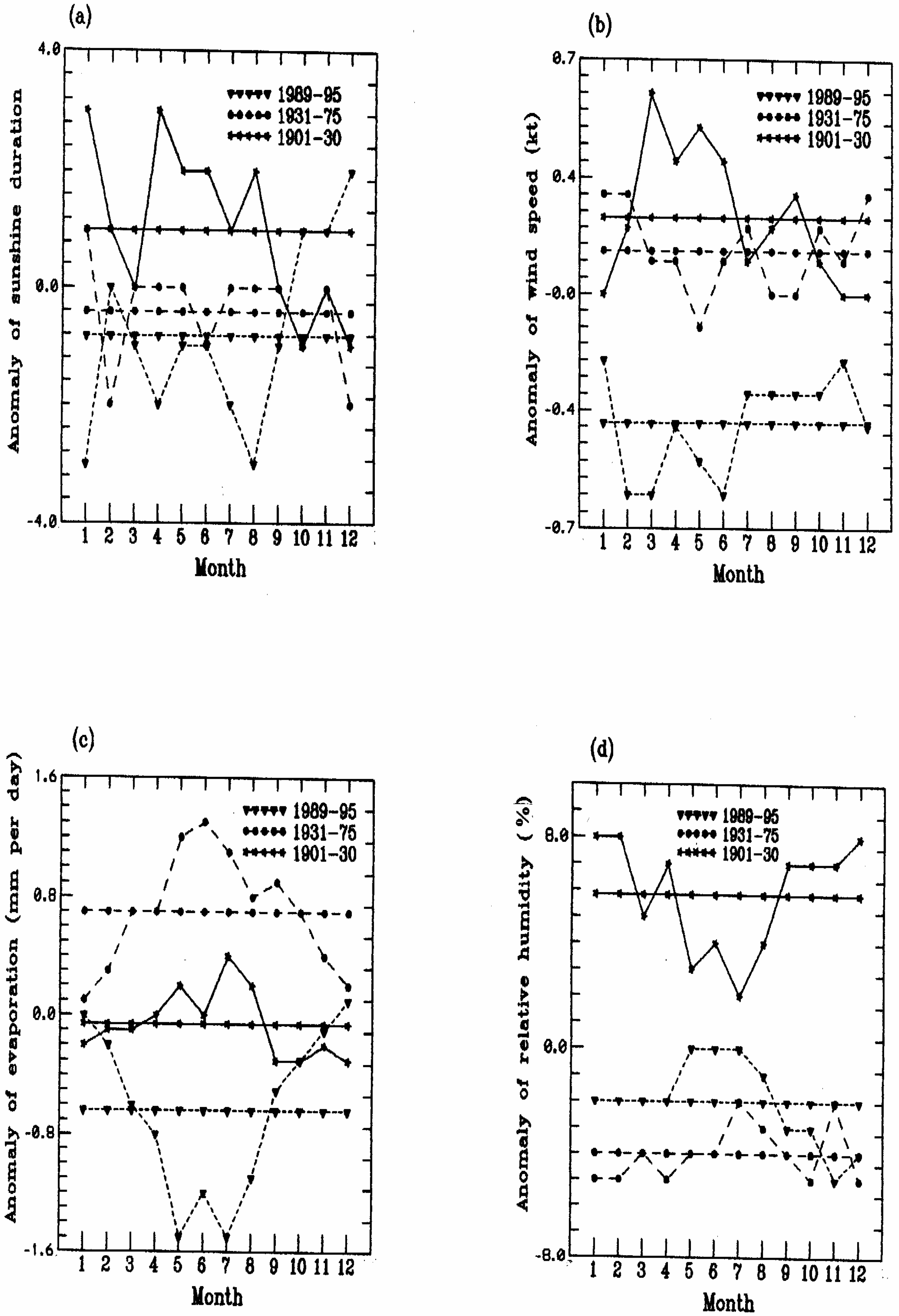

Fig.(4) Variation of monthly mean anomalies in different periods at Giza for:
(a) Sushine duration (b) Wind speed
(c) Evaporation (d) Relative humidity

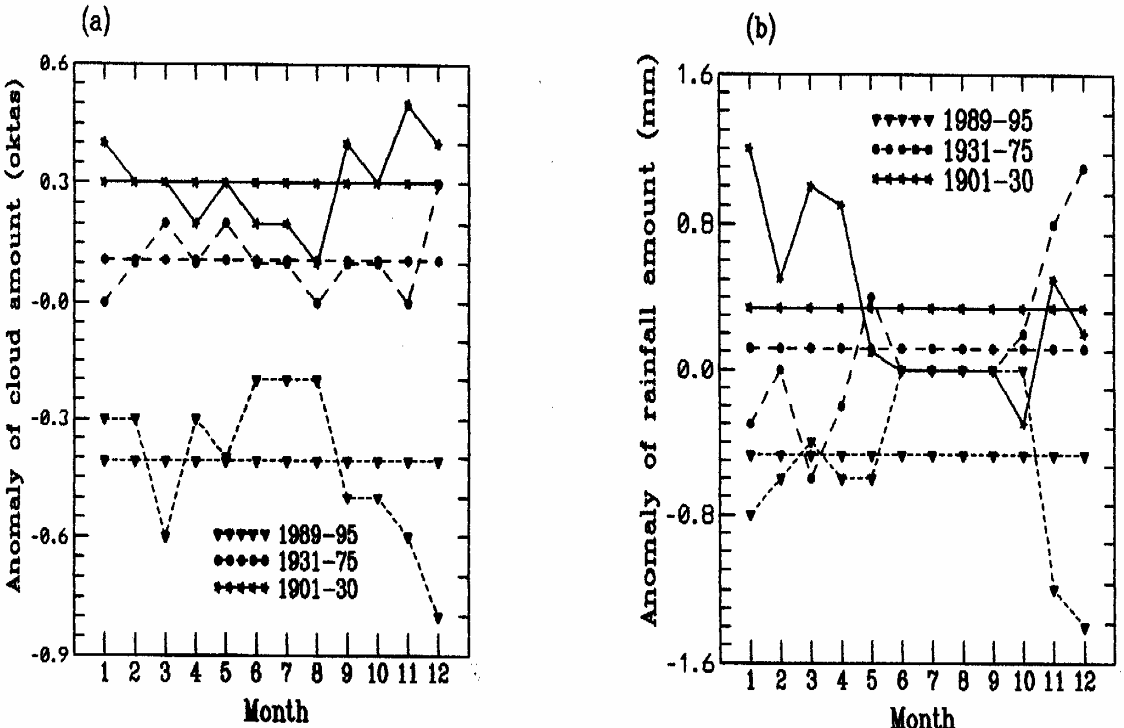

Fig.(5): Variation of monthly mean anomalies in different periods at Giza for:
(a) Cloud amount (b) Rainfall amount

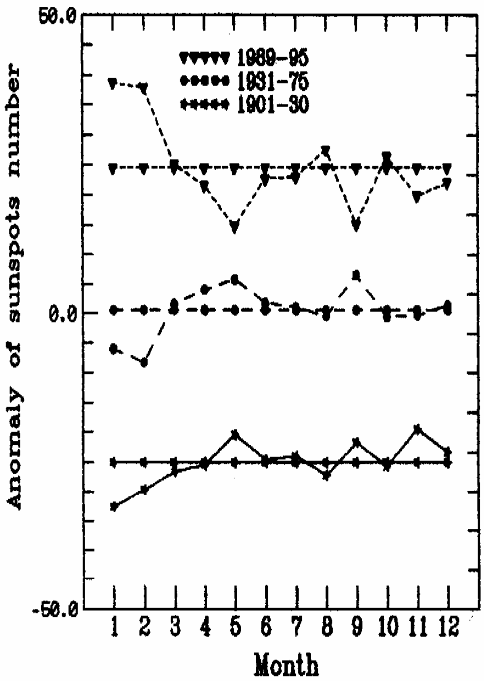

Fig.(6): Variation of monthly mean anomalies of sunspots number in different periods at Giza.

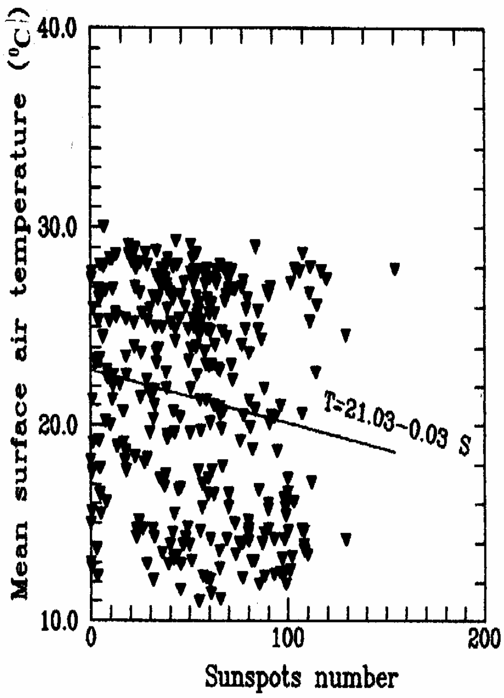

Fig.(7): Relation between sunspots number and surface air temperature.

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