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A STUDY OF ATMOSPHERIC TRANSPARENCY OVER QENA IN UPPER EGYPT

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شفافية الغلاف الجوي لمدينة قنا في مصر العليا

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في هذا البحث تم حساب شفافية الغلاف الجوي لمدينة قنا بمصر العليا وذلك باستخدام قيم الاشعاع الشمسي المباشر المحسوبة من قياسات عملية للاشعاع الشمسي الكلي والمشتت حيث حللت نتائج حسابات المتوسطات الشهرية لمعامل الشفافية في الأيام الصافية والأيام الملبدة بالغيوم وكذلك الأيام المختلطة .

وقد وجد بوجه عام أن قيمة معامل الشفافية تقل باستمرار في اتجاه غروب الشمس الأمر الذي أمكن تعليله بزيادة المحتوى الجوى من الاتربة المعلقة في فترة ما بعد الظهر نتيجة لتأثير تيارات الحمل الناشئة عن تسخين الأرض خلال النهار وما تحمله من معلقات .

كما تأكد التأثير الكبير للسحب في امتصاص أشعة الشمس التي تمر من خلالها مما يؤدي إلى نقص قيمة معامل الشفافية .

وفي هذه الدراسة محاولة لحساب قيمة معامل الشفافية باستخدام قياسات الاشعاع الكلي عند وقت الظهر المحلي في الأيام الصافية والمتوفرة بكثرة وبدقة عالية بالمقارنة لقياسات الاشعاع الشمسي المباشر الغير متيسر الحصول عليها في أماكن عديدة .

أدت هذه المحاولة للحصول على نتائج لمعامل الشفافية تتفق إلى حد كبير مع تلك المستنبطة باستخدام قياسات الاشعاع الشمسي المباشر .

وفي النهاية تم استنباط معادلات تجريبية ذات معاملات أرتباط عالية جداً بين معامل الشفافية والجزء المشتت من الاشعاع الكلي .

Key Words : Aerosl effect, Cloud effect, Diffuse solar radiation, Direct solar radiation, global solar radiation, Transparency coefficient

ABSTRACT

Atmospheric transparency over Qena/Egypt has been studied for direct solar radiation values . which were calculated from global and diffuse solar radiation measurements . The mean monthly of the instantaneously transparency coefficient has been analyzed in clearcloudy . and mixed days . In general . the value of the transparency coefficient was found to decrease in the direction of the sunset hours . owing to the high aerosol content expected in the afternoon time . The clouds deplete significantly the solar energy passed through them and then lead to an obvious decreasing in the transparency coefficient . A try to calculate the transparency coefficient has been done with the aid of the more available global solar radiation measurements . The results are in a good agreement with those obtained for direct solar radiation . The relation between the daily average of the transparency coefficient and the corresponding mean diffuse fraction has been considered . High correlations were found between them in all investigated months and empirical formulae were obtained .

INTRODUCTION

The electromagnetic radiation emitted by the sun covers a wide spectrum of wavelengths , However, 99% of the energy of solar radiation is contained in the wavelength band from 0.15 to 4 μm, with a maximum value at about 0.5 μm.[1] Through its passage in the atmosphere to the surface of the Earth, marked depletion takes place in its energy by scattering and absorption . Gases and particulate matter suspended as aerosol particles in the air participate in these processes .[2] The resultant depletion is small in pure air and increases with increasing amounts of contamination and turbidity.

Qena city is located at the south part of Egypt (Latitude = 26.°10, Longitude = 32.°43, and Elevation = 78m above sea level). It is characterized with a high amount of solar radiation which reaches the earth's surface and which gives us the hope to use it in the future as an energy source instead of the known classical ones. This is of agreat importance to solve the problems resulting from the increase usage of these sources and also from the environmental pollution they cause.

The main point of the present work is to study the depletion of the solar radiation energy, which occurs in the atmosphere of Qena/Egypt. In this concern, the transparency coefficient (Tr) was calculated with the aid of Beer's law using pyranometer measurements of surface solar radiation Its diurnal variation was discussed broadly in view of the corresponding variability of optical air mass, aerosol and some auxiliary meteorolgical observations. Empirical equations were derived to describe the variation of the daily average values of the transparency coefficient in conjunction with the diffuse fraction (D/G) with a very high accuracy. The paper gives also a quick and convenient parameterizations of Beer's formula to calculate the daily average of Tr using the more available global solar radiation measurements compared to the direct ones.

EXPERIMENTAL

Theoretical background and computational techniques

In order to model the interaction between the atmosphere and solar radiation, it is usually assumed that the extinction of the direct solar beam in the atmosphere follows the Beer -Lambert's law (3).

$$I = I_o \exp(-\alpha m) \quad (1)$$

where I is the radiation intensity at the ground, I_o is its intensity outside the atmosphere and m is the relative optical air mass calculated from the solar zenith angle Z using the kasten equation [4].

$$m = 1/(\cos Z + 0.15 / (93.885-Z)^{1.253}) \quad (2)$$

A correction for atmospheric pressure is made by multiplying by p/p. where p is the station pressure and p. is a standard sea level pressure(1001.3 mb). I_o is adjusted to account for the departure of the actual sun - Earth distance R from the mean R*and is given by

$$I_o = I_{sc} (1 + 0.033 \cos(360\, n/365)) \quad (3)$$

in which I_{sc} is the solar constant, taken as 1376 w m^{-2}. and n is the day number of the year. According to eq. 1, the extinction coefficient is given by

$$\alpha = 1/m \ln (I_o / I) \quad (4)$$

from which the transparency coefficient Tr is calculated as:

$$T_r = \exp(-\alpha) \quad (5)$$

Measurements

Since measurement of the direct solar beam is not available in our station. it is determined indirectly through the measurement of global G and diffuse D solar radiation using the following equation

$$G = I \sin h + D \quad (6)$$

where h is the solar elevation. The measurements were carried out using two kipp and Zonen [Model CM 6 B] precision pyranometers, complies with the specification for "first class" pyranometers [5]. One of them was used to measure G. The other was shaded by a shadow band(60 mm width and 610 mm radius). constructed by the author, to measure the diffuse component by eliminating the direct beam. The centering of the sun image on the band was checked daily, ensuring adequate declination and azimuth tracking by the band. A two - channel solar integrator [kipp and Zonen, Model cc 12] was connected to the pyranometers to give the solar irradiance (G and D) in W m^{-2}. Because the shadow band intercepts not only the direct solar beam but also a small part of the diffuse sky radiation, the measured values of D were multiplied by a correction factor given by [6].

$$1/(1 - F/D) \quad (7)$$

$F/D = (2w/\pi\gamma) \cos^3\delta\, (\sin \phi \sin \delta * H^- + \cos \phi \cos \delta \sin H^-$

where ϕ is the latitude of the station.

H^- is the hour angle of the sun at sunrise or sunset, given by

$$H^- = \cos^{-1}(-\tan\phi \tan \delta) \quad (8)$$

δ is the declination angle of the sun.

γ, ω are the radius and the width of the shadow band, respectively.

Depending on the measurement date, and considering the latitude of the station and dimensions of the constructed shadow band, the calculated correction factor varies from 1 to 1.14, which is in a very good agreement with its values determined for other diffusographs [6]. The measurements of global and diffuse solar radiation were carried out hourly from sunrise to sunset in True Solar Time quasi daily in five months, namely February, March, June, July, and August 1992. The corresponding values of the direct solar radiation were determined using eq 6.

The suspended dust particles have been collected on cellulose acetate membrane filter of 0.8 µm pore size and 100 mm diameter using high volume air sampler (F&G model TV-1 BE,USA) at flow rate 3 m^3 hr^{-1}.The sampling period was 3 hours.

The vapor pressure was determined from measurements of air temperature and wet bulb temperature using tables of vapor pressure. prepared by the meteorological Authority of A.R.Egypt according to world Meteorological Organization rules.

RESULTS AND DISCUSSION

The most important parameters, which affect the behavior of the atmospheric transparency are :
i) the optical air mass
ii) the aerosol content in the atmosphere (dust and water vapor) .

At Qena, the optical air mass m shows little changes and approaches the unity over the most hours of the day, except near sunrise and sunset . The number of daily hours, in which the values of the optical air mass approach the unity, increases from 6 hours in February and March to 9 hours in June, July, and August . Consequently, except near sunrise and sunset, the effect of aerosol on the variation of atmospheric transparency may be dominant in this city .

Diurnal patterns of the transparency coefficient

Figure 1 represents the diurnal variation of the transparency coefficient for clear, cloudy and mixed days in the investigated months . From this figure, one can see the following :

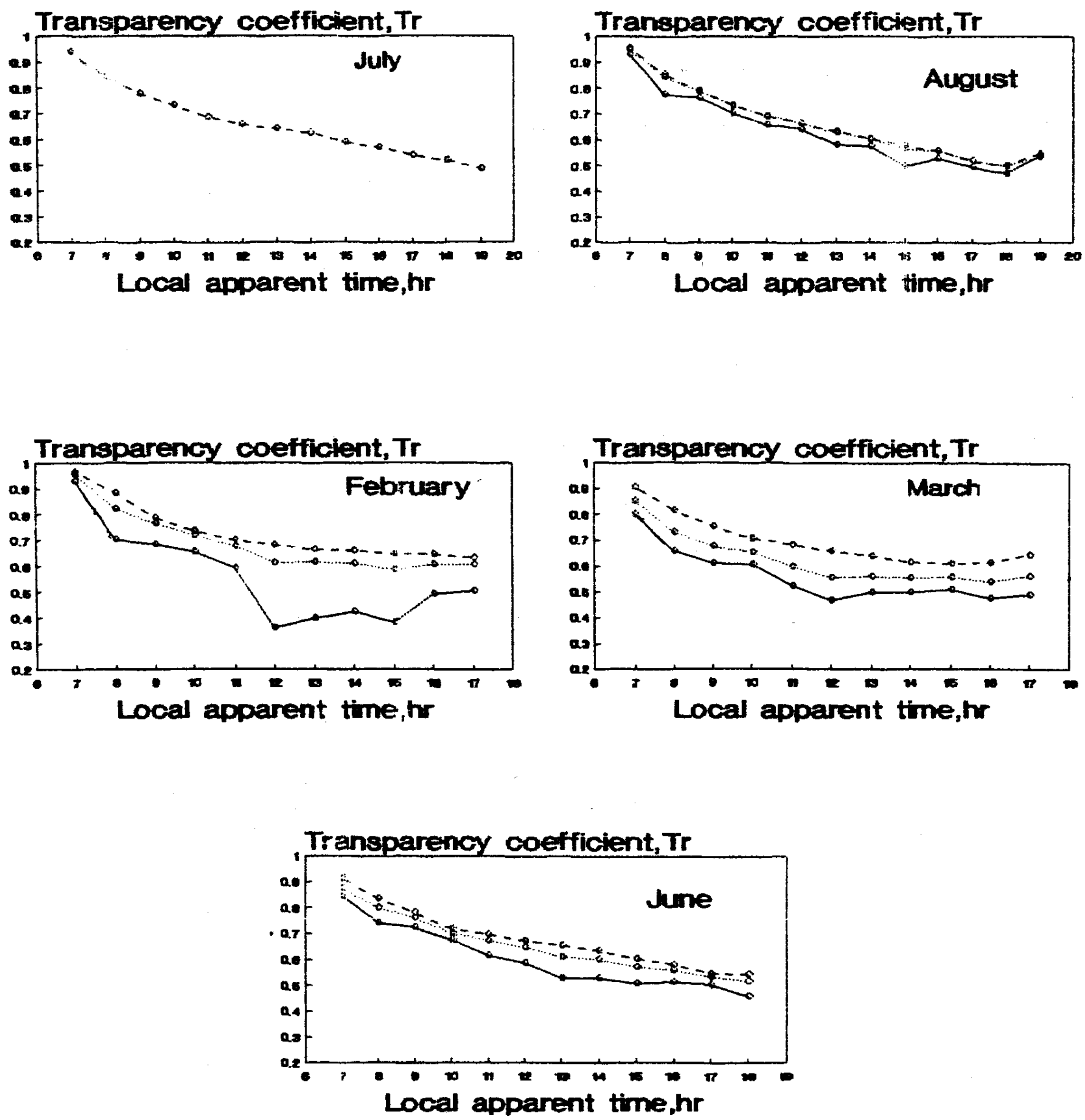


Fig. 1. Diurnal variations of instantaneous values of transparency coefficient.
- dashed line : clear days
- dotted line: mixed days
- solid line: cloudy days

(i) The value of transparency coefficient is maximum in the early morning and then decreases in the direction of the sunset . Generally it is lower in the afternoon hours than in the forenoon ones . This behavior may be explained in terms of the above mentioned parameters affecting the value of the atmospheric transparency, namely the optical air mass and the aerosol content in the atmosphere .

1. The high values of the air mass, which dominates in the early morning, is the reason for the higher values of the transparency coefficient in this time .

2. The decreasing in the transparency coefficient in the rest hours of the day is due to :

a) The high dust content in the atmosphere arising from the well developed vertical mixing of dust particles owing to the increasing in the temperature in these hours . This mixing is more higher in the afternoon than in the forenoon causing higher concentrations of the atmospheric dust particles and consequently low values of the transparency coefficient in the afternoon hours compared to forenoon ones.

The average concentration of dust particles were found to be 11.23, 11.55, 203.6, 546, and 562 μg m^{-3} in the afternoon periods and 7.2, 6.74, 168.4, 444 and 322 μg m^{-3} in the forenoon periods in February, March, June, July and August, respectively .

b) The effect of the water vapor in the atmosphere, which has relatively higher values in the afternoon time in comparison with forenoon time . A correlation study between the vapor pressure and the transparency coefficient shows high correlation between them in the afternoon period indicating the influence of water vapor on Tr in this period . Correlation coefficients of values -0.64, -0.74, -0.89, -0.98 and -0.92 were obtained in February, March, June, July, and August, respectively .

ii) The. average values of the transparency coefficient were higher in the clear days than its corresponding values in the cloudy ones, while its average values at the mixed days are in between . This indicates the influence of the clouds in decreasing the transparency coefficient owing to the great number of water droplets contained in it, which are very active in scattering the direct solar radiation passing through them [7.8] . As seen from the figure, the effect of clouds is clear in February and March, while it is small in June and August . This is due to the large amount of clouds observed in February and March(Avg = 6/8) compared to its amount in June and August(Avg =4/8) . Furthermore, the clouds observed in February and March were dense and dark in comparison with the thin clouds observed in June and August. Also, the variability of the amount and thickness of clouds through the day may be the reason for the somewhat anomalous behavior in the curves, which represent the cloudy days in figure 1. No clouds were observed in July .

In general, the diurnal variation of Tr is complex and shows different micro-fluctuations in different days depending on the optical air mass and the conditions of observations, such as seasons and weather elements [8] .

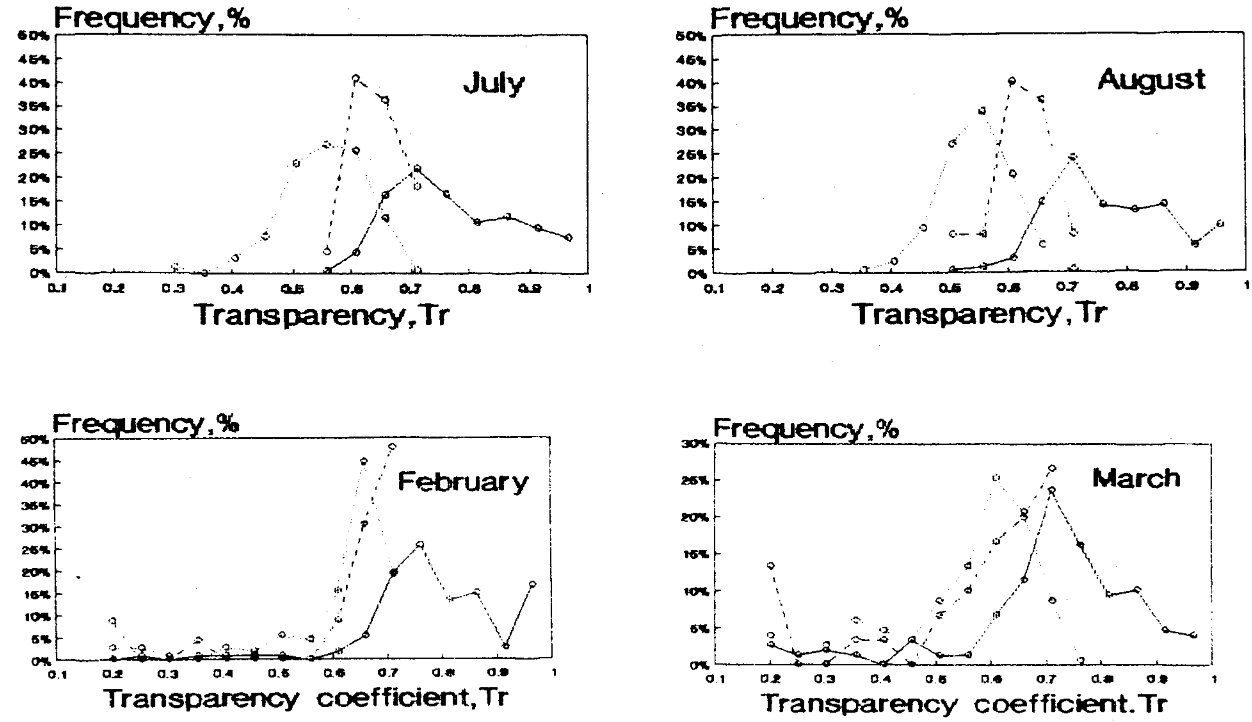
The frequency distribution of transparency coefficient

In this section we try to discuss the variation of transparency coefficient through the different day times with the aid of a statistical treatment to clarify the above deduced results in section 3.1, by calculating the frequency distribution of T_r with respect to the total observations taken at forenoon, noon, and afternoon hours in each of the investigated months . Table 1 summarizes the number of those observations and Fig. 2 represents the results of the calculation. From this figure it is clear that :

Table 1

Number of observation taken at different times of days in defferent months

month / Time	Feb	March	June	July	August
Sunrise -12.00	113	148	132	159	163
12.00	23	30	20	22	25
12.00 Sunset	111	150	122	156	160
Total	247	328	274	337	348



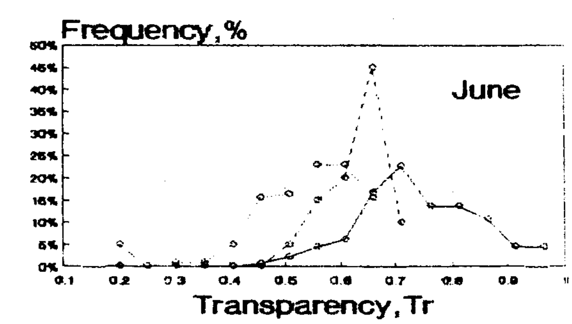


Fig. 2. frequency distribution of transparency coefficient at different day times

- solid line: forenoon
- dashed line: noon
- dotted line : afternoon

i) The frequency curves are generally asymmetric and skewed to the laft (negative skewness) .
ii) The forenoon curves cover the whole obtained class intervals (O.175-0.990) in February and March . while they extend from somewhat higher intervals (0.430 - 0.990). (0.532 - 0.990), and (0.481 - 0.990) in June, July, and August . These curves show maximum frequencies of 25.7% , 23.6% , 22.7% , 22% , and 24% corresponding to transparencies 0.761 in February and 0.710 in the remaining months .

iii) The frequency curves at noon extend in the intermediate region of the transparency ranges (0.481 - 0.735), except for February and March, where the curves skewed to the region of the low transparencies (0.175 - 0.735) . Maximum frequencies in this time of values 47.8% , 27% , 45% , 41% , and 40%, were found corresponding to transparencies 0.710 in February and March, 0.659 in June and 0.608 in July and August .

iv) In the afternoon time, the frequency curves extend in the ranges (0.175 - 0.735) with a maximum frequency of 44.55% at transparency 0.659 in February, (0.175 - 0.786) with a maximum frequency of 25.3% at transparency 0.608 in March, (0.277 - 0.684) with a. maximum frequency of 23% at transparency 0.557 in June, (0.277 - 0.735) with a maximum frequency of 27% at transparency 0.557 and (0.328 - 0.735) with a maximum frequency of 33.8% at transparency 0.557 in July and August, respectively .

The above results obtained from this figure support those concluded from the diurnal patterns in figure 1. The high frequencies of the high transparencies found in the forenoon curves compared to the high frequencies of the low transparencies in the afternoon ones give an evidence for the effect of aerosol and water vapor in decreasing the atmospheric transparency, owing to its high contents in the afternoon hours . The extension of the forenoon curves to the low transparency intervals in February and March indicates the effect of clouds observed in the two months especially in March. in which the number of cloudy days is larger than in February . This appears in the somewhat higher frequencies of low transparency observed in March .

Atmospheric transparency calcuated from global radiation measurements

Because of the measurements of the direct solar radiation are not available at many of solar radiation stations, calculation of the atmospheric transparency using global radiation measurements, which are available with a high accuracy at all solar radiation stations, has to be used . In this paper we discuss a quick and convenient parameterizations of Beer's law to calculate the daily average of the transparency coefficient (T_r) with a high accuracy using the global solar radiation measurements . In spite of the global (direct + diffuse) radiation is not a simple function of a single exponential [9], Beer's law is applicable to it when the measurements be done in clear days and reduced to unit optical air mass (i.e.h=90^o) . This condition eliminates the effect of solar height h and reduces the value of the diffuse solar radiation D to 20% of the global solar radiation G in equation 6 [10] . Consequently the value of direct solar radiation I approaches to large extend (80%) that of global solar radiation and may be then replaced by it in equation 1. In this case, eq 1 can be rewritten as :

$$G = G_0 \exp(-\alpha' m^-) \qquad (9)$$

which gives the extinction coefficient α' in the form

$$\alpha' = (^1/_{m^-}) \ln (G_0/G) \qquad (10)$$

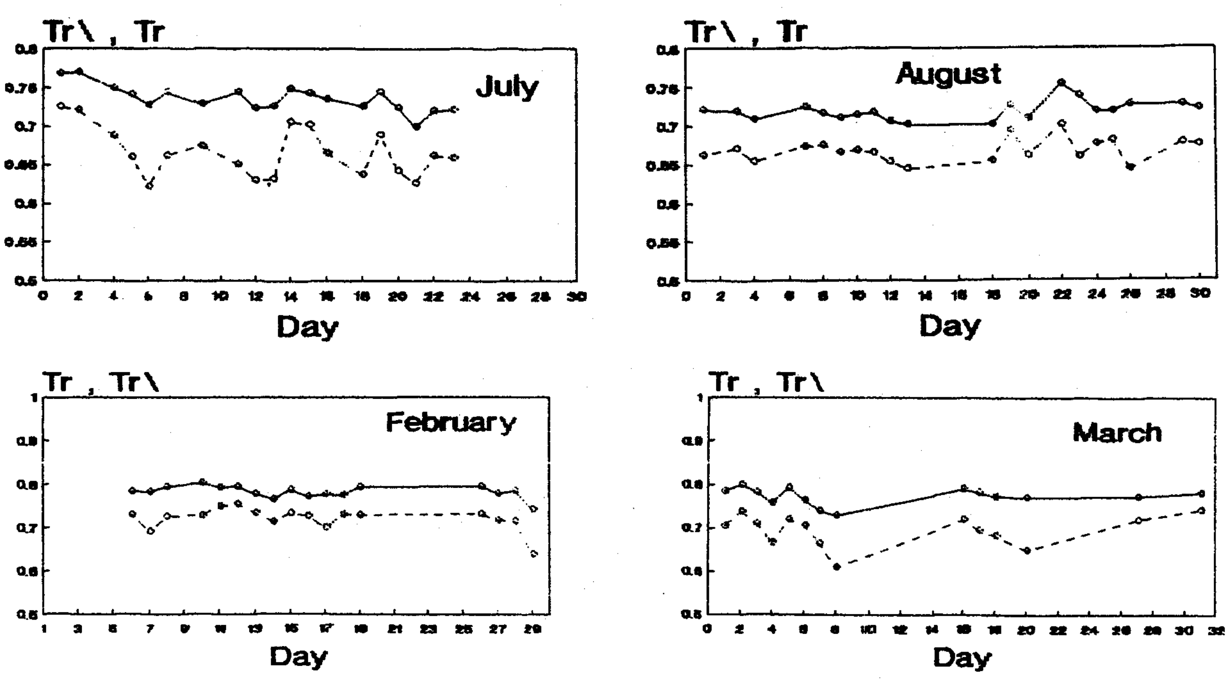
and the transparency coefficient Tr as

$$T'_r = \exp(-\alpha^-) \qquad (11)$$

where m^- is the optical air mass at local noon (which around the unity) . G is the global solar radiation at the surface of the ground and G_0 is the daily extraterrestrial radiation calcuated after [11].

$$G_0 = (24/\pi)\, I_0 (\cos\phi \cos\delta \sin H' + (H' * \pi/180) \sin\phi \sin\delta) \qquad (12)$$

Figure 3. represents the results of the mean daily of the transparency coefficient T'_r calculated using this approach in the considered months and of that calculated using direct solar radiation values T'_r for comparison. From this figure one can see clearly that T'_r for global solar radiation has the same general features of T'_r for direct solar radiarion. The relative deviation of T'_r from T'_r is represented graphically in Fig. 4 for all the investigated months . This figure shows a small relative deviation up to 10-15% for the most numbers of points . which indicates the validity of this representation in studying the atmospheric transparency to acceptable extend . Applications of this method has been used successfully in studying the atmospheric transparency by other authors in Egypt [12,13] .



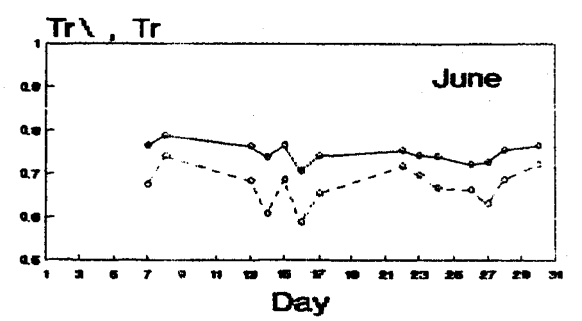


Fig. 3.

Mean daily of transparency coefficient calculated using global T`r) and direct (Tr) solar radiation meas urements.
- solid line: T`r
- dashed line: Tr

The relationship between the transparency coefficient T_r and the diffuse fraction (D/G)

Figure 5 represents the relationships between the average daily values of the transparency coefficient $\bar{T}_r$ and its corresponding mean values of ($\bar{D}$/G) in the investigated months . The figure shows very high correlations between the two variables in all these months , with correlation coefficients equal to -0.97, -0.95 , -0.97 , 0.91, and -0.92 and significance values of less than 0.0001 in February, March, June, July, and August at respective. Empirical equations give the relations between $\bar{T}_r$ / and ($\bar{D}$/G) were found to be in the forms:

$$\bar{T}_r = 0{,}930 - 0.855\,(\bar{D}/G) \quad \text{in February}$$
$$\bar{T}_r = 0{,}937 - 1.001\,(\bar{D}/G) \quad \text{in March}$$
$$\bar{T}_r = 0.861 - 0.825\,(\bar{D}/G) \quad \text{in June} \qquad (13)$$
$$\bar{T}r = 0.854 - 0.818\,(\bar{D}/G) \quad \text{in July}$$
$$\bar{T}r = 0.858 - 0.884\,(\bar{D}/G) \quad \text{in August}$$

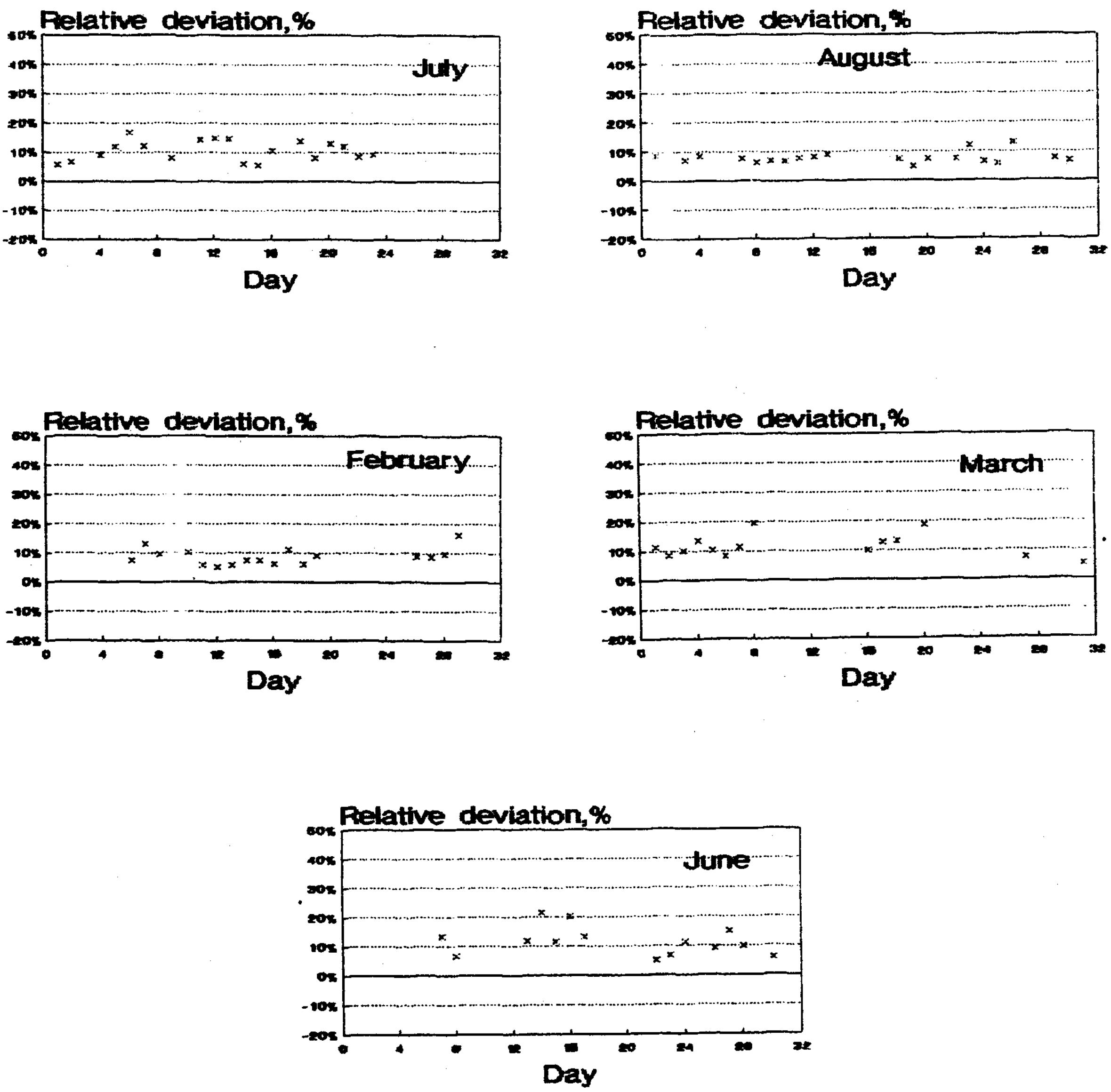
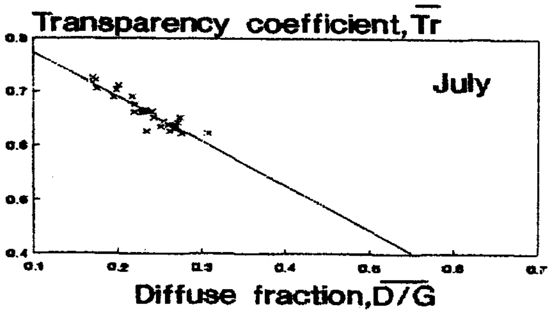
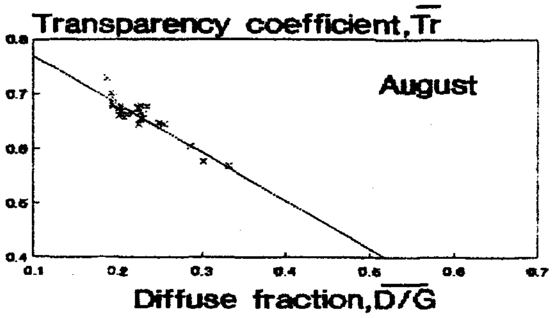
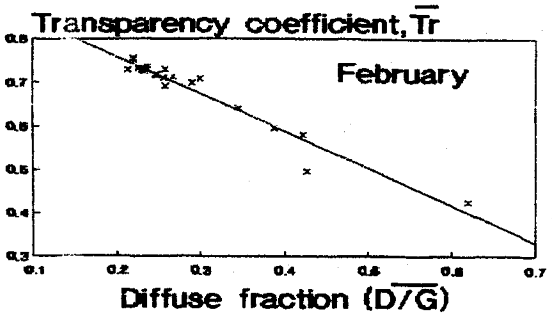


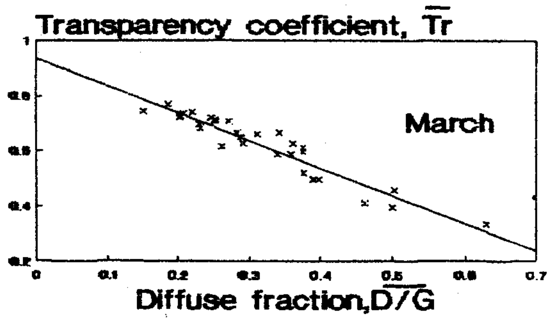
Fig. 4. Relative deviation of transparency coefficient calculated using global solar radiation measurements (T`r) from that calculated using direct ones (Tr).

The relative deviation of the daily average of the predicted transparency coefficient $(\bar{T}_r)_{pred}$ using the above equation from the measured one $(\bar{T}_r)_{rexp}$ as a function of the (D/G) is shown in Figure 6.









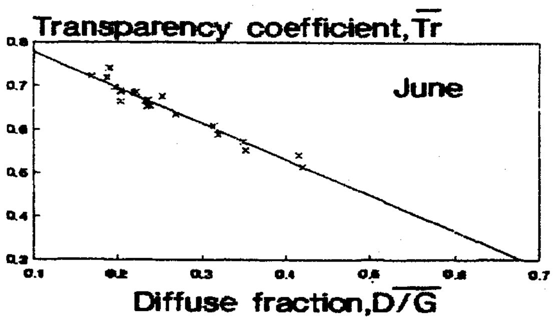
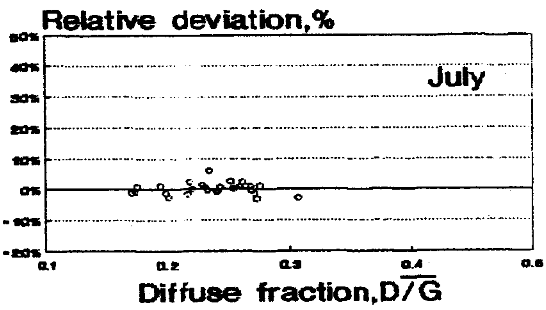
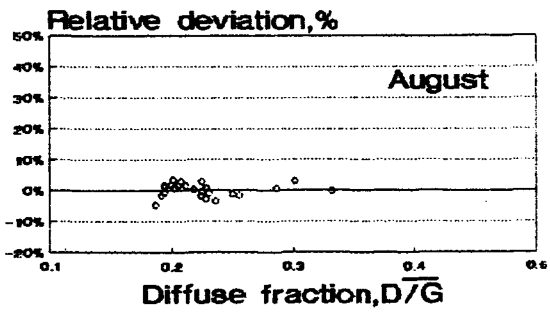
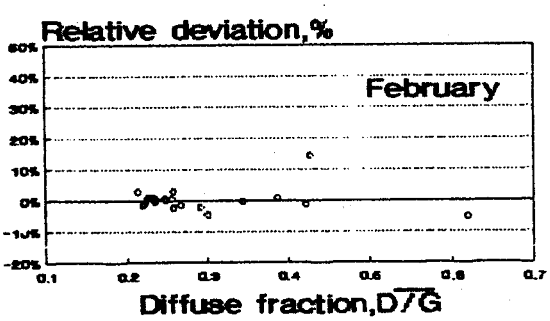


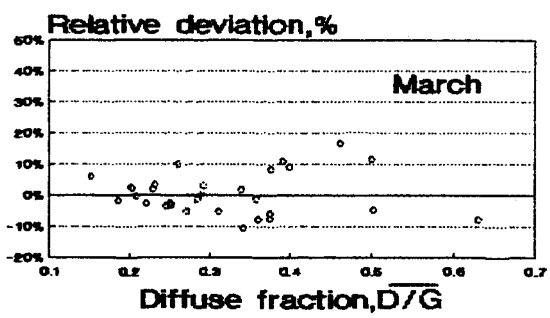
Fig. 5 . Relation between the daily average of transparency coefficient (Tr`) and its corresponding values of diffuse fraction (D/G).

From this figure, it is clear that the relative deviation is low (<< ± 10%), the mater which supports the possibility of using the equation 13 in determining the daily average of transparency coefficient ($\overline{T}_r$) with a very high accuracy with the aid of the measured diffuse fraction ($\overline{D}/G$).









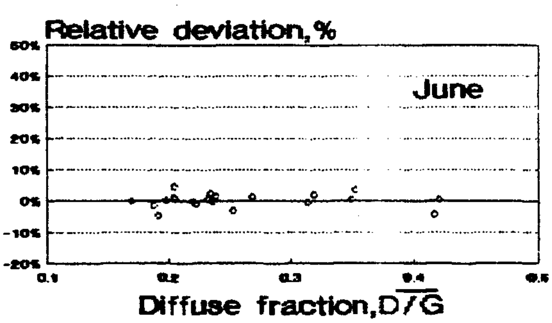


Fig. 6 : Relative deviation of daily average predicted transparency coefficient ($\overline{T}r$) pred from the experimental one (Tr) exp.

The scattering of the points is abvious in this figure in March reflects the effect of clouds observed in this month.

CONCLUSIONS

The atmospheric transparency has been studied in Qena/ Upper Egupt. This Study leads to the following conclusions:-

1. Qena city is generally characterized with high atmospheric transparency, which is a good indcator for the clearness of the atmosphere in this region. This supports the availability of using the abundant solar energy in Qena in many application fields.
2. The atmospheric transparency was found to be lower in the afternoon hours than in the forenoon ones. indicated with the high frequencies of the low transparency intervals obtained in the afternoon times and the high frequencies of the high transparency ones obtained in the forenoon times.

This is due to the high aerosol content arising from the well developed vertical mixing of atmospheric particles in the afternoon hours.

3. One of the most important conclusions is the possibility of using the more available precision data of global solar radiation under certain condition (clear days and unit optical air mass) instead of the rare ones of direct solar rediation. The very good agreement of the transparency coefficients obtained with the both components supports this result.

4. Strong correlations have been found between the average daily transparency coefficients and their corresponding mean diffuse fractions and emirical formulae were derived for these relations in the investigated months, which can be used in determining $\bar{T}_r$ using the measured values of $(\bar{D}/G)$ accurately.

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