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Analysis and correlation of ultraviolet solar radiation from routine meteorological measurements over Egypt

A. I. SALEM

Department of Physics, Faculty of Science, Zagazig University, Egypt

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सार : काहिरा (30° 15' उ., 31° 17' पू.) और आसवान (23° 58' उ., 32° 47' पू.) के क्षैतिज सतह पर मासिक औसत दैनिक भूमंडलीय, जी. और पराबैगनी, यू.वी., सौर विकिरण की घटनाओं के तीन वर्षों (1990 - 92) के मापों को इस शोध पत्र में प्रस्तुत, संसाधित और विश्लेषित किया गया है। यह देखा गया है कि प्राप्त हुए सौर विकिरण घटक जी. और यू.वी. के लिए आकलित मासिक औसत दैनिक मान काहिरा में (18.1 MJ/m², 0.55 MJ/m²) और आसवान में (22.1 MJ/m², 0.71 MJ/m²) थे। मापित सौर विकिरण घटकों पर वायुमंडलीय धुंध के प्रभाव की भी जाँच की गई और इस पर विचार विमर्श किया गया है। पराबैंगनी और भूमंडलीय विकिरण (यू.वी./जी.) के अनुपात का आकलन किया गया है और इसकी तुलना अरब प्रायद्वीप के अन्य स्थानों से की गई। तीन वर्षों की अवधि के दौरान चुने हुए स्थानों पर जी. और यू.वी. के मध्य सहसंबंध का पता लगाने के लिए समाश्रयण विश्लेषण किया गया है और इससे संबंधित संस्तुतशुदा सहसंबंध समीकरणों का भी उल्लेख किया गया है।

चूँकि काहिरा (मिस्र के निचले भागों) और आसवान (मिस्र के ऊपरी भागों) को छोड़कर मिस्र के यू.वी. सौर विकिरण के मौसम विज्ञानिक माप उपलब्ध नहीं हैं। अतः मिस्र के ऊपरी और निचले दोनों क्षेत्रों में किसी भी स्थान के उपलब्ध भूमंडलीय सौर विकिरण मापों के साथ हमारे सहसंबंध समीकरणों का प्रयोग करके उस स्थान के यू.वी. सौर विकिरण को आकलित किया जा सकता है।

ABSTRACT. For three years (1990-92) measurements of the monthly average daily global, G, and ultraviolet, UV, solar radiation incident on a horizontal surface at Cairo (30°15′N, 31°17′E) and Aswan (23°58′N, 32°47′E) are presented, processed and analysed. It was found that the computed monthly average daily values for the obtained solar radiation components, G and UV, were (18.1 MJ/m^2, 0.55 MJ/m^2), for Cairo and (22.1 MJ/m^2, 0.71 MJ/m^2), for Aswan. The effect of atmospheric dust on the measured solar radiation components is also investigated and discussed. The ratio of the ultraviolet to global radiation (UV/G) are calculated and compared with other sites in the Arabian Peninsula. A regression analysis has been done to find a correlation between G and UV at the selected sites during the three year period and the recommended correlation equations have also been stated.

Since the meteorological measurements of UV solar radiation are not available over Egypt, except at Cairo (Lower Egypt) and Aswan (Upper Egypt) stations, our correlation equations can be used to calculate this component from the available global solar radiation measurements at any site in the two zones of Upper and Lower Egypt.

Key words – Ultraviolet solar radiation, Global solar radiation, Atmospheric dust, Regression analysis.

1. Introduction

Measurements of ultraviolet radiation are taken at Egypt for last few tears. Such type of solar radiation is very important because of its biological effects on the earth's surface and the surrounding atmosphere. High doses of ultraviolet radiation, specially band B, causes skin diseases, eye cataract, pigmentation, photo-decomposition, degradation of materials and may also harm crops (Som 1992). Inverse relation is known between the ozone density in the atmosphere and the amount of UV reaching the earth's surface. From this point of view, the

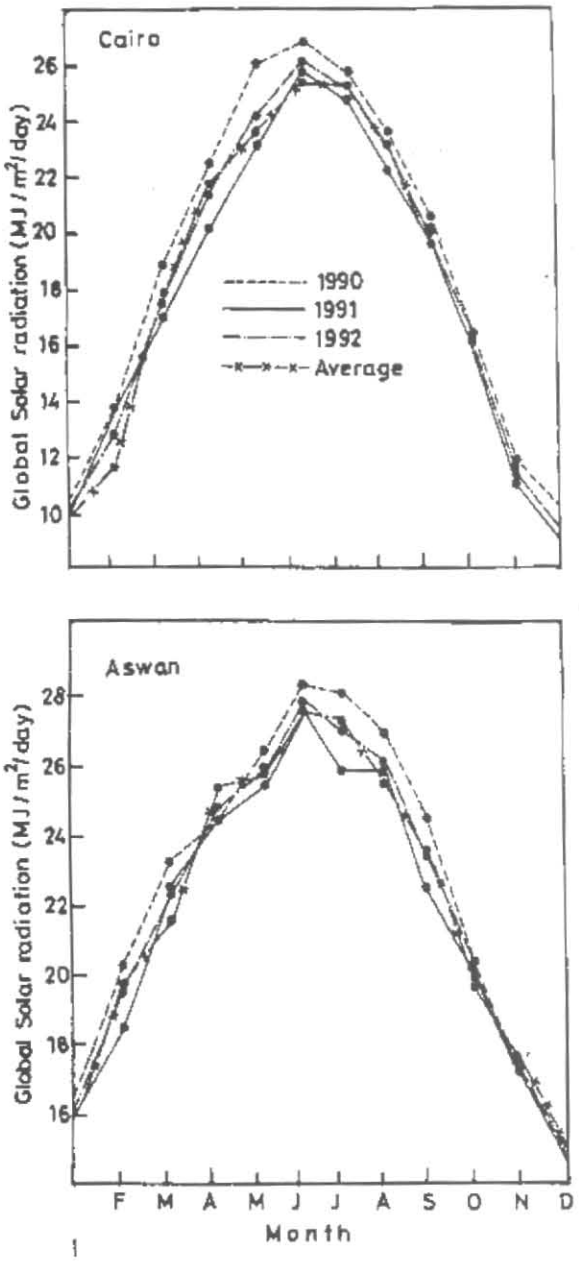

Fig. 1. Monthly average daily distribution of global solar radiation G (MJ/m^2) and the annual average

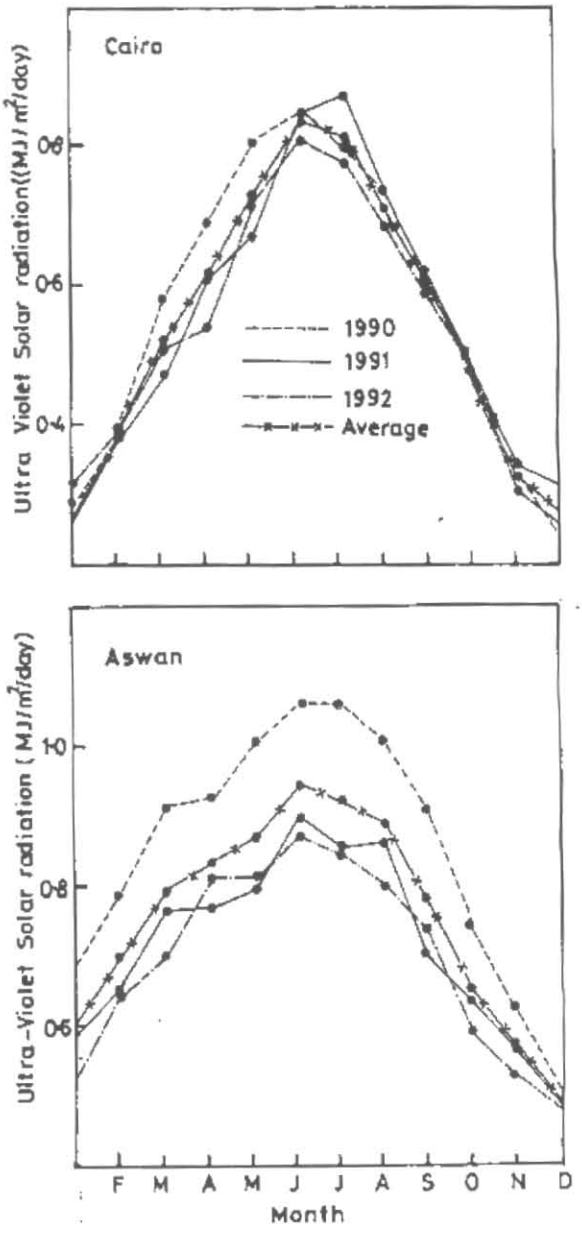

Fig. 2. Monthly average daily measured distribution of Ultra-violet solar radiation, UV (MJ/m^2) and the annual average

UV radiation is highly affected by the ozone which is destroyed by pollutants such as freon refrigerants, spray and atomic bomb tests (Elhadidy *et al.* 1990; Fiester and Grasnick 1992).

In Egypt, measurements of global solar radiation began 1956 at Cairo and 1980 at Aswan. The ultraviolet measurements at Cairo and Aswan were added in 1990 (Mosalam Shaltout *et al.* 1994) using an Epply radiometer which is sensitive to radiation in the wavelength band 295-385 nm (Wilson 1995).

In the present paper, a correlation between the ultraviolet radiation UV and the global solar radiation G at Cairo (13°15'N, 31°17'E) and Aswan (23°58'N, 32°47'E) are investigated. The dependence of the ultraviolet on the atmospheric dust is also studied. The choice of Cairo and Aswan sites was due to two reasons. First: Cairo represents the typical weather conditions of lower Egypt while Aswan represents such conditions at upper Egypt. Second: the ultraviolet radiation data are available for three successive years (1990-92) only for these stations.

TABLE 1

Monthly average daily values of global and Ultraviolet solar radiation in MJ/m² day beside the calculated values of the percentage (UV/G), at both Cairo and Aswan

Month	Cairo			Aswan		
	G	UV	(UV/G) x 100	G	UV	(UV/G) x 100
Jan	9.95	0.268	2.67	16.08	0.599	3.73
Feb	12.8	0.389	2.80	19.65	0.704	3.58
Mar	17.63	0.524	2.97	22.52	0.798	3.70
Apr	21.26	0.617	2.90	24.84	0.837	3.37
May	24.1	0.734	3.04	25.89	0.875	3.38
Jun	26.09	0.838	3.21	27.84	0.948	3.41
Jul	25.31	0.816	3.22	27.05	0.920	3.40
Aug	23.11	0.713	3.09	26.01	0.889	3.42
Sep	20.02	0.593	2.96	23.29	0.777	3.34
Oct	16.10	0.469	2.91	19.84	0.652	3.30
Nov	11.46	0.327	2.85	17.35	0.588	3.39
Dec	9.42	0.272	2.88	14.82	0.484	3.26
Mean	18.01	0.55	3.05	22.1	0.71	3.21

2. Results and discussion

Data on the daily global and ultraviolet solar radiation (G and UV) at Cairo and Aswan were collected over a period of three years, namely 1990, 1991 and 1992. Average monthly data besides the annual mean values, are illustrated Figs. 1and 2 for Cairo and Aswan respectively.

The monthly average daily values for both G and UV at Cairo and Aswan besides the daily variation of UV/G ratio are presented in Table 1. From Table 1, it is clear that the annual daily mean of global solar radiation is 18.01 MJ/m² for Cairo and 22.1 MJ/m² for Aswan. With respect to UV, the corresponding values were 0.55 MJ/m² and 0.71 MJ/m², for Cairo and Aswan respectively. It can also be seen that an average drop is 65% and 68% between the highest values of both G and UV (mainly in June) and the lower values (mainly in January) at Cairo. At Aswan the corresponding drop is 47% for both G and UV average daily values. The large drop in Cairo may be due to the high pollution potential in the plateau region of Cairo city and the stability of the ozone layer during the last three years (Mosalam Shaltout *et al.* 1994). During the three year period of measurements, the highest recorded hourly ultraviolet radiation at Cairo was 1.11 MJ/m² in 4 July 1990 and 1.15 MJ/m² on 3 June 1990 at Aswan. Referring to the ratio (UV/G), see Table 1, it was found that the (UV/G) percentage is higher in summer as compared with winter for Cairo, while Aswan shows the inverse conditions.

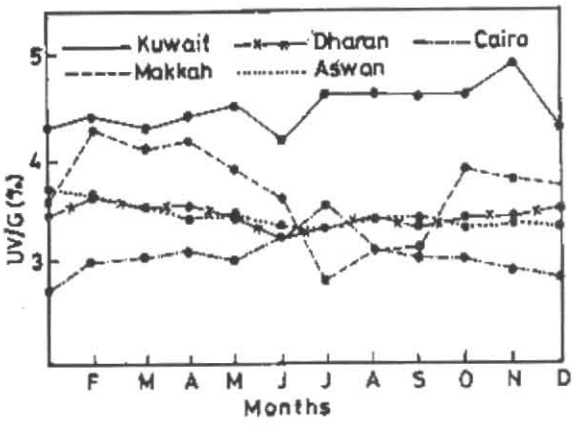

Fig. 3. Monthly variation of UV/G ratio for both Cairo and Aswan as compared with UV/G for Kuwait, Dhahran and Makkah

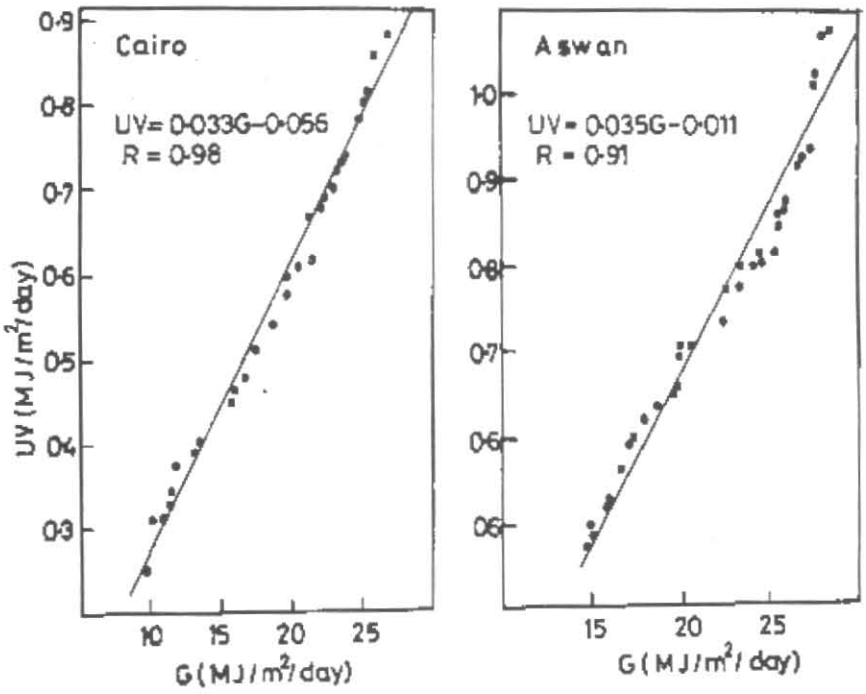

Fig. 4. Correlation between global and ultraviolet solar radiation

TABLE 2

Calculated values for the percentage decrease in the received total daily G and UV solar radiation due to the effect of dust

Date	Cairo % Reduction		Date	Aswan % Reduction	
	UV	G		UV	G
05/Mar 1990 * 22/Mar 1990	44	58	21/Dec 1990 * 31/Dec 1990	57	63
18/Mar 1991* 27/Mar 1991	20	26	17/Apr 1991* 07/Apr 1991	39	37
22/Apr 1992 * 08/Apr 1992	63	32	31/May 1991 * 16/May 1991	49	28
N	N	N	26/Mar 1992 * 14/Mar 1992	57	62
N	N	N	24/Apr 1992 * 22/Apr 1992	26	14
N	N	N	24/May 1992 * 18/May 1992	29	28
Mean	42	39	Mean	43	39

N- Not available, * - Dusty day

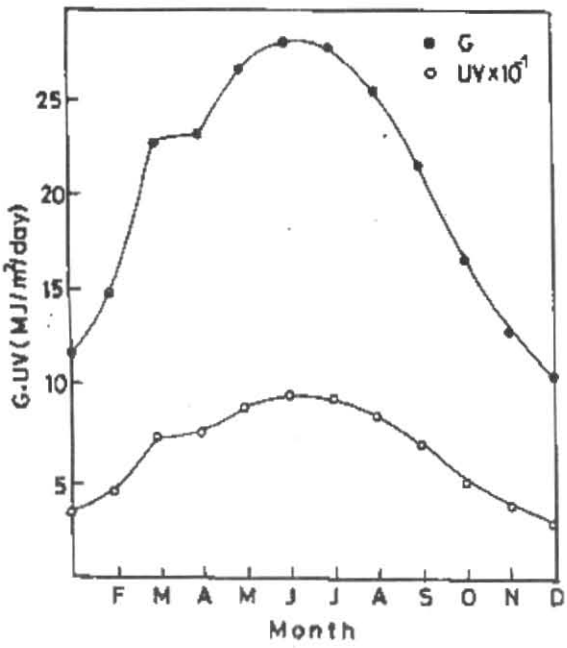

Fig. 5. Average daily distribution for both global and ultra-violet solar radiation components at Al-Arish

To study the effect of atmospheric dust on both global and ultraviolet solar radiation, we scanned the dusty days through the three year period for both Cairo and Aswan. Only three days were available for Cairo while at Aswan six days were available. During the same period of years, from 1990 to 1992, an equal number of dust free days were chosen. The chosen dust free days were in the same year and month of the dusty one. It is of value to note here that the dusty days were chosen with visibility less than 10 km, while dust free days has a visibility of more than 20 km (Sami and Al-Aruri, 1990). Under this choice, percentage of reduction in the received G and UV components were calculated and listed in Table 2. From Table 2, one can notice that the mean percent reduction in the received UV radiation is higher than such reduction in the global solar radiation at both Cairo and Aswan. This agrees with the conclusion, that the UV component of solar radiation is subject to the greatest atmospheric scattering obeying the well-known Rayleigh scattering process (Sami and Al-Aruri, 1990)

Fig. 3 shows the monthly variation of the ratio UV/G for Cairo and Aswan as compared with three sites in the Arabian peninsula [Kuwait city in Kuwait (Al-Aruri *et al.* 1988; Dahran and Makkah in Saudi Arabia- Elhadidy *et al.* 1990 and Khogali & Al-Bar, 1992)]. From this figure we can deduce the following: -

(a) In all sites the ratio UV/G ranged between 2.7% and 4.9%

(b) Cairo ratio during the most months of the year is the lowest relative to the all other sites, due to the high air pollution in Cairo city produced by traffic and industrial activities, specially the surface ozone.

(c) Aswan ratio and its monthly variation is close to that of Dahran in Saudi Arabia.

(d) Kuwait ratio during the most of the months of the year is the highest relative to all other sites. It is possibly due to the effect of Iraq-Iran war during 1980's on the stratosphere of Kuwait, where UV measurements in Kuwait is performed from July 1985 to June 1987 during the war.

2.1. *Correlation between G and UV solar radiation*

Many types of correlation were tried to find out the best fit between G and UV data. It was found that the data are going good with the best linear fit in the form

$$UV = aG \pm b \quad (1)$$

Where a and b are regression coefficients which depend on the weather parameters of the location. Data has been processed using an advanced computer program and the obtained values for a and b were: 0.033, – 0.055 for Cairo and 0.035, – 0.011 for Aswan. The obtained values for the correlation coefficient, R, were 0.98 and 0.91 for Cairo and Aswan respectively. The correlation coefficients show that the data trend is towards the best linear fit correlation. Fig. 4 shows the best linear fit diagrams between G and UV taken through three-year period of data at Cairo and Aswan. The correlation equations investigated were as the following :

$$UV = 0.033G - 0.055;\ R=0.98 \text{ (for Cairo, lower Egypt)} \quad (2)$$

and

$$UV = 0.035G - 0.011;\ R = 0.91 \text{ (for Aswan, upper Egypt)} \quad (3)$$

To test the applicability of our correlation, data of average daily global solar radiation were substituted in Equation (2) to calculate the corresponding values of ultraviolet component of solar radiation at Al-Arish site (31° 50′N, 33° 04′E), in Lower Egypt site.

The global solar radiation data used were averaged from daily measured values during the five-year period from 1985-89 at Al-Arish. The average daily distribution for both measured values of G and calculated values of UV at Al-Arish are shown in Fig. 5.

3. Conclusions

It can be concluded that, there is a gradual decrease in UV radiation falling at the ground level over Egypt especially at Cairo. This decrease is due to the absorption and scattering of UV by air pollutants, mainly the surface ozone. The disadvantage of the data comes from the fact that, the considered period of analysis is short. We can conclude that the correlation equations (2) and (3) can be used to calculate the UV radiation from the available global insulation in the plateau regions of Lower and Upper Egypt. It can also be concluded that, the atmospheric dust has a measurable effect in both global and ultraviolet solar radiation over Egypt.

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