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Studying the ultraviolet and visible solar radiation over Cairo and Aswan and their correlation with climatological parameters

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Abstract. A study of the hourly, monthly, and annual variations of global and ultraviolet solar radiation and the meteorological parameters over a period of four year (1989-1992) over Cairo (30·05°N, 31·17°E) and Aswan (23·58°N, 32·47°E) in Egypt has been done. Measurements were carried out using Eppley ultraviolet radiometers by the Egyption Meteorological Authority. The global solar radiation was recorded using Eppley pyranometers. The correlations between the atmospheric transmission of ultraviolet solar radiation and clearness index and between ultraviolet and global solar radiation for Cairo and Aswan was also done. The correlations between the different variables by the linear regression analysis to estimate an empirical function relating global radiation to ultraviolet radiation and the meteorological parameters (temperature, water vapour pressure, and cloudiness) and a comparitive study between Cairo and Aswan has also been successfully carried out.

Keywords. Ultraviolet solar radiation; correlation; meteorological parameters; global solar radiation.

1. Introduction

Solar energy is the most abundant permanent energy source. The earth receives about 170 trillion kW from this source. Knowledge of global solar irradiance at a site is essential for the proper design and assessment of flat plate type of solar energy conversion systems.

Some of the systems, such as concentrating systems, require information on direct beam component; whereas in the case of tilted plain surfaces, the diffuse component of solar irradiance is also important for the computation of system performance.

In a planetary scale, 17% of solar radiation is absorbed by the atmosphere, 30% is reflected by the constitutents of the atmosphere, 53% reaches the surface of the earth, 31% of it as direct solar radiation and 22% as diffuse radiation.

Ultraviolet solar radiation, which compromises 8·73% of the solar spectrum is more important for its effect on human life. An increase of it can increase the incidence of skin cancer, cataracts and immune deficiencies and many also harm crops, ecosystem and materials. The amount of visible and ultraviolet solar radiation reaching the ground level is greatly affected by atmospheric conditions including type of cloud cover, humidity and size and amount of dust particles.

The aim of this work was to estimate relations between solar radiation components and climatological parameters for Cairo and Aswan.

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2. Variations of ultraviolet and global solar radiation

It is more important to study the hourly, monthly, and annual variations of solar radiation in the solar energy design. Cairo and Aswan are two regions having two different climatological conditions.

Figures 1–3 represent the monthly variation of ultraviolet solar radiation as hourly values for the measured data. The highest intensity value is in June and the lowest is in December. In 1989 the values recorded were higher than in the years of 1990 and 1991 for all months.

There is no symmetry for all months between ultraviolet solar radiation values before noon and during the afternoon hours. The values during the afternoon hours are higher than before noon hour values due to the presence of the International Cairo Airport on the east of the Egyptian Meteorological Authority where the data was measured. The airplanes cause air pollutants in the atmosphere which are blown by the wind from the airport atmosphere towards the Egyptian Meteorological Authority atmosphere.

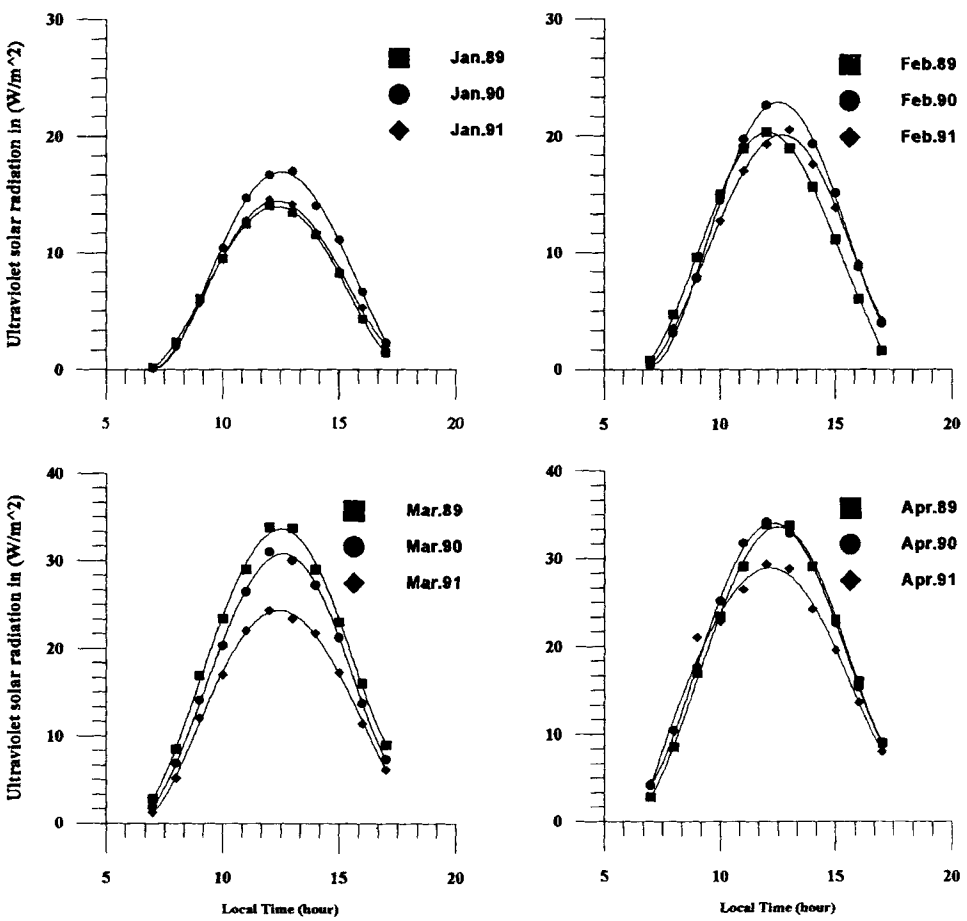

Figure 1. Monthly variation of ultraviolet solar radiation over Cairo in (W/m^2).

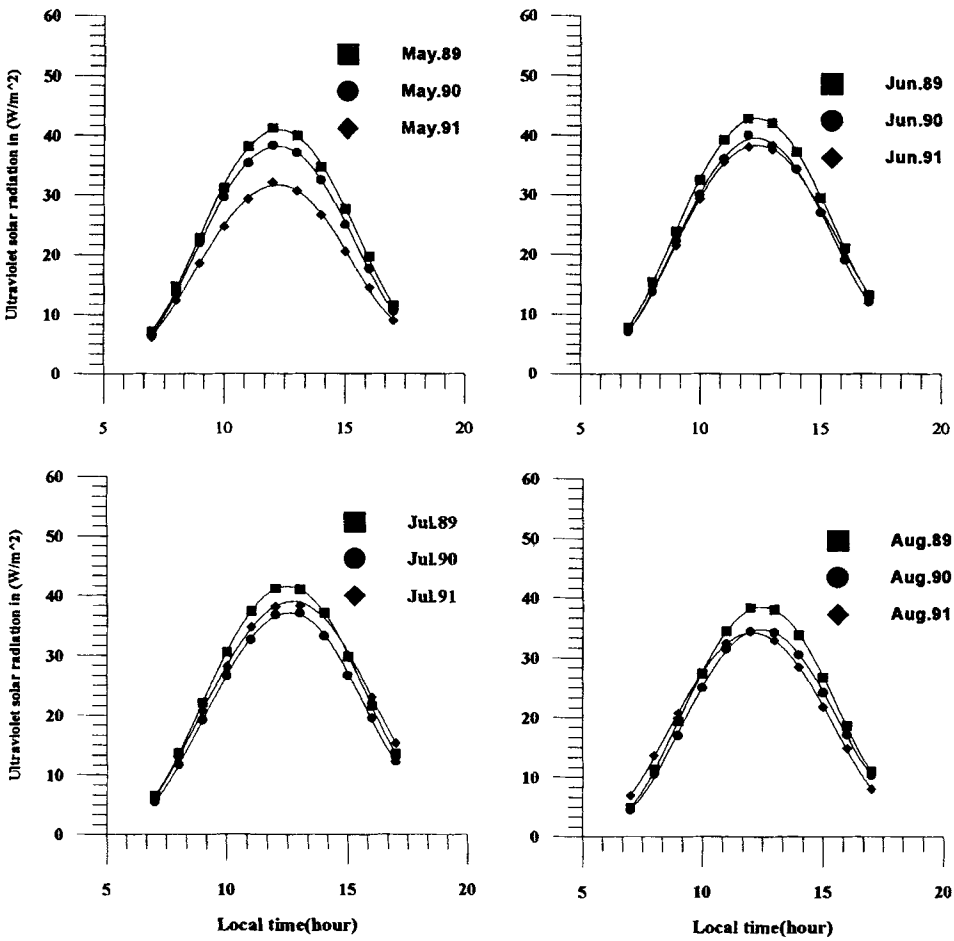

Figure 2. Monthly variation of ultraviolet solar radiation over Cairo in (W/m^2).

Figure 4 represents the annual variations for the ultraviolet solar radiation for Cairo in hourly values which in 1989 is higher than those for the years of 1990 and 1991 at true noon by about 33%.

Figure 5 represents a comparitive study of the ultraviolet and global solar radiation in Cairo and Aswan. The maximum value for both the ultraviolet and global solar radiation is in June while the minimum is in December for the two regions. The difference between Cairo and Aswan for ultraviolet solar radiation is 16% in June while it is 49% in December while the difference for global solar radiation between the two, is 7% in June and 44% in December.

3. Correlation between the solar radiation components

We know the case of the atmosphere, if it is clean or polluted, by calculating the transmission of the atmosphere for the radiation components. Transmission for ultraviolet solar radiation is given as (UV/UV_0) which is the value of ultraviolet solar

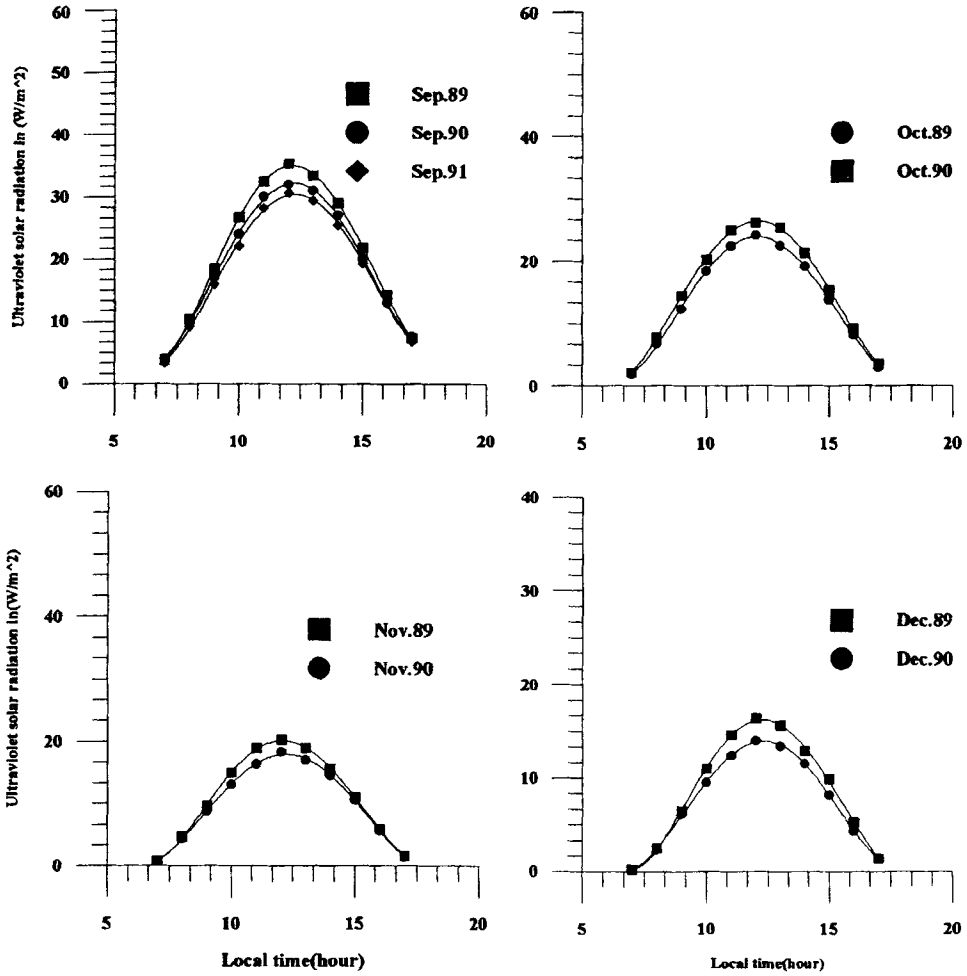

Figure 3. Monthly variation of ultraviolet solar radiation over Cairo in (W/m^2).

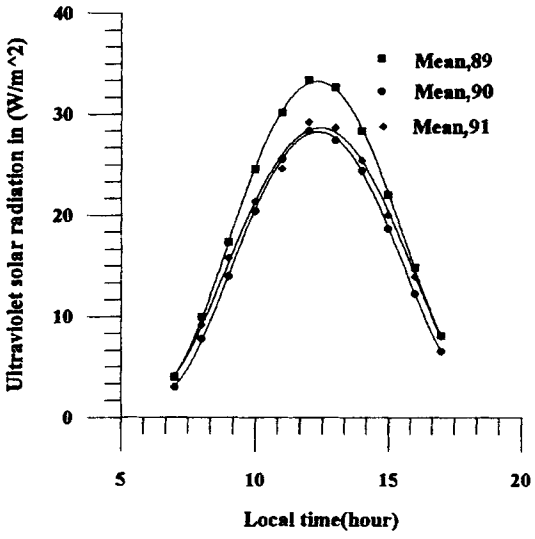

Figure 4. Annual variation of ultraviolet solar radiation over Cairo in (W/m^2).

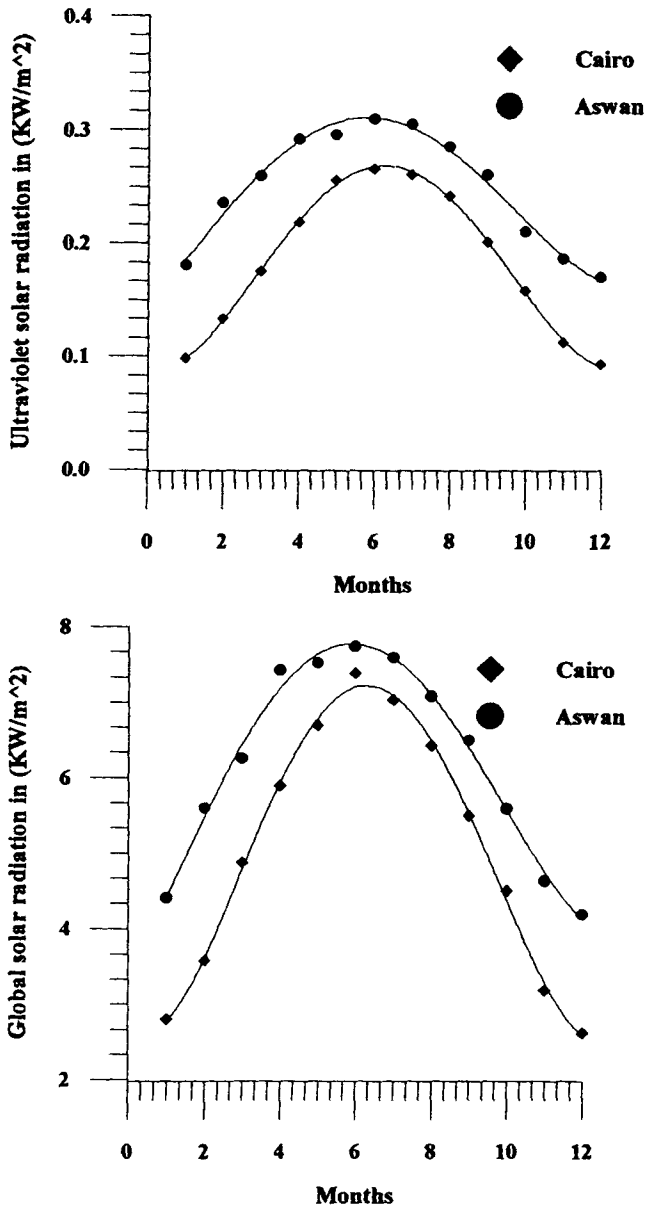

Figure 5. Monthly variation of global and ultraviolet solar radiation over Cairo and Aswan in (KW/m^2).

radiation from ground stations (UV) to the other which is measured outside the atmosphere (UV_0) at the same place and time. Also, for global solar radiation we can give the clearness index which is $Kt = G/G_0$. Figure 6 gives the correlation between (UV/UV_0) and Kt for Cairo and Aswan. We find a very high correlation between (UV/UV_0) and Kt with a correlation coefficient of 96% and a standard error of estimation as 0·099. Also, for Aswan a high correlation with correlation

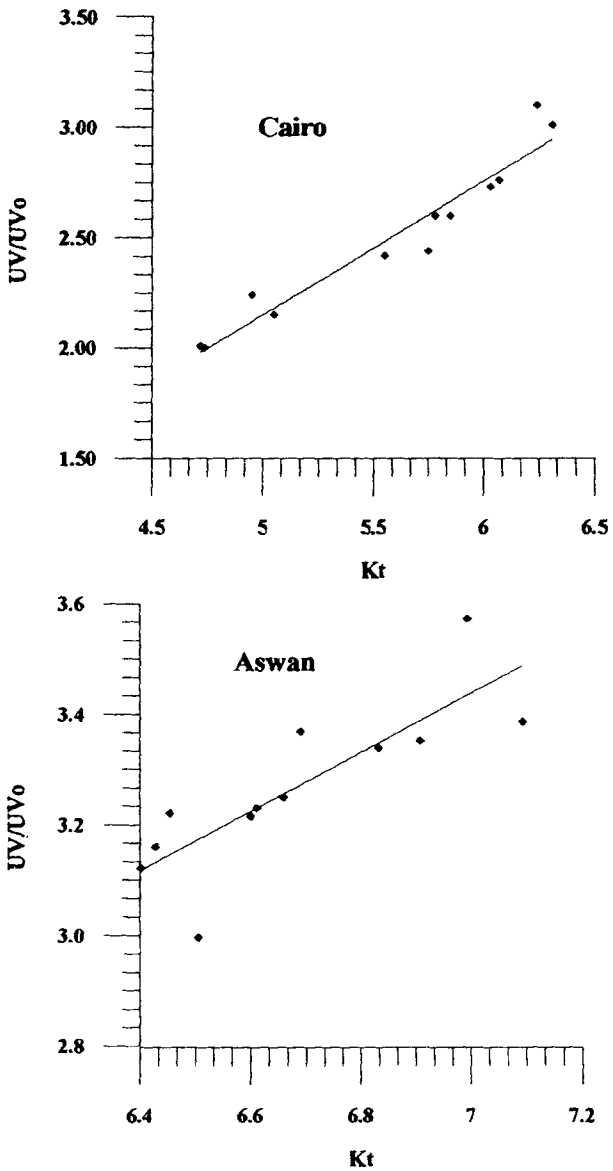

Figure 6. Correlation between transmission of ultraviolet solar radiation with clearness index over Cairo and Aswan.

coefficient 82% and standard error of estimation 0·077 are recorded by the following equations,

Cairo	CC%	R	
$UV/UV_0 = 0{\cdot}61\,Kt - 0{\cdot}897$	96%	0·099	(1)
Aswan			
$UV/UV_0 = 0{\cdot}53\,Kt - 0{\cdot}3$	82%	0·077.	(2)

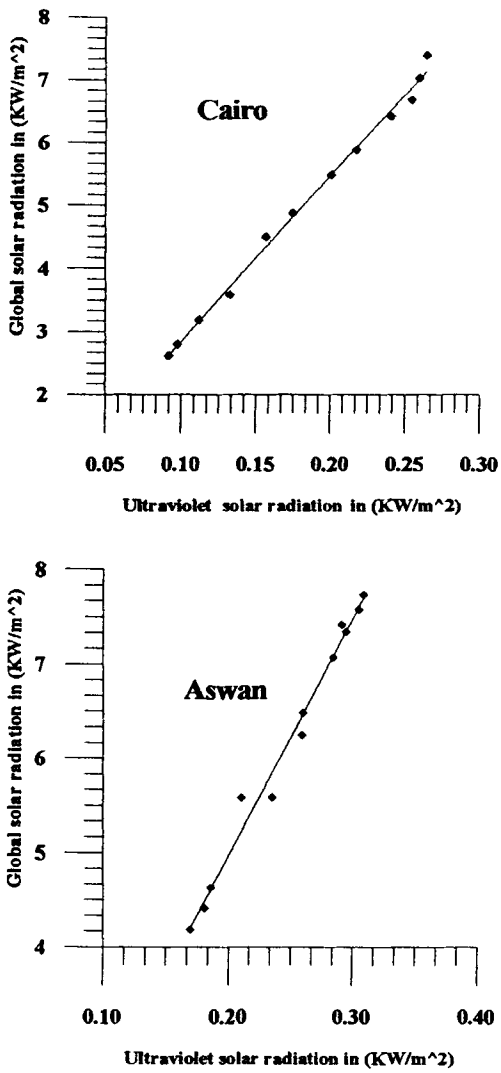

Figure 7. Correlation between ultraviolet and global solar radiation over Cairo and Aswan.

Figure 7 represents the correlation between ultraviolet and global solar radiation for Cairo and Aswan. We find a very high correlation for both Cairo and Aswan as shown by the following equations,

Cairo	CC%	R	
$G = 25{\cdot}1\ UV - 0{\cdot}05$	99·3%	0·27	(3)
Aswan			
$G = 26\ UV + 0{\cdot}25$	99·7%	0·16.	(4)

4. Correlations between radiation components and climatological parameters

Climatological parameters play an important role in affecting the solar radiation values. Figure 8 represents the correlation between the amount of cloudiness in Okta (Cl) and ultraviolet and global solar radiation for Cairo and Aswan. We find a very high negative correlation for the two solar radiation components and the cloudiness which are given by the following equations,

Cairo	CC%	R	
$UV = -0{\cdot}079\,Cl + 0{\cdot}366$	96·5%	0·003	(5)
$G = -2{\cdot}08\,Cl + 9{\cdot}8$	97%	1·79	(6)
Aswan			
$UV = -0{\cdot}255\,Cl + 0{\cdot}4$	93·4%	0·003	(7)
$G = -6{\cdot}5\,Cl + 10{\cdot}1$	94·3%	2.	(8)

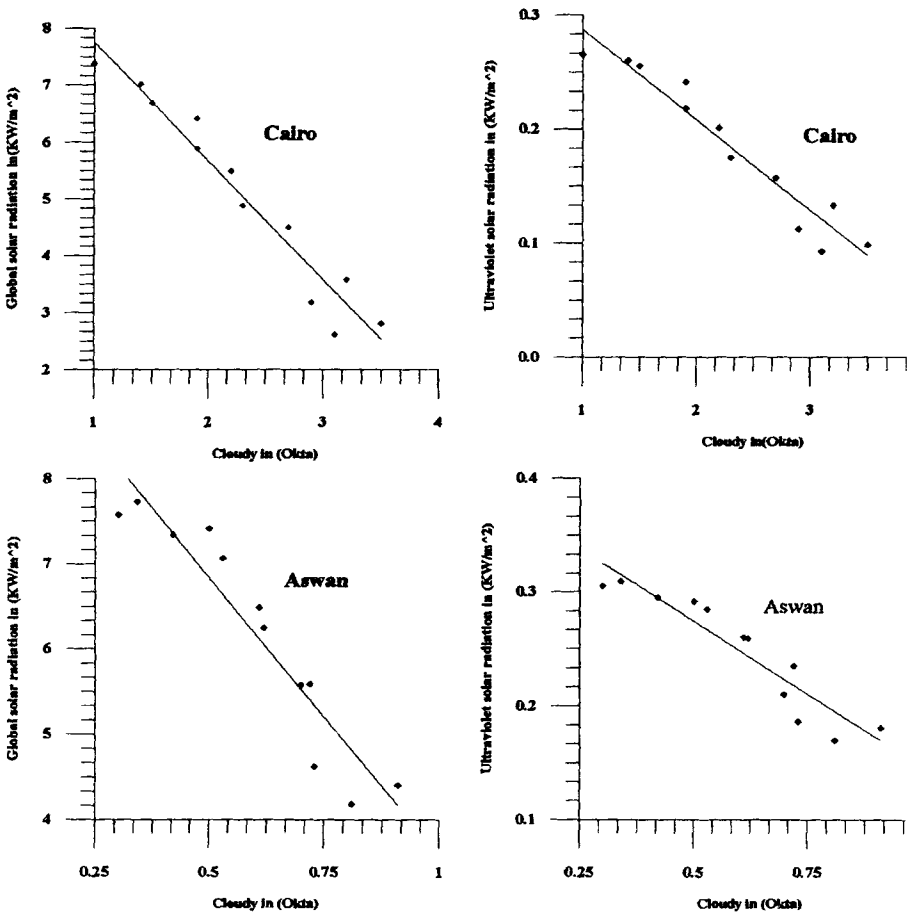

Figure 8. Correlation between radiation components and cloudiness for Cairo and Aswan.

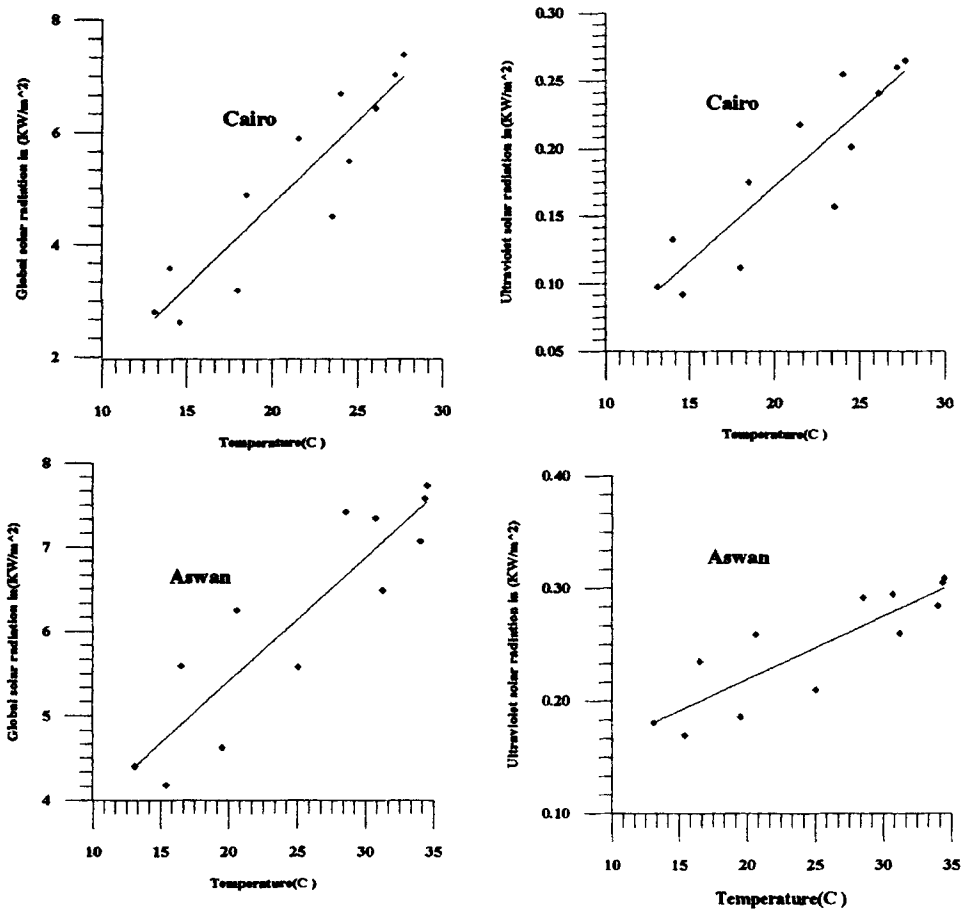

Figure 9. Correlation between radiation components and ambient temperature for Cairo and Aswan.

Figure 9 represents the correlation between the ambient temperature (T) and ultraviolet and global solar radiation for Cairo and Aswan. We find a very high correlation for the two solar radiation components and the ambient temperature which are given by the following equations,

Cairo	CC%	R	
$UV = 0{\cdot}01\,T - 0{\cdot}051$	91%	0·008	(9)
$G = 0{\cdot}295\,T - 1{\cdot}18$	92%	5·1	(10)
Aswan			
$UV = 0{\cdot}005\,T + 0{\cdot}1$	78%	0·007	(11)
$G = 0{\cdot}15\,T + 2{\cdot}47$	91%	3·4.	(12)

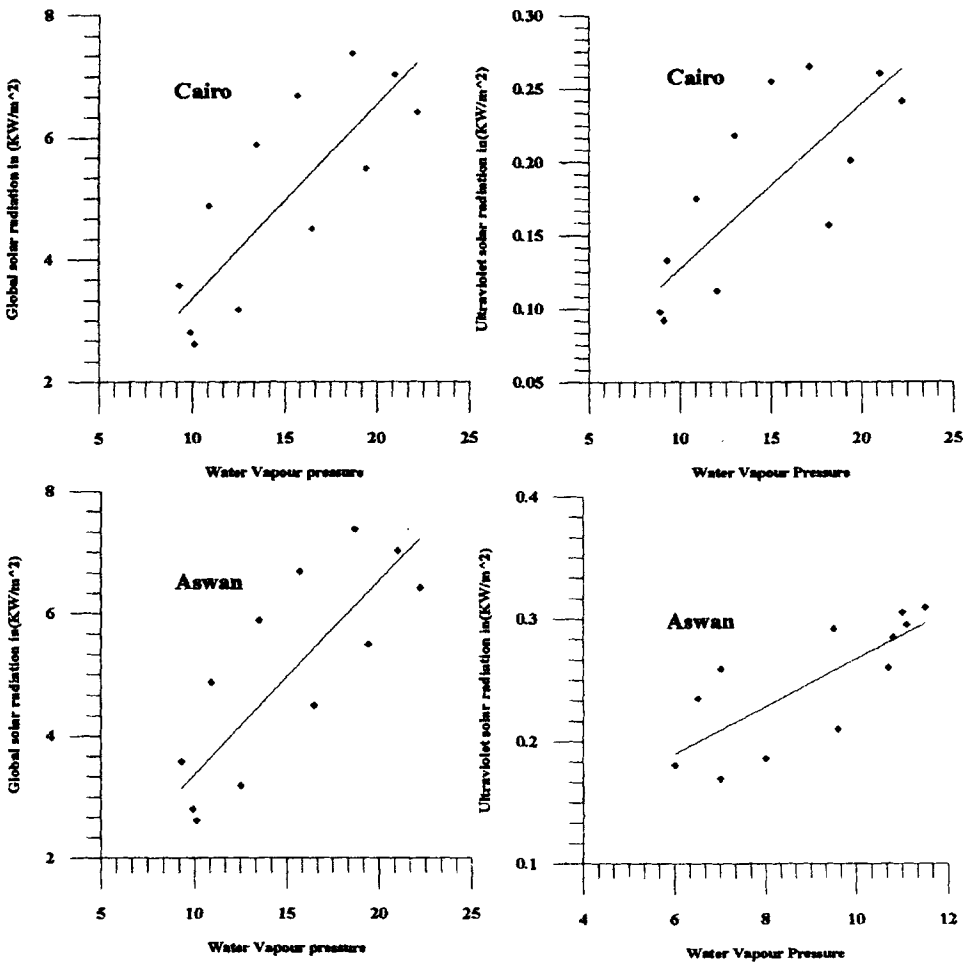

Figure 10. Correlation between radiation components and water vapour pressure for Cairo and Aswan.

Figure 10 represents the correlation between ultraviolet and global solar radiation with water vapour pressure (WV) for Cairo and Aswan. We find a good correlation for the two solar radiation components and the water vapour pressure which are given by the following equations,

Cairo	CC%	R	
$\text{Log}(G) = 0{\cdot}87\,\text{WV} - 0{\cdot}75$	80%	0·54	(13)
$\text{Log}(UV) = 0{\cdot}91\,\text{WV} - 4{\cdot}17$	79%	0·63	(14)
Aswan			
$G = 0{\cdot}52\,\text{WV} + 1{\cdot}47$	82%	6·12	(15)
$UV = 0{\cdot}02\,\text{WV} + 0{\cdot}07$	77%	0·01.	(16)

5. Conclusions

In conclusion, it was found that, (1) The maximum value of ultraviolet solar radiation is in June while the minimum is in December for all months for the two regions. (2) The ultraviolet solar radiation values during the afternoon hours are higher than those values before noon, due to the presence of the International Cairo airport on the east of the Egyptian Meteorological Authority where the data was measured. (3) The ultraviolet solar radiation values for 1989 are higher than those recorded for the years 1990 and 1991 at true noon by about 33%. (4) The global solar radiation difference between Cairo and Aswan is 7% in June while it is 44% in December. (5) There is a very high correlation between (UV/UV_0) and Kt for Cairo and a moderately high one for Aswan, while in the case of global solar radiation we find a very high correlation for both Cairo and Aswan. (6) Very high negative correlations for the two solar radiation components against cloudiness. (7) There is a very high correlation for the two solar radiation components with ambient temperature and a good correlation with water vapour pressure.

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