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Erythemal dose in Qena, Upper Egypt based on solar UV-B measurements from UVB-1 pyranometer and its deviation from EP/TOMS satellite

S. M. El Shazly, A.A. Hassan, Kh. O. Kassem, Emad A. A and E. F. El nobi*

Atmospheric Physics Group, Department of Physics, Faculty of Science,South Valley University, Qena, Egypt

Abstract Biologically active solar Ultraviolet irradiation is monitored in Qena, Upper Egypt (26o 16\ N, 32o 75\ E, 96 m asl) using a UVB-1 pyranometer for the period of 2001-2005. Cloud free condition records of erythemal UV were analyzed to study daily, monthly and seasonally variations. Results shows noontime one-hour average CIE (Commission International d'Eclairge) weighted dose rate can reach up to 285 mW m^{-2} (UV index =11 at solar zenith angle, SZA= 10° - 12°). Comparisons of ground-based measurement with TOMS satellite derived data have been examined. The examination revealed an overestimation of UV indices by TOMS, within the period of measurement, on average by 23±11 %.

Keywords: Ultraviolet index; TOMS satellite data; Ground based measurement; Qena; Upper Egypt

Introduction

The energetic solar UV irradiation is monitored with different ground and satellite based instruments. In addition, different extensive model calculations are used to analyze the UV irradiance especially the UVB in the wavelength range of 280 to 315 nm (Blumthaler et al., 1994; Kylling et al., 2000; WMO, 2003).

The effectiveness of UV of different wavelengths in producing erythema has been determined repeatedly in a number of studies over the Wavelengths necessary to produce a minimally perceptible redness 8 or 24 hr after irradiation.The past 70 years (Diffey, 1982). The technique is to determine the MED doses of UV at a series of reciprocal of the MED is plotted against wavelength and the curve normalized to unity at the most effective wavelength. The MED at a given wavelength in a group of fair-skinned subjects are distributed lognormally. Studies in 254 normal subjects in the North East of England gave the median MED at 300 nm to be 34 mJ/cm^2 with a 95% confidence interval of 14-84 mJ/cm^2 (Diffey and Farr, 1989).

Although the action spectra determined by various workers have shown differences, particularly in the spectral region 250-300 nm, there is good agreement that at wavelengths greater than 300 nm the effectiveness drops very rapidly, falling to efficiency at 320 nm of about 1% of that at 300 nm. Parrish et al., 1982 and Gange et al., 1986 have extended determination of the erythema action spectrum up to

*Corresponding author. Tel.: 0106773556
E-mail address: sayedelshazly@yahoo.com

400 nm and have shown that the erythemal effectiveness of UV decreases with increasing wavelength through the UV spectrum, although the rate of change of effectiveness is much less from 330 to 400 nm, than from 300 to 330 nm. .

Although it can be seen from figure (1) that UV-A irradiation is much less erythmogenic than UV-B irradiation broadly speaking by a factor of 1000, the much higher UV-A irradiance (6.5 %) present in sunlight means that in summertime UV-A irradiation contributes about 15-20% to the sunburn reaction. It is important to say here that of the global UV irradiation at the ground 94 % is UV-A and 6 % is UV-B. However, 17 % of the erythemal UV irradiance is UV-A and 83 % is UV-B.

The UVB irradiation leads to serious adverse effects such as: sunburn, skin ageing, cataracts in humans, reduction in yield and unnecessary growth in certain terrestrial as well as aquatic plants (Grant and Heisler, 2000). Therefore it is important to monitor and follow up carefully the short and long term variations of surface UV dose rate at any place. However, observational data on surface is lacking in the developing countries in the lower latitude where UV dose is expected to be higher and is significant for its adverse effects.

The spectral irradiance at the surface of the earth depends on different factors such as: irradiation from the sun, optical properties of the atmosphere, position of the sun given by the solar zenith angle (SZA), mean sun earth distance and the reflecting property of the surface (Madronich 1993; Dahlback, 1996; Kylling et al., 1998; Kerr, 2003). Among the optical properties of the atmosphere, cloud and aerosols are the complicated factors affecting UV, which are still not very well understood (Ilyas, 1987; Thiel et al., 1997; Grant and Heisler, 2000; Kylling et al., 2000; Kerr, 2003).

Two important parameters must be taken in account when monitoring UV irradiation and considering its effect on the human skin, namely UV index (erythemal UV index) and UV dose. The UV Index is a parameter introduced by the scientist that can be used as an indicator of the UV exposures. It is related to the known erythemal effects of solar UV irradiation on human skin and has been defined as an estimation of the UV levels that are important for the effects on the human skin, where 1 unit equals 25 mW/m^2. It is usually given for local solar noon, when the sun is highest in the sky, and it is valid for clear sky conditions (i.e. effects of cloud shielding part of the UV irradiation are not taken into account). The UV Index can range from 0 (when it is night time) to 15 or 16 (in the tropics at high elevations under clear skies). As shown in Table (1).

UV Index definition has later been standardized and published as a joint recommendation by the World Health Organization (WHO), the World Meteorological Organization (WMO), the United Nations Environment Program (UNEP) and the International Commission on Non-Ionizing Irradiation (ICNIRP). The UV Index is recommended as a way to raise the public awareness about the potential detrimental effects on health from solar UV exposure and to alert people of the need to adopt protective measures. Even for very sensitive fair-skinned people, the risk of short-term and long-term UV damage below a UVI of value 2 is limited, and under normal circumstances no protective measures are needed. If sun protection is required, this should include all protective means, i.e. clothing and sunglasses, shade and sunscreen. The Environmental Protection Agency (EPA) has devised general guidelines to UV index, as shown in Table (2).

The UV index is an artificial quantity derived from the erythemal irradiance, which is an integration of the UV irradiance at the ground weighted by the Commission International de l'Eclairage (CIE). The CIE action spectrum is a model for the susceptibility of the Caucasian skin to sunburn (erythema) as proposed by McKinlay and Diffey (1987) and adopted as a standard by CIE.

The "Minimal Erythemal Dose" MED is used to describe the erythemal potential of UV dose irradiation. MED is defined as the effective UV dose that causes a perceptible reddening of previously unexposed human skin. CIE erythemal action spectrum is recommended for use in assessing the skin damaging effect UV irradiation. However, because human individuals are not equally sensitive to UV irradiation due to different self-protection abilities of their skin (pigmentation), 1 MED varies among the population within the range of between 200 and 500 J/m^2 as shown in Table (3)

The main aim of this paper is to present the EUV irradiation in Qena, Upper Egypt,_see figure (2), and to find out its deviation from satellite data. .This deviation is useful when the observational data on surface is lacking.

Instrument and methods

Ground-based EUV measuring instrument

Hourly values measurements of UV-B at the horizontal surface was carried out by UVB-1 Pyranometer "No. 960842, Yankee Environmental Systems Inc. (YES) was used to measure the total irradiance from 280 to 320 nm". The instrument was installed on the roof of south vally meteorological station, of South Valley University in Qena, see figure (3). It was manufactured by the hourly values of UV-B were recorded by Combilog Data logger (No. 1020, TH.

Friedrichs & CO. "Germany"). These values were used to calculate the EUV through the period of this study (2001-2005), as below.

For example, Suppose you take one UVB-1 instrument voltage reading (V) every k minutes and a total of N readings during the day. If the instrument has a calibration coefficient of C, The total daily MED dose, as defined by the Diffey erythemal action spectrum. Is given by the following

$$\text{MED dose} = \frac{1}{201} \sum_{i=1}^{N} C*0.0716 * 60k * V_i$$

Where ...

The factor C*0.0716 convert the measured voltage to erythemal (Diffey) W/m2

The factor 60*k converts the W/m2 to erythemal J/m2

The factor 201 convert the erythemal J/m2 dose to MED unit (Parrish et al,1982), where the standard definition of the MED unit is 201 J/m2

2.2. Satellite EUV data

The erythemal noontime irradiance data was measured by the Total Ozone Mapping Spectrometer (TOMS) installed on board of NASA's Earth Probe satellite. The Total Ozone Mapping Spectrometer (TOMS), installed on board of NASA's Earth Probe Satellite, measures the Total Ozone Column by an indirect way through the mapping of the Ultraviolet light emitted by the Sun and scattered by the Earth's atmosphere back towards the satellite (London, 1985). Data were obtained through TOMS/NASA webpage (http://jwocky.gsfc.nasa.gov).

Earth Probe Total Ozone Mapping Spectrometer (EP/TOMS) was launched July 2, 1996 and the first full day of data file generation began on July 25, 1996. The Earth Probe instrument has provided continuous data from that time until present, with the exception of a few days in Dec 1997 during which the satellite orbit was boosted from 500km to 750km, and a period in late 1998 when the instrument was in Safe hold.(Seeftp://toms.gsfc.nasa.gov/pub/eptoms/earthprobe_data_coverage.txt/).

Earth Probe EP/TOMS was launched into a 500 km sun synchronous orbit on July 2, 1996. The first EP/TOMS Earth scan data were taken during orbit 216 on July 16, 1996. Normal science operations began during orbit 339 on July 24, 1996. Orbits prior to 7903 (December 4, 1997) were at the initial 500 km altitude. Orbits after 8037 (December 13, 1997) were at 740 km altitude after an orbit boosting maneuver This interface is designed for visualization and analysis of the Earth Probe TOMS Daily Global 1.0°x1.25° Products.

The erythemal noontime irradiance data in mW/m^2 from EP/TOMS have been used for the analysis of the data recorded from UVB-1 pyranometer. Also the data are collected from this site (ftp://toms.gsfc.nasa.gov/pub/eptoms/data/erythemal/) is divided by a conversion factor of 25 and rounded to the nearest whole number. This result in a number that usually ranges from 0 (where there is no sun light) to the mid teens. This value is the UV index.

Example: If EUV at noon =319.6 mW/m^2 then UVI = 319.6 /25 = 12.78 UVI = ~ 13

Results and discussions

Ground EUV climatology

Noontime average EUV irradiation in Qena for the period from 2001- 2005 during clear days, showed a decrease in EUV level in January followed by an increase from March reaching the maximum value in summer months followed by decrease again to December, see Figure (4). Maximum noontime EUV irradiation measured during the study period was 285 mW/m^2 (UV index 11) at solar zenith angle 10°-12°, on 25 July 2001 and 11, 30 June 2005. Noontime UV indices double from December to March.

Comparison between ground-based and satellite Observations

The linear fit of one-hour average noontime UV indices obtained from UVB-1 pyranometer and TOMS noontime indices showed that TOMS values were higher than measured UV indices at ground (Figure 5). The average percentage difference is (23±11%) as shown in (Figure 6).

Deviation between satellite and ground-based measurements can be explained by the fact that there are differences in spatial resolution between the two methods. The field of view of TOMS measurement is about 100 km (Arola et al., 2004), while the ground based instrument has a smaller field of view. Temporal differences can also occur because of difference in timing as TOMS data are from the time of direct overpass of the location, while ground-based measurements are one-hour averages values around satellite overpass time. Averaging ground-based measurements will reduce effects of rapid changing cloud cover. Effects of clouds are not fully taken into account in the UV index retrieval from the satellite (B.K. Bhattarai et al, 2007).

In addition Arola et al. (2004) has found that the factor between TOMS UV and ground-based measurement in Thessaloniki, Greece could reach as high as 4 in dusty environment. Also B.K. Bhattarai et al, (2007) show that frequent dusty events in the atmosphere could also be another cause of higher TOMS UV levels than ground based measurement in Kathmandu. High aerosol content influences the ground-based measurements and is not taken fully into account in the TOMS algorithm for UV index (Krotkov et al., 1998; Arola et al., 2005). This might be the reason for a systematic difference between the data. Finally differences in instrument calibration might be another factor for this discrepancy.

3.3. Variability of UV Index (UVI)

Figures (7) summarize the mean monthly variation of Ground UV index and EP/TOMS UV index. In general, Monthly mean increases from January crossing February, May, showing maximum values at June, July and August then fall down to December . From ground data, we can conclude the following:

- The maximum mean value of UVI (11) was found at spring and summer months (May, June, July and August). According to the EPA general guidelines, as illustrate in table (1), this value is very high and advise to use protective clothing, sun glasses and avoid being in the sun.
- The minimum mean value was found at autumn and winter months (November, December and January). This value range from 4 to 5 and it is corresponding the low and moderate categories according to the EPA classification, see table (1).

From satellite EP/TOMS data, we can conclude the following:

- The maximum mean value of UVI (12) was found at spring and summer months (May, June, July and August). According to the EPA general guidelines, as illustrate in table (1), this value is very high and advise to use protective clothing, sun glasses and avoid being in the sun.
- The minimum mean value was found 5 at December, it is corresponding the moderate categories according to the EPA classification, see table (1).

Conclusion

The study leads to the following important conclusions:

1. For most of the days, the UV index at local noon exceeds 4
2. Through all the period, it is clear that the maximum values of UV indices are recorded at summer months while the minimum ones are recoded winter months
3. The maximum value of UV index, at local noon, was 11 while the minimum one was 4
4. Comparison of ground-based UV with TOMS satellite derived data reveals an overestimation on average by 23±11 %.
5. According to the EPA general guidelines and the obtained results, it is very important to use protective clothing, sun glasses and avoid being in the sun, particularly at noon time in summer months.

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الملخص العربي

الاشعة فوق البنفسجية ذات التأثير البيولوجي المسببه لاحمرار الجلد (الاريسيمال) قد قيست علي قـنا (٢٦° شمالا- ٣٢ ° شرقا-٩٦ م فوق سطح البحر) باستخدام جهاز البرانوميتر (UVB-1) في الفتره من ٢٠٠١ الي ٢٠٠٥

سيد الشاذلي، عبد الجليل حسن، خلف قاسم، عماد علي، إيمان فؤاد السيد النوبي

مجموعة الفبزياء الجوية،قسم الفيزياء،كلية العلوم

جامعة جنوب الوادي (قنا –مصر)

تحت السماء الصافية درست تغيرات الاريسيمال اليومية والشهرية والفصلية , اوضحت النتائج ان الاريسيمال وقت الظهيرة قد تصل الي ٢٨٥ مللي وات/م٢ أي أن معامل الاشعة فوق البنفسجية يساوي١١ عند زوايا ميل الشمس تتراوح من ١٠° - ١٢° .

بمقارنه النتائج الأرضية مع نظائرها من الاقمار الصناعية(TOMS)تبين أن هناك زياده بمقدار ٢٢+١١ ٪ خلال فترة الدراسة .

الكلمات المفتاحية:

معامل الاشعه فوق البنفسجيه، نتائج القمر الصناعي TOMS ، قياسات ارضيه، قنا، صعيد مصر.

Table 1: Exposure category of UV index.

UV Index Prior to May 2004		The New Global Solar UV Index	
Exposure Category	Index Number	Exposure Category	Index Number
MINIMAL	0-2	LOW	1-2
LOW	3-4	MODERATE	3-5
MODERATE	5-6	HIGH	6-7
HIGH	7-9	VERY HIGH	8-10
VERY HIGH	10+	EXTREME	11+

Table 2: The EPA general guidelines of UV index.

Exposure Category	Index Number	Sun Protection Messages
LOW	1-2	• Wear sunglasses on bright days. In winter, reflection off snow can nearly double UV strength. • If you burn easily, cover up and use sunscreen.
MODERATE	3-5	• Take precautions, such as covering up and using sunscreen, if you will be outside. • Stay in shade near midday when the sun is strongest.
HIGH	6-7	• Protection against sunburn is needed. • Reduce time in the sun between 11 a.m. and 4 p.m. • Cover up, wear a hat and sunglasses, and use sunscreen.
VERY HIGH	8-10	• Take extra precautions. Unprotected skin will be damaged and can burn quickly. • Try to avoid the sun between 11 a.m. and 4 p.m. Otherwise, seek shade, cover up, wear a hat and sunglasses, and use sunscreen.
EXTREME	11+	• Take all precautions. Unprotected skin can burn in minutes. Beachgoers should know that white sand and other bright surfaces reflect UV and will increase UV exposure. • Avoid the sun between 11 a.m. and 4 p.m. • Seek shade, cover up, wear a hat and sunglasses, and use sunscreen.

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Table 3: The values of MEDs for different skin types.

Skin type	Tan	Burn	Hair colour	Eye colour	1MED
I	never	always	red	blue	200 J/m^2
II	sometimes	sometimes	blond	blue/green	250 J/m^2
III	always	rarely	brown	gray/brown	350 J/m^2
IV	always	never	black	brown	450 J/m^2

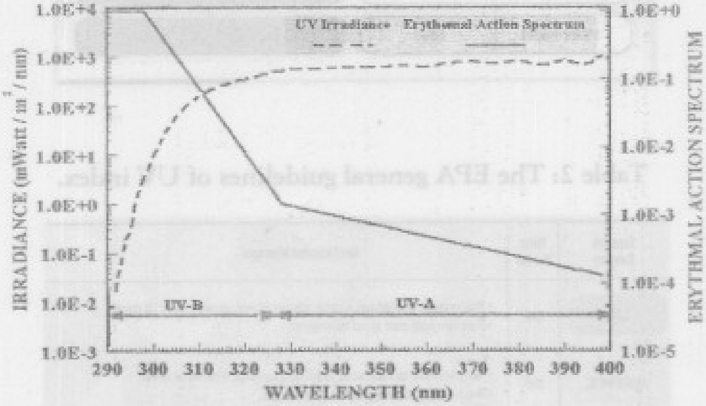


Figure (1): The CIE reference erythemal action spectrum

Figure (2): Map of Egypt, location of studied area

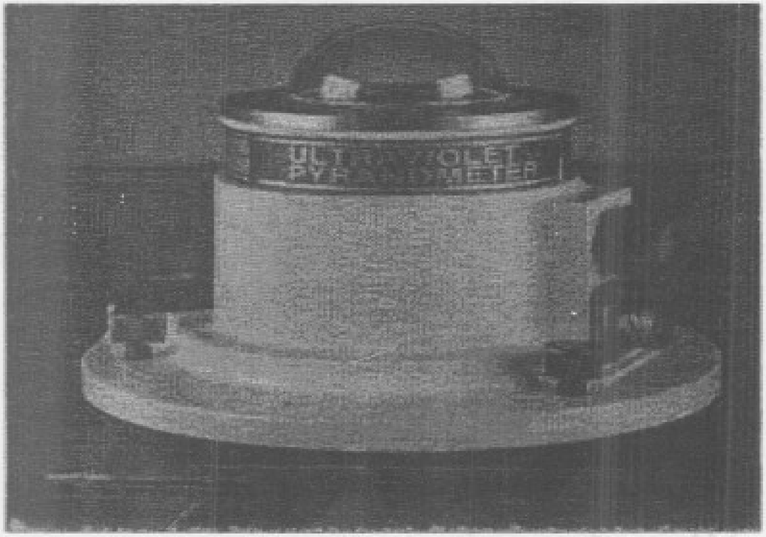


Figure (3): UVB-1 Ultraviolet Pyranometer

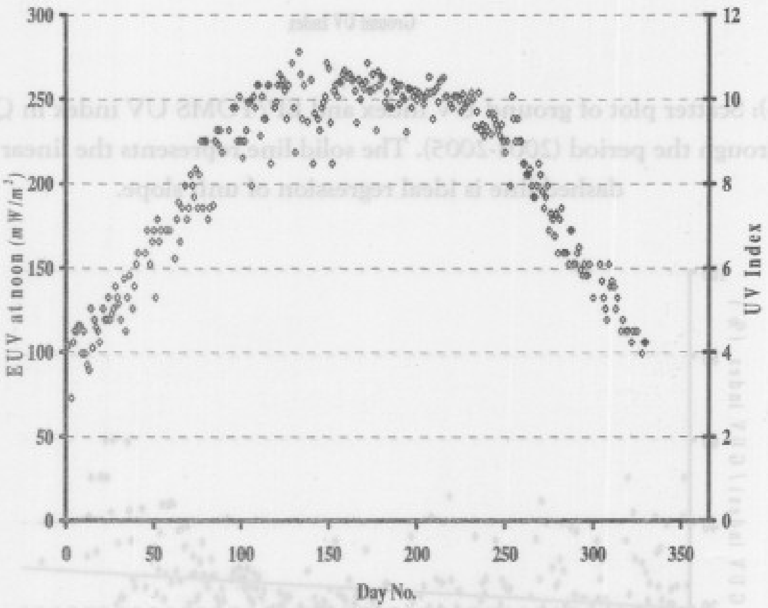


Figure (4): Clear sky ground EUV irradiation at noon (mW/m^2) and UV index in Qena Upper Egypt through the period (2001-2005)

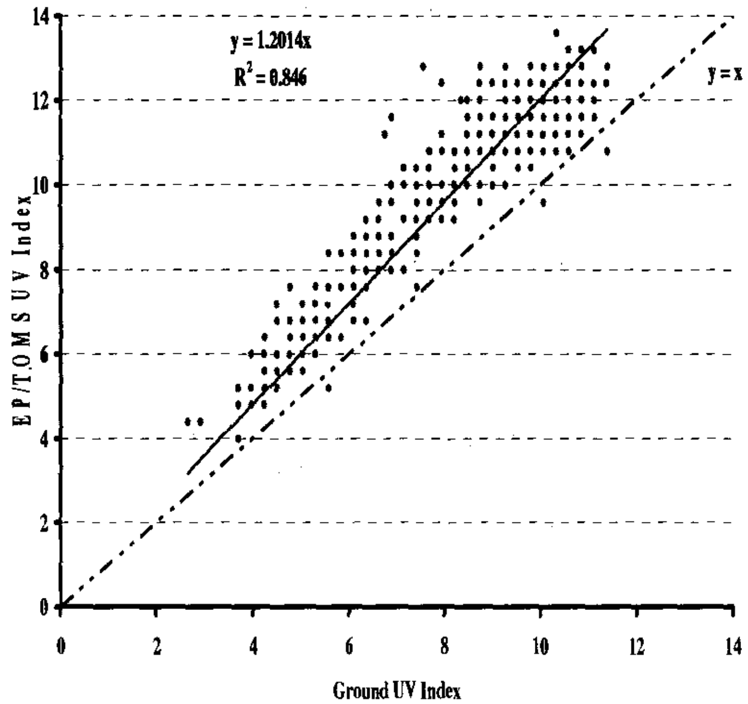


Figure (5): Scatter plot of ground UV index and EP/TOMS UV index in Qena Upper Egypt through the period (2001-2005). The solid line represents the linear fit and the dashed line is ideal regression of unit slope.

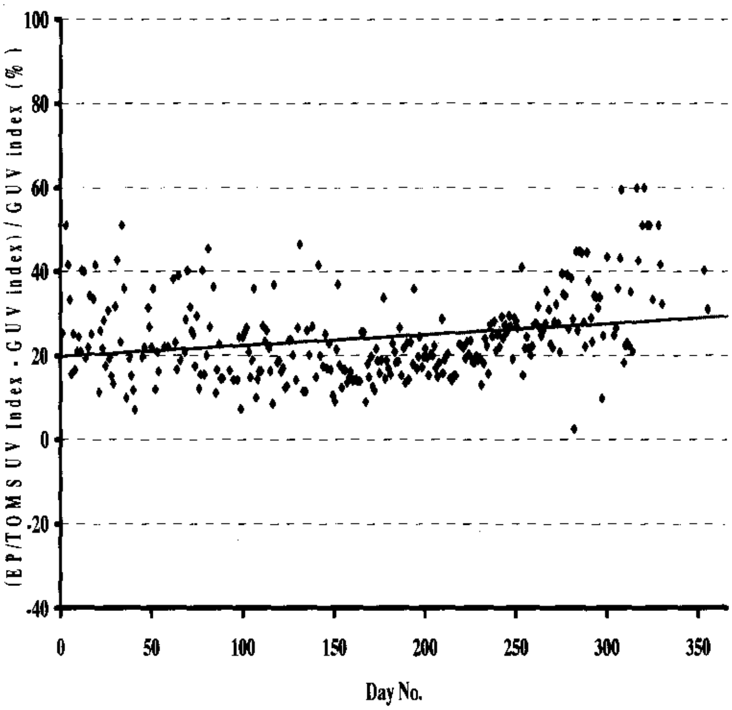


Figure (6): Daily percentage difference of ground UV index and EP/TOMS UV index in Qena Upper Egypt through the period (2001-2005). The solid line represents the linear trend line.

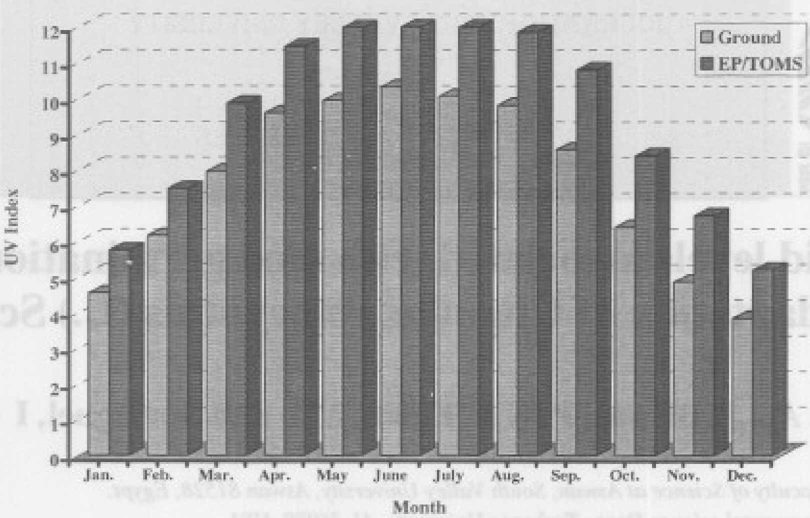
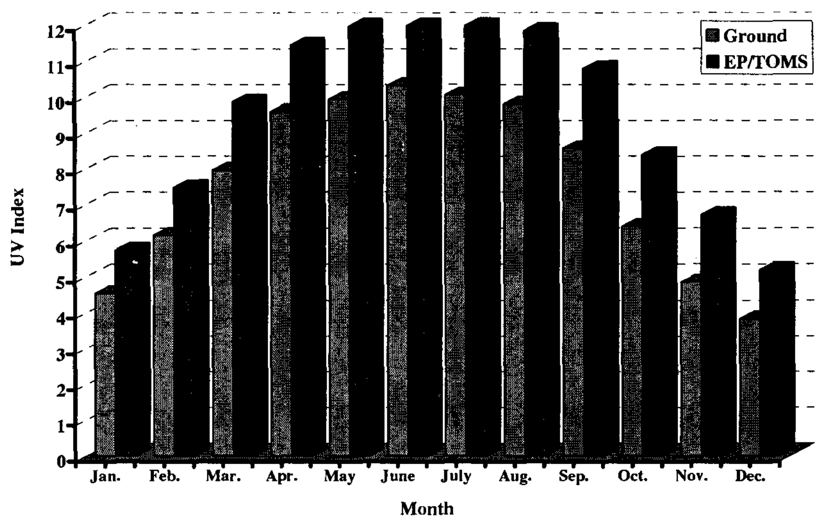


Figure (7): Monthly variation of ground UV index and EP/TOMS UV index in Qena Upper Egypt through the period (2001-2005).



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