

STATISTICAL RELATIONSHIPS BETWEEN SOLAR UVB AND UVA RADIATION AND GLOBAL RADIATION MEASUREMENTS AT TWO SITES IN ISRAEL

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ABSTRACT

Statistical relationships between the hourly radiation intensity values of both ultraviolet-B (UVB) and ultraviolet-A (UVA), and of the corresponding global radiation at two sites in Israel, the Dead Sea and Beer Sheva, are presented using radiation data measured from January 1995 to January 1999. It was determined, based upon the square of the correlation coefficient (r^2), that in the case of the UVB, a quadratic equation provided a better fit of the database, whereas in the case of UVA, a linear equation was sufficient, i.e. no significant improvement in r^2 was obtained using a quadratic equation. Each monthly empirical equation was tested by utilizing measurements from a single month of independent observations. The accuracy of the individual equations was determined by calculating the mean bias error (MBE), the root mean square error (RSME) and the percent coefficient of variation (CV). The results of this statistical analysis showed that, at both sites, the UVA relationships were characterized by a CV of < 10%, with the exception of a single month. In the case of the UVB correlations, the CV values exceeded 10% for more than 75% of the year, both at the Dead Sea and at Beer Sheva. CV values of > 20% were observed for more than a third of the individual months at both the Dead Sea and Beer Sheva. Monthly and seasonal relationships from one site were then tested by applying them to the second site. In both cases, the relationships between both UVA and UVB and global radiation were found to be site-specific. On the basis of this statistical analysis, the UVA relationships were found to be far superior predictors than the corresponding UVB ones. In fact, the UVB relationships have limited applicability for predicting UVB from the corresponding global solar radiation intensity. Copyright © 2000 Royal Meteorological Society.

KEY WORDS: Dead Sea; Beer Sheva; Israel; UVB; UVA; global solar radiation intensities; hourly statistical relationships

1. INTRODUCTION

The growing evidence of global depletion of stratospheric ozone has emphasized the importance of monitoring terrestrial ultraviolet (UV) radiation. Reductions in stratospheric ozone result in increased amounts of solar UV radiation reaching the earth's lower atmosphere and surface. UV radiation affects many chemical and biological processes and any increase in the radiation intensity is of concern, because of the potential adverse effects on the biosphere, on tropospheric air quality and on material such as wood and polymers.

The extraterrestrial solar radiation spectrum contains UVC (spectral range 100–280 nm), UVB (spectral range 280–320 nm), and UVA (spectral range 320–380 nm). However, there is virtually no solar radiation reaching the earth's surface at wavelengths of less than 295 nm, as a result of strong absorption by atmospheric ozone and oxygen, whereas at UV wavelengths greater than 320 nm, i.e. within the UVA range, the ozone absorption is small, and Rayleigh scattering and line absorption by other constituents are the main extinction processes (Barton, 1983). Consequently, the terrestrial UVB radiation intensity is

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two orders of magnitude smaller than the UVA radiation intensity. Nevertheless, any reduction in stratospheric ozone layer depth affects mainly the terrestrial UVB radiation by raising the intensity levels.

The health-associated effects of any potential increase of UVB exposure is the cause of mounting concern about the ozone layer. The UVB, or erythemal UV, is that solar radiation which is considered to be most biologically effective in causing sunburn of human skin and, perhaps, skin cancer. It is also the solar UVB radiation that is most sensitive to changes in the total ozone content of the atmosphere. It is generally assumed that an increase in UVB at the earth's surface would be detrimental to the well-being of animal and plant life. For humans, the problems of increased sunburn, skin cancer and eye disease are usually emphasized, while the general destruction of plant tissue and living cells is also being investigated. These harmful effects of UVB are in fact partially compensated for by some beneficial factors, which include its germicidal action, the production of vitamin D, and the treatment of various skin diseases such as psoriasis, rickets and dermatitis. The health-associated effects of UVA exposure include skin ageing, immuno-suppression of the skin immune system, and potential enhancement of the negative effects of UVB exposure. The treatment of psoriasis by psoralen + UVA (PUVA) has also been used widely in the past, but it has recently come under scrutiny as potentially increasing the risk of cancer (Felipe *et al.*, 1997).

A significant amount of effort has been invested in the study of the intensity of UV radiation as a function of atmospheric conditions, and such efforts have been redoubled in view of the aforementioned recent observations regarding the ozone layer thickness. The main driving force behind such efforts is the lack of a network sufficient in scope monitoring the terrestrial UV radiation, which may partly be a result of the relatively high cost of the instrumentation required to monitor the terrestrial UV radiation.

Green *et al.* (1974) formulated a semi-empirical analytic approach for calculating the terrestrial direct, diffuse and global UV radiation in the 280–340 nm spectral range. Their formula includes the following parameters: wavelength, solar altitude, ozone thickness, aerosol thickness, ground albedo, ground altitude and cloudiness. Green *et al.* (1980) later developed an improved analytical characterization for the diffuse spectral global UV radiation. Frederick and Lubin (1988) developed a radiative transfer model to determine the spectral irradiance at each wavelength between 290 and 400 nm. The input to their model includes the following parameters: ozone field, atmospheric optical thickness, UV surface albedo, site location, day of the year and hour of day. An indication of the activity in this field is the recent publication of a comparison of 18 different radiative transfer models used for UV index calculations (Koepke *et al.*, 1998).

Webb and Steven (1986) used a much less rigorous approach, and developed empirical relationships between the daily integrated totals for UVB radiation as a function of those totals for global radiation on a monthly basis. This study has taken an approach similar to that of Webb and Steven (1986), but has utilized hourly radiation intensity values in order to develop empirical relationships between the hourly radiation intensity values for both UVB and UVA, as a function of the corresponding global radiation intensity values. If such correlations prove to be valid they will, in essence, increase the scope of the UV network, because the number of sites monitoring global radiation far exceed those monitoring UV radiation.

2. MEASUREMENTS

The radiation data on which this study is based are being monitored at two meteorological stations: one is located on the western shore of the Dead Sea, at a site called Neve Zohar; the second is located in Beer Sheva, on the campus of the Ben-Gurion University of the Negev. Beer Sheva is located at a distance of *ca.* 65 km west of Neve Zohar. The site parameters and the annual average daily UVA, UVB and global solar radiation intensities for the two stations are listed in Table I. The instrumentation utilized to measure the UV radiation at both sites is identical and consists of a Solar Light Co. Inc., Model 501A UV-Biometer for the measurement of UVB, and a Solar Light Co. Inc., analog UVA version of Model 501A UV-Biometer, for the measurement of UVA. The global radiation at Neve Zohar is measured by

Table I. Site parameters and annual average daily irradiances for the two meteorological stations

	Neve Zohar (Dead Sea)	Beer Sheva
Site parameters		
Latitude	31°09'N	31°16'N
Longitude	35°15'E	34°48'E
Altitude (m m.s.l.)	−375	+315
Irradiances—annual average daily		
UVA (W/m^2)	259.01	269.33
UVB (MED)	14.03	15.72
Global (kW m^{-2})	5.52	5.39

a Kipp and Zonen, Model CM11 pyranometer, whereas that at the Beer Sheva site is measured with an Eppley, Model PSP pyranometer. A Campbell Scientific Instruments datalogger, located at each site (a Model CR21 at Neve Zohar and a Model CR10 at Beer Sheva), scans the meters at 10 s intervals and calculates and stores average values at 10-min intervals. The average hourly values are then calculated from the corresponding 10-min average values and refer to Israel Standard Time (GMT + 2). A detailed description of the two sites has been outlined in a previous published study (Kudish *et al.*, 1997).

The UVB meter (Model 501 A UV-Biometer) utilizes a detector with a spectral response which mirrors the erythema action spectra (McKinlay and Diffey, 1987), and the radiation intensity is measured in minimum erythema dose per hour (MED/H). One MED/H is defined as a dose which causes minimal redness of skin type 2 (i.e. skin colour between fair and dark) after 1 h of irradiation and is equivalent to 0.0583 W/m^2 . Consequently, its spectral response is normalized to that at 297 nm, and the logarithm of the normalized spectral response degrades linearly with wavelength being ~ 0.01 at 320 nm and ~ 0.001 at 330 nm. The accuracy of the measurement is $\pm 5\%$ for the daily total.

The analog UVA version of Model 501A UV-Biometer measures the irradiating flux in the UVA spectral range in units of W/m^2 . The relative spectral response is normalized to that at ~ 370 nm and is > 0.2 in the range of $320 \text{ nm} \leq \lambda \leq 390 \text{ nm}$, decreasing rapidly outside this range. The accuracy of the measurement is $\pm 5\%$ for the daily total.

The UV meters are returned once a year to Solar Light Co. Inc. for factory calibration checks using secondary standards. The Israel Meteorological Service performs periodic calibration checks on the global radiation pyranometers in the field using a secondary standard and maintains both stations. The deviation of the global pyranometers from the secondary standard are $< \pm 2\%$. The validity of the individual global radiation hourly values was checked in accordance with the World Meteorological Organization (1983) recommendations. Those values that did not comply with these recommendations were considered erroneous and rejected.

3. RESULTS

The UVA relationships for the Neve Zohar site, both monthly and seasonal, are listed in Table II, together with the corresponding years and number of hours comprising the databases and the square of the correlation coefficients (r^2). The UVB correlations for Neve Zohar are presented in a similar fashion in Table III. The r^2 values exceeded 0.98 for all the UVA correlations, the lowest value being 0.982 for February. The r^2 values corresponding to the UVB correlations were observed to be relatively lower than those for the UVA correlations, the minimum being 0.927 for March. UVA and UVB correlations for Beer Sheva are reported in Tables IV and V, and show that r^2 values exceeded 0.98 for all of the UVA correlations; the lowest value was 0.989 for February, whereas in the case of UVB the lowest r^2 value was observed to be 0.932 for the same month. It was observed that a linear equation provided a good fit to

Table II. Relationships between UVA and global hourly radiation intensities at Neve Zohar

	Years (h)	Linear regression ^a	r^2
Monthly			
January	96, 97, 98 (1250)	$y = 0.0443x + 0.2518$	0.988
February	96, 97 (550)	$y = 0.0445x + 0.0648$	0.982
March	95, 96, 97 (1194)	$y = 0.0483x - 0.2307$	0.988
April	95, 96, 97 (975)	$y = 0.0490x - 0.3971$	0.984
May	95, 96, 97 (1300)	$y = 0.0502x - 1.3846$	0.993
June	95, 96, 97 (1247)	$y = 0.0513x - 1.7151$	0.994
July	95, 96, 97 (1293)	$y = 0.0508x - 1.5347$	0.991
August	95, 96, 97 (1257)	$y = 0.0505x - 1.1778$	0.994
September	95, 96, 97 (1260)	$y = 0.0490x - 0.7876$	0.994
October	95, 96, 97 (1301)	$y = 0.0467x - 0.3397$	0.993
November	95, 96, 97 (1260)	$y = 0.0445x + 0.0107$	0.990
December	95, 96, 97 (1291)	$y = 0.0435x + 0.2454$	0.991
Seasonal			
Winter (DJF)	95, 96, 98 (3091)	$y = 0.0440x + 0.2120$	0.988
Spring (MAM)	95, 96, 97 (3469)	$y = 0.0483x - 0.2307$	0.988
Summer (JJA)	95, 96, 97 (3797)	$y = 0.0509x - 1.4628$	0.993
Autumn (SON)	95, 96, 97 (3821)	$y = 0.0474x - 0.4709$	0.992

^a y and x refer to the UVA and global radiation intensities, respectively, both in W/m^2 .

Table III. Relationships between UVB and global radiation intensities at Neve Zohar

	Years (h)	Quadratic equation ^a	r^2
Monthly			
January	96, 97, 98 (1249)	$y = 2 * 10^{-6}x^2 + 1 * 10^{-3}x + 1.8 * 10^{-3}$	0.938
February	96, 97 (550)	$y = 2 * 10^{-6}x^2 + 0.8 * 10^{-3}x + 13.3 * 10^{-3}$	0.939
March	95, 96, 97 (1200)	$y = 3 * 10^{-6}x^2 + 0.6 * 10^{-3}x + 20.3 * 10^{-3}$	0.927
April	95, 96, 97 (1254)	$y = 3 * 10^{-6}x^2 + 0.5 * 10^{-3}x + 10.3 * 10^{-3}$	0.951
May	95, 96, 97 (1287)	$y = 4 * 10^{-6}x^2 - 0.02 * 10^{-3}x + 25.8 * 10^{-3}$	0.974
June	95, 96, 97 (1251)	$y = 4 * 10^{-6}x^2 + 0.3 * 10^{-3}x + 45.8 * 10^{-3}$	0.982
July	95, 96, 97 (1280)	$y = 4 * 10^{-6}x^2 + 0.3 * 10^{-3}x + 48.6 * 10^{-3}$	0.986
August	95, 96, 97 (1293)	$y = 4 * 10^{-6}x^2 - 0.3 * 10^{-3}x + 37.9 * 10^{-3}$	0.993
September	95, 96, 97 (1256)	$y = 4 * 10^{-6}x^2 - 0.08 * 10^{-3}x + 17.3 * 10^{-3}$	0.992
October	95, 96, 97 (1300)	$y = 4 * 10^{-6}x^2 - 0.2 * 10^{-3}x + 13.8 * 10^{-3}$	0.985
November	95, 96, 97 (980)	$y = 3 * 10^{-6}x^2 + 0.5 * 10^{-3}x + 4.4 * 10^{-3}$	0.966
December	95, 96, 97 (923)	$y = 2 * 10^{-6}x^2 + 0.7 * 10^{-3}x + 3.1 * 10^{-3}$	0.958
Seasonal			
Winter (DJF)	95, 96, 97, 98 (2722)	$y = 2 * 10^{-6}x^2 + 1 * 10^{-3}x + 0.3 * 10^{-3}$	0.942
Spring (MAM)	95, 96, 97 (3741)	$y = 3 * 10^{-6}x^2 + 0.2 * 10^{-3}x + 28.3 * 10^{-3}$	0.956
Summer (JJA)	95, 96, 97 (3824)	$y = 4 * 10^{-6}x^2 - 0.3 * 10^{-3}x + 41.4 * 10^{-3}$	0.987
Autumn (SON)	95, 96, 97 (3536)	$y = 4 * 10^{-6}x^2 - 0.05 * 10^{-3}x + 21.9 * 10^{-3}$	0.987

^a y and x refer to the UVB (MED) and global (W/m^2) radiation intensities, respectively.

the UVA experimental data at both sites, and no significant improvement (i.e. higher r^2 values) was obtained when fitting the data with a quadratic equation. In the case of UVB, a visual inspection of the plots of the experimental data at both sites indicated a definite quadratic behaviour, and the corresponding empirical equations resulted in significantly higher r^2 values.

The procedure for testing the validity of the individual correlations utilized an independent set of 12 months of radiation data, from February 1998 to January 1999, not used for calculating these relationships. The validity of a particular monthly correlation was determined by comparing the

Table IV. Relationships between UVA and global radiation intensities at Beer Sheva

	Years (h)	Linear rearesion ^a	r^2
Monthly			
January	96, 97, 98 (1278)	$y = 0.0476x + 0.2571$	0.990
February	96, 97 (584)	$y = 0.0472x + 0.0604$	0.989
March	96, 97 (821)	$y = 0.0494x + 0.0726$	0.990
April	96, 97 (839)	$y = 0.0503x - 0.3311$	0.993
May	96, 97 (867)	$y = 0.0513x - 0.7605$	0.995
June	95, 96, 97 (998)	$y = 0.0519x - 0.8988$	0.995
July	95, 96, 97 (1302)	$y = 0.0514x - 0.5565$	0.996
August	95, 96, 97 (1302)	$y = 0.0515x - 0.5081$	0.997
September	95, 96, 97 (1260)	$y = 0.0508x - 0.3838$	0.996
October	95, 96, 97 (1301)	$y = 0.0495x - 0.1069$	0.996
November	95, 96, 97 (1258)	$y = 0.0478x + 0.1265$	0.993
December	95, 96, 97 (1213)	$y = 0.0469x + 0.2602$	0.992
Seasonal			
Winter (DJF)	95, 96, 97, 98 (3075)	$y = 0.0472x + 0.2299$	0.991
Spring (MAM)	95, 96, 97 (2526)	$y = 0.0505x - 0.3271$	0.994
Summer (JJA)	95, 96, 97 (3602)	$y = 0.0516x - 0.6223$	0.996
Autumn (SON)	95, 96, 97 (3819)	$y = 0.0498x - 0.1893$	0.995

^a y and x refer to the UVA and global radiation intensities, respectively, both in W/m^2 .

Table V. Relationships between UVB and global radiation intensities at Beer Sheva

	Years (h)	Quadratic equation ^a	r^2
Monthly			
January	95, 97, 98 (1302)	$y = 2 * 10^{-6}x^2 + 1.2 * 10^{-3}x - 6.5 * 10^{-3}$	0.941
February	95, 96, 97 (798)	$y = 3 * 10^{-6}x^2 + 0.8 * 10^{-3}x + 8.1 * 10^{-3}$	0.932
March	95, 96, 97 (1240)	$y = 3 * 10^{-6}x^2 + 0.8 * 10^{-3}x + 1.6 * 10^{-3}$	0.940
April	95, 96, 97 (1239)	$y = 3 * 10^{-6}x^2 + 0.9 * 10^{-3}x - 8.9 * 10^{-3}$	0.962
May	95, 96, 97 (1283)	$y = 4 * 10^{-6}x^2 + 0.3 * 10^{-3}x + 6.9 * 10^{-3}$	0.981
June	95, 96, 97 (1245)	$y = 4 * 10^{-6}x^2 + 0.22 * 10^{-3}x + 12 * 10^{-3}$	0.991
July	95, 96, 97 (1288)	$y = 4 * 10^{-6}x^2 + 0.4 * 10^{-3}x + 3 * 10^{-3}$	0.990
August	95, 96, 97 (1297)	$y = 4 * 10^{-6}x^2 + 0.4 * 10^{-3}x + 0.3 * 10^{-3}$	0.991
September	95, 96, 97 (1201)	$y = 4 * 10^{-6}x^2 + 0.3 * 10^{-3}x + 6.8 * 10^{-3}$	0.993
October	95, 96, 97 (1112)	$y = 4 * 10^{-6}x^2 + 0.6 * 10^{-3}x + 0.3 * 10^{-3}$	0.979
November	95, 96 (590)	$y = 3 * 10^{-6}x^2 + 0.6 * 10^{-3}x + 4.2 * 10^{-3}$	0.968
December	95, 96, 97 (640)	$y = 3 * 10^{-6}x^2 + 0.8 * 10^{-3}x + 3.5 * 10^{-3}$	0.961
Seasonal			
Winter (DJF)	95, 96, 97, 98 (2740)	$y = 3 * 10^{-6}x^2 + 1 * 10^{-3}x - 0.2 * 10^{-3}$	0.937
Spring (MAM)	95, 96, 97 (3762)	$y = 4 * 10^{-6}x^2 + 0.6 * 10^{-3}x + 7.1 * 10^{-3}$	0.967
Summer (JJA)	95, 96, 97 (3830)	$y = 4 * 10^{-6}x^2 + 0.4 * 10^{-3}x + 27 * 10^{-3}$	0.991
Autumn (SON)	95, 96, 97 (2903)	$y = 4 * 10^{-6}x^2 + 0.3 * 10^{-3}x + 11.8 * 10^{-3}$	0.987

^a y and x refer to the UVB (MED) and global (W/m^2) radiation intensities, respectively.

calculated with measured UV radiation intensity values by statistical analysis. The criteria used were the mean bias error (MBE), the root mean square error (RMSE) and percent coefficient of variation (CV), in effect reporting the RMSE as a percent of the average radiation intensity value, which indicates the average error to be expected when calculating the radiation intensity from the relationships. In addition, site specificity of these relationships was tested by applying a relationship developed for one site to predict the radiation intensity at the second site, utilizing the same independent set of 12 months of radiation data.

Seasonal correlations were also developed with the aim of simplifying the prediction process, using the definition of the seasons (Tables II, III and IV) determined previously by Ianetz and Kudish (1992, 1994):

Table VI. Validation of relationships for Neve Zohar

	Years (h)	Neve Zohar			Beer Sheva		
		MBE	RMSE	CV (%)	MBE	RMSE	CV (%)
UVA							
Month							
January	99 (373)	0.10	1.03	8.7	0.97	1.64	14.0
February	98 (128)	-0.55	1.47	7.9	0.53	1.33	7.1
March	98 (400)	0.99	2.29	13.2	1.72	2.77	15.9
April	98 (401)	0.56	1.67	7.2	1.27	2.07	9.0
May	98 (416)	-0.38	1.66	7.4	0.76	1.84	8.2
June	98 (419)	-0.12	1.37	5.0	1.04	1.73	6.2
July	98 (434)	0.25	1.33	5.4	1.56	2.06	7.8
August	98 (412)	0.60	1.37	5.6	1.79	2.24	9.1
September	98 (287)	0.43	1.31	6.1	1.67	2.19	10.1
October	98 (369)	0.56	1.21	6.7	1.93	2.37	13.2
November	98 (356)	0.20	0.96	7.2	1.31	1.84	13.9
December	98 (123)	0.01	0.78	7.3	0.85	1.46	13.6
Season							
Winter	98 (251); 99 (373)	-0.11	1.12	8.6	0.82	1.50	11.6
Spring	98 (1217)	0.41	1.89	9.0	1.30	2.32	11.1
Summer	98 (1265)	0.27	1.38	5.2	1.49	2.04	7.8
Autumn	98 (1012)	0.47	1.32	7.6	1.68	2.25	12.9
UVB							
Month							
January	99 (373)	-0.05	0.13	25.2	0.002	0.12	23.1
February	98 (127)	-0.10	0.20	22.0	0.14	0.20	22.1
March	98 (399)	0.12	0.26	30.7	0.18	0.32	37.8
April	98 (401)	0.01	0.22	17.6	0.20	0.32	25.4
May	98 (429)	0.01	0.26	19.0	0.14	0.34	25.0
June	98 (419)	0.23	0.27	15.9	0.14	0.19	10.8
July	98 (434)	0.23	0.27	16.4	0.24	0.29	17.8
August	98 (410)	-0.10	0.14	9.3	0.23	0.28	19.4
September	98 (285)	-0.00 ₄	0.07	6.0	0.16	0.21	17.5
October	98 (372)	-0.08	0.11	11.8	0.23	0.29	30.2
November	98 (331)	-0.02	0.06	10.4	0.01	0.06	9.3
December	98 (123)	-0.08	0.15	30.7	0.03	0.13	26.6
Season							
Winter	98 (250); 99 (373)	-0.04	0.13	21.9	0.10	0.20	33.3
Spring	98 (1229)	-0.13	0.29	24.9	0.34	0.55	45.2
Summer	98 (1263)	-0.11	0.15	9.5	-0.18	0.22	13.8
Autumn	98 (988)	-0.01	0.07	7.3	0.11	0.17	18.2

December–February (DJF); March–May (MAM); June–August (JJA); September–November (SON). The same testing procedure was applied to the seasonal relationships. In this case, the data utilized for testing the validity of the individual seasonal relationships consisted of the corresponding months from the excluded data set.

The results of the validation testing of the correlations are reported in Tables VI and VII for the Neve Zohar and Beer Sheva, respectively. The statistical analysis for the calculated values for a particular site are based upon that site's empirical equation (columns 3–5), followed by those values calculated from the second site's empirical equation (columns 6–8). The year(s) and number of hours comprising the individual databases are also listed.

4. DISCUSSION

It is apparent from the statistical analysis reported in Tables VI and VII that the hourly UVA radiation intensities calculated from global radiation (i.e. calculated from measured hourly global radiation intensities) are in relatively good agreement with the measured values at both sites. This is shown to be the case by all three statistical measures, in relatively low values for MBE, RSME and CV. It is of interest to note that at Neve Zohar, except for 3 odd months and winter, the correlations overestimated the UVA radiation intensities, whereas in Beer Sheva the UVA radiation intensities were always underestimated, e.g. MBE values. The UVA relationships for the seasons were also found to be very good predictors of the corresponding radiation intensities, based upon the statistical analysis. The calculated versus measured UVA radiation intensity values, corresponding to the months with the minimum and maximum CV values

Table VII. Validation of relationships for Beer Sheva

	Years (h)	Neve Zohar			Beer Sheva		
		MBE	RMSE	CV (%)	MBE	RMSE	CV (%)
UVA							
Month							
January	99 (345)	−0.07	1.07	8.2	−0.96	1.51	11.6
February	98 (140)	−1.45	2.25	12.2	−0.00 ₂	3.23	17.5
March	98 (388)	−0.46	1.69	9.0	−1.17	2.10	11.2
April	98 (249)	−1.01	1.76	6.9	−1.72	2.42	9.5
May	98 (415)	−1.38	2.01	7.9	−2.54	3.04	11.9
June	98 (420)	−1.34	1.92	6.4	−2.50	2.91	9.8
July	98 (433)	−1.14	1.89	6.5	−2.45	2.94	10.1
August	98 (144)	−0.78	1.45	5.5	−1.95	2.41	9.2
September	98 (388)	−0.94	1.58	6.7	−2.16	2.68	11.4
October	98 (371)	−0.68	1.38	6.9	−2.01	2.63	13.1
November	98 (338)	−0.59	1.09	7.1	−1.72	2.19	14.2
December	98 (131)	−0.34	0.85	7.0	−1.19	1.64	13.5
Season							
Winter	98 (271); 99 (345)	−0.47	1.36	9.6	−1.40	2.11	15.0
Spring	98 (1052)	−0.91	1.84	8.0	−1.80	2.69	11.6
Summer	98 (997)	−1.27	1.75	6.1	−2.34	2.82	9.7
Autumn	98 (1097)	−0.73	1.44	7.3	−1.94	2.54	12.8
UVB							
Month							
January	99 (345)	−0.07	0.17	27.7	−0.12	0.21	34.6
February	98 (327)	0.00 ₄	0.20	26.8	−0.15	0.29	38.6
March	98 (393)	0.08	0.28	31.7	0.03	0.25	28.6
April	98 (249)	0.11	0.22	15.8	−0.07	0.21	15.2
May	98 (425)	−0.01	0.26	16.6	−0.14	0.29	18.9
June	98 (420)	−0.05	0.15	8.0	0.04	0.14	7.4
July	98 (428)	−0.01	0.09	4.7	−0.02	0.11	5.6
August	98 (139)	−0.00 ₂	0.11	7.0	−0.01	0.11	7.3
September	98 (388)	−0.12	0.22	15.3	−0.28	0.38	26.8
October	98 (370)	0.01	0.12	10.5	−0.29	0.38	33.7
November	98 (314)	−0.13	0.20	27.1	−0.16	0.23	31.7
December	98 (131)	−0.06	0.12	22.3	−0.18	0.27	48.2
Season							
Winter	98 (458); 99 (345)	0.02	0.17	26.1	−0.11	0.22	33.5
Spring	98 (1067)	0.22	0.41	32.3	−0.24	0.41	32.7
Summer	98 (987)	0.04	0.13	6.7	−0.33	0.42	22.6
Autumn	98 (1072)	−0.10	0.18	15.8	−0.22	0.31	27.7

at both sites, are plotted in Figure 1 for (i) Neve Zohar and (ii) Beer Sheva, respectively. In all cases except for February at the Neve Zohar site, the equation developed from a site's database was better suited for predicting its own radiation intensity values than that for the second site. This, in all likelihood, is a manifestation of site-specific characteristics of such types of correlations as observed in numerous other studies, e.g. Ianetz and Kudish (1992).

The UVB relationships were much less successful in predicting the hourly radiation intensities from global radiation. At Neve Zohar, CV values exceeded 10% in all cases except for the months of August and September and for the summer and autumn seasons, whereas in Beer Sheva they exceeded 10% in all cases except for the months of June, July and August, and the summer season. In fact, the CV values exceeded 20% for 4 and 5 months in Neve Zohar and Beer Sheva, respectively. The calculated versus measured UVB radiation intensity values corresponding to the months with the minimum CV values, and for a month with a $CV \approx 15\%$ at both sites are plotted in Figure 2 for (i) Neve Zohar and (ii) Beer Sheva, respectively. Nevertheless, it was observed that for the months characterized by relatively high radiation intensities in this region, April–October, the CV values were less than 20%, and for some months less than 10%. However, it is important to note that, during the peak radiation months, the empirical relationships for calculating the UVB radiation intensities are characterized by a $CV < 20\%$, which may be sufficient if no other information is available. The relatively lower CV values during the peak radiation months is a reflection of the very high frequency of clear sky conditions during this time (Kudish and Ianetz, 1996).

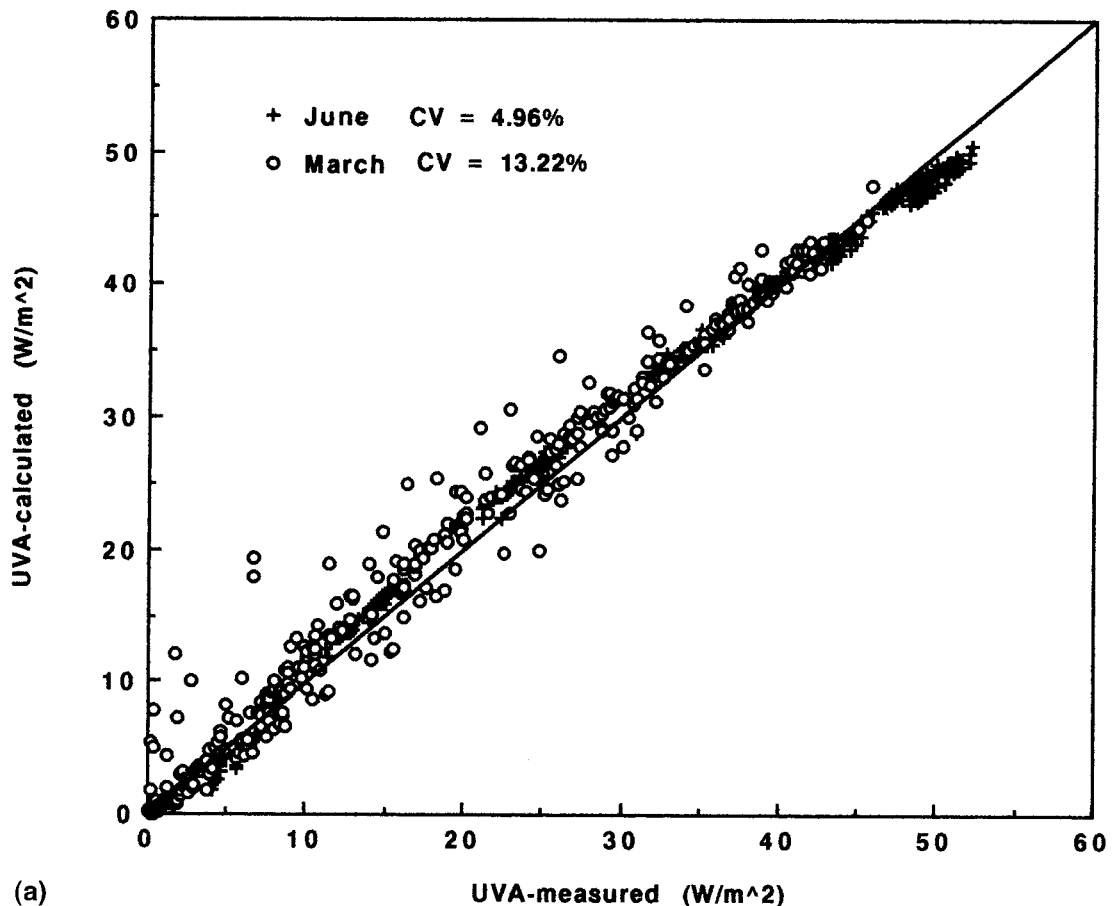


Figure 1. The calculated versus measured UVA radiation intensity values at (a) Neve Zohar for March and June 1998, and (b) Beer Sheva for February and June 1998

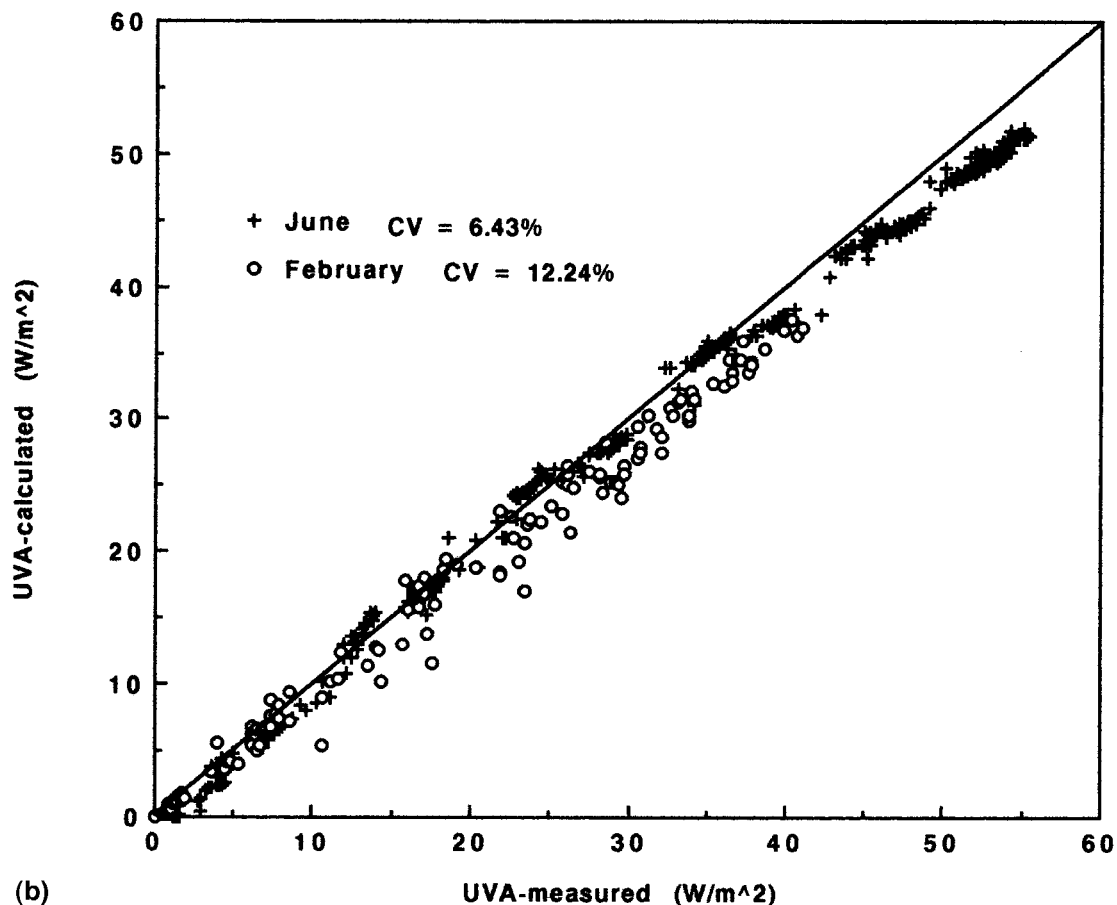


Figure 1 (Continued)

The seasonal relationships were found to be, in general, as good as the corresponding individual monthly predictors. Their CV values were in the range of those corresponding to the individual months comprising the season. This is as expected from the observed similarity between the empirical equations for the 3-month sets comprising a season, as outlined in Tables II, III, IV and V.

The statistical differences between UVA and UVB relationships may be attributed, partially, to the relative magnitude of the parameters involved in the analysis. The UVB radiation intensities are approximately two orders of magnitude smaller than those of the UVA, and the latter are smaller by about a factor of about 20 than the global radiation intensities. These relative magnitudes are also reflected in the coefficients of the correlation equations. Consequently, a small absolute error in the radiation intensity value of the UVB results in a large relative error. In addition, although these relationships are empirical, it is important to note that while ozone plays a dominant role in the attenuation of UVB radiation, it has only a negligible effect on UVA and global radiation. Consequently, there is a greater similarity between UVA and global radiation, than between UVB and global radiation and the better agreement between the former is, therefore, not unexpected.

It is also important to note that although the r^2 values for the UVB correlations were observed to be relatively high (Tables II and III), this was not a guarantee that their predictive ability would be found suitable. The results of the testing of these relationships by an independent set of data from the same site (Tables VI and VII) attest to the opposite outcome. Webb and Steven (1986) developed their correlation's for daily integrated totals of UVB radiation as a function of daily global radiation, using their complete radiation database and utilized the r values as a measure of correlation suitability.

The results of this analysis are quite disappointing, because it is observed that such relations with global irradiance have a very limited applicability with respect to the prediction of the radiation intensity of UVB. This is especially so in that terrestrial UV radiation has become a major public and scientific issue throughout the world. The increased public awareness of the possible impacts of changing UV radiation levels, and the transmission of such information *via* such indicators as the popular daily UVB Index, which indicates the level of the UV radiation intensity expected and recommends the protective actions necessary to the public, is attested to by its frequent appearance in all types of communication media. It would have been useful if such UVB correlations were sufficiently accurate, thereby significantly increasing the scope of sites for which such information would be available.

5. CONCLUSIONS

The conclusions from this study can be summarized as follows:

(i) Relations between UVA and global hourly radiation intensities have been found to be good predictors of UVA hourly radiation intensities. On a monthly and seasonal basis, at both sites, CV values were in almost all cases less than 10%.

(ii) Relations between UVB and global hourly radiation intensities were poor predictors of UVB hourly radiation intensities. On a monthly and seasonal basis, at both sites, CV values were in almost all cases

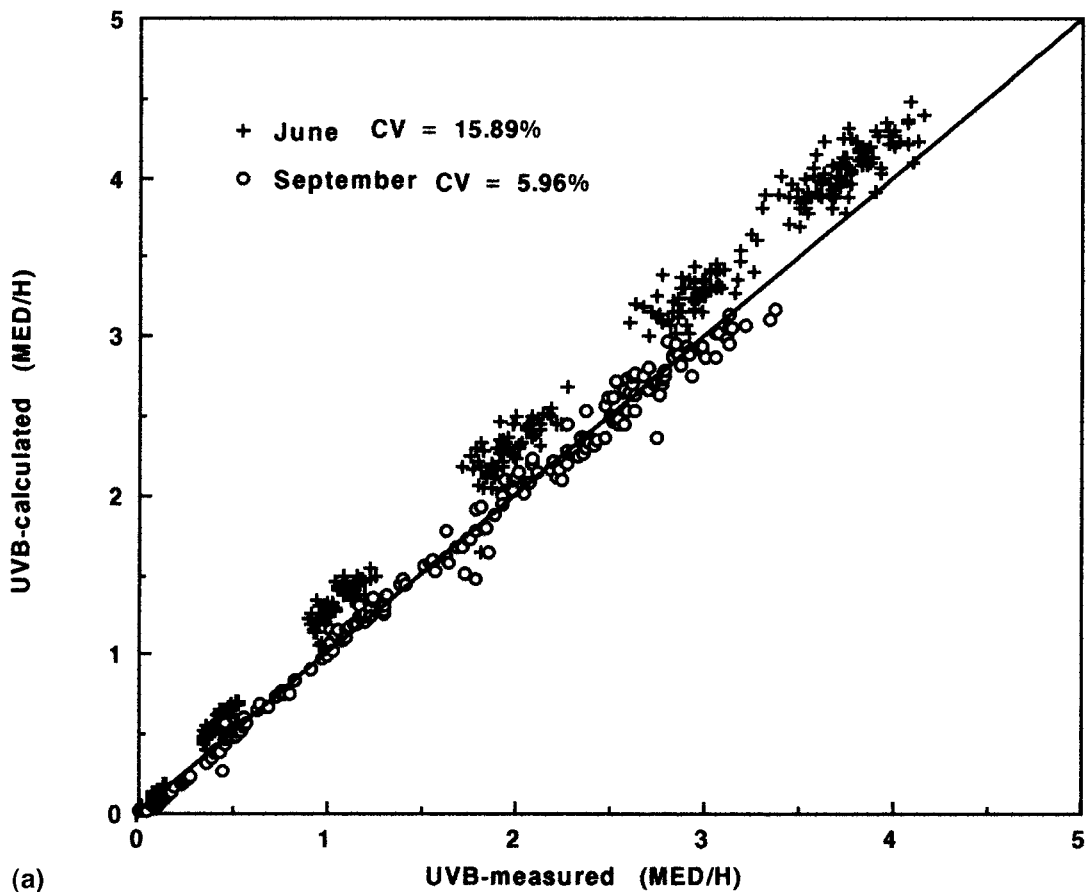


Figure 2. The calculated versus measured UVB radiation intensity values at (a) Neve Zohar for June and September 1998, and (b) Beer Sheva for May and July 1998

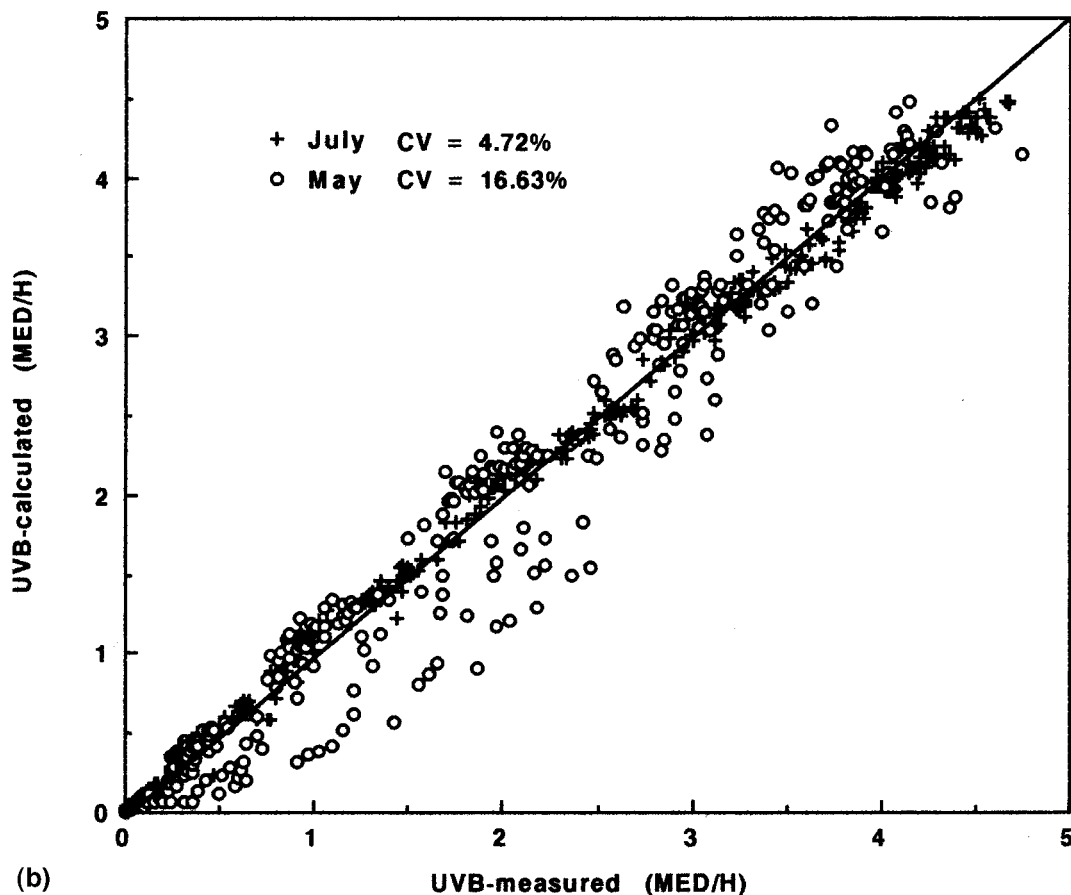


Figure 2 (Continued)

greater than 10%. Nevertheless, it was observed that for the months characterized by relatively high radiation intensities in this region, April–October, the CV values were less than 20%, and for some months and seasons, less than 10%. The relatively lower CV values during the peak radiation months are a reflection of the very high frequency of clear sky conditions during these months.

(iii) The seasonal relationships were found to be as good as the corresponding individual monthly predictors. Their CV values were in the range of those corresponding to the individual months comprising the season.

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