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Comparison of ground-level-measured and satellite-derived erythemal ultraviolet doses in Estonia

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Abstract. A comparison of the ground-level-measured daily erythemal ultraviolet doses at the Tartu/Tõravere meteorological station (58.3° N, 26.5° E; 70 m a.s.l.) with the doses retrieved by the Earth Probe satellite instrument Total Ozone Mapping Spectrometer has been provided for the summer half-years (from vernal equinox to autumnal equinox) of 1998–2001. The linear correlation between the satellite-retrieved and ground-level-measured doses was found to be between 0.93 and 0.95 in different years, with the lowest value registered in extremely cloudy 1998. The mean ratios of the satellite-retrieved to measured values manifest no systematic difference. The daily differences reach 200% in the presence of optically thick low cloudiness. The summer half-year total doses agree within 2%, with the exception of 1998 when the difference reached 6%.

Key words: erythemal UV irradiance and dose, relative sunshine duration, total cloud amount, low cloud amount.

1. INTRODUCTION

The ultraviolet (UV) irradiances and doses are believed to increase at present and in the near future due to the reduction of stratospheric ozone [1]. The increase should be partly compensated by the growth in cloudiness. At the same time, cloudiness could decrease in some regions [2]. The time series of reliable ground-level UV measurements at a few sites cover the last 10–15 years. In Estonia regular measurements of the erythemally weighted (spectral response of the sensor corresponds to the *Commission Internationale de L'Éclairage* (CIE) 1987 [3] standard or DIN 5050) irradiance have been carried out since the beginning of 1998 [4]. It is necessary to have longer data series to study the trends or cyclic climate-related changes in UV radiation at any geographic site. For these purposes different proxies, such as the broadband global irradiance measured by pyranometers, the sunshine duration, and the cloudiness data, could be used [5].

One of the most suitable facilities for the past two decades is the use of satellite UV retrievals. The data from NASA Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) are available for November 1978 to May 1993, from Meteor-3 TOMS with considerable gaps for August 1991 to December 1994, and from the Earth Probe TOMS since August 1996 [6]. Polar orbiting satellite spectrometers such as TOMS are capable of measuring the atmospheric properties once per day at a given location, which restricts their ability to retrieve the total daily UV doses. The surface UV irradiance data derived from satellite measurements are subject to significant uncertainties [7], especially for cloudy situations. Differences between satellite-derived and ground-level-measured doses arise partly because satellite-derived data represent a large-area average single value and the ground-level-measured data an integrated daily continuous record. The effects of clouds and surface albedo are different [8]. The snow cover can enhance the UV irradiance considerably and presents therefore a major problem for the TOMS retrieval algorithm [9,10]. Errors, albeit smaller, occur also in ground-based measurements [11,12]. Regardless of uncertainties the satellite data are an interesting supplement to the local UV climatological data sets. Under cloud-free conditions the accuracy of satellite UV retrieval is limited mainly by a poor knowledge of highly variable aerosol properties, although the aerosol effect on satellite UV retrievals is considered quite small except in the near-tropical areas where the major dust and smoke plumes occur. The TOMS aerosol estimation technique is not sensitive to aerosol absorption close to the ground, which is often the case in urban and other heavily polluted atmospheres [13]. Ultraviolet irradiance reductions of more than 10%, as compared to the satellite-retrieved values, have been recorded at several sites in Europe and Canada [14,15]. In the Southern Hemisphere, due to cleaner air, the biases between satellite-retrieved and ground-based measurements of UV irradiances are insignificant [14].

The present paper provides a comparison of the ground-level-measured and the Earth Probe TOMS retrieved daily erythemal UV doses in erythemally weighted $J_{eff}\,m^{-2}$. The potential for using the TOMS data as a proxy for the estimation of the erythemal doses for recent years is discussed.

2. DATA

Continuous measurements of erythemal UV irradiance at the Tartu/Tõravere meteorological station (58.3° N, 26.5° E; 70 m a.s.l.), belonging to the international Baseline Surface Radiation Network (BSRN), have been carried out since 1 January 1998 using a Scintec UV SET sensor. The instrument has been thermostated and calibrated by the manufacturer in units of MED/h (Minimal

Erythemal Dose per hour) for skin type 2 (MED = 250 J_{eff} m^{-2}, where J_{eff} means the integrated global spectral irradiance multiplied by the CIE standard spectral response for erytheme). None of the broadband instruments matches precisely the CIE standard spectral response and also deviations from the cosine angular response at low solar elevations can be different [16]. Thus some systematic differences between the values of erythemal irradiances and doses recorded by different instruments are common [17]. The instrument installed at the Tartu/Tõravere meteorological station has not participated in the international intercomparison campaigns and has not been recalibrated by deriving the calibration factor through integrating the spectral response weighted global irradiance spectra of the standard traceable lamps. The manufacturer's calibration factor has been checked twice a year in laboratory using a standard quartz halogen (FEL) lamp calibrated by Oriel Instruments (USA) in spectral irradiance traceable to USA National Institute of Standards and Technology (NIST) standards. The uncertainty of the checking was 5–10%. The angular response of the sensor has been checked using a goniometer GS-5. The recorded deviations from the ideal cosine response are ±5% at solar zenith angles below 70°. Spectral response has been checked using the laboratory double monochromator SDL-1 (LOMO, Russia) and has been found to be in agreement with that of the CIE, plus or minus a few per cent.

For the characterization of the weather conditions the parameters related to daily cloudiness such as the relative sunshine duration during a day S (the recorded duration of sunshine divided by the length of day), the daily mean total cloud amount in tenths, the daily mean low cloud amount in tenths, and the daily sum of broadband irradiance Q recorded by pyranometer were used. It was shown in our previous paper [18] that cloudiness is the major factor modulating the daily erythemal doses H and the contribution of ozone variations is rather small in summer.

The sunshine duration is monitored using the Campbell–Stokes sunshine recorder. The instrument detects the duration of irradiance above the level of 120 W m^{-2}, usually not reached when clouds obscure the sun. Early in the morning and late in the evening the sunshine is thus not detected as the irradiance level remains below the threshold. In clear weather the values of S are between 0.85 and 0.95, depending on atmospheric turbidity. The cloud amounts in tenths on low, medium, and high levels are detected visually at half past each hour in local solar time during the daytime. Mean total cloud and mean low cloud amounts are often used as the cloudiness characteristics. The correlation coefficient between the low cloud amount and the total cloud amount in the summer half-years (from spring equinox to autumnal equinox) of 1998–2001 was found to be as high as 0.835. The contribution of the low clouds to total cloudiness is approximately 70%. The correlation coefficient between the daily relative sunshine duration S and the mean total cloud amount was –0.935 and the one between S and the mean low cloud amount was –0.84.

The TOMS-derived values of daily erythemal doses are presented in $J_{eff}\,m^{-2}$. These were calculated using derived values of atmospheric total ozone, scene reflectivities from measurements of backscattered UV radiance, and extra-terrestrial solar flux data [19]. Satellite estimates give regional and global views. The interpolated gridded data are available via the Internet (http://jwocky.gsfc.nasa.gov) with a step of 1.0° in latitude and 1.25° in longitude. The closest grid point to the Tartu/Tõravere meteorological station is the one with the coordinates 58.5° N and 25.6° E. The retrieved erythemal dose values are available when the noon solar elevation is higher than 17.5°, i.e. approximately from 10 February to 1 November. Estimates were expected to be sensitive not to stratospheric ozone profile shape, but to some extent to variations in the distribution of tropospheric ozone. Strong attenuation can arise from the high concentration of ozone in the lower troposphere combined with the high load of absorbing aerosol [20]. In [21] the doses from ground-based spectroradiometric measurements are compared with the TOMS data. It is found that the impact of daily cloudiness variations may be described not realistically as often only one value is available per day. Partly the biases in retrieved doses could be explained by the mountainous and coastal locations of ground-based measurements. Recent studies, using different ozone profiles at the same total column value, have established significant dependence of erythemal UV doses on profile [22,23].

Because the ozone and aerosol profiles, their loads and cloudiness conditions can be different at different sites, no universal relationship between the ground-level-measured and satellite-retrieved daily erythemal UV doses could be expected. The agreement between ground-level-measured and satellite-retrieved doses can be different at different sites as well. It is expected to be better at cleaner sites. The necessity for those comparisons has been underlined in documents issued by the European Community and the World Meteorological Organization.

3. COMPARISON OF DOSES

The Tartu/Tõravere ground-level-measured and TOMS-derived erythemal doses in 1998–2001 were compared within the time intervals from vernal equinox to autumnal equinox, taking 186 days into account. Below, this interval is called the summer half-year. Additionally a comparison was made for the four sunniest summer months (May to August, 123 days) on daily, ten-day, and whole summer half-year levels. The winter half-year was excluded because the satellite data do not cover it fully and the uncertainty of ground-level measurements at low solar elevations is lower than at the elevations reached in the summer half-year. The ground-level-measured and TOMS-derived daily doses in $J_{eff}\,m^{-2}$ during the summer half-year of 2000 are presented in Fig. 1, showing their agreement. An averaged cycle of ground-level-measured clear-weather daily erythemal doses from vernal equinox to autumnal equinox is given in Fig. 2. Initially 45 days of 1998–99 were used, afterwards 50 days of 2000–01 were added. The total ozone values and the noon relative contribution of pyranometer measured diffuse irradiance were checked for each day to avoid systematic deviations from the "normal". For this reason 15 days were excluded. It should be mentioned that due to the spring maximum and autumnal minimum in the total ozone yearly cycle [[24]] the clear-weather daily erythemal doses are also distributed asymmetrically relative to the summer solstice. At the same noon solar elevation the spring daily doses are lower than the autumnal doses. Around equinoxes the difference reaches 25%.

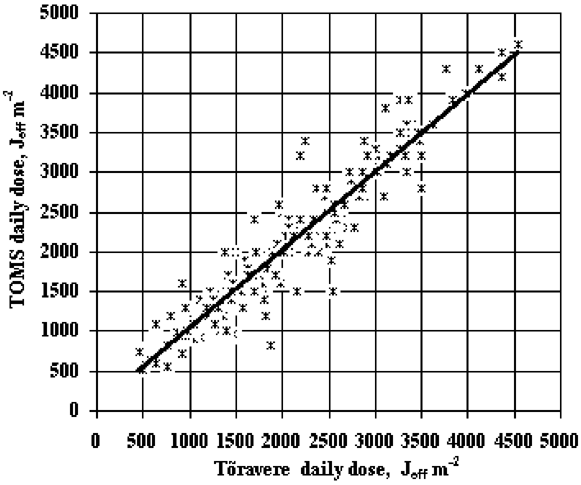

Fig. 1. Comparison of Tõravere ground-level-measured and TOMS-derived daily erythemal doses in the summer half-year of 2000 in units of J_{eff} m^{-2}.

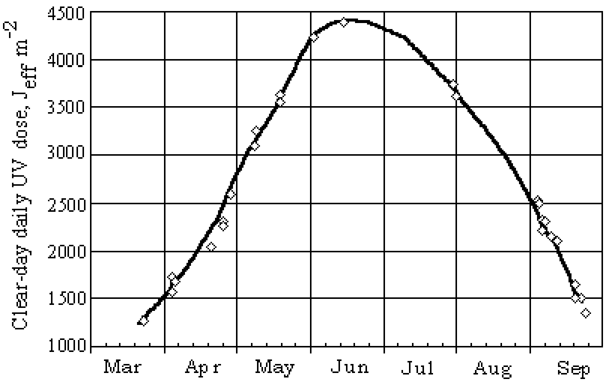

Fig. 2. Best-fitted summer half-year cycle of the assumed clear-weather daily erythemal doses at Tartu/Tõravere in J_{eff} m^{-2}.

To compare TOMS-derived and ground-level-measured doses, first their daily ratios were calculated. The probability density distribution of these ratios for the whole dataset covering 744 days is presented in Fig. 3a in scales with a step of 0.1 in the doses ratio and per cent in frequency. The probability density distributions for almost clear days (133 days) are presented in Fig. 3b and for almost overcast days (160 days) in Fig. 3c. Relative sunshine duration S was used as a criterion. The days with $S > 0.8$ were included in the group of almost clear days and the days with $S < 0.15$ among almost overcast days. The corresponding threshold mean cloud amounts are around 2 tenths and 9 tenths. The descriptive statistics for the whole dataset as well as for almost clear and overcast days are presented in Table 1. The mean ratio of TOMS-derived to

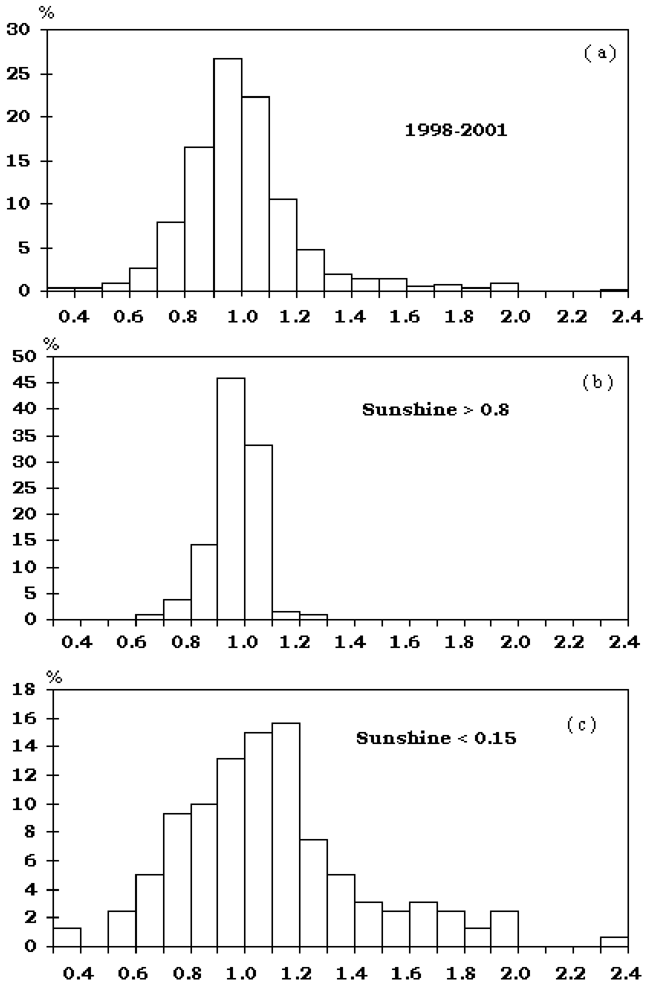

Fig. 3. Ratios of TOMS-derived to Tõravere ground-level-measured daily erythemal doses in summer half-years of 1998–2001: (a) all days; (b) days with relative sunshine $S > 0.8$; (c) days with relative sunshine $S < 0.15$.

Table 1. Descriptive statistics of the TOMS/Tõravere erythemal dose ratios for 1998–2001, including all summer half-year days and separately fine-weather days ($S > 0.8$) and heavily cloudy days ($S < 0.15$). The two lowest rows indicate the contribution of ratio values within ±10 and ±20% of the mean

	All days	$S > 0.8$	$S < 0.15$
Mean	1.006	0.970	1.09
StDev	0.22	0.08	0.34
Min	0.31	0.67	0.31
Max	2.35	1.28	2.35
In ±10%	0.49	0.80	0.28
In ±20%	0.77	0.96	0.45

measured daily doses was found to be 1.006, varying between 0.978 (in 1998) and 1.023 (in 2000) in separate years. For nearly clear days the TOMS-derived values tend to be lower (mean ratio 0.97) and for almost overcast days higher than the measured values (mean ratio 1.09). The left and right wings of the probability density distribution are of different shape, with the left wing being more similar to the normal distribution. The standard deviation in the case of almost overcast days exceeds more than four times the value for almost clear days, manifesting lower confidence of the TOMS-derived values in these conditions. The relationship between the ratio of TOMS-derived to ground-level-measured doses and TOMS-measured thickness of the ozone layer over Tõravere is presented in Fig. 4. The dependence of that ratio on the day number of the year is shown in Fig. 5. Systematic differences related to total ozone were not found. Higher TOMS values were dominating only at the end of March.

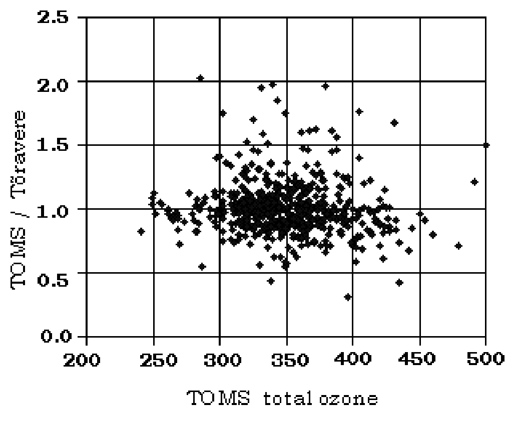

Fig. 4. Relationship between the ratio of TOMS-derived to ground-level-measured erythemal doses and TOMS-measured thickness of the ozone layer over Estonia (DU).

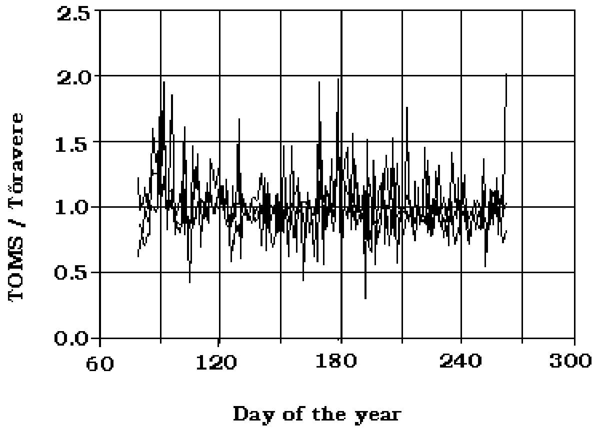

Fig. 5. Dependence of the ratio of TOMS-derived to ground-level-measured erythemal doses on the day number of the year in the summer half-year.

The relationship between the variance of the ratio of TOMS-derived to ground-level-measured erythemal doses and cloudiness-related quantities is illustrated in more detail in Fig. 6. At relative sunshine values above 0.7 (Fig. 6a), as well as at low cloud amounts below 4 tenths (Fig. 6b), the variance of the ratio remains at approximately constant level and increases towards lower relative sunshine and higher low cloud amounts. A similar threshold in the case of total cloud amount was found around the value of 5 tenths (Fig. 6c). At relative sunshine values below 0.2 and both cloud amounts above 8 tenths the standard deviation of the ratio is approximately three times larger than it is above the threshold. At lower total cloud amounts the relative contribution of high and middle level clouds is usually higher than at high total cloud amounts. Small low cloud amounts often appear on the background of significant amounts of two higher level clouds.

The results of the comparison of both daily doses from separate half-years are presented in Table 2. The average coefficient of linear correlation between the ground-level-measured and TOMS-derived daily doses was found to be stable between 0.93 and 0.95 for the whole summer half-year and slightly less, between 0.90 and 0.91, for the period from May to August. The difference of both doses did not exceed ±10% in 40% of cases in 1998 and 50–55% of cases in other years, and ±20% in 73–82% of cases in all years. The biases in daily erythemal doses exceeding ±20% were recorded mainly in the cases where the daily mean low cloud amount was above 6 tenths. Only in a few cases the daily mean total cloud amounts were below 6 tenths (3 days in 1998, 7 days in 1999, 3 days in 2000, 6 days in 2001). In about 50% of cases the biases exceeding ±20% were registered at total cloud amounts above 9 tenths. The largest values, exceeding in some cases the 200% level, were measured mostly on days with a significant contribution of optically thick low clouds, such as the *nimbostratus* or *fracto-nimbus* clouds. For 24 days with clear sky (less than 2 tenths of clouds) in the

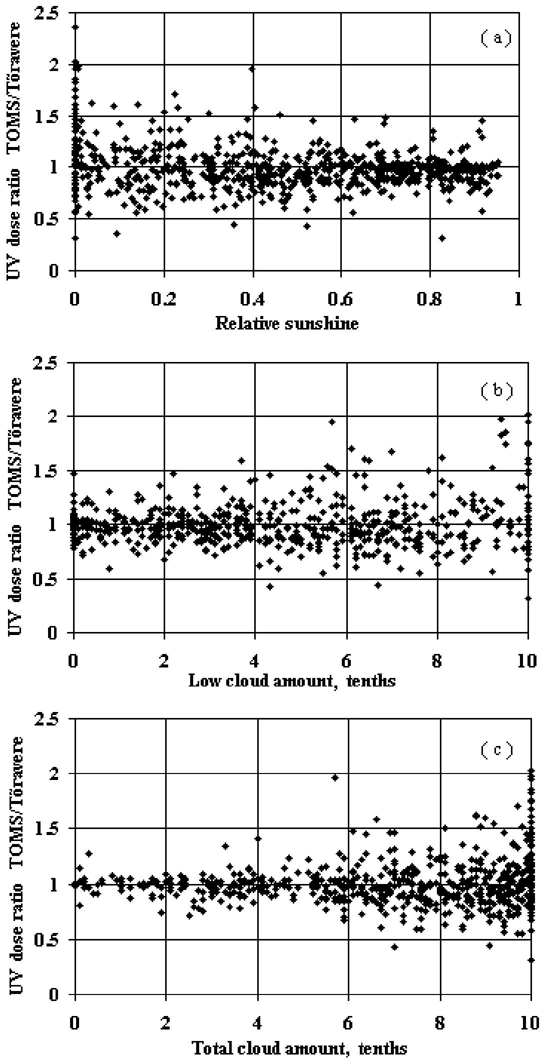

Fig. 6. Dependence of the variance of the ratio of TOMS-derived to Tõravere ground-level-measured daily erythemal doses on relative sunshine (a), low cloud amount (b), and total cloud amount (c) in 1998–2001.

summer half-year of 1999, the mean ratio of TOMS/Tõravere daily doses was 1.00, the extreme values being 0.920 and 1.053. For 45 days, when only *cirrus* or *cumulus* clouds (or both) were present, the mean ratio was 0.97. Moderate amounts of these clouds usually enhance the daily dose. The TOMS-retrieval can underestimate that contribution [8]. Good agreement between the TOMS-retrieved and ground-level-measured daily erythemal doses for low cloud amounts offers a possibility of rough intercomparison of the ground level instruments located simultaneously in persistent high pressure areas.

Table 2. Descriptive statistics of the TOMS/Tõravere erythemal dose ratios for separate summer half-years and for May to August periods. The presented values are: mean value of the daily TOMS/Tõravere dose ratio, its standard deviation and extreme values, coefficient of linear correlation between TOMS and Tõravere daily doses, ratio of TOMS/Tõravere half-year doses, total number of sunshine hours, mean daily relative sunshine duration *S*, mean daily total cloud amount, and mean daily low cloud amount

	1998	1999	2000	2001
Mean	0.978	1.013	1.023	1.007
StDev	0.227	0.209	0.196	0.248
Min	0.31	0.42	0.44	0.36
Max	1.98	2.02	1.76	2.35
Linear correlation	0.93	0.95	0.94	0.94
Total dose ratio	0.940	0.995	1.008	0.987
Sunshine (hours)	1187	1536	1285	1480
Mean *S*	0.403	0.518	0.438	0.491
Total clouds	7.45	6.35	7.05	7.05
Low clouds	5.15	3.50	4.45	4.45
May to August				
Mean	0.953	0.999	1.027	0.985
StDev	0.224	0.175	0.213	0.190
Min	0.31	0.56	0.44	0.44
Max	1.98	2.02	1.76	1.91
Linear correlation	0.90	0.91	0.91	0.91
Total dose ratio	0.95	0.99	1.01	0.99
Mean *S*	0.393	0.551	0.413	0.56
Total clouds	7.75	6.05	7.25	6.45
Low clouds	5.55	3.40	4.85	4.10

The dependence of the ratio of doses on cloudiness conditions on the averaged level of ten-day intervals from the last ten-day period of March to the second ten-day period of September was studied as well. The ten-day mean *S* values vary between 0.18 and 0.75 and the ten-day mean low cloud amounts between 1.5 and 7 tenths. Accidentally the summer half-year daily mean total cloud amounts as well as the daily mean low cloud amounts were equal in 2000 and 2001, but total sunshine duration was 195 hours (15%) longer in 2001 than in 2000. The period from May to August was more cloudy in 2000.

The coefficients of linear correlation on the ten-day mean level between the erythemal doses and cloudiness-related quantities, as well as between the measured and TOMS-derived doses, are presented in Table 3. On such a moderately averaged level the doses are better correlated to the modulating factors (actually to the same factor in different expressions). The ten-day mean ratios of TOMS-derived to ground-level-measured doses vary between 0.83 and 1.20. The values lower than 0.9 and higher than 1.1 make up 14% of the total and are related to cloudy weather. On the monthly level the differences between TOMS-derived and measured doses did not exceed 6.5%, reaching 8% only in one case (May 1998).

Table 3. Coefficients of linear correlation between the ground-level-measured and TOMS-derived erythemal doses and the cloudiness-related quantities (relative sunshine duration *S*, mean total cloud amount, and mean low cloud amount) on the ten-day mean level, and the ten-day mean ratios of TOMS/measured doses

	All	1998	1999	2000	2001
	Ground-level-measured				
S	0.88	0.94	0.93	0.88	0.85
Total clouds	−0.80	−0.84	−0.88	−0.76	−0.76
Low clouds	−0.84	−0.90	−0.73	−0.89	−0.89
	TOMS				
S	0.81	0.87	0.83	0.81	0.81
Total clouds	−0.77	−0.86	−0.77	−0.74	−0.73
Low clouds	−0.85	−0.88	−0.77	−0.89	−0.88
TOMS/measured	0.94	0.98	0.99	0.99	0.99

In the cloudy 1998 the TOMS-derived summer half-year dose was 6% lower and the one for May to August 5% lower than the ground-level-measured doses. In other years the differences in half-year doses were between 0.5% and 1.3%, and the differences in May to August doses below 1%. The values of the standard deviation for the whole half-year were similar in different years. For the May–August subinterval the standard deviations were equal to those for the whole summer half-year or somewhat reduced. The standard deviations for more cloudy summers were higher than for fine-weather summers. The comparison of our ground-level-measured and TOMS-derived daily erythemal doses allows of a conclusion that reliable results for estimating the ground-level erythemal doses can be obtained for the summers for which the TOMS data are available, with some caution considering extremely cloudy summers. For shorter time intervals the reliability depends on the proportion of comparatively fine-weather days within the interval. Possibly due to absorption by aerosols or pollutants at several mid-latitude sites of the Northern Hemisphere, satellite estimates of surface UV radiation were found systematically higher than ground-based spectral or broad-band measurement values [14,15,25]. The atmospheric transmittance over Estonia has improved since 1997 and there is no systematic difference between the ground-level-measured and TOMS-retrieved daily erythemal doses in fine weather. The biases of TOMS-derived and ground-level-measured daily doses in cloudy periods seem to be caused by different spatial and temporal resolutions in estimations of the cloud cover extent and cloud optical depth. It is quite possible that the calibration factor of the Tartu/Tõravere ground-level instrument has some shift relative to the commonly accepted scale of $J_{eff}\,m^{-2}$, exactly compensating the atmosphere-induced bias between its and TOMS-derived values.

4. SUMMARY AND CONCLUSIONS

The four-year (1998–2001) daily erythemal UV doses measured at the Tartu/Tõravere meteorological station by a broadband instrument were compared with the Earth Probe satellite TOMS-derived daily erythemal doses in the periods from vernal equinox to autumnal equinox (over the summer half-years).

Other comparisons of ground-based and satellite-retrieved doses known to the authors of the present paper have used ground-based spectroradiometric data [15,21,25]. The comparisons with the data of broadband instruments collected over longer time periods at different sites should be useful for assessing the reliability of satellite-retrieved data in studies of ground-level UV climatologies.

On the daily level the coefficient of linear correlation between the ground-level-measured and TOMS-derived values in different years varied between 0.93 and 0.95. On the level of ten-day means the correlation was higher (coefficient values between 0.98 and 0.99).

Both the ground-level-measured and the TOMS-derived values correlated closely with cloudiness-related characteristics, such as the daily relative sunshine duration, the daily mean total cloud amount, and the daily mean low cloud amount. The highest correlation was recorded between the erythemal doses and relative sunshine duration (see Table 3). The next strongest correlation was the negative correlation between the erythemal doses and the low cloud amount.

The correlation between the cloudiness-related characteristics was quite strong as well. On the ten-day level the strongest correlation was the negative correlation between the mean relative sunshine duration and the total cloud amount (–0.935). The linear correlation between the total cloud amount and low cloud amount was 0.835 and the one between the relative sunshine duration and low cloud amount was –0.84.

For the whole dataset the mean ratio of TOMS-derived to ground-level-measured daily erythemal doses was close to 1 (1.006). On the daily level about half the values (49%) did not differ more than ±10% and about 77% of the values differed by ±20%. The largest biases were about 200%, mostly in case of dense clouds. Only 2.5% of the cases outside the ±20% range were connected to daily mean cloud amounts below 6 tenths. The variance of the ratio of TOMS-derived to ground-level-measured doses remains on approximately constant level at relative sunshine above 0.7, total cloud amount below 5 tenths, and low cloud amount below 4 tenths. At relative sunshine below 0.2 and both cloud amounts above 8 tenths the standard deviation reaches 300% of the value above the mentioned threshold. In separating almost clear days (with daily mean relative sunshine duration more than 0.8) and almost overcast days (with the daily mean relative sunshine duration below 0.15), significant differences were found in statistical characteristics of the ratio of doses. The probability density distribution for almost clear days was sharp, with the largest deviation from the mean of 33% and standard deviation of 8%. For the broad probability density distribution of almost overcast days these values were 135% and 34%, respectively. No dependence between total ozone value and the ratio of TOMS-derived to ground-level-measured daily erythemal doses was found.

The observed differences between TOMS-derived and ground-level-measured erythemal doses are reduced for data averaged over longer periods, as noticed by [15]. In Estonian climatic conditions the TOMS-derived erythemal doses integrated over the entire summer half-year, or at least several months, are in agreement with the ground-level-measured values within ±2%, except for the summers with anomalously high amounts of optically thick low clouds.

The TOMS data could be used as a proxy for estimating the summer half-year total erythemal doses back to 1979. In case of persistent highs the TOMS data allow some comparison of the ground-level based erythemally weighted instruments.

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Eesti maapinnal mõõdetud ja satelliidilt hinnatud erüteemkiirguse dooside võrdlus

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On võrreldud ajavahemiku 1998–2001 suvistel poolaastatel (kevadisest pööripäevast sügisese pööripäevani) Tõravere meteoroloogiajaamas (58,3° põhjalaiust,

26,5° idapikkust, 70 m üle merepinna) sensoriga UV SET vahetult mõõdetud ja satelliidilt Earth Probe aparatuuri TOMS (*Total Ozone Mapping Spectrometer*) abil määratud erüteemkiirguse päevadoose. Erinevalt mitmetest põhjapoolkera kesklaiuste rohkem saastatud atmosfääriga piirkondadest ei ilmnenud süstemaatilist erinevust maa peal mõõdetud ja satelliidilt hinnatud dooside vahel. Nelja suvise poolaasta Tõravere ja satelliidi andmete keskmine päevaste väärtuste suhe oli 1,006. Pooltel juhtudel jäi kummagi doosi erinevus alla 10% ja 77% juhtudel alla 20%. Selgete ja vähese pilvisusega ilmadega jäi dooside erinevus ±10% piiridesse 80%-l juhtudest. Isegi kuni kahe korrani küündivad suured kõrvalekalded esinesid valdavalt madala lauspilvisusega päevadel. Lauspilves ilmade korral osutus kummagi doosi suhte väärtuste standardhälve üle nelja korra suuremaks kui selgete ilmadega. Korrelatsioonikordaja väärtused Tõraveres mõõdetud ja satelliidilt hinnatud dooside vahel olid eri suvedel 0,93 ja 0,95 vahel. Pilvisust iseloomustavatest suurustest oli korrelatsioonikordaja erüteemse päevadoosiga kõige kõrgem (0,88 maapealsete mõõtmiste ja 0,81 satelliidi andmetega) päikesepaiste suhtelisel kestusel (päikesepaiste registreeritud kestus jagatud päeva pikkusega). Erinevused suviste poolaastate maa peal mõõdetud ja satelliidilt hinnatud summaarsete erüteemsete dooside vahel mahuvad ±2% piiresse, välja arvatud erakordselt pilvise suvega 1998. aasta, kui satelliidilt hinnatud doos osutus maa peal mõõdetust 6% võrra väiksemaks.