Atmos. Chem. Phys. Discuss., 8, S2343–S2351, 2008
www.atmos-chem-phys-discuss.net/8/S2343/2008/

Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Personal UV exposure on a ski-field at an alpine site" *by* A. M. Siani et al.

A. M. Siani et al.

Received and published: 5 May 2008

The authors thank the referee for the positive comments and the constructive criticism.

In the manuscript the UV dose of skiers recorded with PS dosimeters is compared to the measured horizontal irradiance. Also the change of skin colour is analysed. The paper gives useful information on use and sensitivity of PS dosimeters. The ER for skiers and instructors are compared, but there is little discussion on about the effect of ambient conditions to the ER.

Author Comment, AC: At the beginning of section 3.4 the following statements will be included:

"In Table 2 Exposure Ratio results for the spring and winter campaigns at each PS dosimeter change (approximately every two hours) are reported in terms of median, minimum (min.) and maximum (max.) values. It can be seen that the behaviour of ER is not necessarily similar to the corresponding ambient doses (see section 3.2) that occurred between 12:00 and 14:00 LT due to the shorter atmospheric path of radiation and the smaller solar zenith angle. In fact, although Exposure Ratio is determined using ambient dose, it also depends on the personal dose which is influenced by individual factors such as time and the duration of exposure, body posture and orientation to the sun."

The UV-radiation and the sensitivity of PS dosimeters have strong dependency of altitude. The effect of the skier's altitude to the ER should be estimated and discussed.

AC: In section 3.4 the following statements will be also included: "The limit of polysulphone dosimetry is that it does not allow to record individual exposure such photoelectronic captors. This technique requires a careful quantification of the calibration curve (ambient dose versus PS film absorbance changes prior and post exposure) nearby the site under investigation (Casale et al. 2006). Although a variability was observed among the c values of calibration curves at the sites at different altitude, an average altitude of 2100 m a.s.l. for ambient dose and also for the calibration curve was assumed. Due to the lack of information on specific altitude during skiing it was not possible to analyse the altitude dependency of ER. Personal doses should tend to increase with altitude and with combined factors (Rayleigh scattering, a smaller amount of tropospheric gases and albedo). Consequently an increase of ER can be observed but at the same time, individual body posture, repetitive movements during the activity, individual positions related to the sun, can be also responsible of high values of ER."

Times spend indoors and in shade were also asked in the questionnaire, so effect of these should also be discussed.

AC: The following statements will be also included in section 3.4: "The dose received by the specific anatomical location (in this study the forehead) depends also on the activity index i.e. the proportion of time spent at the sun. This suggests that lower ER values observed could be related to more time spent indoor and in shade. On the other hand low personal doses can be also found when volunteers spent all their time in the sun depending on their postural activity."

The ER should also be compared to theoretical calculations. Koepke and Mech calculated UV-irradiances to tilted surfaces in various conditions. (Koepke P. and M. Mech.: UV irradiance on arbitrarily oriented surfaces: variation with atmospheric and ground properties, Theor. Appl. Climatol. 81, 25-32, 2005) With snow and 3000 m altitude the highest theoretical ER was 1.44 for surface tilted towards sun. In the manuscript the highest ER was 1.72, so some discussion on the results obtained in the study and theoretical results should be made.

AC: The following comments will be added in section 3.4 pag. 2756 Line 2: "The ER maximum values found in this study result to be higher than theoretical calculations performed by Kopke and Mech (2005). In that study they found an ER of 1.44 for a tilted surface at a 45° zenith angle, located at an altitude of 3000 m, with a clear atmosphere without aerosol, with snow albedo of 0.9 and solar zenith angle of 60°. Although an exact comparison between the two results is not simple due to the different conditions, a discussion on the discrepancy can be provided. The theoretical value is influenced by the direct radiation as well as all sky diffuse radiation. The highest measured value is related to a vertically oriented dosimeter (the body location is the forehead) worn by volunteers skiing in a downhill direction mainly facing towards the sun. In this case the direct component may be comparable to Koepke's while the diffuse component includes also the contribution of the surface. In addition the reflected component plays a key role in almost doubling the value of ER at the site of the field campaign."

The following reference will be also included in the list of references:

Koepke, P. and Mech, M.: UV irradiance on arbitrarily oriented surfaces: variation with atmospheric and ground properties, Theor.Appl. Climatol. 81, 25-32, 2005

Specific comments

Page 2746, L17: How the UV exposures are not sensitive to sunscreen use? Does

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this mean that the sunscreen use does not affect to dose received by the individual, or the dose measured by the dosimeter or dose this mean that use of sunscreen did not change the behaviour of skiers?

AC: It will be specified "It was found that the use of sunscreen and individual skin phototype did not produce significant variations in ER across instructor/skier group by day and by seasons ($p>0.05$)."

Page 2746, L21: What is inappropriate sunscreen use?

AC: The statement will be modified as follows: "It seems that sunscreen use only at the beginning of the exposure or in a few cases a couple of times during exposure (at difference with the specific instructions sheets), was not sufficient to change significantly skin colorimetric parameters across participants."

Page 2748, L10: Which international limit (and what weighting is used)? The ICNIRP exposure limit is 50 J/m2 with ICNIRP defined weighting.

AC: Moehrle et al considered a threshold limit value of about 80 Jm-2 per 8-h work period using the CIE reference spectrum (1987)normalized at 298 nm. This will be specified in that page as follows: "They found that UV levels in these occupations exceed nine to 53 times the threshold limit value of 80 Jm-2 per 8-h work period (using the CIE reference spectrum normalized at 298 nm)".

Page 2748, L29: what is the expected change caused by UV for the colorimetric values?

AC: To our knowledge there is no published data regarding the pre and post UV exposure colorimetric measures.

Page 2749, L5: What is the altitude range for skiers?

AC: The altitude range will be included in section 2.1 as follows "The altitude of ski slopes ranges from 1700 m a.s.l. to 2500 m a.s.l."

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Page 2750, paragraph 2.3: What does "well calibrated" mean? If the first meter is well calibrated and nothing is said about the two other meters, does this mean that the two other meters are not well calibrated?

AC: See the attached modified section 2.3

Page 2751, L2: Can the calculation of ER be expressed as a formula?

AC: In section 2.5 Exposure Ratio will be better defined as follows: "Exposure Ratio (ER) is defined as the ratio between the personal dose on a selected anatomical site (as defined in section 2.4) and the corresponding ambient dose on a horizontal plane (as defined in section 2.3) during the same exposure period. ER provides the percentage of ambient dose received by the anatomical location. The personal dose was derived using the PS calibration curve and the ambient dose was measured by the radiometer installed at the site under study. The ER is less dependent on the environmental exposure conditions than the personal dose, allowing to compare different exposure conditions and periods. The use of the ER attenuates the effect of local environmental factors accentuating individual habits and posture during exposure (Antoine et al., 2007). ER can be expressed by the following formula:

ER = DosePS/DoseHoriz = c(DeltaA +Delta A^2+9DeltaA^3)/DoseHoriz (2)

DosePS is the personal dose as measured by the PS dosimeter worn by the volunteers and retrieved from the calibration curve at the site. DoseHoriz is the corresponding ambient dose on a horizontal plane provided by the radiometer. The overall uncertainty on ER was estimated to be +/- 20% as derived from the error propagation formula taking into account an uncertainty of 10% in the ambient dose provided by radiometer combined with the uncertainty of personal dose of 10%."

Antoine, M, Sottas, P.E., Bulliard J.L., Venez, D.: Effective exposure to solar UV in building workers: influence of local and individual factors, Journal of Exposure Science and Environmental Epidemiology, 17, 58-68, 2007.

Page 2751, L19: What does the normalization mean? Were the dose results compared to the ambient dose at 2100 a.s.l.? The coefficient c for PS dosimeters depended on altitude, what value of c was used?

AC: In L19 of page 2751 the following statements will replace the old ones: "Due to the altitude range of ski slopes (1700- 2500 m a.s.l.) Exposure Ratio was used taking into account the ambient UV dose measured by the radiometer installed at La Thuile-Les Suches ski field. The altitude of 2100 a.s.l. was assumed as an average altitude of the ski field. Thus the c coefficient in equation (2) was determined from the calibration curve at that site."

Table 3, titles for winter values should be edited; there are three columns and four titles.

AC: There was a format mistake in Table 3. New re-edited Table 3 will replace the old Table 3 in the revised manuscript.

In table the spring days are 31. March, 2. April, 3. April and 4. April. In the figure 2 there is a new day 1. April and 4. April is missing.

AC: April 1st was not taken into account in the study because sky conditions were completely cloudy. In Fig.2 there was a mistake in the label. Following suggestion of Referee 1 a new Fig.2 plotting UV index vs time will replace the old one and the following statements will be added in section 3.2.: "In both campaigns ambient UV doses were recorded from 10:00 LT to 16:00 LT under almost clear sky conditions (April 1st was completely cloudy and on April 2nd scattered conditions occurred in the afternoon, but on this day the volunteers wore the dosimeters only in the first part of the day). Fig.2 shows ambient dose rate recorded at La Thuile-Les Suches during the spring campaign expressed as the dimensionless UV Index (ambient dose rate divided by 25mWm-2 ,Cost-713, 2000). In that period daily total ozone ranged from 330 DU to 369 DU and solar zenith angles (SZA) were $41^\circ < SZA < 54^\circ$. The data presented in this figure clearly shows the intense environmental UV radiation that the participants were exposed to at this site. In winter a total ozone of 300 DU and $64^\circ < SZA < 70^\circ$ were experienced and UV index peaks was about 2. Assuming a comparable environment within days of each campaign, the average of ambient doses at each time interval for both campaigns were: in spring 1018 Jm-2 (10:00-12:00 LT), 1130 Jm-2 (12:00-14:00 LT), 825 Jm-2 (14:00-16:00 LT); in winter 246 Jm-2 (10:00-12:00 LT), 349 (12:00-14:00 LT), 183 Jm-2 (14:00-16:00 LT). It can be noticed that the highest values occurred between 12:00 and 14:00 LT due to the shorter atmospheric path of radiation and the smaller solar zenith angle."

COST-713 Action: UV Index for the Public. European, Communities, Brussels, 27, 2000.

2.3 Ambient UV dose measurements The ambient erythemal dose (hereafter called ambient dose) is defined as the incident erythemally weighted irradiance (dose rate) on a horizontal surface over a specified period of time, expressed in Joules per square meter, Jm-2 (Parisi et al., 2005). In this study the C.I.E erythemal action spectrum (1987) was considered. Ambient doses were measured using a calibrated broad-band UV-S-AE-T radiometer (Kipp&Zonen, The Netherlands), installed, for both field campaigns, on the roof of the building of Espace S. Bernardo cable car directly on the ski-field at La Thuile-Les Suches (45.7°N, 6.6°E, 2100 m a.s.l.). In addition UV doses were also recorded by a broad-band radiometer (model UVB-1, Yankee Environmental System, MA, USA) operational at the headquarter of ARPA at Saint Christophe, Aosta (45.8°N, 7.4°E, 569m a.s.l.), and by a second UV-S-AE-T broad-band radiometer in operation at ARPA station at Les Granges (45.7°N, 6.6°E, 1640m a.s.l.). The radiometers have a spectral response approximately matching the skin erythemal action spectrum (C.I.E., 1987) and they provide the erythemal dose rate between 280 and 400 nm with a sampling time of 10 seconds. All UV instruments belong to ARPA Valle d'Aosta. The calibration of the three broad-band radiometers is performed by Calibration Measurement Softwaresolutions (CMS) in Austria every year with the reference to the CMS Bentham spectroradiometer. The estimated uncertainty of the spectroradiometer is 5%. Values of erythemal dose rates are obtained using a calibration matrix (Groeb-

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ner et al., 2006) as a function of solar zenith angle and total ozone amounts. The ozone data were obtained using the Ozone Monitoring Instrument (OMI) at the time of measurement. In addition periodic checks of the three broad-band radiometers are performed by ARPA with reference to a Bentham double monochromator spectroradiometer installed at Saint Christophe according to Seckmeyer et al., 2006. The ARPA spectroradiometer is intercompared with the travelling standard QASUME spectroradiometer (Groebner et al., 2005) from the PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center) every two years and is calibrated every month by a local operator by means of 200W calibration lamps. The lamps were calibrated by the PMOD/WRC. The overall uncertainty of broad-band radiometers combined with the uncertainty of the reference spectroradiometer is estimated to be 10%.

C.I.E. (Commission Internationale d'Eclairage Research Note. A reference action spectrum for ultraviolet induced erythema in human skin. CIE J 1987; 6: 17-22).

Gröbner,J., Hülsen, G., Vuilleumier, L., Blumthaler, M., Vilaplana, Walker, D., Gil, J. E.,: Report of the PMOD/WRC-COST Calibration and Intercomparison of Erythemal radiometers Davos, Switzerland 28 July – 23 August 2006,(http://i115srv.vu-wien.ac.at/uv/COST726/Cost726.htm

Gröbner, J., Schreder J., Kazadzis S, Bais, A. F., Blumthaler, M., Görts P., Tax, R., Koskela, T., Seckmeyer, G., Webb, A. R., Rembges, D.:Traveling reference spectroradiometer for routine quality assurance of spectral solar ultraviolet irradiance measurements, Appl. Opt., 44, 5321–5331, 2005.

Ozone monitoring Instrument (OMI), ozone data available at: http://jwocky.gsfc.nasa.gov/ozone/ozone_v8.html, 2008.

Parisi, A.V.: Physics concepts of solar ultraviolet radiation by distance education, Eur J Phys, 26(2), 313-320, 2005.

Seckmeyer, G., Bais A.,F, G. Bernhard, M. Blumthaler, C. R. Booth, R. L. Lantz, R. L.

McKenzie, P. Disterhoft, and A. Webb:Instruments to measure solar ultraviolet radiation. Part 2: Broadband instruments measuring erythemally weighted solar irradiance, WMO/GAW 164 (World Meteorological Organization, Geneva) 1-50, 2006.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 2745, 2008.

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