Atmos. Chem. Phys. Discuss., 8, S2330–S2342, 2008
www.atmos-chem-phys-discuss.net/8/S2330/2008/

Atmospheric Chemistry and Physics Discussions

ACPD

8, S2330–S2342, 2008

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

General comments The authors present a well done study on personal exposure of skiers. They provide a lot of interesting data.

Author Comments, AC: The authors thank the referee for the positive comments and the constructive criticism.

In some case it would be very helpful to give some additional explanation or discussion e.g. the ER are quite high taking into account a period of 2 hours.

AC:In section 2.5 Exposure Ratio will be better defined in the revised manuscript 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

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

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.

How were the skiers brought up the mountain in respect to the sun? Lifting direction is mostly opposite of downhill direction in respect to the sun.

AC: Such information will be included in section 2.1 of the revised manuscript: "A spring (March 30-April 4, 2006) and a winter (January 29-30, 2007) field campaigns were carried out at La Thuile-Les Suches ski field (45.7°N, 6.6°E, 2100m a.s.l.) which has mostly ski slopes oriented towards east direction and chair-lifts and ski-lifts, on the average, oriented towards northwest-west."

I agree with Rev.2 and 3 that there is a lack in the description of the calibration procedure e.g. also for the broadband meters. It is not clear if the measurements are corrected in respect to solar height and total ozone....

AC:See the modified sections 2.3 and 2.4 at the end of the answers.

ACPD

8, S2330–S2342, 2008

Interactive Comment

I appreciate very much the application of skin colorimetry. But there is a lack in the description of skin colorimetry. It becomes not clear what L*, a* and b* and a change in these 3 parameters means. For example: What is the range of human skin colour in this colour system? Can the skin type defined with these measurements? This information should be given to the reader... How is a change in pigmentation defined? how is an erythema defined?

AC: Section 2.6 will be modified as follows: "2.6 Skin colour measurements For each participant, measurements of skin colour on the forearm (constitutive pigmentation) and on an exposed site, the cheek, were carried out before and after the exposure using a Minolta spectrophotometer (model CM26000d). This instrument is based on physical measurement of reflected light, through an integrating sphere, at specific wavelengths (400-700 nm at 10 nm steps) which correspond to the spectrum of visible light. With this instrument it is possible to measure skin colour in the L*, a*, b* system as defined by the Commission Internationale de l'Eclairage (CIE 1976). Colorimetric values are expressed in terms of: L* (luminance) which gives the relative brightness on a scale from 0 (black) to 100 (white); a* (redness) which represents the balance between red (positive value) and green (negative value) on a scale from +60 to -60; b* (yellowness) measures the colour saturation between yellow (positive value) and blue (negative value) on a scale from +60 to -60. The Minolta spectrophotometer was used since it is recommended for the objective measurement of skin pigmentation and its changes (Park et al., 2002). Alaluf et al (2002a) report that there are, mostly with European subjects, close associations between a* values and erythema or blood flow in the skin. Alaluf et al (2002a, 2002b) found that colorimetric parameters of human skin depend on the ethnic skin types. For the European: L* ranges from 30-65 on photoprotected site to 30-54 for photoexposed site; a* ranges from 4-7 on photoprotected site to 4-13 for photoexposed site; b* ranges from 8-13 on photoprotected site to 8-19 for photoexposed site. The traditional skin phototype classification (Fitzpatrick,1974) is based on the observation of hair and eye colours, skin pigmentation, burning and tanning tendency. Colorimetric reading (L*, a*, b*) shows a poor ability to correctly

ACPD

8, S2330–S2342, 2008

Interactive Comment

classify the intermediate phototypes II and III (Rubegni et al., 1997;WHO, 2006). In this study colorimetry measurements before and after exposure on an exposed and on a non-exposed site were taken into account only to evaluate UV-induced pigmentation change. A pigmentation change was defined when a statistically significant difference in any of L*, a*, b* was observed between pre and post UV exposure."

The above reference will be also added in the list of reference :

Alaluf, S., Atkins, D., Barrett, K., Blount, M., Carter, N, Heath, A.: The impact of epidermal melanin on objective measurements of human skin colour, Pigment. Cell. Res., 15, 119-126,2002a.

Alaluf, S., Atkins, D., Barrett, K., Blount, M., Carter, N, Heath, A.: Ethnic variation in melanin content and composition in photo exposed and photo protected human skin, Pigment. Cell. Res., 15, 112-118, 2002b.

C.I.E.: CIE 1976 uniform color spaces, Colorimetry, CIE publication, 15.2, 29-32, 1986.

Fitzpatrick, T.B., M., Pathak, J.A., Parrish: Protection of human skin against the effects of the sunburn ultraviolet (290-320 nm). Sunlight and Man: Normal and Abnormal Photobiologic Responses, eds MA Pathak, LC Harber, M Seiji & A Kukita; consulting ed. TB Fitzpatrick, Tokyo: University of Tokyo Press, 751, 1974.

Park, S.B., Huh, C.H., Choe, Y.B.,Youn J.I.,: Time course of ultraviolet-induced skin reactions evaluated by two different reflectance spectrophotometers: DermaSpectrophotometer and Minolta spectrophotometer CM-2002, Photodermatol. Photoimmunol. Photomed., 18, 23-28, 2002.

Rubegni, P., Cevenini, G., Flori, M.L., Fimiani, M., Stanghellini, E., Molinu, A., Barbini, P., Andreassi, L.: Relationship between skin color and sun exposure history: a statistical classification approach, Photochem Photobiol., 65(2), 347-51, 1997."

In addition in the Introduction, the following information will be added: "The amount of solar ultraviolet (UV) radiation at the Earth's surface depends on the incoming solar

ACPD
8, S2330–S2342, 2008

energy and the transmission properties of the atmosphere as well as the features of the site such as surface topography, orientation and albedo (Kerr, 2003). Solar UV radiation is known to have a significant impact on human health (skin and eyes are critical targets for UV exposure). Long term exposure is the major risk factor leading to premature skin aging, skin cancers (non-melanoma skin cancers, squamous and basal cell carcinoma, and melanoma) and cataract (McCarthy and Taylor, 2002; Norval et al.,2007; WHO, 2006). Acute effects consist in erythema (sunburn, i.e. cutaneous inflammatory reaction due to excessive solar UV exposure, Norval et al.,2007), photodermatoses, immunosuppression, phototoxicity/photoallergy and pigmentation (tanning) and in some eye pathologies (Diffey, 2004). On the other hand the synthesis of Vitamin D is the most beneficial effect on human health (Norval et al., 2007)."

McCarthy, C.A. and Taylor, Diffey 2004 nd H.R and Norval et al , 2007 will be included in the references list:

McCarthy, C.A. and Taylor, H.R.: A review of the epidemiological evidence linking ultraviolet radiation and cataract, Dev. Ophtalmol., 35, 21-21, 2002.

Diffey, B.L., Climate change, ozone depletion and the impact on ultraviolet exposure on human skin, Phys.Med. Biol., 49, R1-11, 2004.

Norval, M., P. Cullen, A.P., de Gruijl, F. R., Longstreth, J., Takizawa Y., Lucas, R. M., Noonan, F. P., van der Leu,n J. C.: The effects on human health from stratospheric ozone depletion and its interactions with climate change, Photochem. Photobiol. Sci., 6, 232 - 251, DOI: 10.1039/b700018a, 2007.

Specific comments 2746, l20: It is not necessary to introduce L*a*b* here: delete "had on average ... exposure e.g"

AC: As requested by referee_3 that "L*, a*, b* should be properly explained in the abstract" the following information will be added in pag 2746 L19: "Measuring skin color in the CIE L*, a*, b* system was also carried out on the forearm and cheek of

ACPD

8, S2330–S2342, 2008

Interactive Comment

each volunteers before and after exposure. L* is the luminance, a* is a measure of redness and b* is a measure of yellowness."

2747, l13: Reference Bener !!!

AC: The following references will be included in the introduction and in the list of references:

Bener, P.: Investigation of the spectral intensity of ultraviolet sky and sun+sky radiation (between 297.5 and 370 nm) under different conditions of cloudless weather at 1590m a.s.l., Contract AF61(052)-54, Technical Summary n.1, Physikalisch-Meteorologisches Observatorium Davos, Davos Platz, Switzerland, 1960.

Bener, P.: The diurnal and annual variations of the spectral intensity of UV sky and global radiation on cloudless days at Davos, 1590 m a.sl., Contract AF61(052)-618, Technical Summary n.2, Physikalisch-Meteorologisches Observatorium Davos, Davos Platz, Switzerland, 1963.

2748, l6: There is a paper about building workers in the Alps: Antoine et al., Journal of Exposure Science and Environmental Epidemiology (2007) 17, 58-68, but have used opto-electronic devices

AC: The above paper will be mentioned in the introduction at page 2748 Line 20 as follows: "Antoine et al.(2007) assessed effective short term exposure among building workers in a mountain area at three different altitudes(500 m, 1500 m, 2500 m a.s.l.) in the South of Switzerland using spore film dosimeters on five body location. They found that personal measured doses between workers and body area showed high variability due the local conditions and individual factors and ranged from 0 to 200% of ambient doses."

The reference will be included in the list of references : 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,

ACPD
8, S2330–S2342, 2008

Interactive Comment

17, 58-68, 2007.

2750 l4: well calibrated? (see above and Rev.2+3)

AC:See the modified section 2.3

2750 l12: is it CIE 1987?

AC: At pag 2750 L12 the following reference will be included: "The radiometers have a spectral response matching the skin erythemal action spectrum (CIE, 1987)" and the following reference will be included in the list of references :C.I.E. (Commission Internationale d'Eclairage), Research Note: A reference action spectrum for ultraviolet induced erythema in human skin C.I.E. J., 6 17-22,1987.

2752 l1: Could not found Park et al. 2002 in the list of references

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

Park, S.B, Uuh, C.H., Choe, Y. B., Youn, J.I.: Time course of ultraviolet-induced skin reactions evaluated by two different reflectance spectrophotometers: DermaSpectrophotometer and Minolta spectrophotometer CM-2002, Photodermatology, Photoimmunology & Photomedicine, 18, 23-28, 2002.

2752 l3: Explain what these filters are used for or delete this sentence.

AC: As suggested by the referee the sentence will be deleted.

2752 l4: If the instruments delivers spectra how are the values of L*a*b* calculated.

AC: The instrument gives in addition to L*,a*, b* values, the graphs of reflectance vs wavelength which were not used in the analysis and for this reason the following statement" Results are usually displayed as a graph showing reflectance vs. wavelength" will be deleted in the section 2.6.

2752 l5: give a the reference for: CIE (CIE 1976) and Skin colour categories using the ITA-angle (arctan of L* and b*): Chardon et al. 1990

ACPD

8, S2330–S2342, 2008

Interactive Comment

AC: In modified section 2.6, (see above) the suggested reference will be included: C.I.E.: CIE 1976 uniform color spaces, Colorimetry, CIE publication, 15.2, 29-32, 1986.

ITA-angle to classify skin colour category was not calculated and then reference about Chardon will be not included.

2752 l6...: What is the range in L*a*b* of human skin?

AC: This information will be included in the modified section 2.6 (see above)

2752 l24: Reference Fitzpatrick (1974) and/or WHO 2002

AC: At pag. 2749 L21 and at pag. 2752 L24 the reference on Fitzpatrick (1974) will be added:

Fitzpatrick, T.B., M., Pathak, J.A., Parrish: Protection of human skin against the effects of the sunburn ultraviolet (290-320 nm). Sunlight and Man: Normal and Abnormal Photobiologic Responses, eds MA Pathak, LC Harber, M Seiji & A Kukita; consulting ed. TB Fitzpatrick, Tokyo: University of Tokyo Press, 751, 1974.

2752 l24: How was the skin type estimated?

AC: At page 2749 L19 how the skin types were estimated will be included in the text "In addition the research team of Sapienza-University of Rome, on the basis of the observation of hair and eye colours, skin pigmentation and questions on burning and tanning tendency, diagnosed the skin photo-type of participants according to the classification of Fitzpatrick skin types (Fitzpatrick, 1974; WHO, 2006), before each field campaign."

2755 l1-l19: This paragraph could be shorted since many of the values e.g. min, max can be found in Table 2. I would not use not statistical significant if p is in the range of 5%-10% maybe weak significance;

AC: The authors would prefer not to shorten the above paragraph. Page 2755 L6 will be modified as follows "Additionally, there were weak significant differences in skiers across ER related to the three time slots (p= 0.104)."

ACPD

8, S2330–S2342, 2008

Interactive Comment

2756 l14-l16: This paragraph is rather discussing, should be moved in conclusions.

AC: Above suggestion was accepted.

Table 2: Column of ER10-12 in winter lists the same values as ER10-12 in spring.

AC: There was a format mistake in Table 2 which will be replaced by the new Table.

Table 3: day5: median, min and max for skiers are identical?

AC: On day 5 only one skier participated and for this reason median, minimum and maximum values are identical. Such information will be included at pag 2755 L22.

Figure 2: Dose rate should be given also in units of UV-Index. Figure 2: I can not believe that the length of the day is 4500 min =75hours

AC: Section 3.2 will be modified as follows: "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".

ACPD

8, S2330–S2342, 2008

Interactive Comment

The following new reference will be added: COST-713 Action: UV Index for the Public. European, Communities, Brussels, 27, 2000.

The horizontal axis scale of old Fig2 was wrong, because data were collected each 10 seconds (from this the abnormal maximum values). A new Fig.2 plotting UV index versus Local Time will be included in the revised manuscript.

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 (Groebner 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.

2.4 Polysulphone dosimetry

ACPD

8, S2330–S2342, 2008

Interactive Comment

Polysulphone (PS) dosimetry is widely accepted as a reliable and useful technique in the assessment of personal UV exposure (Diffey, 1989; Kimlin, 2003). The spectral response of polysulphone is similar to the erythemal action spectrum (Diffey, 1984. This methodology is suitable to quantify the erythemally effective UV dose received by an anatomical site (the incident erythemally weighted irradiance on an anatomical site over a specified period of time, in Jm-2, hereafter called personal dose or exposure on a specific anatomical site). This polymer, when exposed to UV radiation, increases its optical absorbancy in the UV range. The change in PS film absorbancy (DeltaA) at 330 nm (post-pre exposure), depends on the effective dose absorbed by the dosimeter. PS dosimetry requires a careful determination of the calibration curve. This curve is obtained by exposing the PS dosimeters on horizontal plane at specific time intervals and simultaneously by measuring the ambient UV dose using a calibrated instrument (broad-band radiometer or spectroradiometer). The curve can be parameterized by a coefficient, c, multiplying a cubic polynomial function (Diffey, 1984; Diffey, 1989):

D= c(DeltaA+DeltaAˆ2+9DeltaAˆ3) (1)

where D (personal dose) is expressed in kJm-2.

This curve can be determined in situ or it can be derived once total ozone and solar zenith angle are known to take into account the local environmental conditions of the site (Casale et al., 2006). Three sites at different altitude were chosen in order to investigate on the variability of PS calibration curves: the lowest site of Saint Christophe, at Les Grange and at La Thuile-Les Suches ski field. At each site a series of dosimeters (from the same batch of those used during the field campaigns) were exposed on a horizontal plane to solar UV radiation from 10:00 to 16:00 LT in order to cover the entire range of solar zenith angles which can be viewed from the dosimeter worn by the volunteer. Dosimeters were removed at specific time intervals and at the same time UV dose rates were measured by the nearby broad band radiometer. The absorbance changes versus the corresponding ambient UV doses provided the calibration curve at that site. The uncertainty associated with doses, estimated by equation 1, depends on

ACPD
8, S2330–S2342, 2008

Interactive Comment

random errors, because systematic uncertainties are removed when dosimeters have the same thickness (in this case 40micrometer thick) and belong to the same batch (Diffey, 1989). The uncertainty on D was estimated to be +/-10% as derived from the error propagation formula taking into account an uncertainty of 0.001 on DeltaA (Diffey, 1989).

Casale, G.R., M. Borra, A. Colosimo, M. Colucci, A. Militello, A.M. Siani, R. Sisto: Variability among polysulphone calibration curves, Phys. Med. Biol. 51, 4413-4427, 2006.

Diffey, B. L.: Ultraviolet Radiation dosimetry with polysulphone film. Radiation Measurement in Photobiology, London Academic Press 135-159, 1989.

Diffey, B. L.: Personal Ultraviolet Radiation Dosimetry with Polysulphone Film Badges Photodermatol. 1, 151-157, 1984.

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

ACPD

8, S2330–S2342, 2008

Interactive Comment