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# SOLAR UVB-ALBEDO OF VARIOUS SURFACES

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**Abstract**—Measurements of the albedo of various surfaces in open grounds show significant differences for solar UVB radiation and total solar radiation (0.3–3 μm). Above grassland, that albedo for solar UVB radiation is significantly smaller than that for total solar radiation (UVB: 1.3%, total: 20.7%); contrary to that, the albedo for UVB radiation is significantly higher above new dry snow (UVB: 94.4%, total: 87.0%). Consequences resulting therefrom are being quantitatively discussed with respect to the solar radiant exposure of individuals standing outdoors. Keratitis solaris, for example, hardly occurs in snow-free terrain, even at high solar irradiance in summer; it occurs, however, in snow-covered terrain, in spite of low solar irradiance in winter and spring.

## INTRODUCTION

The albedo is of decisive importance for solar UVB radiant exposure of individuals standing outdoors. The term 'albedo' indicates the ratio of reflected radiation to incident radiation, each radiation flux integrated over the respective hemisphere. It can be related to the total spectral range of the incident radiation or to a selective spectral interval ('spectral albedo'). Based on previous spectral measurements of the albedo, presumptions are made that the albedo of natural surfaces differs considerably as far as the solar UVB radiation and the total solar radiation are concerned (Dirmhirn, 1964; Green, 1980 and 1981; Paltridge and Platt, 1976). The influence of the albedo on the radiant exposure of differently orientated planes is analyzed according to the prevailing natural conditions. Comparative measurements of the albedo for solar UVB radiation and total solar radiation are submitted in detail for 14 different surfaces in Alpine regions. Present measurements have been carried out simultaneously for both spectral ranges at each location of measurement, contrary to studies so far available in literature (Iqbal, 1983; Sliney, 1986).

## MATERIALS AND METHODS

For the measurements of the solar UVB-albedo, a portable Robertson–Berger Sunburn Meter (Robertson, 1972; Berger, 1976; DeLuisi and Harris, 1983) was used. The spectral sensitivity of this detector is well-adjusted to the action spectrum of erythema (DIN 5031, 1979). By approximation, the measured albedo for the erythemic range of solar radiation can also be applied for other biological reactions in the UVB-range, collected in the hazard spectrum (Sliney, 1972). The albedo for total solar radiation (wavelength from 0.3 μm to 3 μm) was measured with a star-pyranometer. In order to comprehend the range of variation of the albedo of a certain type of surface, various points of measurement have been selected for each type of surface. Allowance was made for the standard conditions of measurements as horizontal detector surface, measuring heights of 30–50 cm, and observation of disturbing influences of shadows. Measurements were carried out both with direct sunlight and with overcast sky, and no essential differences were noted. This result led to the conclusion, that the deviation of the cosine response of the Robertson–Berger Meter has no significant influence on the measured albedo. In order to obtain the mean value for each site of measurement, 5 individual readings were taken at one and the same place with both detectors.

## RESULTS

Figure 1 shows the variation of the albedo for the solar erythemic range ($a_{er}$)* as compared with the albedo for total solar radiation ($a_t$) for different types of surfaces. The values for snow surfaces originate from Ambach *et al.* (1986). The individual ranges of the maximum and minimum values obtained are indicated by hatched columns. It can be noted in general that for snow-free surfaces $a_{er}$ is significantly smaller than $a_t$, when very dirty glacier ice does actually show the smallest difference in the albedo values of both spectral ranges and grassland the largest difference. The mean values of each type of surface agree satisfactorily with data from respective literature (Iqbal, 1983; Sliney, 1986).

Contrary to the albedo obtained for snow-free surfaces, $a_{er}$ is significantly higher than $a_t$ for new dry snow surfaces (Fig. 1). For wet new snow and wet old snow as well as for dry old snow, a wide range of variation results because of the varying natural conditions.

In Fig. 2, the albedo of the individual points of measurements is shown, whereby the axes for $a_t$ and $a_{er}$ are scaled in the same manner. Therefore measured values, showing the same albedo for both spectral ranges, are represented by a straight line of 45°. Figure 2a shows the albedo for snow-covered surfaces. Two groups of measured values can clearly be distinguished—points of measurement with $a_t <$

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†*Abbreviations*: $a_t$, albedo for total solar radiation; $a_{er}$, albedo for erythemic range of solar radiation.

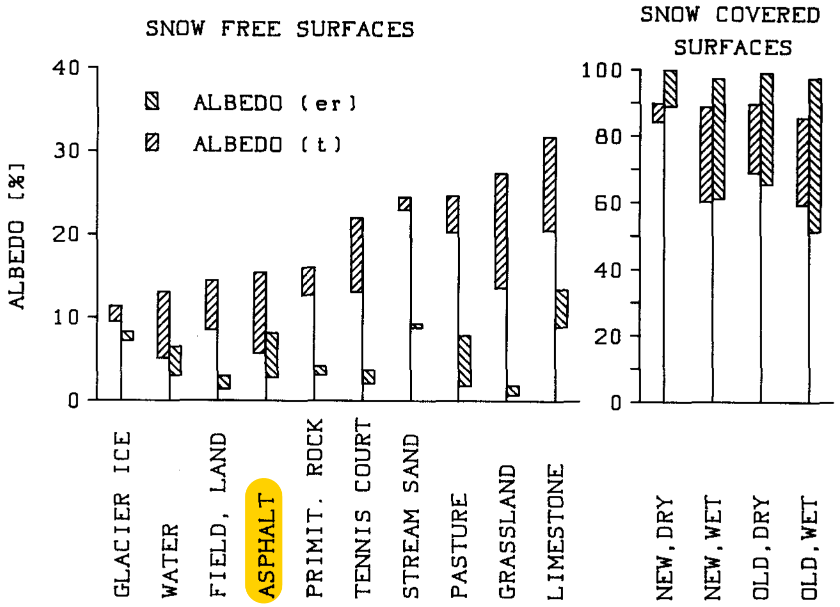


Figure 1. Albedo for total solar radiation and erythemic range of solar radiation for snow-free and snow-covered surfaces. Hatched columns mark the variation between minimum and maximum values measured.

$a_{er}$ and points of measurement with $a_t > a_{er}$. The first group corresponds to points of measurement above clean snow surfaces, the second group to points of measurement above slightly dirty snow surfaces. The highest albedo was measured above new, dry snow, amounting to 100% for $a_{er}$ and to 90% for $a_t$.

Figure 2b shows the albedo for snow-free surfaces. For simplicity sake, four different types of snow-free surfaces only are distinguished in Fig. 2b, i.e. grassland, glacier ice, limestone, and all other types of snow-free surfaces. For all cases it holds true that $a_t > a_{er}$. The largest difference between $a_t$ and $a_{er}$ was observed above grassland ($a_{er}$ = 1.3%, $a_t$ = 20.7%), more detailed data are available from Table 1.

## DISCUSSION

The strongly different UVB albedo of various surfaces does have consequences on the solar UVB radiant exposure of human beings in open grounds. For numerical considerations on the radiant exposure depending on albedo, calculations for horizontal and inclined surfaces have been carried out. These calculations are based on actually measured values of direct and diffuse erythema dose on cloudless days at Jungfraujoch (3576 m above sea level, Bernese Alps, Switzerland) in the course of the seasons of the year (Blumthaler *et al.*, 1985). Since the diffuse sky radiation was measured above snow covered terrain only, the diffuse sky radiation for snow-free surfaces was obtained by conversion according to Bener (1960). By means of these data, the radiant exposure of a deliberately orientated

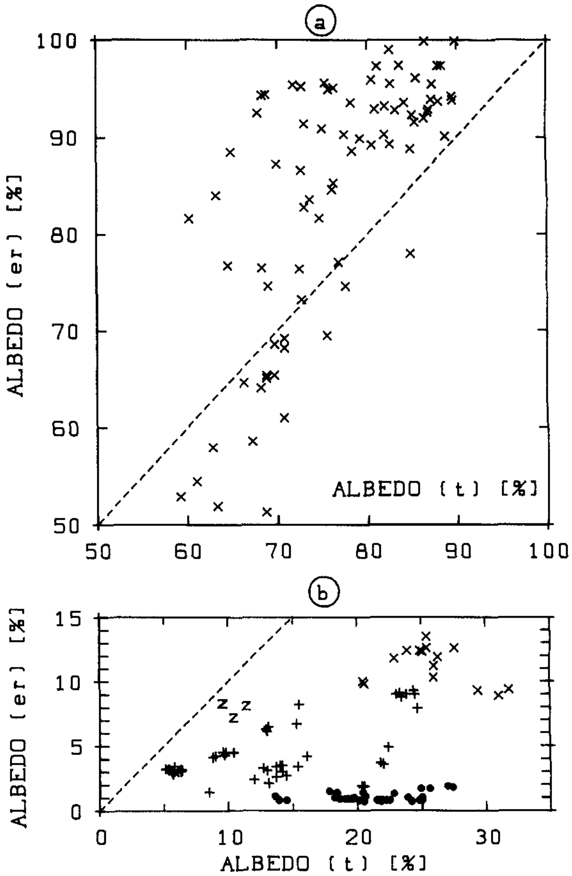


Figure 2. Albedo for total solar radiation *vs* albedo for erythemic range of solar radiation. (a) Snow-covered terrain. (b) Snow-free terrain, subdivided into 4 groups: ●—grassland; ×—limestone; z—glacier ice, very dirty; +—all other snow-free surfaces.

Table 1. Mean values of the albedo for total solar radiation and erythemic range of solar radiation and number of sites of measurement for different types of surfaces

| | Number of sites of measurement | Mean values %) | | Remarks |
|---|---|---|---|---|
| | | $a_t$ | $a_{er}$ | |
| Glacier Ice | 4 | 10.5 | 7.8 | Very dirty |
| Water | 15 | 9.1 | 4.8 | Clear waters, bog-lake, river |
| Field, land | 5 | 11.5 | 2.2 | Varying moisture |
| Asphalt | 12 | 10.6 | 5.5 | Differently worn |
| Primitive rock | 7 | 14.4 | 3.7 | Different size, partly overgrown by lichens |
| Tennis court | 3 | 17.6 | 2.9 | Polyuretan, differently worn |
| Stream sand | 8 | 23.8 | 9.1 | Sedimentation on embankment |
| Alpine pasture | 5 | 22.5 | 4.9 | Transversed by limestone |
| Grassland, corn | 40 | 20.7 | 1.3 | Varying heights |
| Limestone | 15 | 26.2 | 11.2 | Rock debris of different size |
| New dry snow | 7 | 87.0 | 94.4 | High mountain area |
| New wet snow | 21 | 74.5 | 79.2 | High mountain area, varyingly dirty |
| Old dry snow | 9 | 79.2 | 82.2 | High mountain area, varyingly dirty |
| Old wet snow | 40 | 72.4 | 74.4 | High mountain area, varyingly dirty |

surface under a cloudless sky was calculated as a function of solar elevation and albedo.

A particularly strong influence of the albedo on radiant exposure results for target surfaces directed downwards and vertically Northwards; for target surfaces orientated horizontally upwards and vertically Southwards, this influence is comparatively small. Because of the differences in albedo at the transition from snow-free to snow-covered ground, a target surface directed downwards is exposed more strongly to solar erythemic radiation by a factor of 16 and to total solar radiation by a factor of 5. These figures were obtained by calculating the ratios of the albedo-values for snow-covered and snow-free ground for solar erythemic radiation and for total solar radiation. The averaged measured values of $a_t$ = 17% and $a_{er}$ = 5% for snow-free ground and $a_t$ = 85% and $a_{er}$ = 90% for snow-covered ground were used.

A further aspect results for the occurrence of keratitis solaris, which is also approximated by the UV-hazard spectrum. Because of the particularly low albedo values for UVB radiation above snow-free ground, keratitis solaris does hardly become manifest in snow-free mountain terrain in summer, even in spite of the high radiant exposure during this season. Critical situations develop only because of snow-covered surfaces, due to the particularly high UVB-albedo of the snow-covered ground. Because of this fact, keratitis solaris may already occur in winter and spring, in spite of a comparatively small radiant exposure during these seasons (Sliney, 1980; Diffey, 1982). This is confirmed by a study over 3 years in the Austrian Alps, where the occurrence of keratitis solaris during the months March to May was observed (Blumthaler *et al.*, 1987). All patients had spent several hours in snow-covered mountain terrain. In contrast, no cases of keratitis solaris were observed after exposure in snow-free terrain even in summer. Thereby the importance of the albedo for the occurrence of keratitis solaris is confirmed.

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## REFERENCES

Ambach, W. and H. Eisner (1986) Albedo verschiedener Schneeoberflaechen fuer erythemwirksame solare Strahlung. *Wetter und Leben* **38**, 1–4.

Bener, P. (1960) Investigation on the spectral intensity of ultraviolet sky and sun + sky radiation under different conditions of cloudless weather at 1590 m a.s.1. *United States Air Forces Contract AF* **61**(052)-54, Davos, Switzerland.

Berger, D. S. (1976) The sunburning ultraviolet meter—design and performance. *Photochem. Photobiol.* **24**, 587–593.

Blumthaler, M., W. Ambach and H. Canaval (1985) Seasonal variation of solar UV-radiation at a high mountain station. *Photochem. Photobiol.* **42**, 147–152.

Blumthaler, M., W. Ambach and F. Daxecker (1987) On the threshold radiant exposure for keratitis solaris. *Invest. Ophthalmol. Vis. Sci.* **28**, 1713–1716.

DeLuisi, J. and M. Harris (1983) A determination of the absolute radiant energy of a Robertson–Berger meter Sunburn Unit. *Atmos. Environ.* **17**, 751–758.

Diffey, B. (1982) Ultraviolet radiation in medicine. *Medical Physics Handbooks* 11, p. 105. A. Hilger Ltd, Bristol.

DIN 5031 (1979) *Deutsche Normen, Strahlungsphysik im optischen Bereich und Lichttechnik*; Teil 10, pp. 1–8. (Vornorm). Beuth Verlag, Berlin.

Dirmhirn, I. (1964) *Das Strahlungsfeld im Lebensraum*. pp. 124–134. Akademische Verlagsgesellschaft, Frankfurt am Main.

Doda, D. and A. Green (1980) Surface reflectance measurements in the UV from an airborne platform—part 1. *Appl. Opt.* **19**, 2140–2145.

Doda, D. and A. Green (1981) Surface reflectance

measurements in the UV from an airborne platform—part 2. *Appl. Opt.* **20**, 636–642.
Iqbal, M. (1983) *An Introduction to Solar Radiation*, pp. 288–290. Academic Press, Canada.
Paltridge, G. and C. Platt (1976) *Radiative Processes in Meteorology and Climatology*, pp. 131. American Elsevier, New York.
Robertson, D. F. (1972) Solar ultraviolet radiation in relation to human skinburn and cancer. Ph.D. Thesis, University of Queensland, Australia.
Sliney, D. (1986) Physical factors in cataractogenesis: ambient ultraviolet radiation and temperature. *Invest. Ophthal. Vis. Sci.* **27**, 781–790.
Sliney, D. (1972) The merits of an envelope action spectrum for ultraviolet radiation exposure criteria. *Am. Ind. Hyg. Ass. J.* **33**, 644–653.
Sliney, D. and W. Wolbarsht (1980) *Safety with Lasers and Other Optical Sources*, pp. 101–245. Plenum Press, New York.