VPLYV SNEHOVEJ POKRÝVKY, NADMORSKEJ VÝŠKY A OBLAČNOSTI NA HUSTOTU TOKU SLNEČNÉHO UV-B ŽIARENIA

EFFECT OF SNOW COVER, ALTITUDE AND CLOUDS ON THE SOLAR UV-B RADIATION

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Abstract. Effect of snow cover and altitude (with respect to local surface albedo) on clear-sky solar UV-B radiation was studied using broadband global UV-B irradiance measurements at three positions in the High Tatras Mountains. Sensitivity of the UV-B radiation to the surface albedo change was expressed using comparison between UV-B irradiances observed under condition with continuous snow cover and without snow at investigated places. Increase of the snow effect on the UV-B irradiance and enlargement of differences between investigated places was observed for large solar zenith angles (SZA). This behavior relates to non-lambertian character of investigated surfaces and local differences in surface albedo in snow and no-snow conditions. Snow cover induced increase of the UV-B irradiances 3 – 12 % for SZA 45°, 19 – 33 % for SZA 70° was calculated. Vertical gradient of the UV-B irradiance was studied with respect to local surface albedo differences. UV-B irradiance vertical change 5 – 7% per 1000 m was determined for period without snow cover, 13 – 14% per 1000 m for continuous snow cover at investigated places, and 22 % per 1000 m increase for continuous snow cover at higher altitude position and lower position without any snow. Effect of clouds on the UV-B and global solar radiation was expressed by cloud attenuation factor. UV-B radiation attenuation by clouds was compared with cloud effect on solar global radiation under snow and no-snow conditions.

Key words

UV-B radiation, snow cover, altitude, cloud

Introduction

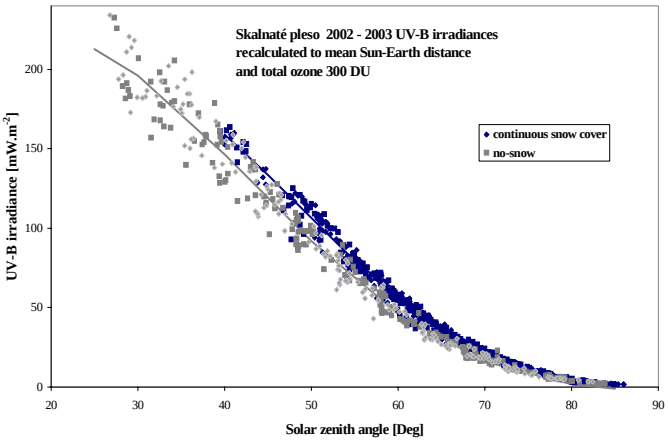
Prolongation of snow cover for periods, when the Sun culminates at small zenith angles, sharp altitudal differences between horizontally close places, complexity of terrain and typical cloudiness regime are phenomena significantly affecting short-term changes of UV-B radiation in the mountains. Effect of both snow cover and altitude on clear-sky solar UV-B radiation can be diminished or amplified according to atmospheric aerosol content and optical properties. Neither surface albedo nor optical properties of aerosols are currently observed parameters in the UV-range at investigated observatories.

Although total ozone change effect on the UV-B radiation is well established, there are still differences between vertical gradients and snow cover effect determination on UV-B radiation from different localities.

Clouds play important role in the solar radiation annual course in the mountain regions. Convective clouds affect solar radiation for a whole warm-half of year in the High Tatras. Exact determination of cloud effect on the solar radiation requires complete knowledge on cloud vertical range and its microphysical properties. Part of sky covered by cloud, predominant cloud genera and altitude of cloud base are currently observed parameters of clouds, but they

are usually strongly affected by subjective character of cloud observations. Many empirical models express cloud effect on the UV-B or global radiation using simple relation between solar radiation and cloud cover. Several studies confirm greater transmittance of UV radiation trough the clouds in comparison with visible range of solar spectrum. Generally clouds attenuate solar UV-B radiation, but at some circumstances clouds could cause UV-B irradiance enhancement. Snow cover compensates UV-B radiation attenuation by clouds, especially by overcast condition.

Figure 1. Clear-sky UV-B irradiances observed under



snow and no-snow condition at Skalnaté pleso.

Data and methods

Global solar UV-B radiation was measured by broadband UV-biometers (Solar Light comp.) located at different positions at southeasterly oriented High Tatras mountain slope: Poprad-Gánovce – valley position (GA: 49.03N, 20.32E, 706 a.s.l.), Stará Lesná - foot-hill position (SL: 49.15N, 20.28E, 810 a.s.l.) and Skalnaté pleso – slope position (SP: 49.18N, 20.18E, 1778 a.s.l.). Hourly averaged UV-B irradiances were taken into account. Stability of the UV-B devices is regularly checked by comparison with standard instrument. Location of UV-B devices is 1m above active surface, except Poprad-Gánovce UV-B sensor located 13 m above active surface. Surface properties are registered hourly at Skalnaté pleso and Stará Lesná and in climatological time of observation at Poprad-Gánovce. Clear-sky data were selected on the basis of heliograph records. Integral surface albedo registered at Stará Lesná is 0.22±0.02 for snow-free surface and 0.71±0.05 for snow condition, surface albedo at Skalnaté pleso is 0.18±0.03 for no-snow surface and 0.82±0.10 for snow-covered surface.

Sept. 2002 – Aug. 2003 measurements were elaborated. All UV-B data were recalculated to average Sun - Earth distance and to total ozone content 300 DU using Poprad-Gánovce total ozone measurements and TUV (total ultraviolet-visible) radiative transfer model (Madronich, 1993).

Table 1. Relative differences between clear-sky solar UV-B irradiances observed by snow covered surface and snow free surface at three localities: Skalnaté pleso (SP), Stará Lesná (SL) and Poprad-Gánovce (GA). UV-B data are recalculated to total ozone 300 DU.

Relative increase of UV-B radiation caused by snow cover [%]			
SZA	GA	SL	SP
70°	24	19	33
60°	12	14	21
50°	4	12	15
45°	3	11	12

Recalculated clear-sky UV-B data observed under snow and no-snow condition were plotted as a function of SZA, fitted by polynomial function and compared (Fig. 1).

For vertical change of the UV-B radiation determination were the data subdivided into four groups: (I) compared places without snow, (II) compared places with continuous snow cover, (III) high altitude position with continuous snow cover, low position without snow, (IV) high place with non-continuous snow cover, low position without any snow. Differences between Skalnaté pleso and Poprad-Gánovce were calculated for period Oct. 2001

– May 2002. Differences between Skalnaté pleso and Poprad-Gánovce were determined for period Sept. 2002 – Aug. 2003.

Cloud effect on global and UV-B radiation was expressed by cloud attenuation factor (CF). CF factor was defined as a ratio between solar irradiance observed under condition with cloud cover 2/10 – 10/10 to solar irradiance observed by cloud cover 0 – 1/10. Hourly characteristics of cloud cover in tenths, predominant cloud sort and estimated cloud base altitude were available.

Relation between clouds and solar radiation was studied with respect to SZA (Fig. 2) and snow cover.

Table 2 Relative differences between UV-B irradiances observed at Skalnaté pleso (SP) vs. Poprad-Gánovce (GA) and Skalnaté pleso vs. Stará Lesná (SL) with respect to different local albedo I - IV (see text). Vertical UV-B change recalculated per 1000 m altitude difference is in brackets.

Relative differences between UV-B irradiances [%]		
Data group	(SP – GA)/GA	(SP – SL)/SL
I	5 (5)	7 (7)
II	14 (13)	14 (14)
III	24 (22)	22 (22)
IV	13 (12)	15 (15)

Results and conclusions

Relative increase of UV-B irradiance caused by snow cover is summarized in Tab. 1. Decrease of snow effect on the UV-B radiation is remarkable at Poprad-Gánovce observatory due to UV-B sensor localization at higher position above active surface. Increase of the UV-B irradiances 11 – 12% was obtained for SZA 45° from experimental data at observatories Stará Lesná and Skalnaté pleso. Increase of snow effect on UV-B radiation for large SZA is observed at all investigated places.

Small vertical increase of UV-B radiation (5 - 7% per 1000 m altitude change) was determined for no-snow condition. Strong increase of the UV-B radiation vertical gradient to 22% caused by combination of altitude increase and local albedo differences was determined from experimental data (Tab.2).

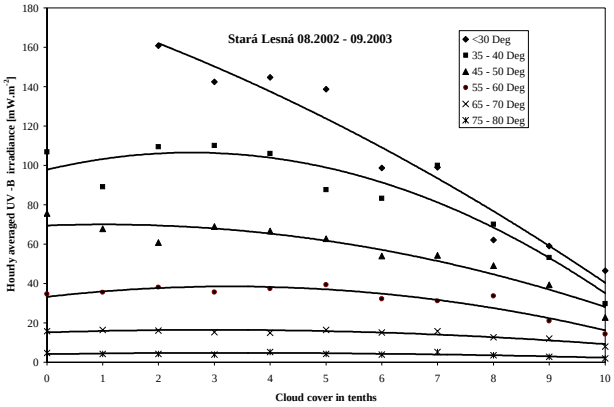


Figure 2. Hourly averaged UV-B irradiances as a function of cloud cover for selected SZA observed at Stará Lesná.

Comparison of UV-B and global solar radiation attenuation by clouds allows make following conclusions:

- CF factor calculated for UV-B irradiances is greater in comparison with CF factor for global solar radiation under condition with: SZA > 35°, cloud cover 2/10 – 10/10 and both no-snow and snow condition. That means less attenuation of UV-B radiation with clouds.
- Increase of the UV-B radiation CF factor observed by snow cover and overcast sky is 58 – 103% in comparison with no-snow surface. UV-B CF factor 0.5 – 0.6 was observed for overcast sky and snow covered surface, 0.3 – 0.5 for no-snow surface. CF factor of global radiation is in range 0.3 - 0.5 (snow cover and overcast sky).
- CF factors determined for no-snow condition at Stará Lesná and Poprad-Gánovce are greater than CF values obtained at mountain observatory Skalnaté pleso.
- CF factor value greater than 1.0 was observed for UV-B and global irradiances only by snow

condition.

It is necessary to take into account typical mountain character of clouds – predominant convective clouds occurrence in warm half-year and low clouds in whole year. Situations with pure middle and high clouds are in the High Tatras unusual.

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Súhrn

Merania slnečného UV žiarenia použitím širokopásmových UV-biometrov v troch rôznych lokalitách v oblasti Vysokých Tatier boli použité na zistenie vplyvu snehovej pokrývky, nadmorskej výšky a oblačnosti na hustotu toku slnečného žiarenia v UV-B oblasti spektra.

Vplyv albeda povrchu na hustotu toku UV-B žiarenia bol vyjadrený porovnaním údajov pozorovaných za jasnej oblohy bez snehovej pokrývky a za prítomnosti súvislej snehovej pokrývky. Hodnoty hustoty toku UV-B žiarenia boli pred porovnaním prepočítané na rovnakú vzdialenosť Zeme a Slnka a rovnakú hodnotu množstva celkového ozónu 300 D.U. Zistený nárast vplyvu snehovej pokrývky na UV-B žiarenie a nárast rozdielov medzi jednotlivými stanicami so zväčšujúcim sa zenitovým uhlom Slnka súvisí jednak s nelambertovským charakterom povrchu a taktiež s lokálnymi rozdielmi albeda povrchu pre podmienky so snehom a bez snehu. Nárast hustotu toku UV-B žiarenia o

3 – 12 % bol vypočítaný pre najmenší zenitový uhol Slnka 45°, kedy sa na všetkých staniciach pozorovala súvislá snehová okrývka a 19 – 33 % pre zenitový uhol Slnka 70°.

Vertikálny gradient hustoty toku UV-B žiarenia bol sledovaný s ohľadom na lokálne rozdiely albeda povrchu porovnávaných staníc, hlavne na rozdiely v pokrytí povrchu snehovou pokrývkou. Zvýšenie hustoty toku UV-B žiarenia o 5 – 7% pri náraste nadmorskej výšky o 1000 m bol zistený pre podmienky bez snehovej pokrývky, o 13 – 14%/1000 m pre podmienky so spojitou snehovou pokrývkou na porovnávaných staniciach. Zvýšenie hustoty toku UV-B žiarenia o 22 % /1000 m bolo pozorované za podmienok so spojitou snehovou pokrývkou na vyššie položenej horskej stanici a nižšie položenej stanici bez snehu.

Vplyv oblačnosti bol vyjadrný pomocou faktora zoslabenia žiarenia oblačnosťou. Bol porovnávaný vplyv oblačnosti na globálne UV-B a celkové globálne slnečné žiarenie s ohľadom na zenitový uhol Slnka. Osobitne bol študovaný kombinovaný vplyv oblačnosti a snehovej pokrývky na hustotu toku slnečného UV-B žiarenia.

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