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ULTRAVIOLET RADIATION ALBEDO OF NATURAL SURFACES

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Abstract. This article presents measurement results of intensity of solar UVA and UVB radiation, as well as UV radiation albedo from various surfaces. The intensity of albedo was measured from natural surfaces, such as: sand, grass, water, and snow. The paper also presents measurements of solar emitted UVA and UVB radiation intensity in the shadow. Ultraviolet radiation intensity and surface albedo was measured using a handy UVA radiation radiometer UVA – 365HA, with spectral response of 320–390 nm and a handy UVB radiation radiometer PMA2201, with spectral response of 280–320 nm. The results of measurements show that snow has the maximum albedo – from 50 to 60 per cent, sand – 10 per cent, and the minimum albedo is for grass – 2 or 3 per cent. The data of experimental measurements of UVA and UVB radiation in the shadow show that maximum reduction of intensity of UVA radiation up to 80%, was at 1 p.m. in comparison with reduction of intensity of UVB radiation to 70% at 2 p.m.

Keywords: UVA radiation, UVB radiation, radiation intensity, albedo.

1. Introduction

Radiation of longer ultraviolet (UV) wavelengths of 320–400 nm, designated as UVA, plays an essential role in formation of Vitamin D by the skin. However, it can have a harmful impact causing sunburn on human skin and cataracts in our eyes. Radiation of shorter wavelengths of 290–320 nm, designated as UVB, causes damage at the molecular level to the fundamental building block of any organism – deoxyribonucleic acid (DNA). Ultraviolet B radiation, harmful to living organisms, represents a small portion of the spectrum, from 290 to 320 nanometer wavelengths and represents about 1% of total radiation, reaching the Earth's surface (Palancar and Toselli 2004).

The albedo is the ratio of the sunlight reflected by an object of the light it receives. The numbers that describe albedo go from 0 (no light reflected) to 1 (all light reflected), or can be expressed in percentage.

Solar radiation, reaching the ground, is affected by solar output and the Earth-Sun distance. The amount and spectral distribution of solar UV radiation depends on a number of factors, including reflective characteristics of the ground – albedo.

The average albedo of our planet is around 0,3: it means that 30 per cent of the sunlight that reaches the Earth is reemitted to the space.

The albedo of the Earth surface is nearly dark in the UVB part of the spectrum with values typically between 3 and 5%. So a very small component of the UV radiation is reflected upwards. Even water has a relatively low albedo, only of 10 per cent. Sand is brighter- with a ratio of 30 per cent. But snow is the most reflective surface. A pure fresh snow surface, uninterrupted for several miles can have an albedo of 80%. However, such situations are rare in the mid-latitudes. Most frequently, the terrain there is not flat and has vegetation that extends upwards beyond the snow surface. These factors reduce the albedo to more like 50% for fresh snow. As snow ages or melts its reflective qualities decrease to a ratio of 30%. Due to snow's higher albedo, UV conditions on ski slopes can achieve summer conditions (Long 2006a, 2006b).

Of all the sunlight that passes through the atmosphere annually, only 51 per cent has a direct effect on our planet (Fig. 1). This energy is used to heat the Earth surface and lower atmosphere, melt and evaporate water, and run photosynthesis in plants. Of the other 49%, 4% is reflected back to the space by the Earth's surface, 26% is scattered or reflected by clouds and atmospheric particles, and 19% is absorbed by atmospheric gases, particles, and clouds (Pidwirny 2004).

Several facts are known about the radiation: 1) more than 90% of UV radiation can penetrate trough bright clouds; 2) clear snow reflects about 80% of UV radiation, which can cause sunburn; 3) 60% of UV radiation can usually be received in time period from 10 a.m. to 12 a.m.; 4) in shadow the intensity of UV radiation decreases to 50% and more; 5) sand reflects for about 25% of UV radiation; 6) indoor workers receive less of UV radiation than outdoor workers; 7) 50 cm below the surface of water the intensity of UV radiation decreases to 40%; 8) when the altitude increases, every 300 m increase intensity of UV radiation by about 4% (every 1000 m increases the intensity of UV radiation approximately by 10–12%) (Davies 1993).

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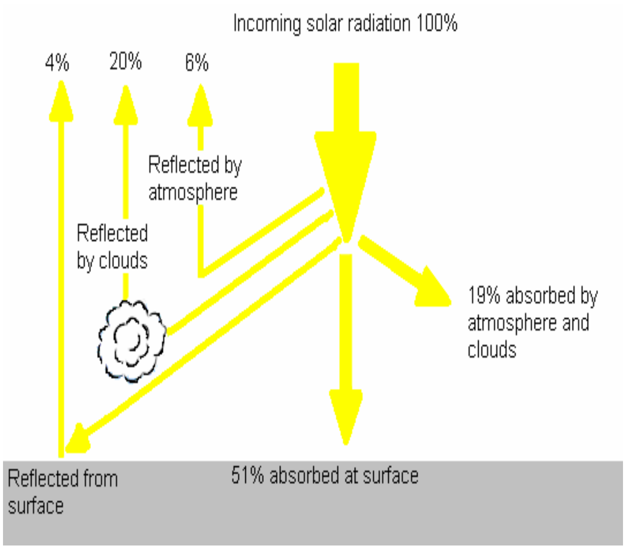

Fig 1. Global modification of incoming solar radiation by atmospheric and surface processes (Pidwirny 2004)

In cloudless conditions the irradiance on a tilted plane, in comparison to that on a horizontal flat surface, is increased in the position towards the sun, but reduced in other orientations. The increase is strongest for low sun in combination with clear atmosphere and high ground albedo, which is typical for snow covered mountain conditions (Koepke and Mech 2005).

Surface reflection affects UV radiation both through direct reflections towards the target, and by enhancing the diffuse down-welling radiation. The relatively sparse measurements of surface reflectivity (albedo) in the UV range were reviewed by Blumthaler 1993; Madronich 1993 a; Madronich 1993b. It has been proved, that values usually fall below 10 per cent for vegetation, but are highly variable for ice (7–75%) and snow (20–100%). High reflections may be of some importance to the geographical and seasonal UV distributions because they apply preferentially to colder climates.

The data in Table 1 (Long 2006b) shows the relationship between albedo of different surfaces and intensity of UV radiation. For example, if surface albedo is 0,1, intensity of UV radiation increases for about 3% and if surface albedo is 0,7, intensity of UV radiation increases for about 39%.

Table 1. UV radiation intensity response to albedo changes (Long 2006b)

Albedo	Percental increase of UV radiation intensity
0,1	3
0,2	8
0,3	12
0,4	19
0,5	24
0,6	31
0,7	39
0,8	47
0,9	57
1,0	68

For the people, spending a lot of time on the beach in summer, harmful increase of UV radiation intensity can cause the following health problems: skin cancer and other skin disorders, cataracts and other eyesight damages, immune system suppression and so on. For this reason, UV radiation intensity and albedo of sand, water, grass and moss was measured at the Baltic seaside in Juodkrantė (55°33’, 21°07’).

Moreover, seeing that snow cover dramatically affects the amount of UV radiation reflected from the surface and that albedo is highly important for studies of UV exposure, albedo of snow was measured.

2. Methodology

As part of the investigation, measurements of the intensity of solar emitted UVA and UVB radiation as well as UV radiation albedo of various natural surfaces were measured. Proportion of radiation was measured from different surfaces, such as: sand, grass, moss, wood, water, gravel, snow, as well as artificial surfaces, for example: asphalt, pavement, chippings, concrete, silicate brick, polystyrene, galvanized tin.

Ultraviolet radiation intensity and surface albedo was gauged using a handy UVA radiometer UVA – 365 HA, with spectral response of 320–390 nm and a handy UVB radiation radiometer PMA2201, with spectral response of 280–320 nm (Fig. 2).

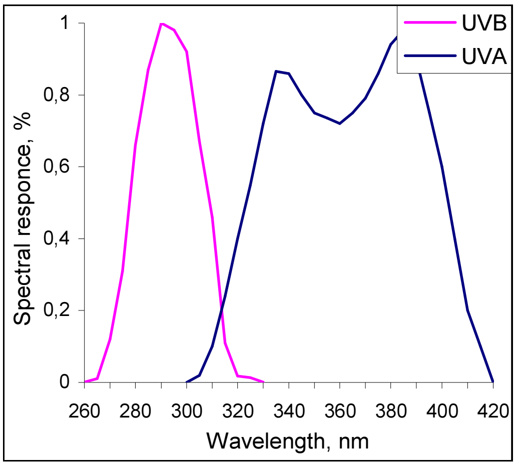

Fig. 2. Spectral characteristic of UVA detector 365 HA and UVB detector PMA 2201

The determination error for UVA and UVB radiation intensity amounted to 10%.

Surface albedo calculation:

$$A = \frac{I_1}{I_2}, \qquad (1)$$

where I_1 is the Sun UV radiation intensity, I_2 is UV radiation intensity reflected from the surface.

Taking the measurements of UV intensity, radiometric detectors were directed sunwards, and measuring UV radiation intensity reflected from the surface, radiometric detectors were diverted from the surface at a distance of 0,5 meters.

3. Measurement results

During the periods of May–June 2005 and 2006 albedo of sand, green grass and water was measured at the Baltic seaside in Juodkrantė (55°33'N and 21°07'E) in clear sky conditions. Also measurements of reflectivity of snow on a smooth field were taken in January 2006, in clear sky conditions. The research proved the thesis, that fresh, clean snow can reflect till 80% of solar emitted UV radiation. This work, containing about 800 values, presents average data of measurements, calculated for May–June 2005–2006 period.

Average results of UVA and UVB radiation intensity measurements for the time mentioned before are presented in Fig. 3. Data analysis showed that the average UVA and UVB radiation value difference was middling twenty times.

As you can see in Fig. 3, the intensity of UVA radiation varies from 1,5 mW/cm^2 in the morning, to the maximum value – 2,3 mW/cm^2 in the midday and 2,2 mW/cm^2 in the afternoon. UVB radiation varies from 0,006 mW/cm^2 in the morning, to the maximum value – 0,013 mW/cm^2 in the midday and 0,01 mW/cm^2 in the afternoon (Fig. 3).

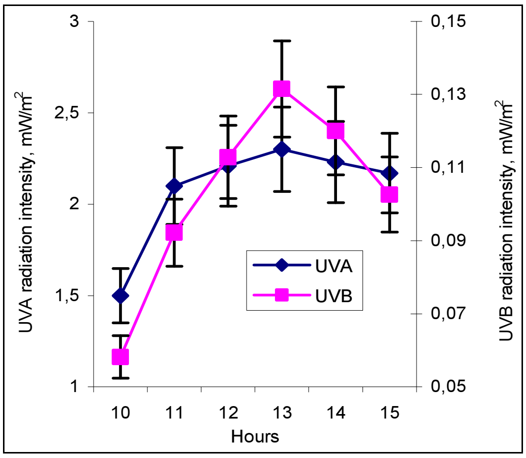

Fig. 3. UVA and UVB radiation intensity in Juodkrantė in clear sky conditions (mean data for May–June 2005, 2006)

Figures above show the average results of experimental measurements of intensity of UVA and UVB radiation and proportion of radiation from different surfaces. Solar emitted intensity of UV radiation is compared with albedo of different surfaces.

Figures 4 and 5 present the average results of albedo measurements of sand, grass and water. The albedo of different surfaces varies from 0,01 to 0,17.

As part of investigation, measurements of sand were taken on the seaside beach. Presented average data shows, that minimal UVA radiation albedo of sand is about 0,13 in time period from 11 a.m. till 3 p.m. Maximum degree of about 0,17 was registered in the morning.

Moreover, albedo of sand in the morning or in the afternoon is higher both for UVA and UVB radiation. Obtained results show, that at noon UVA radiation albedo of sand is about 13%, UVB – 7%. Sand can reflect about 25% of UV radiation and may increase UV exposure on the beach.

It was determined that minimal UVA radiation albedo of all examined surfaces is from grass – about 0,02. The maximum determined albedo was from sand – 0,17. For example, the figure for wood and asphalt is about 0,085, gravel and pavement is about 0,075.

The albedo of UVB radiation of different surfaces varies from 0,02 to 0,13. The average data of experimental measurements of all examined surfaces shows that minimal UVB radiation albedo is from grass – about 0,02, as well as in the case of UVA radiation. The maximum determined reflectivity of light was from sand – about 0,13. For example, UVB albedo of wood and asphalt is about 0,06, gravel about 0,06 and pavement is about 0,05.

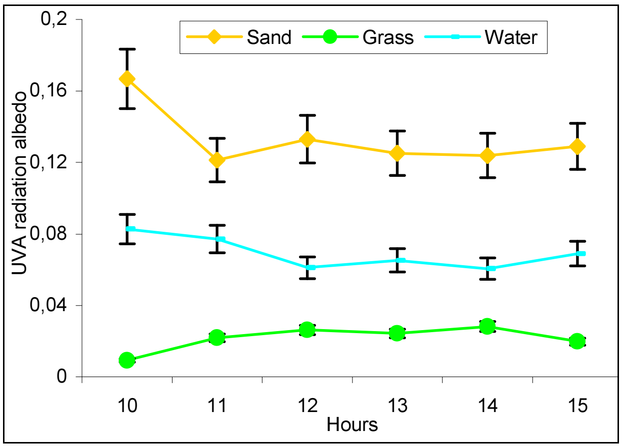

Fig. 4. UVA radiation albedo of sand, grass and water at the Baltic seaside in Juodkrantė (mean data for May–June 2005, 2006, clear sky conditions)

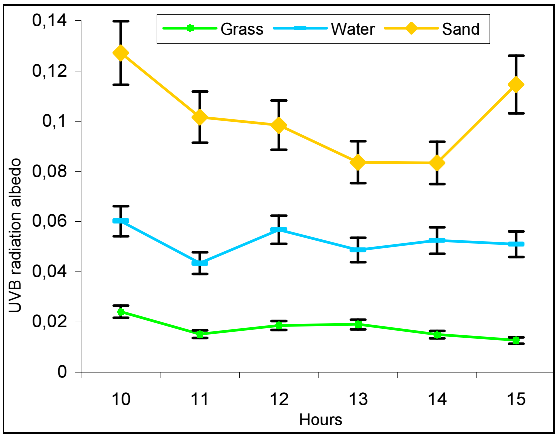

Fig. 5. UVB radiation albedo of sand, grass and water at the Baltic seaside (mean data for May–June 2005, 2006, clear sky conditions)

The average data of our performed experimental measurements of sea water UV radiation albedo is about 0,07 for UVA and about 0,05 for UVB (Figs. 4 and 5).

Presented results of experimental measurements (taken during the day time) of intensity of UV albedo from different surfaces show no uniform shape in their value. The reason of that may be different solar zenith angle, refraction angles of different minerals in the sand – quarts, feldspar, limenit, garnet or declination of leaves of the grass, or at least minimal disturbance of the surface of water during experimental measurements.

Table 2. The UVA and UVB radiation and visible light albedo from sand, grass, water and snow

Surface	UVA albedo, %	UVB albedo, %	Part of UVA albedo, %	Part of UVB albedo, %	Visible light albedo, %
Sand	13	9	59	41	20–30
Grass	2	2	50	50	15–25
Water	7	5	58	42	3–10
Snow	94	88	52	48	50–95

Explanation: Visible light albedo was determined in the work of Bray *et al.* 1966.

Results of UVA and UVB albedo measurements and percentage of all UV radiation are shown in Table 2. UV radiation part is compared to the visible light albedo. The measured UV radiation of sand is about 40% lower than visible light albedo, UV radiation proportion and visible light percentage of water is within the same boundaries. However, visible light albedo of grass is about ten times bigger than measured UV radiation albedo. Of all analysed surfaces the maximum UV albedo is from snow bearing resemblance to visible light reflection of snow.

The aim of the research was to analyse, not show the statistical dependence an average UVA, UVB radiation intensity and albedo of side by side situated surfaces: sand, grass and water at the Baltic seaside.

Correlation coefficients of average UVA, and UVB radiation intensity and UVA and UVB radiation albedo from sand, water and grass are presented in Figs. 6 and 7. What is more, coefficients between UV radiation intensity and the reflectivity of sand, grass and water were calculated.

The research accomplished the relation analysis for sand, grass and water. Correlation coefficients varied from 0,93 between UVA radiation intensity from the Sun and albedo of sand, to 0,93 between UVA radiation intensity from the Sun and grass. Correlation number varied from 0,89 between UVB radiation intensity from the Sun and albedo of sand, to 0,64 between UVB radiation intensity from the Sun and water.

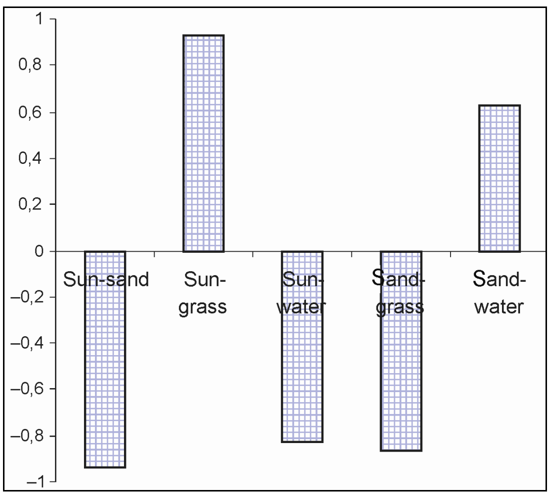

Fig. 6. Correlation coefficients between UVA radiation intensity and albedo of sand, grass and water

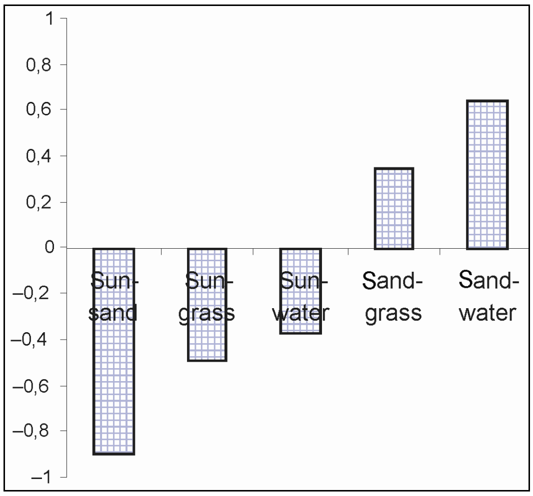

Fig. 7. Correlation coefficients between UVB radiation intensity and albedo of sand, grass and water

Correlation coefficients between UVA radiation intensity and albedoes of sand (–0,93), water (–0,83); or between sand and grass reflectivity (–0,86) show a strong inverse relationship.

Similarly, correlation coefficient between UVB radiation intensity and sand albedo (–0,90) shows strong inverse relationship. Relationship between UVB radiation intensity and albedoes of grass (–0,49) and water (–0,32); or between sand and grass (0,34) is tenuous.

Figs. 8 and 9 show the average results of UVA and UVB radiation intensity from the Sun and their course in the shadow of grass-grown timbered house in Juodkrantė.

It is very important to know that location in the shadow can significantly reduce the intensity of UV radiation. According to Davies 1993, in the shadow intensity of UV radiation decreases to 50% and more. It was observed, that at noon shadow reduces UVA radiation four times (Fig. 8), UVB – by half (Fig. 9).

The average results of experimental measurements show that the shape of intensity of both UVA and UVB radiation synchronise with the solar UV radiation intensity. The intensity of UV radiation varies from minimal values in the morning and evening to maximum in the afternoon. The average data in Fig. 10 presents a variation of intensity of UVA and UVB radiation in the shadow during the day. It was determined that reduction of intensity of UVA radiation decreases for about 10% more than intensity of UVB radiation. The data of experimental measurements show that maximum reduction of intensity of UVA radiation (81%) was at 1 p.m. in comparison to the reduction of intensity of UVB radiation (69%) at 2 p.m.

It was measured, that natural surfaces such as grass and water reflect less than 10% of the incidental UV radiation. Fresh snow, on the other hand, may reflect up to about 80% of the incidental UV radiation. On a cloudless spring day reflection of snow on inclined surfaces may increase the UV irradiance to summer values. High reflec-

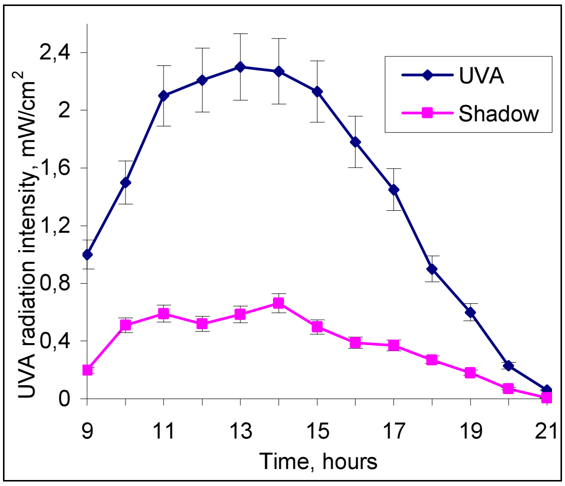

Fig. 8. UVA radiation intensity from the Sun and its course in the shadow of timbered house (mean data for 2005 May–June 2005–2006, clear sky conditions data)

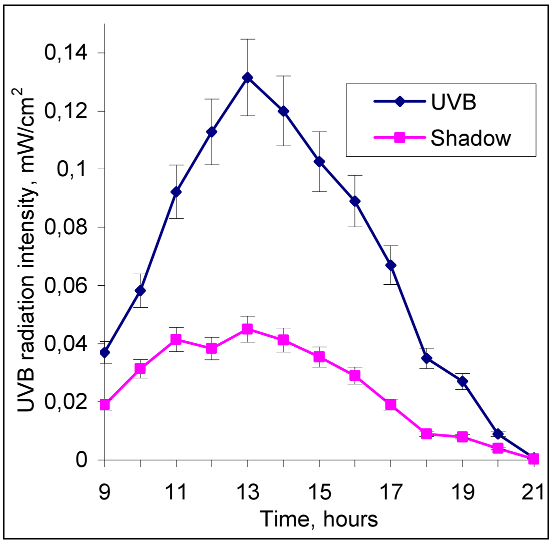

Fig. 9. UVB radiation intensity from the Sun and its course in the shadow of timbered house (mean data for May–June 2005–2006, clear sky conditions data)

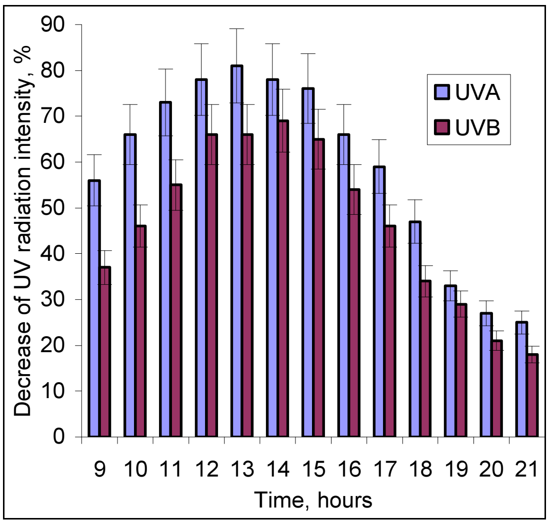

Fig. 10. UVA and UVB radiation course in the shadow of timbered house

tivity of snow cover means a considerable wintertime risk of damage from UV rays for many animal species. For people the risk is particularly big to the neck, nose, and face. Reflected UV light can be a potential danger, causing damage both for people's and animal's eyesight (Blumthaler and Ambach 1988).

The average results of experimental measurements of albedo in clear sky conditions of fresh clean snow on a smooth field are presented in Fig. 11. It was determined that the lowest reflection of about 40 per cent is usually in the morning and in the evening. Results presented in Fig. 11 show the change of values of albedo of UV radiation during the day time. The maximum albedo of both and UVA and UVB radiation is in the afternoon, when intensity of solar emitted UV radiation is the highhest. The average data of experimental measurements show that maximum albedo of UVA radiation (of about 94%) was at 1 p.m. in comparison with albedo of UVB radiation of about 88% at 2 p.m. The measurements of albedo were performed on fresh snow with big crystals.

It must be said, that our experimental measurement results correspond with the results presented by other scientists. (Davies 1993; Blumthaler 1993; Madronich 1993a; 1993b).

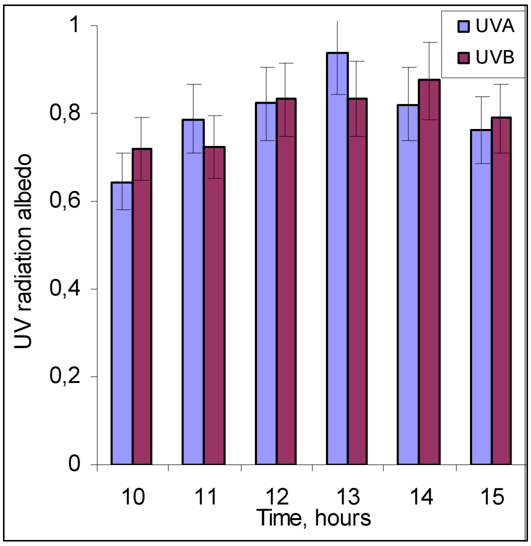

Fig. 11. UVA and UVB radiation albedo of fresh snow on a smooth field (mean data for January 2006, clear sky conditions)

4. Conclusions

1. In clear sky conditions snow has the maximum albedo of all natural surfaces – about 90 per cent, sand has about 10 per cent, whereas grass has the lowest albedo – about 2–3 per cent.

2. Correlation coefficients between average UVA radiation intensity and sand (–0,93) or water albedo (–0,83); between sand and grass albedo (–0,86) and between UVB radiation intensity and sand reflectivity (–0,90) show strong inverse relationship.

3. Intensity of UVA radiation in the shadow decreases for about 10% more than intensity of UVB radiation. The maximum reduction of intensity of UVA radia-

tion about 80% was at 1 p.m. in comparison to reduction of intensity of UVB radiation 70% at 2 p.m.

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NATŪRALIŲ PAVIRŠIŲ ULTRAVIOLETINĖS SPINDULIUOTĖS ALBEDAS

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S a n t r a u k a

Pateikti saulės skleidžiamos UVA ir UVB spinduliuotės intensyvumo ir įvairių paviršių UV spinduliuotės albedo matavimų rezultatai. Matuotas įvairių natūralių paviršių albedas: smėlio, žolės, vandens, sniego. Ultravioletinės spinduliuotės intensyvumas ir įvairių paviršių albedas matuotas nešiojamaisiais radiometrais: UVA spinduliuotės – UVA-365 HA, kurio daviklis registruoja UV spinduliuotę nuo 320 iki 400 nm, ir UVB spinduliuotės – PMA2201, kurio daviklis registruoja UV spinduliuotę nuo 280 iki 320 nm. Atlikus eksperimentus nustatyta, kad iš natūralių paviršių didžiausias albedas yra sniego – apie 80–90 %, smėlio – 10 %, mažiausias – žolės, apie 2–3 %. Atlikta saulės skleidžiamos UVA, UVB spinduliuotės intensyvumo ir šalia esančių paviršių albedo ryšio analizė. Didžiausi koreliacijos koeficientai gauti: tarp UVA spinduliuotės intensyvumo ir smėlio albedo (–0,93), tarp UVA spinduliuotės intensyvumo ir žolės albedo (0,93), tarp UVB spinduliuotės intensyvumo ir smėlio albedo (–0,89). Atlikus UVA ir UVB spinduliuotės intensyvumo matavimus šešėlyje, nustatyta, kad labiausiai UVA spinduliuotė sumažėja apie 13 val. (80 %), o UVB – apie 14 val. (70 %).

Reikšminiai žodžiai: UVA spinduliuotė, UVB spinduliuotė, spinduliuotės intensyvumas, albedas.

АЛЬБЕДО УЛЬТРАФИОЛЕТОВОГО ИЗЛУЧЕНИЯ НАТУРАЛЬНЫХ ПОВЕРХНОСТЕЙ

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Р е з ю м е

Представлены результаты измерения интенсивности УФА и УФБ солнечного излучения, а также УФ альбедо различных поверхностей. Измерялись альбедо натуральных материалов: песка, травы, воды, снега. Интенсивность ультрафиолетового излучения и альбедо различных поверхностей измерялись переносными радиометрами: УФА излучение – УФА–365 HA, датчик которого регистрирует УФ излучение в пределах 320–400 нм, и УФБ излучение – PMA2201, датчик которого регистрирует УФ излучение в пределах 280–320 нм. Результаты экспериментов показали, что наибольшее альбедо у натуральных веществ: около 80–90 % – у снега, 10 % – у песка, наименьшее (около 2–3 %) – у травы. Проведен анализ связи между солнечной интенсивностью УФА излучения, УФБ излучения и альбедо находящихся рядом друг с другом поверхностей. Наибольшие коэффициенты корреляции получены между интенсивностью УФА излучения и альбедо песка (–0,93), между интенсивностью УФА излучения и альбедо травы (0,93), между интенсивностью УФБ излучения и альбедо песка (–0,89). После проведения измерений интенсивности УФА и УФБ излучений в тени установлено, что больше всего УФА излучение уменьшается около 13 ч (80 %), а УФБ – около 14 ч (70 %).

Ключевые слова: УФА излучение, УФБ излучение, интенсивность излучения, альбедо.

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