COMPONENTS OF THE RADIATION BALANCE AND THEIR REGIME IN THE SUMMER OF 1994/95 AT H. ARCTOWSKI STATION (THE SOUTH SHETLANDS)

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1. Introduction

In December, 1994, at the Polish Henryk Arctowski Antarctic Station (King George Island, South Shetlands archipelago) with geographic co-ordinates φ = 62°09'42"S, λ = 058°28'10"W (Fig.1) the Czech scientific program was started, linking up freely with the international programme BIOTAS (Biological Investigation of Terrestrial Antarctic Systems), solved at present at this base.

The Czech project, whose main applicant is the Department of Geography, Faculty of Science, Masaryk University in Brno, represents the implementation of the programme approved by the Grant Agency of the Czech Republic entitled: Changes in the Energetic Balance and UV Radiation and their Effect on the Natural Ecosystems of the Antarctica which is planned for the period of three years. The main objective of this programme is finding the impacts of time changes of the energetic balance of the active surface and UV-B radiation mainly on communities of lower plants in the course of their vegetation period - i.e. the south polar summer.

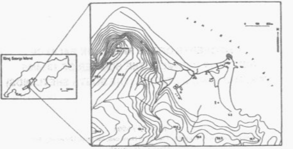


Fig. 1. A schematic map of King George Island and the surroundings of H. Arctowski base
1 - automatic station, 2 - UV-Biometer

Schematyczna mapa Wyspy Króla Jerzego i otoczenia Stacji im. H. Arctowskiego
1 - automatyczna stacja meteorologiczna, 2 - stacja pomiarów UV

The programme was started in the summer period of 1994/95 by a comprehensive measurement of the components of the energetic balance and UV-B radiation. Similar comprehensive energetic measurements have not been so far carried out at any station located at King George Island (Arctowski - Poland, Artigas - Uruguay, Bellingshausen - Russia, Copacabana - USA, Ferraz - Brazil, Great Wall - China, Jubany - Argentina, King Sejong - South Korea, Marsh/Frei - Chile), and from this view it thus brings the first information about the complex of energetic conditions of the existence of plant ecosystems on that island.

Only at some stations (Bellingshausen, Ferraz, Great Wall and King Sejong) measurement of global radiation is carried out at present and/or of UV-B radiation (Ferraz, King Sejong).

In the present contribution partial results are presented of the starting measurement of the components of the radiation balance of the active surface, i.e. global and reflected solar radiation, longwave terrestrial surface radiation and the downward atmospheric radiation. The results of measuring the intensity of UV-B radiation are published elsewhere.

The automatic station for measuring radiation fluxes and heat fluxes was installed in the central part of the shore vegetation oasis situated south of the Arctowski Station (Fig.1) and it was put in operation on 8 Dec.1994. The measurement was finished on 12 Mar.1995.

For measuring the individual fluxes of radiation energy were used:

1. global solar radiation - pyranometer Kipp-Sonen, type CM-5,
2. reflected solar radiation - the same instrument,
3. radiation balance - pyrradiometer Schenk, type 8111.

The last of the above instruments measures with the upper part of the doubled sensor the sum of the global and the downward radiation of the atmosphere, with the lower part the sum of the radiation reflected by the surface and its longwave radiation. The subtraction of the intensity of global radiation from the total intensity from the upper sensor of the pyrradiometer yields information about the downward atmospheric radiation, and a similar subtraction of the reflected radiation from the total lower sensor intensity information about the radiation of the active surface.

All radiation sensors were located at the height of 1.5 m above the ground completely covered with low vegetation in which, as for the area, there prevailed the grass Deschampsia antarctica (60%) and mosses - mainly Pseudoleskea antarctica and Brachythecium austro-salebrosum (40%) with isolated occurrences of blossoming Colobanthus quitensis.

Regime of the fluxes of radiation energy in summer, 1994/95

Before the analysis proper of the regime of radiation fluxes it is necessary to state that the relief in the vicinity of the station of their measurement is not, despite its indentation, so much elevated (maximum elevation - Point Thomas - reaches the height of only 174 m above the sea level; Fig.1) that it would significantly reduce the duration of direct solar radiation. The height of the real horizon over the mathematical one is evidenced by Fig. 2, to which also the trajectories of the Sun have been included on the day of the start of the measurement, on the day of the summer solstice of the southern hemisphere and at the end of the summer (12 Mar.), when the pyrradiometer was dismounted and taken for calibration.

The total reduction of direct radiation on 8 Dec. reaches about 2 hrs at the heights of the Sun below 8° (before it sets). On 21 Dec. it reaches 2 h at practically the same height angle before the sunset and on 12 Mar. it lasts again two hours to the maximum height of the Sun of about 11°. Expressed with reference to the theoretically possible duration of sunshine it represents by 10.5, 13.4 and 15.3%, respectively, less. With respect to the small relative height of the horizon around the azimuths of the sunrise and the sunset it is, however, possible to state that this reduction does not significantly participate on the reduction of the daily possible supply of the radiation energy of the direct radiation.

The duration of sunshine in the random regions of the Antarctica is very significantly affected by great cloudiness of prevailingly frontal origin. As follows from Fig.3, in the period studied the real sunshine duration approaches the theoretically possible one in only one case (9 Jan.1995), when it reached 88.1% of its value. From the following Table 1 it follows that in 33 days of the Antarctic summer of 1994/95 the real sunshine duration did not exceed 10% of the possible duration, and in only 17 days did it exceed its half length, its mean length reaching a mere 26.2%. It is thus evident that the main source of primary energy for the active surface is there, from the time point of view, diffuse radiation.

In further procession of the results of measuring the radiation fluxes their time regime, from the point of view of the daily variation (instantaneous intensity), as well as that of the whole period processed (daily sums) was evaluated with respect to the true solar time (TST). The correction to this time was introduced in the three-day step of averaging the TST values in accordance with the recommendation of the WMO published by Fröhlich and London (1986).

An idea about the mean daily regime of the components of the radiation and its character at the prevailence of radiation and/or at great cloudiness is given by data from Figs. 4-6. For their compilation data from the basic time step of the working regime of the automatic station were used, i.e. ten-minute mean values from the beginning of each complete hour. Each of the figures yields an idea about the mean daily regime of the intensity of global solar radiation (I_G), solar radiation reflected by the surface (I_R), longwave terrestrial active surface radiation ($I\uparrow$) and downward longwave atmospheric radiation ($I\downarrow$). This information is complemented by mean variations of the balance of shortwave (I_s^*) and longwave (I_L^*) radiation and albedo (α).

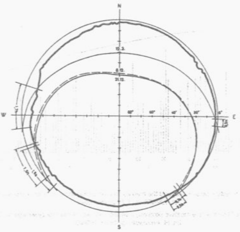


Fig. 2. The relative height of the actual horizon and the Sun's trajectories at the beginning (8 Dec.1994) and at the end (12 Mar.1995) of the measurements and on the day of the winter solstice from the position of the automatic station AMET-NOEL (see Fig.1). Sectors and numbers on the circumference denote the retardation (acceleration) of the sunrise and the sunset [h], respectively, conditioned by the relative height

Względne przesłonięcie horyzontu i trajektorie Słońca w dniu rozpoczęcia (08.12.94) i zakończenia (12.03.95) obserwacji oraz w dniu przesilenia zimowego dla stacji automatycznej AMET-NOEL (patrz Ryc. 1). Zaznaczone sektory i liczby oznaczają odpowiednio opóźnienie (przyspieszenie) wschodu i zachodu Słońca [h], uwarunkowane przesłonięciem horyzontu

Table 1

Number of days with a different degree of the actual duration of sunshine with respect to the theoretically possible one [%] in the period of 8 Dec.94 - 12 Mar.95 at H. Arctowski St.

Liczba dni z różnym stopniem usłonecznienia rzeczywistego w stosunku do teoretycznie możliwego [%] w okresie 08.12.1994 -12.03.1995 na Stacji im. H. Arctowskiego

Interval of actual duration as percentage of the possible one	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	>80
number of days	33.0	17.0	12.0	8.0	9.0	5.0	9.0	2.0	1.0

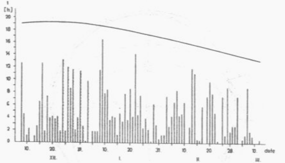


Fig. 3. The actual (abscissae) and the theoretical (curve) sunshine duration in the summer of 1994/95 at H. Arctowski base

Zmierzone i teoretycznie możliwe (krzywa) wartości usłonecznienia rzeczywistego na Stacji im. H. Arctowskiego latem 1994/95

From Fig. 4 it follows that the mean level of the daily maximum of I_G reaches the value near 500 W/m^2, the albedo at the culmination of the Sun and at the maximum intensity of I_R being 103 W/m^2 20.6% (the highest mean value of albedo at 08 h, i.e. 21.8%, is only insignificantly higher).

The value of albedo in the period of the day is subject to a more or less symmetric change in the sense of the growth from the morning minimum at 03 h (15.4%) to the level slightly exceeding 20% (interval 05 -17 h), to drop again up to 20 h to 13.3%. The above facts witness a somewhat better penetration of solar radiation into the low, prevailingly moss stand at great zenith distances of the Sun (this problem is evaluated lower in detail in the analysis of the daily regime of the components of the radiation balance at extreme values of cloudiness). The mean daily albedo (19.5%) is near the upper limit of the tundra albedo, and/or that of meadow stands described e.g. by Sellers (1972) or Oliver and Fairbridge (1987).

The balance of the shortwave radiation (I_S*) reaches the maximum (353.2 W/m^2) identically with the maximum of I_G, its mean daily value being

164.9 W/m². The symmetry of the daily regime of I_G and I_R is understandable due to the minimum relative height of the horizon, at the same time witnessing the absence of the daily variation of cloudiness which is unambiguously eliminated by advection causes of its origin.

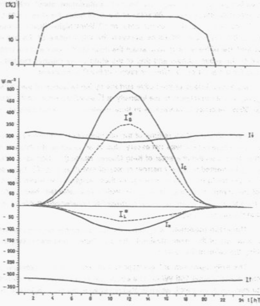


Fig. 4. The mean daily variation of components of the radiation balance of the active surface of the vegetation oasis at H. Arctowski base in the summer of 1994/95 (I_G - global radiation, I_R - reflected radiation, I↓ - downward atmospheric radiation, I↑ - longwave radiation of the active surface, I_s^*, I_L^* - shortwave and longwave radiation balance, respectively)

Średnia dobowa zmienność składników bilansu promieniowania czynnej powierzchni wegetacyjnej na Stacji im. H. Arctowskiego latem 1994/95

The two longwave radiation fluxes - I↑ and I↓ - are quite near as to the level (I↑ is on the average only by 22.8 W/m^2 i.e. by 7% higher than I↓. The daily regime of I↑ is evidently conditioned by the daily variation of the active surface temperature (I↑ reaches its maximum about noon and its minimum about midnight), in the case of I↓ the daily regime of its intensity is contrary, which is evidently connected with the phase shift of the daily variation of air temperature with height (I↓ reaches its maximum about midnight and its minimum about noon). Whereas in the night hours the differences of I↑ and I↓ are very small (I↓ is by the order of 10^0 W/m^2 higher than I↑), thus witnessing the minimum difference between the temperature of the active surface and that of the atmosphere, about the noon the difference of the temperature of the active surface and that of the atmosphere reaches the greatest value (of the order of 10^1 W/m^2) in favour of the I↑ component.

Maximum losses of the active surface by the reflection of the radiation (I_R) represent - in relation to the intensity of I↑ about the noon - only values near 30%, whereas I↓ represents in time maxima of I_G about 55% of its value.

Describing the daily regime of the components of radiation balance at minimum cloudiness it was necessary, due to an absolute prevalence of advection effects on the character of King George Island (i.e. increased cloudiness), to be limited to a very narrow choice of five days (Fig. 5). Even so was it necessary to use a freer criterion for their selection (the mean cloudiness of the terms of 12 and 18 h UTC), which was reflected, besides the small number of processed days, by a somewhat unbalanced profile of the curves in the respective figure.

The mean maximum of I_G under the above weather regime reaches almost a double of the mean maximum for the whole period processed, approaching the value of 950 W/m^2.

The daily maximum of I_G corresponds, of course, to the maximum of I_R which reaches almost 195 W/m^2. The above two fluxes of radiation correspond to each other very well, which is also reflected in the daily regime of the albedo (α).

This is, like in the case in Fig. 4 in the prevailing part of the period of the day, very constant and keeps, with the exception of the morning and evening hours, on the level very near the mean daily variation for the whole summer season. The prevalence of direct radiation is significantly reflected only in the steeper initial increase and the evening drop in the α values (in the

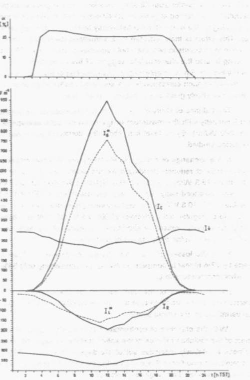


Fig. 5. T ext see Fig. 4, on days with little cloudiness
(8, 16, 24 Dec.1994, 8 and 9 Jan.1995)

Średnia dobowa zmienność składników bilansu promieniowania czynnej powierzchni wegetacyjnej na Stacji im. H. Arctowskiego latem 1994/95 dla dni z małym zachmurzeniem interval 3rd-4th h, and/or 20th-22nd h). This illustrates a good absorption of direct radiation, absorbed at great zenith distances of the Sun in the morning in the evening by the moss stand substantially better than at small zenith distances. This effect is then reflected by a somewhat decreased value of the daily mean in comparison with the whole summer season (= 18.9%). Worth mentioning is also the characteristic sagging of the curve of the daily variation of α which, in Fig. 4, is only hinted. The reduction of the values of in the hours about the noon corresponds to a somewhat better absorption of solar radiation at relatively great zenith distances of the Sun.

The balance of shortwave radiation (I_S*) reaches its maximum (759 W/m^2) identically with the maximum of I_G and on the daily average is amounts to 360 W/m^2). By its level it is about the double of the mean for the whole period studied.

In the exchange of energy via the longwave radiation losses prevail unambiguously at reduced cloudiness for the whole day. I↑, as compared with I↓, is by 75.3 W/m^2 (i.e. by 22.5%) higher in the daily mean. While I↑ has a much balanced daily regime (with the maximum of 371.7 W/m^2 and the minimum of 310.8 W/m^2), the corresponding time changes of I↓ are somewhat more irregular, with extremes of 305.3 and 212.3 W/m^2, respectively. The most probable reason of short-time anomalies of the daily regime of I↓ are irregularities in the daily regime of cloudiness.

Energetic losses of the active surface by means of I↑ are on the average by 72% higher in comparison with I_R, I↓ representing only 58% of its value when compared with I_G.

Mutual relations of the daily regimes of I↓ and I↑ have a similar character even at the radiation character of the weather as in the case of the mean variations for the whole period.

With the objective of confrontation of the daily regime of the components of the radiation balance of the active surface on days with maximum cloudiness a relatively extensive set of six days was selected (Fig. 6), on which minimum cloudiness 9 occurred in the daily observation terms and the occurrence of low-level cloud genera occurred.

Despite the shape differences of the curves of the daily regime of the components of the radiation balance in Figs. 4 and 6 it can be stated that practically all balance components reach a level near that of maxima presented in the following Table 2 on those days. Somewhat more significant differences can only be stated in the component I_G. The tabulated pairs of values I_G and I_R document the significance of the effect of on the whole high values of cloudiness in the summer season on their level which in the case of daily maxima of I_G and I_R is on clouded days only by 126.2 and 37.6 W/m², respectively, lower than the mean one.

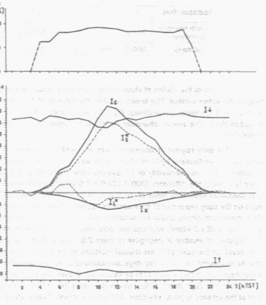


Fig. 6. Text see Fig. 4, on days with large cloudiness (11, 12 and 13 Dec.1994, 5, 6, and 7 Jan.1995)

Średnia dobowa zmienność składników bilansu promieniowania czynnej powierzchni wegetacyjnej na Stacji im. H. Arctowskiego latem 1994/95 dla dni z dużym zachmurzeniem

Table 2

The mean daily maxima of intensity of global (I_G) and reflected (I_R) radiation, downward atmospheric radiation (I↓) and longwave radiation of the active surface (I↑) [W/m²] on days with large cloudiness and in the whole period studied, 8 Dec.94 - 12 Mar.95 at H. Arctowski

Średnie dobowe maksima natężenia promieniowania całkowitego (I_G) i odbitego (I_R), zwrotnego promieniowania atmosfery (I↓) oraz długofalowego promieniowania powierzchni Ziemi (I↑) [W·m⁻²] w dniach z dużym zachmurzeniem i w ciągu całego rozpatrywanego okresu 08.12.1994 - 12.03.1995 na Stacji im. H. Arctowskiego

Radiation flux	I_G	I_R	I↓	I↑
days with maximum cloudiness	374.0	70.1	390.7	341.0
all days	500.2	107.7	322.0	341.3

Typical of the choice of clouded days is a somewhat reduced reflectivity of the active surface. The mean reaches the value of 16.5%, thus being by 3.0 and 2.4% lower, respectively, than the total mean or the mean of the radiation days. The overall character of the daily regime of α is, however, maintained.

The daily regime of longwave fluxes of radiation is relatively inconspicuous, and particularly by I↓ relatively unbalanced. In its consequences it is reflected in the time variability of I_L*. Between the mean value of I↑ and I↓ there is a negligible difference (330.0-327.0 = 3.0 W/m²), which in hourly values fluctuates within the limits of -51.0 and 39.2 W/m². The effect of cloudiness on the daily regime of I↑ thus appears logically chiefly in the level of the daily maximum which, unlike the radiation days (371.7 W/m²), reaches only the value of 351.7 W/m², whereas the difference of the daily minima in the two regimes of weather is negligible (a mere 2.9 W/m² in favour of the clouded days). In the case of I↓ the mutual relations of daily maxima and minima, in comparing the clear sky days and clouded ones, are opposite. Increased cloudiness asserts itself both by increasing the level of the maximum of I↓ (in clear sky days 305.3 W/m², in clouded days 344.0 W/m²), as well as that of the minimum (clear sky days: 211.9 W/m²,clouded days: 262.0 W/m²)

Energetic losses via I↑ are, in comparison with I_R, on the average significantly higher than at clear sky weather (they exceed the mean of I_R by almost 90%). The same holds, unlike clear sky weather, for I↓ which, on the average, exceeds I_G by 49.4%.

Table 3

Extreme values of intensity of global (I_G) and reflected solar radiation (I_R), downward atmospheric radiation (I↓) and longwave radiation of the active surface (I↑) [W/m²] in the period of 8 Dec.94 - 12 Mar.95 at H. Arctowski station

Ekstremalne wartości natężenia promieniowania całkowitego (I_G) i odbitego (I_R), zwrotnego promieniowania atmosfery (I↓) oraz długofalowego promieniowania powierzchni Ziemi (I↑) [W m⁻²] w okresie 08.12.1994 - 12.03.1995 na Stacji im. H. Arctowskiego

Radiation flux	I_G	I_R	I↓	I↑
maximum	1280.2	321.8*	430.7	534.9
date	31.1	3.03	12.03	12.03
minimum	0.0	0.0	269.7	265.4
date	-	-	10.03	10.03

*) without snow cover

As a supplement of the above information can serve Table 3 in which there are listed absolute extremes of the fluxes of radiation energy for the whole period analyzed.

The regime of radiation fluxes in the whole period of the summer activity was evaluated at the level of their daily sums (Fig. 7).

Typical of the time changes of the daily summary intensities of global radiation (I_G) is their large fluctuation at the maximum of 33.83 MJ/m², minimum 3.24 MJ/m² and the mean value of 16.50 MJ/m². Characteristic of the partial maxima is the dropping trend from the beginning to the end of the measurements. Two basic factors evidently participate in the great variability of I_G: the change in the sunshine between the beginning and the end of the period of measurement (theoretically from 19.35 h to 13.03 h) and the cloudiness.

A smaller effect of the reduction of the theoretical radiation duration is reflected in Fig. 7 in the dropping trend of partial maxima I_G, whereas the regime of cloudiness in a more abrupt fluctuation of the other values.

Different significance of the two factors was besides, also confirmed statistically by the application of the double analysis of variance. In its application (see e.g. Kreyszig, 1973) the set I_G was divided into 7 groups (intervals of the theoretical sunshine duration , 1 h) and 8 classes (intervals of cloudiness , one-tenth from 2 to 10). The evaluation of the effect of the both factors at the significance level 0.05 confirmed the statistical significance only in the cloudiness. This result must, however, be taken with some reserve and eva-

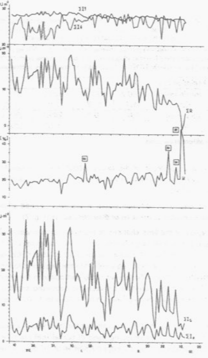


Fig. 7. Regime of the daily summary intensities of components of the radiation balance of the active surface at H. Arctowski base in the summer of 1994/95 (I_G - global radiation, I_R - reflected radiation, $\bar{\alpha}$ - mean daily albedo, I↓ - downward atmospheric radiation, I↑ - longwave radiation of the active surface, ΣR* - radiation balance)

Zmienność dobowych sum składników bilansu radiacyjnego powierzchni czynnej na Stacji im. H. Arctowskiego latem 1994/95 (I_G - promieniowanie całkowite, I_R - promieniowanie odbite, $\bar{\alpha}$ - średnie dobowe albedo, I↓ - promieniowanie zwrotne atmosfery, I↑ - długofalowe promieniowanie powierzchni czynnej, ΣR - bilans promieniowania) luated only as the confirmation of the difference of significance of the two factors and not as an argument for refusing the effect of sunshine duration on the regime of I_G.

The above conclusion led to the expression of the regression dependence of I_G on the mean cloudiness ($\bar{C}$) presented in Fig. 8. Despite the variance of the correlation field, again documenting less significant effects of further factors (besides the above sunshine duration also e.g. the representation of cloud genera) the value of the correlation coefficient ($r_{CG} = -0.699$) on the significance level 0.05 is statistically significant, documenting thus the prevalence of effects of cloudiness on I_G over the other factors. According to the coefficient of determination ($r^2 = 0.489$) about 49% of all changes in I_G are affected by this cause.

The dropping trend from the beginning to the end of the summer of 1994/95, typical of the I_G regime, is shown in the case of daily summary intensities of reflected radiation (I_R) only as a hint (Fig. 7). This also witnesses the fact that in the course of summer, despite the drop in the value of I_G the reflectivity of the surface of the vegetation oasis grows. The mean intensity of I_R amounts to 3.41 MJ/m^2 (at extreme values 7.38 and 0.63 MJ/m^2, respectively). The mean albedo of 20.4% corresponds to the above values and the corresponding I_G with extremes of 23.2 and 11.8%.

Typical of the summer regime of the mean daily albedo ($\bar{\alpha}$), (Fig. 7) is, despite some fluctuation, is some growth, beside which are conspicuously the values of $\bar{\alpha}$ on the days with the snow cover (17 Jan., 3, 7, 10 and 11 Mar., 1995) at the absolute maximum of $\bar{\alpha}$ = 56.9% on 10 Mar. The second exception - the minimum of $\bar{\alpha}$ stated above (4 Jan., 1995) is due to great cloudiness with the prevalence of St and Ns with the base at the height of about 100 - 150 m.

A gradual growth of $\bar{\alpha}$ led to the study of the relation of I_G and I_R, presented graphically in Fig. 9. In it was found that in the mutual relation of the two variables there was a significant time change on 8 Jan., 1995. Whereas in the first part of the summer the dependence of I_R on I_G is steeper and very close (the respective correlation coefficient is 0.997 and the regression relation is expressed by the equation: $I_R = 0.218 \cdot I_G - 0.670$), the relation of the two radiation fluxes changes from the above date into a less steep one ($I_R = 0.245 \cdot I_G - 0.470$), but it keeps its high closeness (correlation coefficient = 0.987). That means that at the same I_G the intensity of I_R increases.

Looking for the reason of this change it is necessary to take into consideration the precipitation character of the first half of the summer of

1994/95. December, extremely pure in precipitation (monthly sum 3.9 mm) and the first half of January (up to 17 Jan. only 8.8 mm precipitation fell) resulted, together with the gradual drying of the substrate, saturated after the initial summer ablation of snow by the melt water, also to the drying of the vegetation, mostly moss, layer and in its becoming yellow (i.e. in the growth of the albedo). The rate of change in the dependence of I_R on I_G is then connected with the character of the weather at the beginning of January. From 1 to 7 Jan. there prevailed days with large cloudiness (i.e. with low values of I_G and/or I_R), at which the differences between the two regression lines are minimal. The subsequent drop in cloudiness, and thus also the growth of I_G was also reflected by the growth of I_R practically in a leap and thus also by a change in the regression relation.

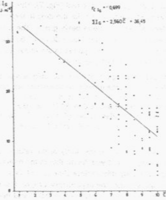


Fig. 8. Regression dependence of the daily summary intensities of global radiation (I_G) on mean cloudiness ($\bar{C}$) from the terms of observation 09 and 15 h LMT (12 and 18 UTC) at H. Arctowski station in the summer of 1994/95

Zależność dobowych sum promieniowania całkowitego (I_G) od średniego zachmurzenia ogólnego ($\bar{C}$) z terminów obserwacyjnych 12 i 18 UTC na Stacji im. H. Arctowskiego latem 1994/95.

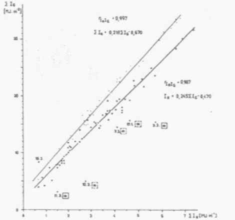


Fig. 9. Regression dependence of the daily sums of reflected radiation (I_R) on the daily sums of global radiation (I_G), completed by correlation coefficients ($r_{I_R I_G}$) and regression equations. The thin line - from 8 Dec.1994 to 7 Jan.1995, the thick line - from 8 Jan.1995 to 12 Mar.1995

Zależność dobowych sum promieniowania odbitego (I_R) od sum dobowych promieniowania całkowitego (I_G), uzupełniona współczynnikiem korelacji i równaniem regresji. Linia cienka - 08.12.94 do 07.01.95, linia pogrubiona - 08.12.95 do 12.03.95

In the evaluation of the relation of daily sums of the intensity of global radiation (I_G) and the daily sums of the intensity of extraterrestrial radiation (I_E) it is possible to state at the beginning that the values of I_E exceed I_G on the average by almost 60% (the mean transmissivity of the atmosphere $\overline{P}$ is 43.9% for the period studied). As follows from Fig.10, the mutual relation of I_G and I_E considerably variable ($\overline{P}$ fluctuates within the limits of 12.4 and 77.5%). The basic reason of the fluctuation of the values of $\overline{P}$ is, as can be understood, the variability of cloudiness, the occurrence and the amount of cloud genera on the individual days, conditioned almost unambiguously by advection causes.

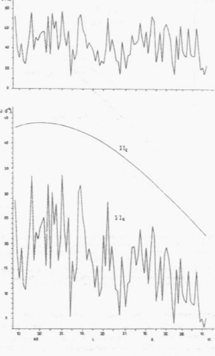


Fig. 10. Regime of the daily sums of global (I_G) and extraterrestrial radiation (I_E) and the mean daily atmospheric transmissivity ($\bar{P}$) at H. Arctowski station in the summer of 1994/95

Przebieg dobowych sum promieniowania całkowitego (I_G) i promieniowania na górnej granicy atmosfery (I_E) oraz średnich dobowych wartości wskaźnika przezroczystości atmosfery ($\bar{P}$) na Stacji im. H. Arctowskiego latem 1994/95

Evaluating the dependence of $\bar{P}$ on the mean daily cloudiness $\bar{C}$ in the terms 09 and 15 h LMT (12 and 18 UTC), (Fig.11) via correlation and regression a significantly close linkage was found of the two variables, expressed in the figure by the above correlation coefficient and the equation of a second-degree polynomial. From the profile of the regression line it follows that at small cloudiness (0 - 4 tenths) the value of P is logically the highest (exceeding 70%) and much invariable. With increasing cloudiness in the interval from 5 to 9 it drops significantly to the level little exceeding 30%, at which it again quite logically stabilizes. Characteristic of the interval 5 - 10 is the increased variance of empirically found values of $\bar{P}$ which is evidently due to the differences in the representation of the individual genera of high-level, medium-level and low-level clouds, but also (as was found by a more detailed analysis of clouds of the individual levels) to the areal distribution of th cloud fields towards the position of the Sun.

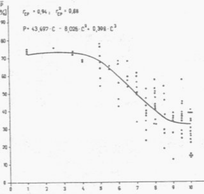


Fig. 11. Regression dependence of mean atmospheric transmissivity ($\bar{P}$) on mean cloudiness from the terms 12 and 18 h UTC (09 and 15 h MLT) at H. Arctowski station in the summer of 1994/95

Zależność średniej wartości wskaźnika przezroczystości atmosfery ($\bar{P}$) od średniego zachmurzenia ogólnego z terminów obserwacyjnych 12 i 18 UTC na Stacji im. H. Arctowskiego latem 1994/95

Table 4

Selections of days with constant wind direction at synoptic terms 09 and 15 h LMT (12 and 18 UTC) with mean cloudiness $\overline{C}$ (in tenths) and mean atmospheric transmissivity $\overline{P}$ (%) in the period of 8 Dec 94 - 12 Mar 95 at H. Arctowski station

Średnie zachmurzenie $\overline{C}$ (w dziesiętnych) i średni wskaźnik przezroczystości atmosfery $\overline{P}$ (%) dla wybranych dni ze stałym kierunkiem wiatru w terminach synoptycznych 12 i 18 UTC w okresie 08.12.1994 -12.03.1995 na Stacji im. H. Arctowskiego

Wind direction - N			Wind direction - NW			Wind direction - W		
Date	C	P	Date	C	P	Date	C	P
12.12.	9.5	37.8	15.12.	7.5	52.4	27.12.	4.0	59.3
18.12.	8.0	51.0	25.12.	10.0	34.0	09.01.	1.0	74.8
02.01.	8.0	42.1	12.01.	8.0	39.6	13.02.	6.0	73.0
04.01.	9.5	12.4	14.01.	6.0	42.0	22.02.	3.5	49.5
19.01.	10.0	27.4	20.01.	8.0	35.0	06.03.	8.5	32.7
04.02.	7.5	42.9	05.03.	8.0	32.6	mean	5.2	56.0
06.02.	7.0	48.7	12.03.	7.0	39.9			
09.02.	8.0	41.3	mean	7.8	39.4			
11.02.	9.5	35.5				Wind direction - SW		
24.02.	10.0	14.2				Date	C	P
04.03.	9.0	34.7				16.12.	5.0	76.5
mean	8.7	35.3	Wind direction - SE			22.12.	8.0	57.4
			Date	C	P	30.12.	9.0	46.9
Wind direction - S			12.12.	10.0	26.9	11.01.	8.5	53.9
Date	C	P	05.01.	10.0	14.7	02.02.	7.5	34.1
16.01.	8.5	27.5	17.01.	10.0	38.4	14.02.	6.0	68.0
16.02.	8.5	29.2	10.03.	10.0	22.1	27.02.	5.0	64.0
17.03.	10.0	28.6	11.03.	10.0	14.7	03.03.	5.5	61.5
mean	9.5	28.3	mean	10.0	23.4	mean	6.8	57.8

The described facts led subsequently to a more detailed analysis of the effects of cloudiness on the value of $\overline{P}$. The input assumption of this analysis is the unambiguous prevalence and frequent alteration of frontal cloud systems for the whole region of the northern part of the Antarctic Peninsula and the South Shetlands. That is conditioned by a very intense exchange of air masses in that space and, connected with it, the fluctuation of the baric field and a quick movement of atmospheric fronts, and/or their series (see e.g. Schwerdtfeger and Amaturo, 1979, or Schwerdtfeger, 1987)

For evaluating advection effects on cloudiness and thus also on the value of $\overline{P}$ at the H. Arctowski base out of the term observation significantly numerous days were selected with constant wind direction at synoptic terms

09 and 15 h MLT (12 and 18 UTC) which, together with the mean cloudiness $\bar{C}$ at these terms and with $\bar{P}$ are included in Table 4.

Despite a certain roughness of the criterion employed, from Table 4 it is evident that both cloudiness and on it dependent atmosphere transmissivity are considerably affected by the direction of advection. The highest value of $\bar{C}$ (and thus the lowest $\bar{P}$) are bound on wind directions SE and S, the lowest $\bar{C}$ and the highest P on directions SW and W. The values of $\bar{C}$ and $\bar{P}$, under advection from N and NW are situated between the two extremes.

The above facts have their causes on the one hand in the character of the baric field, on the other hand in the position of frontal systems and their cloud fields bound to the individual pressure formations. It is thus necessary to note these causes at least in a short description.

For the baric field at advection from SE (Fig.12 A) the South Shetlands are situated within a series of two to four as a rule inexpressive, areally less extensive depressions, interconnected with one another. These depressions encircle the Antarctic Peninsula from W, N and/or E. The SE advection is conditioned by the position of the centre of one of the N - NE depressions from King George Island. The island is immediately within the reach of frontal systems of one or two depressions.

The S advection is conditioned by the existence of two primary depressions (Fig.12 B), one of which is situated W of the Antarctic Peninsula and the other NE (E) of its northern corner. Both of them are interconnected by a trough of low pressure. The South Shetlands are situated below the circulation influence of the more eastern of them near its S - SE margin, i.e. in the space of the southern advection and in the immediate proximity of its frontal system.

The character of the baric field at the advection from SW (Fig.12 C) is similar to that at the advection from SW, provided that the position of the individual depressions is different with respect to King George Island from the situations at SE advection. The island is found in an inconspicuous pressure field between two cyclones or at the N - NW margin of the only depression out of the reach of frontal cloud systems.

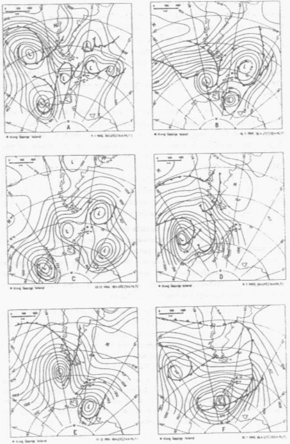
The W advection (Fig. 12 D) is determined by a conspicuous and extensive depression, reaching by its E margin as far as the Weddell Sea, with the centre W of the Antarctic Peninsula, or a group of depressions less pronounced with a similar position of centres. King George Island is situated at the N - NE margin of an extensive depression. The above depression can be even doubled (centres W of the Antarctic Peninsula and above the Weddell Sea). Frontal systems bound to this depression are in those cases shifted to the W of the South Shetlands, which results in the diminution of cloudiness.

With the wind direction N the South Shetlands are found at the E - SE margin of one or two depressions (Fig. 12 E) with the centre west of the Antarctic Peninsula at φ approximately 50 - 60° S. From this depression in some cases a trough of low pressure starts towards N. Along the E margin of the depression there occur outbreaks of warmer air from higher latitudes. Frontal systems bound to this depression are on the geographical latitude of the South Shetlands as a rule already occluded and King George Island is found at their E margin in those days, which conditions a little reduced cloudiness.

At NW advection (Fig.12 F) the South Shetlands are situated on the NE margin of the primary depression (or of a group of partial depressions) above the Antarctic Peninsula, W to NW from its frontal system. A further frontal system, bound to the depression above the SE Pacific (i.e. conspicuously to the west of the South Shetlands) is only shifting to the space of the Antarctic peninsula. King George Island is thus as a rule situated at an inconspicuous interface of margins of cloud fields of the two frontal systems, which is the fundamental condition of a somewhat lower cloudiness.

Fig. 12 Near the ground synoptic maps of the space between South America and the Antarctica at significantly numerous directions of advection in the region of King George Island. Copied unadapted from facsimiles published by the Chilean Meteorological Service in Valparaiso (A - SE advection, B - S advection, C - SW advection, D - W advection, E - N advection, F - NW advection)

Mapy analizy dolnej ilustrujące odpowiednie kierunki adwekcji mas powietrza w rejon Wyspy Króla Jerzego. Kopie z map faksymilowych Chilijskiej Służby Meteorologicznej w Valparaiso (A - adwekcja SE, B - adwekcja S, C - adwekcja SW, D - adwekcja W, E - adwekcja N, F - adwekcja NW)


A
King George Island
B
King George Island
C
King George Island
D
King George Island
E
King George Island
F
King George Island

From the preceding description it follows that the cloudiness in the space of the South Shetlands is a very dynamically developing meteorological phenomenon, typical by its considerable time variability conditioned by quick changes of the pressure field as well as the position of atmospheric fronts. Despite the above facts it is, however, possible to find, in the development of the pressure field and the frontal systems, characteristic and repeating moments of their development. To a significant extent they condition the cloudiness and thus also the variability of the transmissivity of the atmosphere.

The regimes of the daily sums of the downward atmospheric radiation ($\Sigma I\downarrow$) and the radiation of the active surface ($\Sigma I\uparrow$), (Fig. 7) do not exhibit such a great fluctuation in the summer season as does I_G. Substantially larger time variability is, however, in comparison with $\Sigma I\uparrow$, typical of $\Sigma I\downarrow$. Whereas the values of $\Sigma I\uparrow$ fluctuate with the mean of 28.07 MJ/m^2 only within the limits 29.38 and 26.45 MJ/m^2, the extremes of $\Sigma I\downarrow$ are 28.70 and 20.95 MJ/m^2 (the mean of $\Sigma I\downarrow$ = 26.08 MJ/m^2). The values of $\Sigma I\uparrow$ reach their maxi- mum in the period from 22 Dec. to 13 Jan. and then they drop very slowly until the end of the period analyzed - thus corresponding relatively well with the regime of the active surface temperature.

Characteristic of $\Sigma I\downarrow$ is, despite considerable initial fluctuation until 25 Jan., the total increase, and afterwards only a hinted, again time variable drop towards the conclusion of the series of measurements. This time development evidently reflects not only the variability of the cloudiness (partial maxima of I correspond well with partial minima of I_G), but also the total warming of the radiating atmosphere in the first half of the summer and its gradual cooling towards the beginning of March.

The described bond of $\Sigma I\uparrow$ on the active surface temperature is logical and it is therefore not necessary to deal with it. But the influencing of the values of $\Sigma I\uparrow$ by the cloudiness deserves closer attention. Its effect on $\Sigma I\downarrow$ was, like in the case of I_G, evaluated via regression and correlation (Fig. 13 A, B). As the criterion of cloudiness was this time used the mean ($\bar{C}$) of all four basic observation terms 00, 06, 12 and 18 h UTC.

Looking more closely at the variability of I conditioned by $\bar{C}$ it was found that this variable was affected by the direction of advection. The whole sample $\bar{C}$ was therefore divided into two partial ones - at the stabilized advection direction N, NW and W (n = 42) and SW, S and SE (n = 20). The fundamental direction criterion for these selections was the occurrence of one or two neighbouring directions in at least three observation terms of the day. The remaining 33 days with a variable wind direction of with prevailing calm were excluded from the procession.

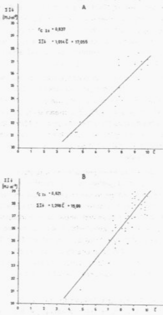


Fig. 13. Regression dependence of daily summary intensities of downward atmosphere radiation (I↓) on mean cloudiness ($\bar{C}$ - from terms 03, 09, 15 and 21 h LMT at H. Arctowski station under wind directions SW - S - SE (A) and N - NW - N (B)

Zależność dobowych sum zwrotnego promieniowania atmosfery (I↓) od średniego zachmurzenia ogólnego ($\bar{C}$ - z terminów 06,12,18,00 UTC przy kierunkach wiatrów SW-S-SE (A) i N-NW-N (B)

In the two partial pairs of sets it is possible to state a practically identical level of the closeness of the relation of the two variables (see correlation coefficients in Fig. 13 A,B), but they differ by the slopes of the regression lines. In the case of air advection from the southern quadrant ((Fig. 13 A) the increase in $\Sigma I\downarrow$, conditioned by the increase in $\bar{C}$, is slower than under advection from N, NW and W. That means that the overall colder air flowing under the southern advection over the South Shetlands radiates at the same cloudiness less intensely than the warmer air flowing to that space from N - W. The decisive effect of the advection direction is reflected the more conspicuously, the greater is $\bar{C}$. At minimum values of $\bar{C}$ about 3 to 4 tenths the effect of the wind direction on $\Sigma I\downarrow$ is negligible.

The regime of the daily sums of the radiation balance (ΣR^*) reflects, as follows from Fig. 7, mainly the time variability I_G. For the whole summer season the values of ΣR^* are positive, with maxima of 19.63 MJ/m^2 (16 Dec. 1994) and 19.62 MJ/m^2 (9 Jan.1995). The mean daily gain of radiating energy for the whole period analyzed amounts to 11.1 MJ/m^2 on the active surface. An idea of the summary intensities of the individual radiation fluxes, the shortwave, longwave and total radiation balances for the whole summer season is represented in Table 5.

Even though it has been compiled in a relatively rough step of one month and despite the incompleteness of December and March, it yields a fundamental idea of the change in the relation of the individual fluxes of radiating energy in the course of summer. Besides the evaluated increase in the albedo (in March, 1995 3 days with snow cover participate significantly in it) and a relative drop in I_G connected with it, also a marked relative increase in the longwave radiation fluxes towards I_G is evident from it; it is, at the same time, accompanied by a drop in energy losses via effective radiation. The radiation balance is subject to far smaller changes from month to month, with a logical culmination in January, i.e. at the time of the "culminating" summer.

From Table 5 there also follows the fact mentioned above, that a significant part of the shortwave solar radiation (on the average 78.6%) is absorbed by the surface of the vegetation oasis. At the same time there appear relatively small longwave radiation losses via effective radiation (on the average -12.5%), which, in its effect, results in a relatively significant value of the radiation energy which, after transformation to the heat energy, is absorbed by the substrate of the active surface (on the average 66.1%).

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Table 5

Summary (ΣΣ) and mean (Σ) daily summary intensities of global (I_G) and reflected (I_R) solar radiation, downward atmospheric radiation (I↓) and the radiation of the Earth surface (I↑), shortwave (I_S), longwave (I_L) and total (R) radiation balance and their percentual shares of the value I_G at H. Arctowski base in individual months and in the whole summer season of 1994/95 (8 Dec.1994 - 12 Mar.1995)

Sumy całkowite (ΣΣ) i średnie sumy dobowe (Σ) natężenia promieniowania całkowitego (I_G) i odbitego (I_R), zwrotnego promieniowania atmosfery (I↓) oraz długofalowego promieniowania powierzchni Ziemi (I↑), krótkofalowy (I_S), długofalowy (I_L) i całkowity (R) bilanse promieniowania i ich procentowy udział w odniesieniu do wartości I_G na Stacji im. H. Arctowskiego w poszczególnych miesiącach i dla całego okresu 08.12.1994 -12.03.1995

Radiation flux	Period									
	08-31.12.		01-31.01.		01-28.02.		01-12.03. *		08,12-12.03.	
	ΣΣ	Σ	ΣΣ	Σ	ΣΣ	Σ	ΣΣ	Σ	ΣΣ	Σ
	[MJ/m²]									
I_G	532.73	22.20	520.97	16.81	366.66	13.10	97.43	8.12	1517.79	15.98
I_R	-98.80	-4.12	-107.73	-3.48	-92.05	-3.29	-26.20	-2.18	-324.78	-3.42
I_S	433.93	18.08	413.24	13.33	274.61	9.81	71.23	5.84	1193.01	12.56
	[%]									
I_G	100.0		100.0		100.0		100.0		100.0	
I_R	18.5		20.7		25.1		26.9		21.4	
I_S	81.5		79.3		74.9		73.1		78.6	
	[MJ/m²]									
I↓	578.76	24.12	578.76	24.12	748.10	26.72	317.23	24.44	2477.51	26.08
I↑	-680.85	-28.37	-680.85	-28.37	-782.70	-27.95	-327.85	-27.32	-2667.10	-28.07
I^*_L	-102.09	-4.25	-102.09	-4.25	-34.59	-1.24	-10.61	-0.88	-189.49	-1.99
I↓	108.6		160.0		204.0		325.6		163.2	
I↑	127.8		168.1		213.5		336.5		175.7	
I^*_L	19.2		8.1		9.4		1.1		12.5	
	[MJ/m²]									
R*	331.84	13.83	370.94	11.97	240.02	8.57	60.62	5.1	1003.42	10.56
	[%]									
R*	67.1		71.2		65.5		62.2		66.1	

In an effort of confronting Table 5 with the data of other summer seasons from the locality of measurements it was necessary to be limited to the results of only one measurement of the intensity of global radiation carried out at H. Arctowski station in 1980, adapted and published by Marsz and Styszyńska (1994), (Table 6).

Table 6

Monthly summary and mean daily sums of the intensity of global radiation ($\Sigma\Sigma I_G$ and ΣI_G, respectively) in the summer months of the year 1980 and in the summer of 1994/95 at H. Arctowski station (data in brackets are related to incomplete monthly periods)

Sumy miesięczne ($\Sigma\Sigma I_G$) i średnie sumy dobowe (ΣI_G) promieniowania całkowitego w miesiącach letnich roku 1980 i podczas lata 1994/95 na Stacji im. H. Arctowskiego (dane w nawiasach dotyczą niepełnych okresów miesięcznych)

Month	1980		1994/95	
	$\Sigma\Sigma I_G$ [MJ/m^2]	ΣI_G [MJ/m^2]	$\Sigma\Sigma I_G$ [MJ/m^2]	ΣI_G [MJ/m^2]
XII	740.44	23.89	(532.73)	22.10
I	498.10	16.07	520.97	16.81
II	302.99	10.82	366.66	13.10
III	263.32	8.49	(97.43)	8.12

From them it follows that the summer of 1994/95 was typical at least in February by increased sums of global radiation. But those data do not, unfortunately, permit (not by the fault of the authors quoted) more extensive conclusions.

Conclusion

From what has been presented so far it follows that at least two of the fluxes of radiation energy (i.e. the total solar radiation and the downward atmospheric radiation) are not only at the H. Arctowski station at King George Island, but in the whole space of the South Shetlands and the northern corner of the Antarctic peninsula very substantially affected by the character of weather whose most marked expressions are the direction of advection of air masses and, connected with it, cloudiness and air temperature. This fact was verified both by the dynamics of the time changes of the individual radiation fluxes, and by the application of statistical methods documenting different weights of factors affecting the radiation.

The two remaining radiation fluxes - i.e. reflected radiation and the radiation of the active surface - depend on the regime of the weather indirectly by the way it conditions the mutual relation of direct and diffuse radiation in the flux of global radiation, and/or how it affects the temperature and moisture properties of the active surface and its substrate.

Although in the above text only short (i.e. practically three-month) series of measuring the components of the balance of radiation are analyzed, they document convincingly enough a number of facts whose existence was considered, but not quantitatively documented.

The specificities of the regime of the radiation balance and its components must understandably be necessarily projected further into the heat balance. Its components were measured in parallel with the radiation ones and they are the subject of further procession. The measurements of the components of the radiation balance in the summer of 1994/95 were continued to a limited extent (only global and reflected solar radiation) for the whole year 1995 and at the beginning of the summer of 1995/96 again renewed in full scope with the objective of publishing the processed results in the present journal again.

References

Fröhlich C., London J., 1986, [ed.], Revised instruction manual and radiation instruments and measurements. WMO?TD-No.149, Word Climate Research Programme.

Marsz A., Styszyńska A., 1994, Pomiar promieniowania całkowitego na Stacji Arctowskiego z roku 1980. Problemy Klimatologii Polarnej 4, WSM Gdynia, s.59-64.

Oliver J.E., Fainbridge R.W., 1987, [ed.], The Encyclopedia of Climatology. Van Nostrand Reinhold, New York, ss.986.

Schwerdtfeger W., 1987, Pogoda i klimat Antarktiki. Gidrometeoizdat, Leningrad, ss.264.

Schwerdtfeger W., Amaturo L.R., 1979, Wind and Weather around the Antarctic Peninsula. Research Report, Dep. of Meteorology, University of Wisconsin, ss.86.

Sellers W.D., 1972, Physical Climatology. University of Chicago Press, Chicago, ss.272.

SKŁADNIKI BILANSU PROMIENIOWANIA I ICH PRZEBIEG LATEM 1994/95 NA STACJI im. H. ARCTOWSKIEGO (SZETLANDY POŁUDNIOWE)

Streszczenie

W grudniu 1994 na Polskiej Stacji Antarktycznej im. H. Arctowskiego rozpoczęto realizację trzyletniego programu badawczego prowadzonego przez Katedrę Geografii z Wydziału Naukowego Uniwersytetu im. Masaryka w Brnie z Republiki Czeskiej.

Tematem badań jest określenie zmian w bilansie energetycznym i promieniowaniu UV i ich wpływ na naturalne ekosystemy Antarktyki, a zwłaszcza określenie wpływu okresowych zmian w bilansie energetycznym powierzchni czynnej i promieniowaniu UV-B na zbiorowiska roślin niższych w trakcie ich okresu wegetacyjnego, tzn. podczas antarktycznego lata.

Realizację programu rozpoczęto latem 1994/95 serią obszernych pomiarów składników bilansu energetycznego i promieniowania UV-B. Pomiary o takim zakresie nie były do tej pory realizowane na żadnej z ośmiu pozostałych stacji usytuowanych na Wyspie Króla Jerzego. Dlatego też wnoszą pierwsze informacje o złożonych warunkach energetycznych egzystencji ekosystemu roślinnego tej wyspy.

Niniejsza publikacja zawiera częściowe rezultaty z początkowego okresu pomiarów składników bilansu radiacyjnego, t.j. promieniowania całkowitego i odbitego, długofalowego promieniowania Ziemi i promieniowania zwrotnego atmosfery.

Automatyczna stacja do pomiarów strumieni energii i ciepła została usytuowana w środkowej części przybrzeżnej oazy wegetacyjnej (mszarnika), na południe od ogródka meteorologicznego (ryc. 1) i rozpoczęła pracę 08.12. 1994. Pomiary w wymienionym zakresie trwały do 12.03.1995. Do pomiarów promieniowania używano:

1. promieniowanie całkowite - pyranometr Kipp-Sonnen, typ CM-5,
2. promieniowanie odbite - pyranometr Kipp-Sonnen, typ CM-5,
3. bilans radiacyjny - pyrradiometr Schenk, typ 8111.

Wszystkie rejestratory usytuowane zostały 1.5 m nad powierzchnią gruntu pokrytą w całości przez trawę i mchy.

Zmiany strumieni energii promienistej latem 1994/95

Przed analizą przebiegu zmierzonych strumieni energii promienistej dokonano pomiarów przesłonięcia horyzontu i oszacowano jego wpływ na redukcję bezpośredniego promieniowania słonecznego docierającego do przyrządów. Stwierdzono, że przesłonięcie horyzontu nie wpływa w znaczący sposób na zmniejszenie możliwego usłonecznienia rzeczywistego. Ilustruje to ryc. 2. Dla dni 08.12; 21.12 i 12.03 usłonecznienie możliwe byłoby o około 2 h krótsze niż teoretycznie możliwe (10.5, 13.4 i 15.3%, odpowiednio). Prowadzi to do wniosków, że ta redukcja nie wpływa w znaczący sposób na ograniczenie dziennego możliwego dopływu radiacji w formie promieniowania bezpośredniego.

Usłonecznienie rzeczywiste w Antarktyce pozostaje pod znacznym wpływem zachmurzenia, w większości frontalnego pochodzenia. Potwierdza to ryc. 3 i dane zawarte w tablicy 1. Analiza tych danych daje także obraz roli promieniowania rozproszonego w kształtowaniu bilansu promieniowania.

Pogląd na przebiegi dobowe składników promieniowania i ich charakter przy różnych stopniach zachmurzenia oddają ryc. 4 - 6. Do ich wykonania wykorzystano dane z podstawowego okresu pomiarowego stacji automatycznej (10-minutowe średnie rozpoczynające każdą pełną godzinę). Ryciny dają obraz dobowych zmian w natężeniu promieniowania całkowitego, odbitego, długofalowego promieniowania Ziemi i promieniowania zwrotnego atmosfery. Obraz dopełniają uśrednione przebiegi bilansu promieniowania krótko- i długofalowego oraz wartości albedo. Średnie maksima oraz wartości ekstremalne poszczególnych składników bilansu zawierają tablice 2 i 3, a przebieg dobowych sum poszczególnych strumieni energii w okresie lata 1994/95 ilustruje rycina 7.

Wykazano statystycznie istotną zależność dobowych sum promieniowania całkowitego od średniego zachmurzenia ogólnego z dwóch terminów obserwacyjnych pory dziennej (ryc. 8) jak również wysoki stopień korelacji pomiędzy promieniowaniem całkowitym i odbitym na poziomie sum dobowych (ryc. 9).

Związki zachodzące pomiędzy ilością promieniowania docierającego do górnej granicy atmosfery i promieniowaniem całkowitym oddaje ryc.10 Prezentowany wskaźnik przezroczystości atmosfery ($P = I_G \cdot I_E^{-1} \cdot 100\%$) wykazuje związki ze średnim zachmurzeniem ogólnym w porze dziennej (ryc.

11) i kierunkami adwekcji mas powietrza (tablica 4). Zależność promieniowania zwrotnego atmosfery od średniego dobowego zachmurzenia ogólnego zawierają ryciny 13 A i B, obrazujące także wpływ kierunku adwekcji (temperatury napływającej masy powietrza) na wielkość zwrotnego promieniowania atmosfery. Wielkości poszczególnych strumieni energii w postaci średnich sum dobowych, sum miesięcznych i dla całego rozpatrywanego okresu zawiera tablica 5.

Przedstawione wyniki pozwoliły sformułować następujące wnioski:

- promieniowanie całkowite i zwrotne promieniowanie atmosfery w rejonie Szetlandów Południowych pozostają pod wpływem charakteru pogody t.j. kierunku adwekcji mas powietrza i związanych z tym zachmurzeniem i temperaturą powietrza,
- promieniowanie odbite i promieniowanie długofalowe powierzchni czynnej podlegają wpływowi pogody w sposób pośredni, warunkując wzajemne relacje między promieniowaniem bezpośrednim i rozproszonym w strumieniu promieniowania całkowitego jak również wpływając na temperaturę i wilgotność powierzchni czynnej.

Stwierdzone osobliwości reżimu bilansu radiacyjnego i jego składowych winny się uzewnętrznić również w bilansie cieplnym powierzchni czynnej, którego składniki mierzone były równolegle. Zagadnienie to stanowi temat przyszłych badań.

Pomiary składników bilansu promieniowania były w okrojonym zakresie (promieniowanie całkowite i odbite) kontynuowane przez cały rok 1995 a z początkiem lata 1995/96 wznowiono pomiary w pełnym poprzednim zakresie.