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Radiation conditions in the Hornsund area (Spitsbergen)*

ABSTRACT: On the basis of a year-long series of actinometric measurements performed in the vicinity of Polish Polar Station at Hornsund, this paper presents the characteristic of the value of solar radiation incoming at the active surface, of absorbed and net radiation. The maximum intensity of the direct solar radiation was 822 Wm^{-2}, the annual sum total of total radiation was 2611 MJm^{-2}, whereas the mean yearly albedo was 59%. The zero-crossing of the 24-hour sums of the net radiation towards negative values occurred at the turn of September and October.

Key words: Arctic Spitsbergen meteorology, tundra radiation balance

1. Introduction

One of the most important processes affecting the natural elements of the polar environment is energy exchange by way of radiation.

The structure of the radiation balance in the vicinity of the Polish Polar Station at Hornsund ($\varphi = 77°00'$ N, $\lambda = 15°33'$ E) is determined by yearly and 24-hour changes in the insolation period and the incidence angle of solar rays, singular to the polar zone. The period of uninterrupted supply of solar radiation (polar day) lasts here from 25 April to 18 August, with the height of the Sun over the horizon reaching 36° (Fig. 1). It is then that, just as in the day part of 24 hours in the summer and autumn seasons, the radiation balance of a given active surface (tundra, snow cover) can be expressed by the equation (Oke 1982)

$$Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow = K^* + L^*,$$

* The research, within Problem MR.I.29B.6, was carried out on the basis of measurements performed in the framework of the expedition of the Polish Academy of Sciences to Spitsbergen in 1980/1981.

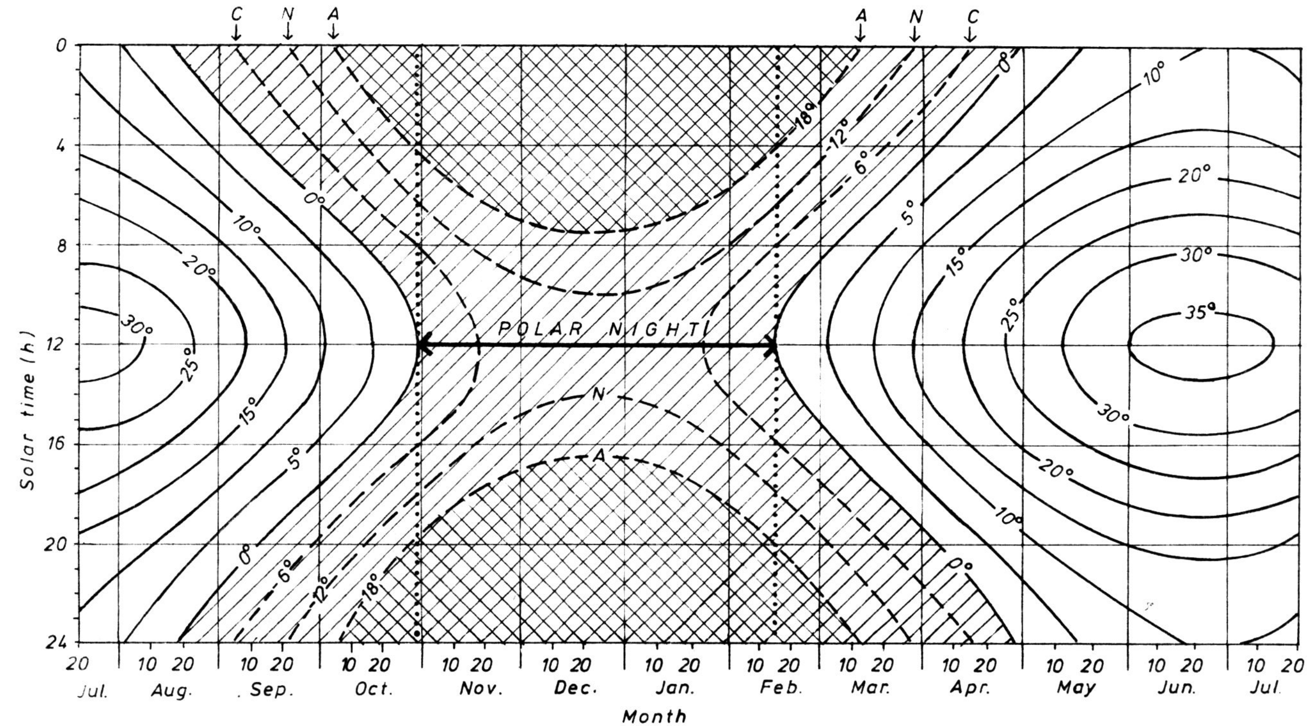

Fig. 1. Isopletes of the height of the Sun and the twilight effects at Hornsund ($\varphi = 77°00'N$, $\lambda = 15°33'$ E). The dashed area covers the period when the Sun stays under the horizon. C — boundary of civil twilight, N — boundary of nautical twilight, A — boundary of astronomical twilight

where Q^* is the net radiation (the net flux of downward and upward radiation over the whole radiation spectrum range), K^* is the net shortwave radiation, L^* is the net longwave radiation, $K\downarrow$ is the total solar radiation (the sum of direct and diffuse radiation), $K\uparrow$ is the reflected radiation, $L\downarrow$ is the counter radiation from the atmosphere and $L\uparrow$ is the terrestrial radiation.

In turn, in the polar night period, when the Sun is always below the horizon (from 29 October to 14 February), there are only energy fluxes emitted by the active surface and by the atmosphere towards its base. The radiation balance equation is simplified to the form

$$Q^* = L\downarrow - L\uparrow = L^*$$

The information published previously on the radiation conditions in the tundra in the Hornsund area, includes only the magnitudes of the total solar radiation and is based on the results of actinometric measurements carried out at the Polish Polar Station during the winter 1957/1958 (Baranowski 1968) and in the summer months of 1970 and 1971 (Baranowski and Głowicki 1974, 1975). They were used for the interpretation of a large number of glacial phenomena occurring contemporarily in Spitsbergen (Baranowski 1977).

The present elaboration contains a preliminary analysis of the results of a year-long series of measurements of the main components of the radiation balance in the tundra, carried out by the author within the framework of the research programme of the expedition of the Polish Academy of Sciences to Spitsbergen in 1980/1981 (Niewiadomski 1982).

2. Method and material

The actinometric investigations were carried out in the area of the base meteorological station at Hornsund, situated on the Fuglebergsletta lowlands, within a flat terrace 10 m over the sea level.

The active surface over which the devices were set up was constituted for most of the year (from 31 October to 30 June) by snow cover with a thickness not exceeding 48 cm. In turn, in the summer and autumn periods, it was the tundra soil, derived from sea sand, covered with moss and lichen clusters (Szerszeń 1965).

The measurement set up included a CM 7 model solarialbedometer and a Funk net pyrradiometer, with recording millivoltmeters, manufactured by the KFAP company, and a Linke–Feussner radiometer, equipped with the filters OG1, RG2 and RG8. The devices were compared, both before and after the research period, with the secondary standard at the Institute of Meteorology and Water Management in Warsaw, with consideration given to the International Pyrheliometric Scale of 1980 · (WRR — 1980).

The measurement work was carried out from 21 July, 1980, to 20 July, 1981, in keeping with the methodology observed in the network of actinometric stations in Poland (Podogrocki, unpublished).

The basic material for elaboration, obtained from recording tapes and periodical measurements, includes the following data:

— for a yearlong research cycle: hourly, 24-hour and monthly values of solar radiation energy (covered by the spectrum range 0.3 — 3.0 μm) both of total, absorbed and reflected by the horizontally oriented active surface,

— for the period from 21 July to 31 December, 1980: hourly, 24-hour and monthly magnitudes of the net radiation (so-called radiation balance) and the net longwave radiation.

— for a dozen-odd days of good weather in 1981: the instantaneous values of the intensity of direct solar radiation over the full spectrum range and its particular intervals.

3. Results and discussion

3.1. Radiation intensity

The energy effect of direct solar radiation at Hornsund is not very large despite the considerable translucency of the atmosphere. This results from large radiation extinction, conditioned by the long path of rays in the atmosphere with relatively low heights of the Sun.

The highest measured value of the intensity of direct radiation (on a black surface set perpendicularly to the incidence direction of the rays) was 822 Wm^{-2} and occurred on 16 July, 1981, at 13.04 of the real solar time. In Poland (Kołobrzeg) these values reach 942 Wm^{-2} (Kühn and Żółtowska 1977).

The intensity of direct radiation at Hornsund decreases with decreasing incidence angle of the solar rays. A very close relationship was found to exist between these elements (but only for the height interval of the Sun 10° — 35°), which is confirmed by the high correlation coefficient $r = 0.95$ (with $n = 60$). The intensity of direct radiation, calculated from regression equations for the 30° height of the Sun, is 778 Wm^{-2}, while for 10° it is only 523 Wm^{-2}, giving on the horizontal plane, respectively, 389 Wm^{-2} and 91 Wm^{-2} (Table I).

Table II shows the values of the radiation intensity registered at Hornsund over the whole range of the solar spectrum and the accompanying values for the different spectrum intervals. These data apply only to the most favourable conditions of the radiation transmission, determined by the highest height of the Sun here and the uncloudy atmosphere. The part of the visible range spectrum in the direct radiation is contained in the limits 41—44%. The other 56—59% is infrared radiation. The percentage part of shortwave radiation (31 — 33%) shows here values much lower than those observed in Iceland (Wójcik 1973) and in Poland (Kühn and Żółtowska 1977).

Table I

Mean values of the intensity of direct radiation Wm^{-2} at given heights of the Sun at Hornsund in 1981

Radiation kind	Height of the Sun				
	10°	15°	20°	25°	30°
S	523	590	654	717	778
S'	91	152	224	303	389

S — radiation flux an the normal surface
S' — radiation flux on the horizontal surface

Table II

Characteristic values of the intensity of direct radiation (Wm^{-2}) over the whole spectrum range and its chosen intervals for the 30°—35° height of the Sun at Hornsund in 1981

Month		S	S_A	S_B	S_C	S_{IR}	Number of measurement
May	$\bar{X}$	784	126	243	325	459	11
	max	815	139	265	346	476	
June	$\bar{X}$	782	132	253	334	448	5
	max	801	140	266	350	458	
July	$\bar{X}$	803	142	263	351	452	6
	max	822	147	275	368	464	

S — whole spectrum range
S_A — blue and violet colours ($\lambda < 0{,}525\,\mu m$)
S_B — shortwave radiation ($\lambda < 0{,}630\,\mu m$)
S_C — visible radiation ($\lambda < 0{,}710\,\mu m$)
S_{IR} — infrared ($\lambda > 0.710\,\mu m$)
$\bar{X}$ — arthmetic mean

Table III shows the values of the intensity of the total radiation (the sum of direct and diffuse radiation onto the horizontal plane) at Hornsund for the conditions of mean real cloudiness. During the noon culmination these values vary in a year from 20 Wm^{-2} in February to 439 Wm^{-2} in May. The June drop in the energy effect of the incoming solar radiation is related to the high degree of cloudiness in the summer season, characteristic of this part of the Arctic (Vowinckel and Orvig 1973).

Mean hourly values of the intensity of the total radiation (Wm^{-2}) at Hornsund in

Month	1	2	3	4	5	6	7	8	9	10	11
July 1980*)	29	32	44	51	69	101	149	185	210	238	229
August	7	9	14	26	48	74	102	129	147	170	191
September	—	—	—	—	3	11	30	54	81	105	121
October	—	—	—	—	—	—	—	4	13	22	31
February 1981	—	—	—	—	—	—	—	—	—	5	12
March	—	—	—	—	—	7	21	46	83	118	152
April	2	4	12	29	61	104	155	209	252	291	323
May	38	46	84	113	140	190	242	297	344	380	425
June	68	79	113	144	174	229	272	347	373	392	422
July**)	46	51	77	102	146	187	223	266	292	302	328

*) between: 21 and 31 July
**) between: 1 and 20 July

Mean hourly values of the intensity of the net radiation (Wm^{-2}) at

Month	1	2	3	4	5	6	7	8	9	10	11
July 1980*)	5	9	14	18	31	47	67	85	113	123	119
August	−9	−8	−2	3	11	26	41	62	74	84	96
September	−18	−15	−15	−14	−11	−6	3	14	27	45	54
October	−26	−27	−25	−27	−26	−29	−29	−27	−23	−18	−18
November	−34	−34	−33	−33	−34	−32	−32	−31	−32	−32	−33
December	−33	−32	−31	−34	−34	−34	−32	−33	−35	−36	−35

*) between 21 and 31 July

The character of the daily behaviour of the intensity of the total radiation in particular months (Fig. 2) depends first of all on the incidence angle of solar rays. Most months show a rather regular curve of the behaviour, while in June and July a considerable drop in the intensity of the total radiation can be seen in the hours about the noon. This results from the modifying effect of convection clouds occurring as a consequence of the formation of local systems of air circulation over the highly heterogeneous base of the south part of Hornsund Fiord.

In all months, there is a distinct asymmetry of the daily behaviour of the intensity of the total radiation with respect to the noon. It is expressed by the occurrence, with the same heights of the Sun, of a higher energy effect in the p.m. part of the 24 hours (Fig. 2). The a.m. daily

Table III

the research period 1980/1981

Hour												
12	13	14	15	16	17	18	19	20	21	22	23	24
238	236	241	235	192	167	144	121	88	59	37	28	27
198	209	187	163	149	128	90	60	49	28	16	8	6
128	125	118	103	79	57	33	12	3	—	—	—	—
40	40	28	16	6	1	—	—	—	—	—	—	—
20	21	17	9	2	—	—	—	—	—	—	—	—
177	172	162	134	94	53	23	6	—	—	—	—	—
339	346	326	290	249	194	144	95	53	25	10	4	3
439	421	413	389	332	284	233	198	158	106	62	48	43
431	431	410	376	342	307	259	204	177	134	100	74	66
255	346	348	313	276	255	214	174	115	90	67	55	53

Table IV

Hornsund in 1980

Hour												
12	13	14	15	16	17	18	19	20	21	22	23	24
118	115	117	110	94	75	61	43	23	13	8	4	2
99	99	93	79	74	59	36	25	14	3	−3	−7	−8
55	53	50	45	34	19	6	−4	−10	−12	−13	−14	−15
−19	−17	−18	−22	−25	−28	−27	−28	−28	−28	−28	−27	−27
−32	−35	−36	−36	−34	−37	−38	−37	−38	−36	−33	−33	−33
−34	−34	−33	−35	−36	−35	−35	−35	−34	−32	−31	−33	−33

arcs of the Sun proceed here over the often high-situated glaciers and moraines, from which volatile powdered material, the source of aerosol decreasing the translucency of the air, is blown out.

The magnitude of the intensity of the net radiation, and also its sing (positive or negative), is affected by the time-differentiated structure of the particular components which make it up. It follows from Table IV that in July (polar day), the net radiation is positive throughout the 24 hours, while the magnitude of its intensity is determined above all by the continuous and high, particularly at noon, supply of the solar radiation energy. Between 9 and 15 hours, the net radiation exceeds 100 Wm^{-2}.

The 24-hour behaviour of the intensity of the net radiation in August and September reflects distinctly the respective changes in the incidence

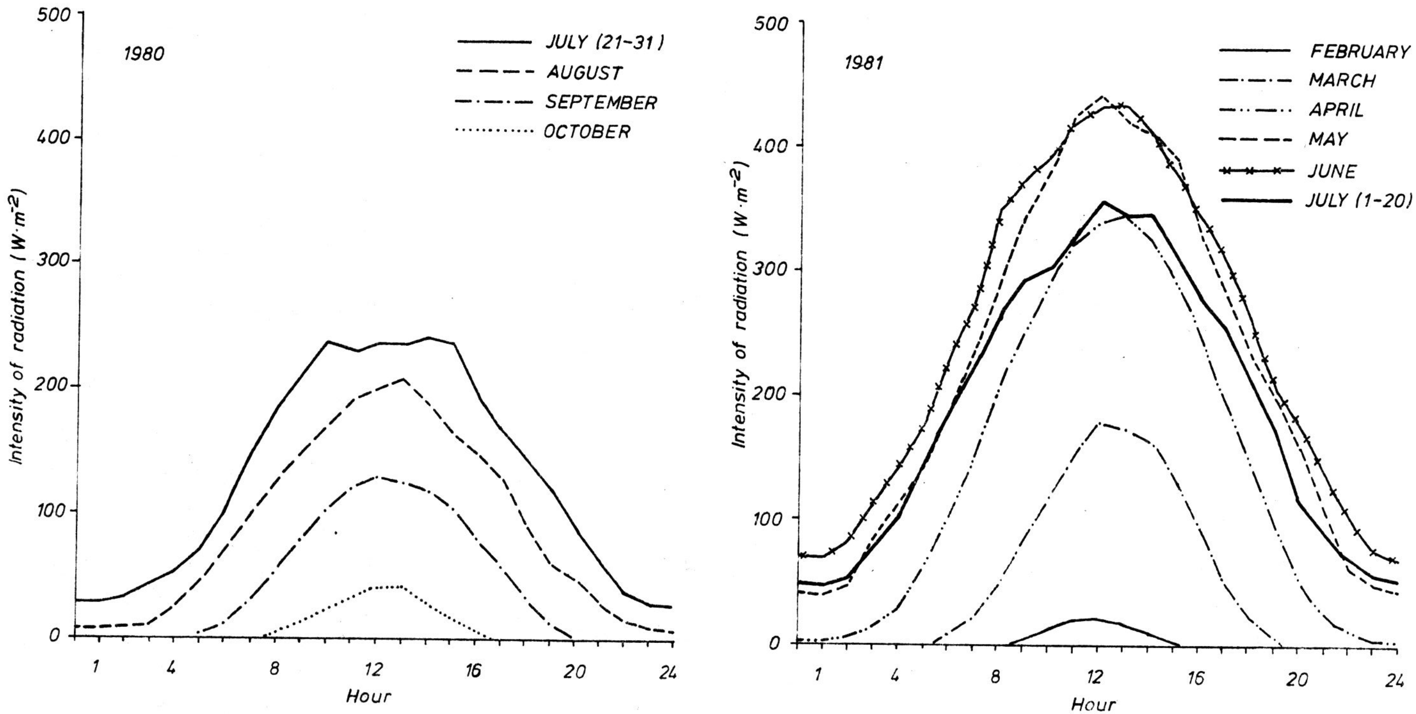

Fig. 2. Daily behaviour of the intensity of the total radiation at Hornsund in successive months of 1980 and 1981

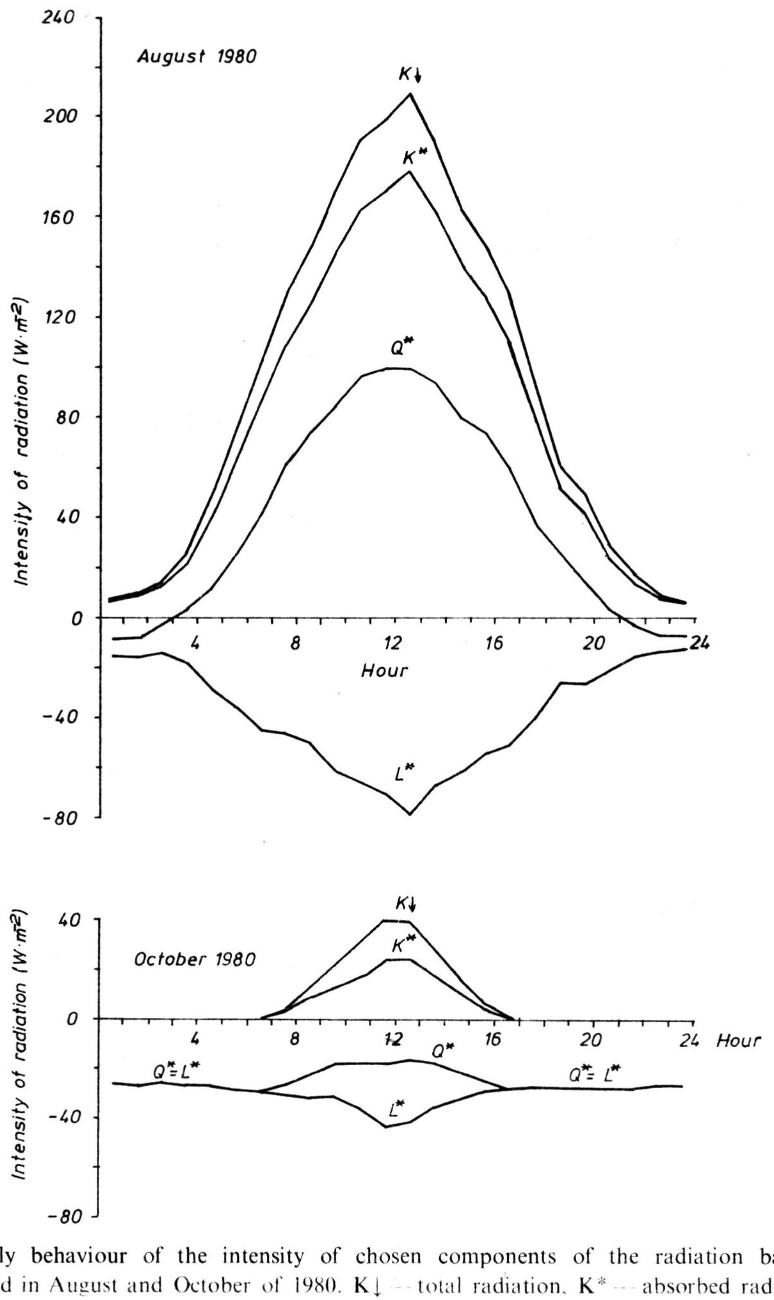

Fig. 3. Daily behaviour of the intensity of chosen components of the radiation balance at Hornsund in August and October of 1980. K↓ — total radiation, K* — absorbed radiation, L* — net longwave radiation, Q* — net radiation

angle of solar rays and the durations of the day and night parts of the 24-hours (Fig. 3, Table IV). During the day, the net radiation is positive, and it is negative at night.

In October, the surface of the tundra in the Hornsund area loses energy already during the whole 24-hours (Fig. 3). The supply of solar raaıa..ɔn, limited to a few hours about the noon, does not have a deciding effect on the formation of the magnitude of the intensity of the net radiation.

During the first part of the polar night (November, December), the intensity of the net radiation varies between $-31\ Wm^{-2}$ and $-38\ Wm^{-2}$ (Table IV), while its 24-hour behaviour is regular.

3.2. Sums of the components of the radiation balance

The yearly sum of the total radiation at Hornsund, from 21 July, 1980, to 20 July, 1981 (Table V), reached 2611 MJm^{-2} (725 $kWhm^{-2}$) (1 $kWhm^{-2}$ = 3.6 MJm^{-2} = 86 cal cm^{-2}). The respective magnitude of insolation in Poland (Kołobrzeg) is 3756 MJm^{-2} $year^{-1}$ (Podogrocki 1970).

Table V

Monthly and yearly sums of the total radiation ($MJ \cdot m^{-2}$) in Spitsbergen in the particular research period

Month	Hornsund 1980/1981	Hornsund 1957/1958*)	Isfiord Radio 1951 — 1960**)
August	246	280	276
September	115	63	115
October	20	17	15
February	4	4	2
March	139	96	88
April	380	285	311
May	605	423	488
June	640	398	512
July	462	353	462***)
Yearly sum	2611	1919	2236

*) acc. to Ba8
) acc. to Baranowski 1968
**) acc. to Sprinnangr 1968
***) sum of the 3rd decade of July 1980 and 1st — 2nd decades of July 1981

Table V also gives, for comparison, the yearly and monthly values of insolation for Hornsund in the period of the International Geophysical Year and for the Isfiord Radio ($\varphi = 78°N$, $\lambda = 14°E$). The differentiation shown here results above all from the different conditions of atmospheric radiation transmission within the particular research periods.

The coefficient of the atmospheric transmission, giving information on the part of insolation at the ground surface in the supply of solar radiation to the top of the atmosphere, was at Hornsund: 45% for the period 1980/1981, and 33% for 1957/1958. At the Isfiord Radio its ten-year mean (1951—1960) was 56% (Spinnangr 1968).

The data from the research period 1980/1981 indicate that the yearly behaviour of the 24-hour sums of the total radiation at Hornsund do not always correspond to the general trend in the changes of extraterrestrial radiation (Fig. 4). The particularly high radiation loss in the atmosphere, brought about particularly by absorption and reflection from clouds, occur in some decades of the summer and autumn seasons. The lowest coefficients of the atmospheric transmission in a year come in the second decade of August (22%) and the third decade of September (19%). They are the periods of the highest degree of cloudiness in a year (93—94%).

Spring and the early summer are the favourable seasons in terms of the conditions of solar energy supply. The third decade of April is distinct here, when the active surface is reached by as much as 72% of extraterrestrial radiation. The 24-hour sums of the total radiation in this decade are not, however, among the highest in a year (Fig. 4), in view of the relatively low heights of the Sun over the horizon and the rather short period of insolation.

The highest mean monthly 24-hour sums of the total radiation (Table VI) occur in June (21.3 MJm^{-2}). In North Poland (Kołobrzeg), in June the mean 24-hour sum of the total radiation is 21.6 MJm^{-2} (Podogrocki 1970).

In the yearly research period 1980/1981, the surface of the tundra and the snow cover in the area of the Polish Polar Station at Hornsund absorbed only 41% (1060 MJm^{-2} $year^{-1}$) of the energy of the incoming solar radiation. The remaining 59% (1551 MJm^{-2} $year^{-1}$) is the loss caused by reflection (albedo). A similar yearly value of the albedo (55%) was found in the tundra zone of Alaska (Maykut and Church 1973).

The highest sums of absorbed radiation (Table VI) occur in the early summer just after (the show cover has melted). The mean 24-hour sum in the second decade of July, 1981, is 15.0 MJm^{-2}, i.e. as much as 89% of the energy of the total radiation.

Throughout the summer season, the mean values of the tundra albedo vary between 11 and 16% (Fig. 4).

In spring (March — May), when the underlying surface of the atmosphere is snow cover, the albedo is characterized by high and little variable values (80—89%). In turn, in February the albedo exceeds 90%, which results above all from the low incidence angle of solar rays.

The measurement data gathered in the course of the expedition permits an analysis to be carried out for the formation of the net radiation sums only from July to December.

It follows from the data contained in Table VII that from 21 July

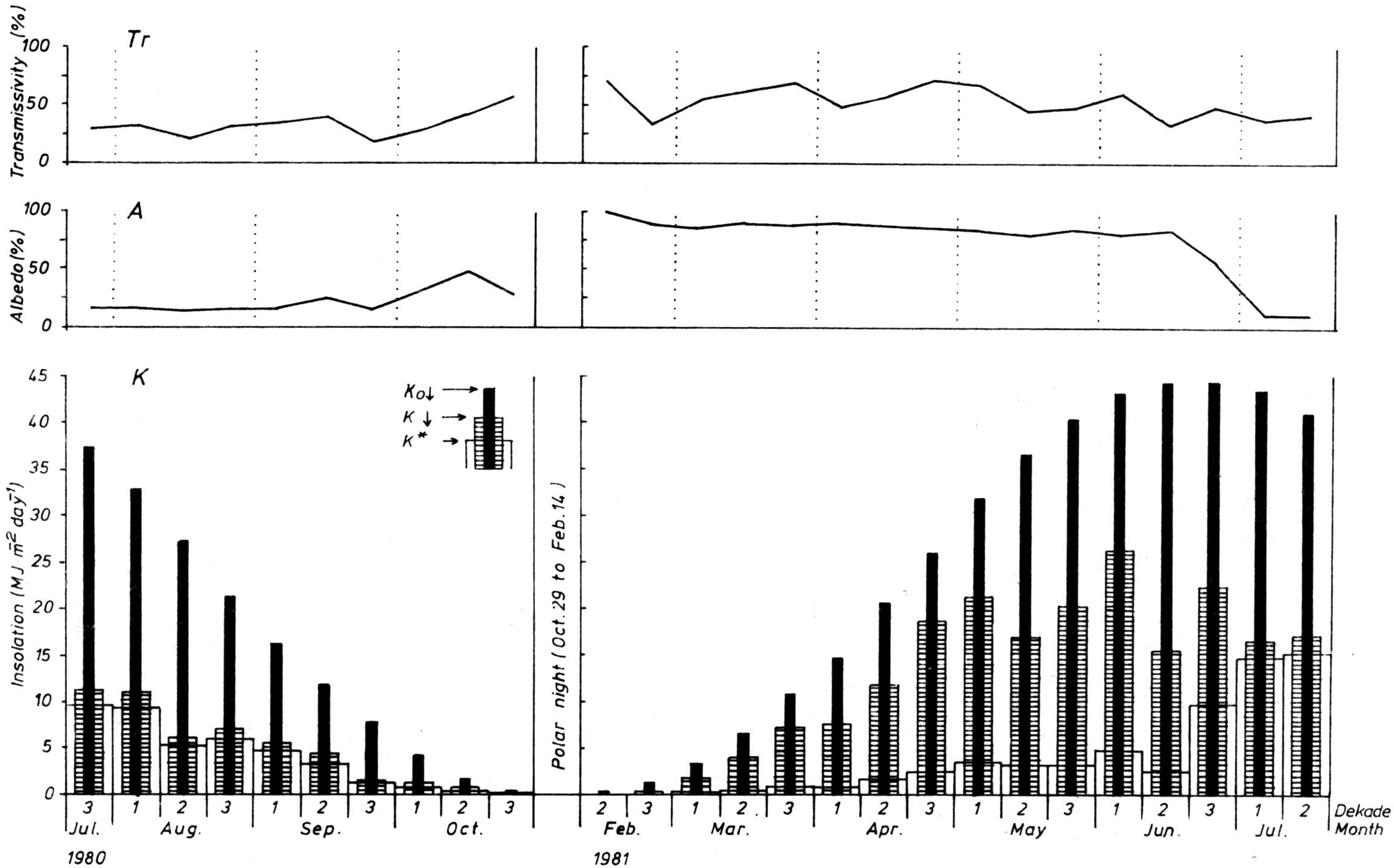

Fig. 4. Mean 24-hour sums of solar radiation at the top of the atmosphere and the ground surface (K) and the albedo (A), and the coefficient of the atmospheric transmission (Tr) at Hornsund for successive decades of the research period 1980/1981. $K_o\downarrow$ extraterrestrial radiation $K\downarrow$ — total radiation (at the gound surface), K^* — radiation absorbed by the active surface

Table VI

Characteristic values of the 24-hour sums of solar radiation ($MJ \cdot m^{-2}$ 24-hours^{-1}) at Hornsund in the research period 1980/1981

Month	Total radiation				Reflected radiation				Absorbed radiation				Number of measurement days
	$\bar{X}$	S.D.	max	min	$\bar{X}$	S.D.	max	min	$\bar{X}$	S.D.	max	min	
July 1980*)	11,3	5,6	22,8	4,2	1,8	0,8	3,6	0,5	9,5	4,8	19,2	3,7	11
August	7,9	4,7	18,2	1,7	1,2	0,8	3,0	0,1	6,7	3,9	15,2	1,5	31
September	3,8	1,5	9,9	0,1	0,7	0,6	1,9	0,0	3,1	2,4	8,0	0,1	30
October	0,8	0,5	1,8	0,1	0,3	0,3	1,2	0,0	0,5	0,4	1,4	0,0	28
February	0,3	0,2	0,8	0,0	0,3	0,2	0,7	0,0	0,0	0,0	0,2	0,0	14
March	4,5	2,7	11,4	1,2	4,0	2,3	9,1	1,1	0,5	0,5	2,3	0,1	31
April	12,7	5,4	21,4	4,0	11,0	4,6	18,8	3,8	1,7	0,8	3,0	0,2	30
May	19,5	6,7	29,2	7,2	16,1	5,5	24,1	5,5	3,4	1,5	7,8	1,0	31
June	21,3	6,1	30,3	7,4	15,6	5,4	24,6	5,1	5,7	4,0	17,3	0,9	30
July ***)	16,9	6,4	31,3	9,4	1,9	1,2	5,8	0,7	15,0	5,2	26,1	8,7	20

$\bar{X}$ — Arithmetic mean
S.D. — Standard deviation
*) — between 21 and 31 July
**) — between 29 October and 14 February no incoming solar radiation
***) — between 1 and 20 July

Table VII

Characteristic values of the 24-hour sum of the net radiation ($MJ \cdot m^{-2}$ 24 $hours^{-1}$) at Hornsund in 1980

Month	X̄	S.D.	max	min	Number of measurement days
July*)	5,1	2,6	10,9	2,0	11
August	3,4	1,9	7,1	0,7	31
September	1,0	1,0	2,8	−1,0	30
October	−2,2	1,5	0,2	−5,2	31
November	−2,9	1,6	0.0	−4,8	30
December	−2,9	1,2	−0,5	−4,7	31

X̄ — arithmetic mean
S.D. — Standard deviation
*) — between 21 and 31 July

to the end of September, positive 24-hour sums of the net radiation dominate. The joint sum for the whole period was 189 MJm^{-2}, as an result of the contribution of the energy gain in the form of net shortwave radiation (the radiation absorbed by the tundra) with the value of 407 MJm^{-2} and the loss by way of effective radiation, reaching together 218 MJm^{-2}.

In October, the low energy gain from the radiation absorbed by the tundra (12 MJm^{-2} $month^{-1}$) does not compensate for the considerable loss resulting from the net longwave radiation −79 MJm^{-2} $month^{-1}$). As a consequence, the net radiation is −67 MJm^{-2} $month^{-1}$. The large energy loss by way of effective radiation (up to 5.8 MJm^{-2} 24 $hours^{-1}$) is related above all to a relatively low degree of cloudiness (Fig. 5) and also to the low content of steam in the air.

The sum of the net radiation over the period of the two initial months of the polar night (November — December) is — 177 MJm^{-2}. The 24-hour sums do not yet reach positive values, an effect of which is the systematic cooling of the surface of the tundra (Fig. 5), stopped periodically in the course of the intense advection of warm air from the lower latitudes.

The Author wishes to thank Mrs. Danuta Wielbińska, M.Sc., for the initiative of taking the subject, Dr. Janusz Podogrocki for the preparation of the measurment devices and to Mr Antoni Barański, M. Sc., for assistance in carrying out the actinometric measurements in Spitsbergen.

4. Conclusions

4.1. The most outstanding feature of the climate of the Hornsund area is the very distinct seasonality of the structure of the radiation balance, resulting from the position in the polar zone. A deciding role

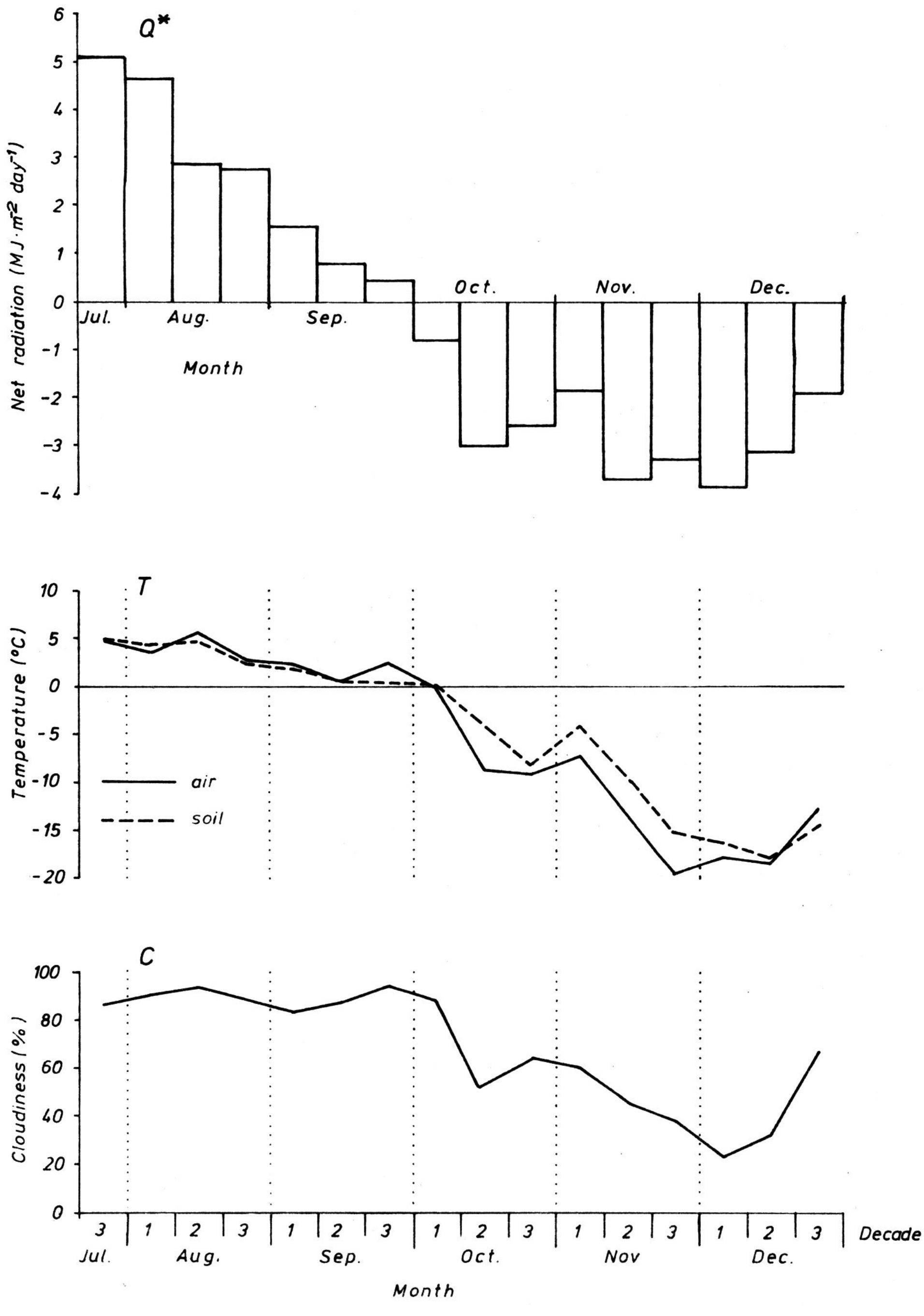

Fig. 5. Mean 24-hour sums of the net radiation (Q*), mean 24-hour air temperatures and those of the soil surface (T) and the mean degree of cloudiness (C) at Hornsund for successive decades between 21 July — 31 December 1980

in this is played by astronomical elements (the duration of the insolation period and the height of the Sun over the horizon).

4.2. The effect of local climate conditions is reflected here in the very low values of the yearly sums of the total radiation. They are recognized to be among the lowest on the Earth (Baranowski 1968).

4.3. The effect of the underlying surface of the atmosphere is conspicuous mainly in the considerable seasonal differentiation of the radiation absorbed by the active surface.

4.4. The results presented here can be used in the interpretation of temperature changes in the surface layer of the tundra and the atmosphere layer adjacent to it.

4.5. The elaboration of a full characteistic of the radiation climate of the Hornsund area requires at least a 10 — year series of observation data from different polar environments.

5. Резюме

В период от 21 июля 1980 до 20 июля 1981 года возле Польской полярной станции в Горнзунде проводились систематические актинометрические измерения.

Из полученных данных следует, что основным фактором, определяющим структуру радиационного баланса поверхности тундры и снежного покрова, являются, особенные в полярной зоне, годовые и суточные изменения продолжительности инсоляции и высоты солнца (фиг. 1, табл. 1). Максимальная измеренная величина потока прямой солнечной радиации сотавляла 822 $W m^{-2}$. При самых больших углах падения солнечных лучей почти половина (41—44%) энергии прямой радиации заключается в видимой области спектра (таблица II).

Максимальные средние часовые величины потока прямой солнечной радиации наблюдаются в часах около полдня (фиг. 2, табл. III) и в мае достигают 439 $W m^{-2}$.

Радиационный баланс только в июле является положительным в течение целых суток (таблица IV, фиг. 3). В течение полярной ночи суточный ход радиации является ровным а величины потока радиации умещаются в границах от -31 $W m^{-2}$ до -38 $W m^{-2}$.

Годичная сумма суммарной радиации составляет 2611 $MJ m^{-2}$ (таблица V) из чего только 41% поглощает подстилающая поверхность. В отношении притока солнечной энергии привилегированным периодом является весна и начало лета, когда до подстилающей поверхности достигает в некоторых декадах даже 72% радиации на верхней границе атмосферы (фиг. 4). Найболее крупные суммы радиации поглощаются подстилающей поверностью ранним летом (таблица VI). Во второй декаде июля они составляют 89% энергии суммарной радиации.

Летом и в течение всего сентября преобладают положительные суточные суммы радиационного баланса (таблица VII, фиг. 5). Сумма радиационного баланса в период двух первых месяцев полярной зимы (ноябрь-декабрь) составляет -177 $MJ m^{-2}$.

6. Streszczenie

W okresie od 21 lipca 1980 do 20 lipca 1981 roku prowadzono systematyczne pomiary aktynometryczne w otoczeniu Polskiej Stacji Polarnej w Hornsundzie.

Z otrzymanych danych wynika, że podstawowym czynnikiem, określającym strukturę bilansu promieniowania powierzchni tundry i pokrywy śnieżnej są, osobliwe dla strefy polarnej, roczne i dobowe zmiany czasu trwania insolacji i wysokości słońca (Fig. 1, Tablica I). Maksymalna znierzona wielkość natężenia promieniowania bezpośredniego wynosiła 822 $W \cdot m^{-2}$. Przy najwyższych kątach padania promieni słonecznych, niemal połowa (41—44%) energii promieniowania bezpośredniego przypada na zakres widma widzialnego (Tablica II). Maksymalne średnie godzinne wartości natężenia promieniowania całkowitego występują w godzinach okołopołudniowych (Fig. 2, Tablica III) i dochodzą w maju do 439 $W \cdot m^{-2}$. Całkowity bilans promieniowania tylko w lipcu jest dodatni w ciągu całej doby (Tablica IV, Fig. 3). W okresie nocy polarnej jego przebieg dobowy jest wyrównany, a wartości natężenia mieszczą się w granicach od -31 $W \cdot m^{-2}$ do -38 $W \cdot m^{-2}$.

Suma roczna promieniowania całkowitego wynosi 2611 $MJ \cdot m^{-2}$ (Tablica V) z czego tylko 41% pochłania powierzchnia czynna. Uprzywilejowanym okresem pod względem dopływu energii słonecznej jest wiosna i początek lata, kiedy to do powierzchni czynnej dociera w niektórych dekadach aż 72% promieniowania pozaatmosferycznego (Fig. 4). Najwyższe sumy promieniowania pochłoniętego przez powierzchnię czynną przypadają na wczesne lato (Tablica VI). W 2 dekadzie lipca stanowią one 89% energii promieniowania całkowitego.

W okresie lata i przez cały wrzesień dominują dodatnie sumy dobowe całkowitego bilansu promieniowania (Tablica VII Fig. 5). Suma całkowitego bilansu promieniowania za okres dwóch pierwszych miesięcy nocy polarnej (listopad — grudzień), wynosi — 177 $MJ \cdot m^{-2}$.

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