PROPERTIES OF THE SURFACE RADIATION BUDGET
AT MIZUHO STATION, ANTARCTICA IN 1979
(EXTENDED ABSTRACT)

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Within the framework of the Japanese Polar Experiment (POLEX-South) (KAWAGUCHI, 1978; KUSUNOKI, 1981), radiation budget measurements were made at Mizuho Station (70°42′S, 44°20′E, 2230 m a.s.l.), East Antarctica for three years since February 1979. Global and reflected shortwave radiation as well as downward and upward longwave radiation were measured at the height of 1.5 m above the snow surface and at the top of a 30 m tower. Direct solar radiation was also measured at the snow surface. Details of the installation of the measurement system (MAE *et al.*, 1981) and calibration of the sensors (YAMANOUCHI *et al.*, 1981a) have already been reported and the basic data of radiation components were published by YAMANOUCHI *et al.* (1981b) and ISHIKAWA *et al.* (1982a).

In the present paper, major properties of components of the surface radiation budget are outlined from the data measured in 1979. The radiation climate of Mizuho Station was already discussed by YAMANOUCHI *et al.* (1982), compared to that of the other Antarctic stations.

1) Properties of shortwave radiation

The albedo of the snow surface was very high and was about 80–82% on an average. Under the overcast sky, the albedo increased to more than 86% on a daily average. The albedo showed a strong dependence on the solar zenith angle, and became large when the solar elevation decreased, just as expected from the theoretical calculations (WISCOMBE and WARREN, 1980). The snow albedo also depended strongly on the wavelength; the albedo was more than 95% for 0.3–0.7 μm and less than 70% for 0.7–2.8 μm.

Because of the low density of atmospheric molecules on account of the high altitude of the station, small amount of aerosols ($\beta \leq 0.01$) (YAMANOUCHI, 1982) and small amount of water vapor content (YAMANOUCHI and WADA, 1981), the depletion of direct solar radiation was small.

In spite of the above statement, the diffuse component of global radiation was unexpectedly large, more than 70 W/m² at 30° of solar elevation as shown in Fig. 1. Amounts of diffuse radiation due to Rayleigh scattering at sea level are also shown in the figure for the cases of surface albedo 0 and 80%, respectively. On account of the high surface albedo, Rayleigh scattering for 80% albedo increased to become
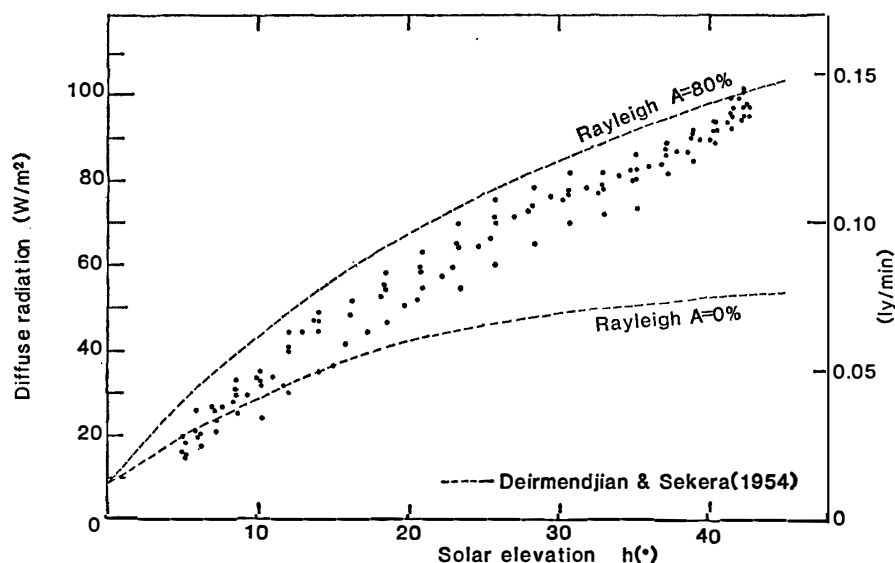
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Fig. 1   Diffuse radiation flux at Mizuho Station and theoretical estimates of
Rayleigh scattering at sea level by DEIRMENDJIAN and SEKERA (1954).

twice as large as that for 0% albedo. This was owing to the multiple reflection by
the snow surface and atmospheric layer. Rayleigh scattering at Mizuho Station was
expected to be about three fourths of that at sea level, a little smaller than the
measured diffuse components. This expected difference is explained by the scattering
due to aerosols.

The influence of cloud cover in reducing the global radiation was small on
account of multiple reflection of transmitted radiation between the snow surface
and the cloud base, just as expected from the foregoing paragraph, and also as
pointed out by KAWAGUCHI and SASAKI (1975). For the altostratus, one of the
thickest clouds observed at Mizuho, the global radiation amounted to about 67%
of that for a clear sky at the solar elevation of 30°. At normal places of low
albedo, the corresponding decrease of the global radiation was much more serious
than at Mizuho; it amounted to 30–40% of that for a clear sky (KONDRATYEV,
1969).

Four pronounced properties stated above for Mizuho Station hold also at other
inland stations, such as Plateau (79°15′S, 40°30′E, 3630 m a.s.l.; KUHN et al.,
1977) and Pionerskaya (69°44′S, 95°30′E, 2700 m a.s.l.; RUSIN, 1964) where the
snow cover constantly exists; however, they do not hold in the summer season at
Syowa Station (69°00′S, 39°35′E, s.l.; KAWAGUCHI, 1979) where the snow cover
disappears.

2)   Properties of longwave radiation

The influence of clouds was very large, acting to increase the downward long-
wave radiation L_d. In the winter season under thick clouds, L_d occasionally doubled
compared to its value for clear sky, and amounted to about L_u.

The effect of the surface inversion is clearly illustrated in Fig. 2. In order to
express the cooling effect by the longwave radiation at various places or seasons of
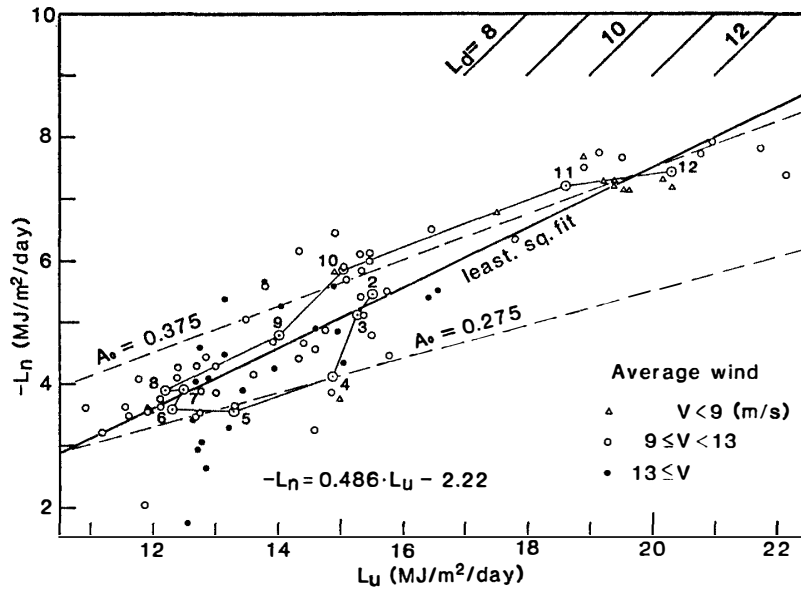
Fig. 2. Diagram of daily net longwave flux L_n against L_u and L_d (only for clear days).

diverse temperature, the Ångström ratio,

$$A_0 = -\frac{L_n}{L_u} = 1 - \frac{L_d}{L_u},$$

was introduced, where L_n, L_d and L_u are the net, downward and upward longwave radiations, respectively. In the figure, the variation along the line with constant A_0 means that the ratio of L_d to L_u is constant, and transition to the region of small A_0 means that L_u decreases more rapidly than L_d, namely, the inversion was strengthened. In the figure, the inversion is strong from April (4) to July (7) and weak from October (10) to December (12).

At Mizuho Station, drifting snow was occasionally high on account of high wind speed, and its effect on the longwave radiation appeared when the wind speed became higher than about 13–14 m/s and the visibility became lower than about 100 m. Drifting snow made L_d large and A_0 small at 1.5 m height. However, the effect at 30 m height was negligible and led to the difference of L_d with the height. This situation corresponds to the drifting density of the order of 1 g/m³ (BUDD et al., 1966) and this drifting density will be realized at 10 cm height with a wind of 10 m/s which is usual at Mizuho. The effect of drifting snow cannot be neglected in the radiation budget at the real surface.

The amount of water vapor in the atmosphere was small to contribute to L_d. Especially in the winter season, the contribution was not apparent on account of the large effect of the surface inversion. However, in the season of weak inversion, the contribution of water vapor amount was distinct and approximated by an empirical formula.

Causes of pronounced properties of longwave radiation at Mizuho Station stated above varied according to the seasons and were not always common among the inland stations. At Plateau Station, where the average wind speed was low and

the surface inversion was much stronger than at Mizuho Station, the absolute value of L_n was as small as 15 W/m^2 in winter, and the seasonal variation was proportional to that at Mizuho (Table 1). Pionerskaya Station was also in the katabatic wind zone, as Mizuho was, and L_n was similar in winter. However, the seasonal trend of L_n was different from that at Mizuho, and L_n in summer was about a half of L_n at Mizuho.

3) Total radiation balance

The daily variation of the net radiation was due mainly to the variation of cloud cover. The net radiation would shift to a positive direction by clouds as the results of shortwave and longwave properties. Daily amounts of net radiation remained negative throughout the year on clear days, and whether the monthly

Table 1. Monthly average radiation fluxes at four stations, Antarctica (W/m^2).

Station		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Syowa (1967–1968) (KAWAGUCHI, 1979)	S_d	291	187	84	27	3	0	0	12	74	170	284	339	122
	S_u	79	47	29	9	1	0	0	1	53	103	134	141	50
	S_n	212	140	55	18	2	0	0	11	21	67	150	198	72
	L_d	250	242	245	232	226	211	197	203	184	202	231	247	222
	L_u	312	296	289	274	264	252	241	242	236	261	291	308	271
	L_n	-62	-54	-44	-42	-38	-41	-44	-39	-52	-59	-60	-61	-49
	R_n	150	86	11	-24	-36	-41	-44	-28	-31	8	90	137	23
Mizuho (1979) (Present work)	S_d		(206)	120	29	2	0	0	13	75	196	324	417	(121)
	S_u		(170)	96	21	1	0	0	10	60	160	267	342	(98)
	S_n		(37)	23	8	1	0	0	3	15	37	58	77	(23)
	L_d		(159)	154	158	132	127	128	128	131	131	162	166	(142)
	L_u		(203)	188	183	163	158	159	160	170	187	222	243	(184)
	L_n		(-44)	-35	-25	-31	-30	-31	-33	-39	-56	-61	-77	(-42)
	R_n		(-7)	-11	-17	-30	-30	-31	-30	-23	-19	-2	0	(-19)
Pionerskaya (1956–1958) (RUSIN, 1964)	S_d	367	244	128	35	2	0	0	10	75	187	314	378	145
	S_u	300	202	107	30	2	0	0	8	73	163	271	319	123
	S_n	67	42	21	5	0	0	0	2	2	24	43	59	22
	L_d	179	143	136	142	134	116	123	118	131	139	163	190	143
	L_u	222	191	174	171	159	142	148	145	156	171	194	222	175
	L_n	-43	-48	-38	-29	-26	-26	-26	-27	-26	-32	-32	-32	-32
	R_n	24	-6	-71	-24	-25	-26	-26	-25	-24	-8	11	27	-10
Plateau (1967) (KUHN et al., 1977)	S_d	381	239	81	7	0	0	0	1	38	166	348	454	143
	S_u	314	206	70	6	0	0	0	1	31	147	302	372	120
	S_n	68	34	12	1	0	0	0	0	7	19	46	82	22
	L_d	119	108	94	75	93	81	96	75	85	86	113	119	95
	L_u	175	143	117	92	109	94	112	90	107	119	158	187	125
	L_n	-55	-36	-23	-17	-16	-13	-16	-16	-22	-34	-45	-69	-30
	R_n	13	-2	-11	-17	-16	-13	-16	-15	-15	-15	1	13	-8

( ): after February 18.

amounts became positive or negative depended on the cloud amount (YAMANOUCHI *et al.*, 1981a; ISHIKAWA *et al.*, 1982b).

As shown in Table 1, the amounts of net radiation R_n for the four stations were in line with the height of the stations or average air temperature. However, in summer, the relationship in winter months did not hold on account of different conditions which occurred at each station, such as disappearance of snow cover at Syowa Station, large amount of L_d at Pionerskaya Station, and so on. Mizuho Station lies in an area of large radiation cooling in Antarctica.

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(Received May 20, 1982)