SOME RADIATION PROPERTIES AT MIZUHO STATION, EAST ANTARCTICA IN 1980

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Abstract: Measurements of radiation components were carried out at Mizuho Station in a period from 1979 to 1981, selecting the heights 1.0 and 30 m (the top of a meteorological tower), as a part of the Polar Experiment in Antarctica (POLEX-South), with the following findings on radiation properties from data obtained in 1980: The annual mean value of net radiation was about −26 ly/day (−1.1 MJ/m^2·day). Concerning the amount of outgoing long-wave (terrestrial) and incoming long-wave (atmospheric) radiation, the former was expressed by the temperature near the snow surface with adequate accuracy; the latter was fairly sensitive to the cloud amount; a difference in the latter between two different heights was much greater than that in the former, especially in the austral winter. Finally the presence of a surface temperature inversion had some influences on the atmospheric radiation.

1. Introduction

Extensive studies have been done on the radiation budget of Antarctica, *e.g.* by LILJEQUIST (1956), DALRYMPLE *et al.* (1963), KUHN *et al.* (1977), WELLER (1968) and CARROLL (1982), their results having been obtained mainly in the coastal or interior regions of the continent. On the other hand radiation measurements on the continental slope are few, where the meteorological condition is characterized by the katabatic wind with continuous drifting snow and surface temperature inversion. With an elevation of 2230 m above sea level, Mizuho Station (70.7°S, 44.3°E) is located on the continental slope in a typical katabatic wind zone in East Antarctica. At this station the program of POLEX-South, which was described by KUSUNOKI (1981) and KOBAYASHI *et al.* (1982), was carried out from February 1979 to December 1981 by the members of the Japanese Antarctic Research Expedition (JARE-20–JARE-22). Under this program the present research was pursued by making measurements of the amounts of radiation components with a view to studying the radiation budget as well as the effect on it of drifting snow and surface temperature inversion. YAMANOUCHI *et al.* (1981, 1982) reported time variations of radiation components in 1979. The present paper describes some properties of the radiation at Mizuho Station by using the data in 1980.

2. Instrumentation and Calibration

The spectral measurements of the global and reflected solar radiation which were carried out in 1979 were omitted in 1980, but other components of radiation were measured in the same way as was established by the members of JARE-20 in 1979. Namely, incoming and outgoing short-wave and long-wave radiation were

Table 1. Observed quantities items and instruments.

Height	Item	Instrument		
1.0 m	Incoming short-wave radiation	Pyranometer	EKO MS-800	No. F78511
	Outgoing short-wave radiation	Pyranometer	ECO MS-800	No. F78502
	Incoming long-wave radiation	Pyrgeometer	Eppley PIR	No. 17372F3
	Outgoing long-wave radiation	Pyrgeometer	Eppley PIR	No. 17366F3
30 m	Incoming short-wave radiation	Pyranometer	EKO MS-800	No. F78508
	Outgoing short-wave radiation	Pyranometer	EKO MS-800	No. F78512
	Incoming long-wave radiation	Pyrgeometer	Eppley PIR	No. 17374F3
	Outgoing long-wave radiation	Pyrgeometer	Eppley PIR	No. 17375F3

obtained by using pyranometers and by pyrgeometers at two different heights (1.0 and 30 m) above the snow surface, respectively. The sensors used in the observations of 1980 are listed in Table 1. A detailed description of the methods of radiation measurement and the calibration of the pyranometers and pyrgeometers have been given by YAMANOUCHI *et al.* (1981). Calibration of the pyranometer is affected by the following factors; temperature, incident solar angle, aging-response, and spectral dependence (MIYAKE *et al.*, 1979). The total error due to these factors is said to be at most ±2.5% for the present pyranometer model MS-800. As the incident solar angle becomes low (below 15°), the sensitivity of the pyranometer becomes poor, but heat energy is small at such a low solar angle. For the present analysis of the short-wave radiation, the sensitivity constants of pyranometers specified by the manufacturer were used.

Meanwhile, for the incoming long-wave radiation, a pyrgeometer at a height of 1.0 m was fitted with a shading ring in order to eliminate the heating effect of the hemispherical dome due to direct solar radiation. But the pyrgeometer at a height of 30 m was not fitted with one; therefore, the correction factor proposed by YAMANOUCHI *et al.* (1981) was used.

3. Observational Results

3.1. Daily and seasonal variations of radiation components

Figure 1 shows daily variations of the long-wave and net radiation at the height

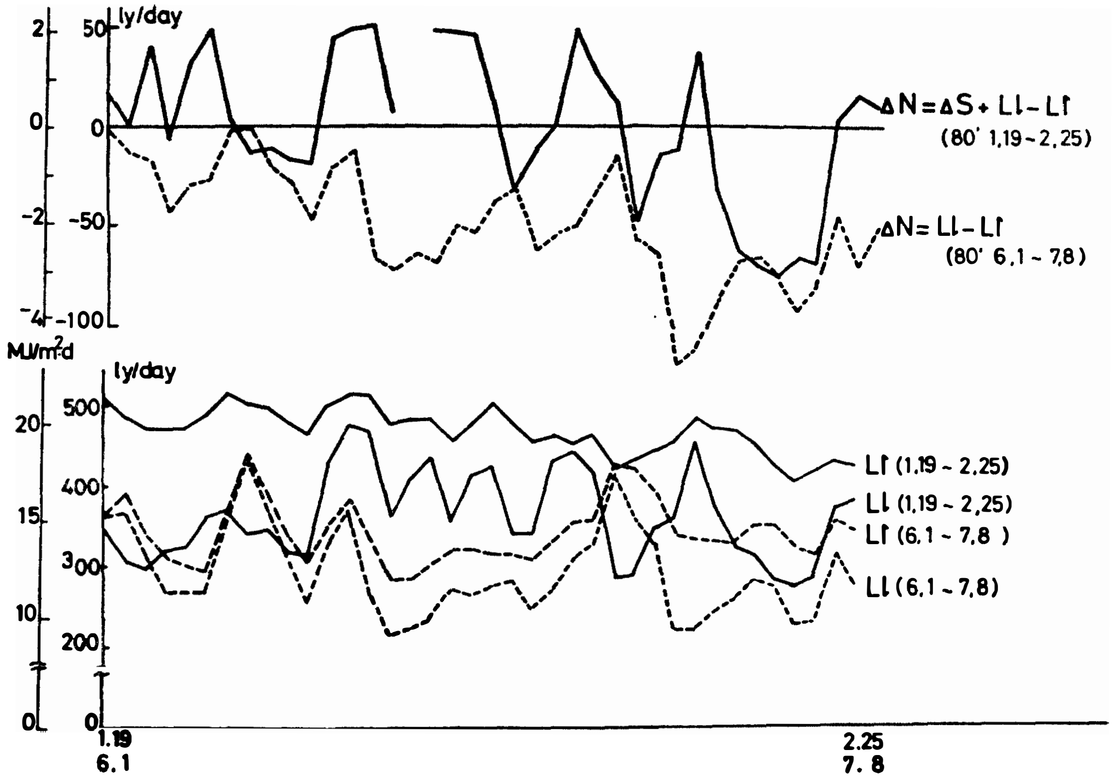

Fig. 1. Daily variations of net and long-wave radiation at the surface of Mizuho Station in austral summer and winter in 1980.

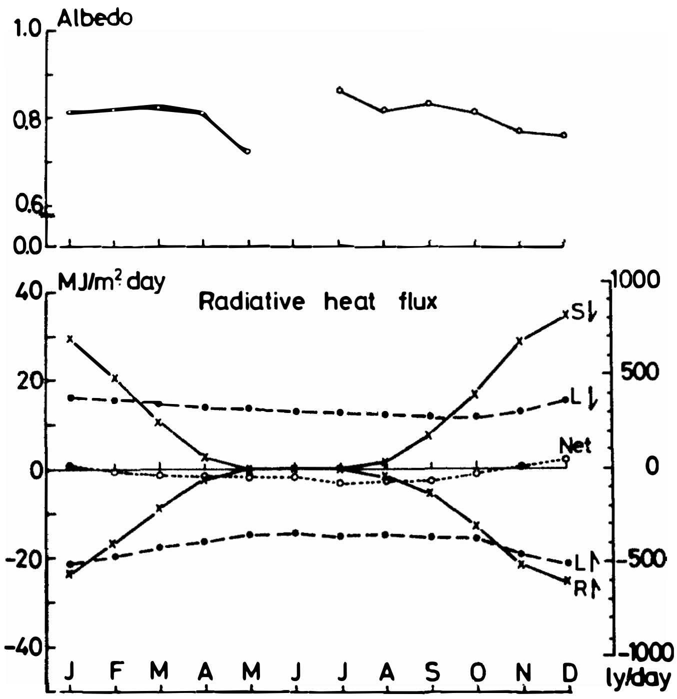

Fig. 2. Monthly means of radiation components at the surface of Mizuho Station in 1980.

of 1.0 m in the austral summer and winter in 1980. The amount of the incoming long-wave radiation ($L\downarrow$) is lower than that of the outgoing long-wave radiation ($L\uparrow$) in both seasons. A comparison between the amount of incoming and outgoing long-wave radiation shows that the former is more changeable than the latter. Each is larger in summer than the value in winter.

Figure 2 shows the monthly means of radiation components as well as surface albedo obtained at the surface. The maximum values of every component appear in December. The short-wave radiation varies in such wide ranges as 850–0 ly/day (35.6–0 MJ/m^2·day) for the incoming and 610–0 ly/day (25.6–0 MJ/m^2·day) for the reflected. The surface albedo is around 0.8, but it is slightly reduced after winter due to the formation of sastrugi under the pyranometer with its face downward. Compared with variations of the short-wave radiation, seasonal variations of the incoming and the outgoing long-wave radiation are small throughout the whole year, namely, 400–270 ly/day (16.8–11.3 MJ/m^2·day) for the incoming and 500–350 ly/day (21.0–14.7 MJ/m^2·day) for the outgoing. Figure 2 also shows mean values of net radiation, which have negative values except in the austral summer.

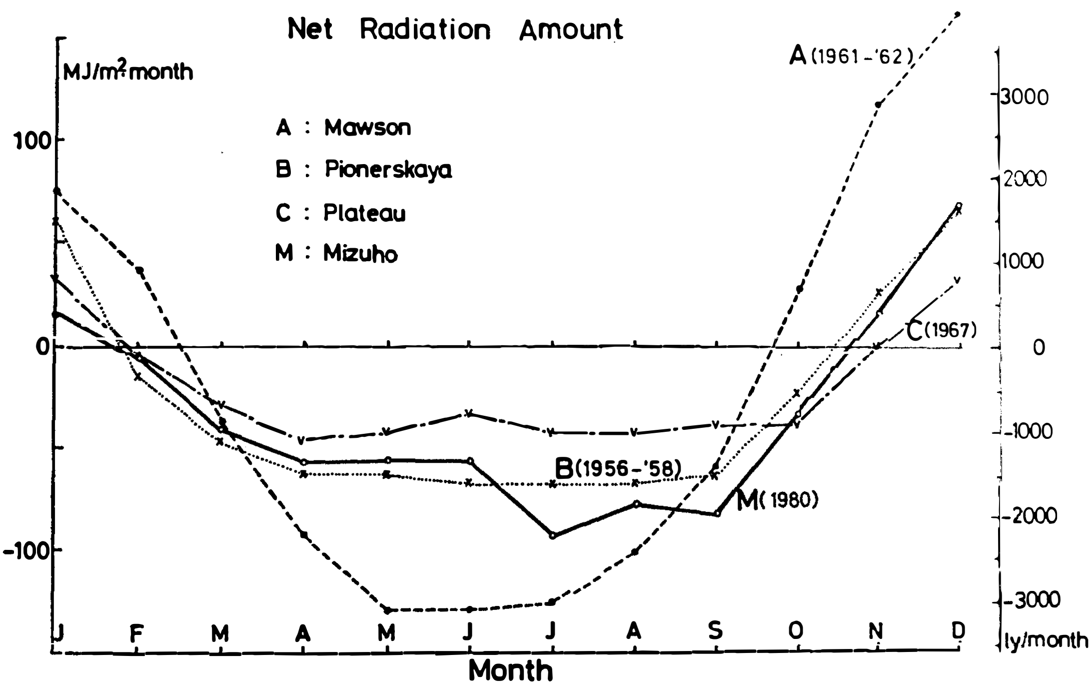

Fig 3. Comparison of net radiation at Mizuho with three other Antarctic stations.

Table 2. Meteorological stations in Antarctica.

Symbol	Station	Long.	Lat.	Elevation (m)	Period
A	Mawson	62. 9°E	67. 6°S	8	1961–1962
B	Pionerskaya	95. 5°E	69. 7°S	2740	1956–1958
C	Plateau	40. 5°E	79. 2°S	3624	1967
M	Mizuho	44. 3°E	70. 7°S	2230	1980

The minimum value of the monthly mean is about -93 ly/day (-3.9 MJ/m^2·day) in July and the maximum is about 70 ly/day (2.9 MJ/m^2·day) in December. The annual mean at Mizuho Station is -25.9 ly/day (-1.1 MJ/m^2·day).

Quoting values from KUHN *et al.* (1977), Fig. 3 shows a comparison of Mizuho Station and three other Antarctic stations concerning the amount of net radiation, in which A, B, C and M represent Mawson, Pionerskaya, Plateau and Mizuho, respectively. The values are listed on Table 2. Station A is located in a coastal region, B and M in the katabatic wind zone, and C in the interior continent. The meteorological condition of the coastal region is characterized by the following two points: One is the high positive balance of the short-wave radiation in summer owing to the low surface albedo and the other is the remarkable negative balance of long-wave radiation because of the relatively high surface temperature in winter. Therefore, the variation of net radiation at A is fairly large. On the other hand, the Plateau is marked by low temperature and high surface albedo in all seasons. Consequently the variation of net radiation at C is relatively small. The net radiation at Mizuho lies between A and C, and is similar to B. Namely, Mizuho is located in the same radiational circumstances as Pionerskaya.

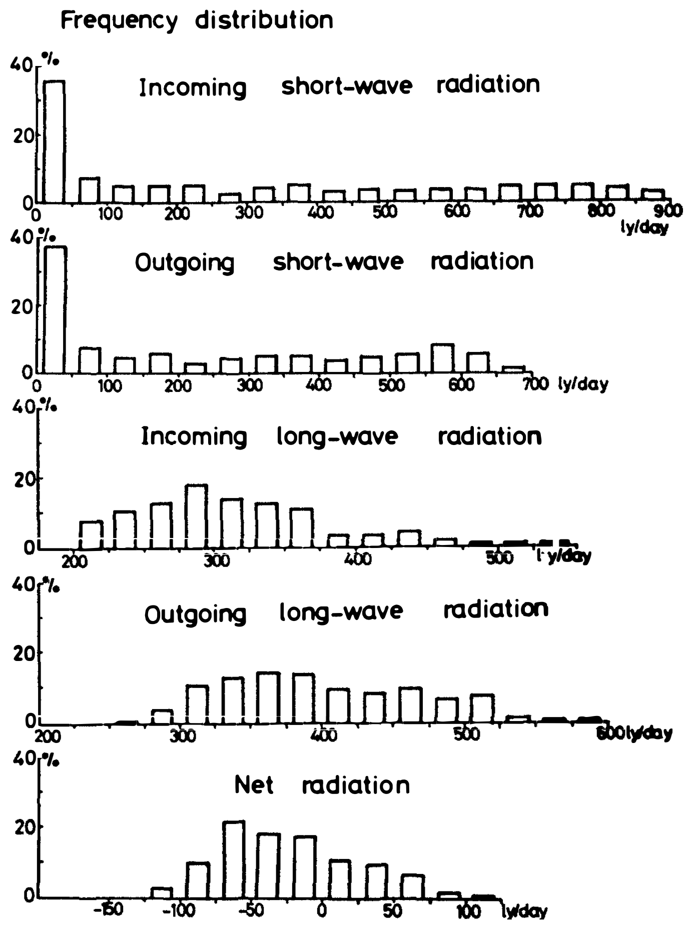

Fig. 4. Frequency distributions of daily averages of radiation components.

Frequency distributions of daily means of radiation components throughout the year are shown in Fig. 4. For two components of short-wave radiation they have even distributions except below 50 ly/day (2.1 $MJ/m^2\cdot$day). At Mizuho about 70 polar nights last in a year and they are included below 50 ly/day (2.1 $MJ/m^2\cdot$day) in this frequency distribution. For long-wave radiation it is distributed between 550–200 ly/day (23.0–8.4 $MJ/m^2\cdot$day) for the incoming radiation and 600–250 ly/day (25.1–10.5 $MJ/m^2\cdot$day) for the outgoing radiation, but the extreme values appear around 375–200 ly/day (15.7–8.4 $MJ/m^2\cdot$day) for the former and 525–300 ly/day (22.0–12.6 $MJ/m^2\cdot$day) for the latter. Net radiation is mainly distributed in the range from −75.0–0 ly/day (−3.1–0 $MJ/m^2\cdot$day).

3.2. Relations between long-wave radiation and air temperature

A dry snow surface is said to act as a black body for long-wave radiation. Figure 5 presents the relation between the outgoing long-wave radiation at the surface and air temperature measured at 1.7 m height. Cloud amount is taken as a parameter, namely, (○): $C<2$, (●): $2\leqq C\leqq 8$, and (△): $C>8$. The ordinate represents the amount of daily radiation and the abscissa the amount of black body

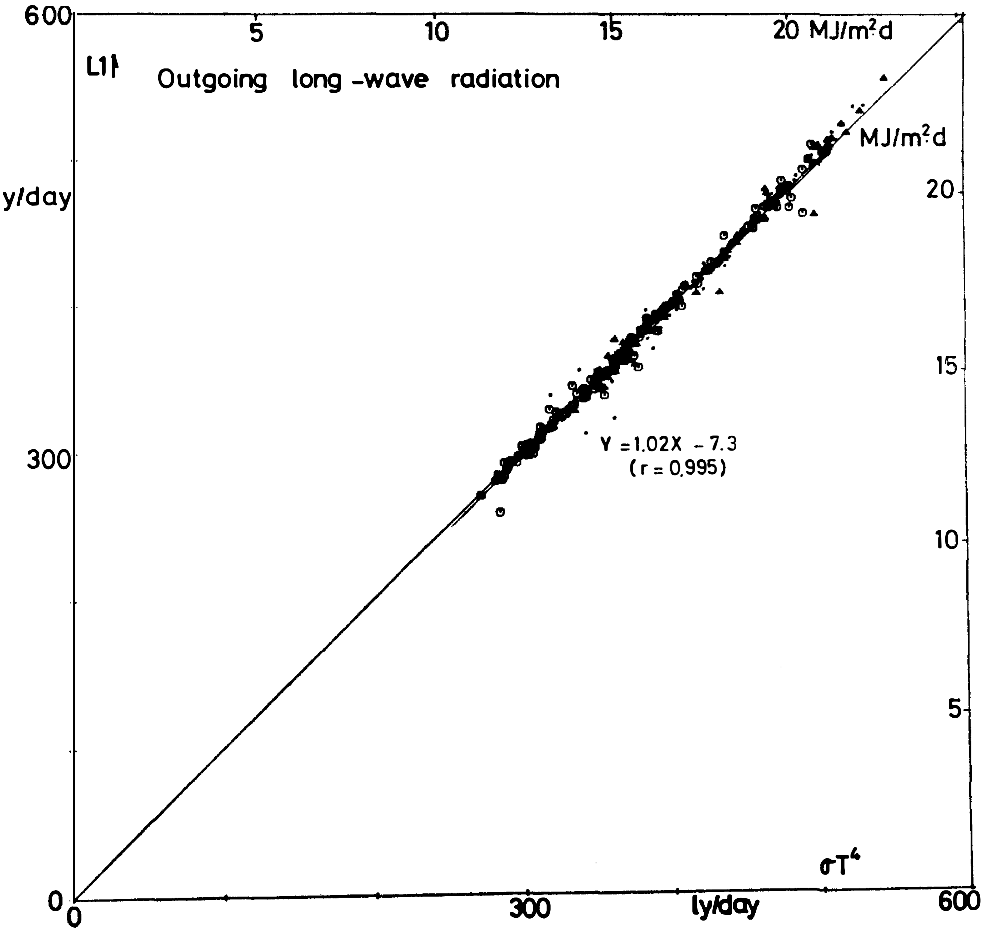

Fig. 5. Relation between the amount of outgoing long-wave radiation and air temperature.

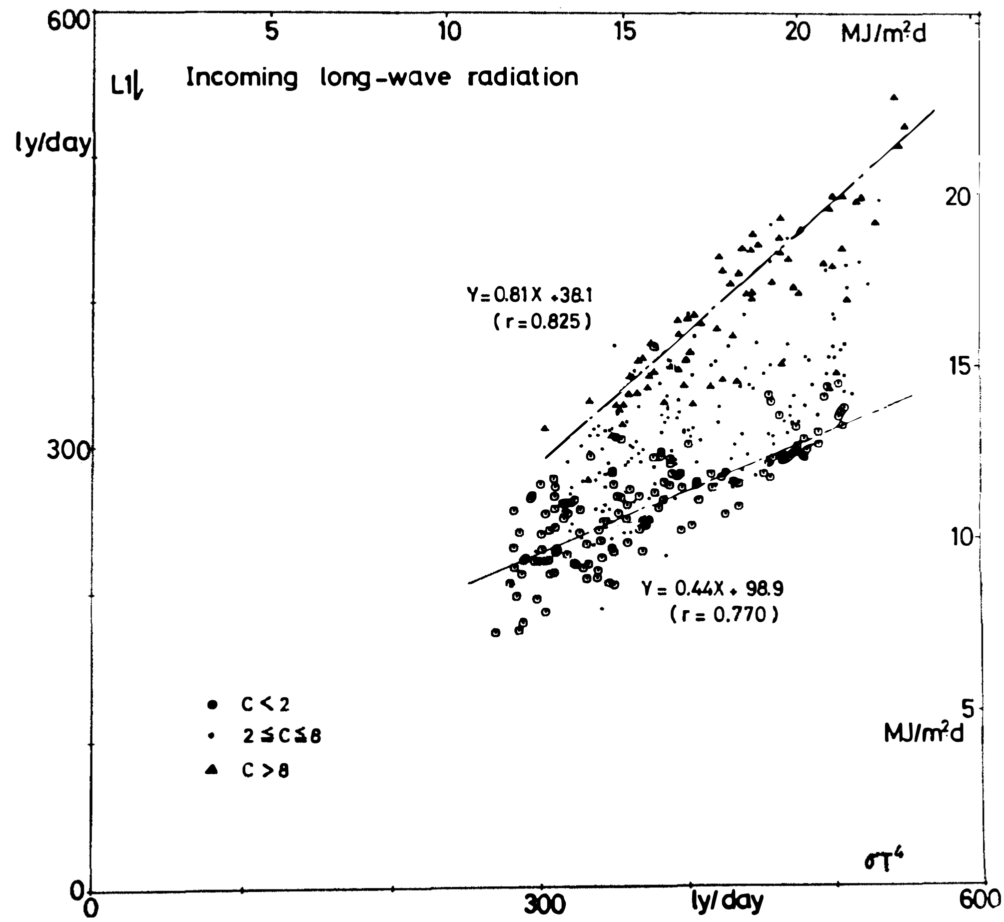

Fig. 6. Same as Fig. 5 but for the incoming long-wave radiation.

radiation calculated by using air temperature. It is obvious from this figure that the outgoing long-wave radiation can be expressed by temperature independently of the cloud amount. Then, Fig. 6 shows how the amount of the incoming long-wave radiation is related to air temperature. Observed values are scattered widely, apparently depending on the cloud amount. Two best-fit equations are derived by using the least squares method, one for overcast days and one for clear days. On cloudy days the atmospheric radiation must be expressed by the amount of black body radiation from the cloud base.

It is shown from this figure that the amounts of atmospheric radiation on cloudy days are nearly the same as the amounts of black body radiation estimated from air temperatures near the snow surface. This means that the heights of cloud bases are not so high and cloud base temperatures are close to the air temperatures measured near the snow surface. The incoming long-wave radiation is smaller on cloudless days than on cloudy days, even if the temperature is the same. Vapor pressure data have not been analyzed yet, so no empirical equation like the Brunt type has been obtained. Considering the effects on the incoming long-wave radiation of the temperature inversion, cloud amount and vapor pressure, a better equation that expresses the relation between them would be desirable in the future.

3.3. Comparison with the long-wave radiation measured at two heights

Mizuho Station is located in a typical katabatic wind zone, where drifting snow is observed within a few meters above the surface and a strong surface temperature inversion persists for a long time except summer as mentioned earlier. In order to investigate the radiation characteristics of the low drifting layer near the surface, radiation components were measured at the top of the meteorological tower, which was erected by JARE-20 members. Figures 7a–8b show the radiation components at two different heights, the abscissa representing values at the surface and the ordinate values at the top of the tower. For incoming short-wave radiation, values at both heights are nearly the same, and they have a good correlation (Fig. 7a). For reflected short-wave radiation values at the height of 30 m are smaller than at the height of 1 m by about 7% (Fig. 7b) in spite of a good correlation. The amount of reflected short-wave radiation was not corrected for the tower shading effect; therefore such an influence may appear. For the long-wave radiation (Figs. 8a and 8b) values at two different heights are scattered widely, especially for incoming long-wave radiation in the region under 400 ly/day (16.8 MJ/m^2·day) (Fig. 8a). A systematic error due to instruments does not appear. Correlations of each component are still high, but relatively small compared with those of short-wave radiation.

Figure 9 shows long-wave radiation components and differences of each component (ΔL) between two different heights (1 and 30 m), which are averaged for every 10 days. Values measured at the higher altitude generally exceed those mea-

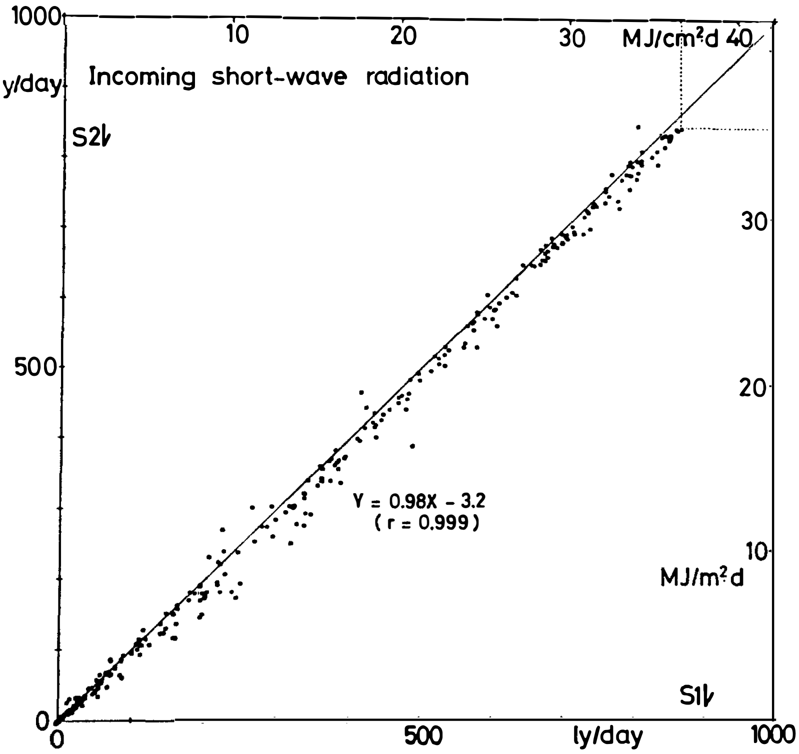

Fig. 7a. Comparison of the amount of incoming short-wave radiation between at 1.0 and 30 m in height.

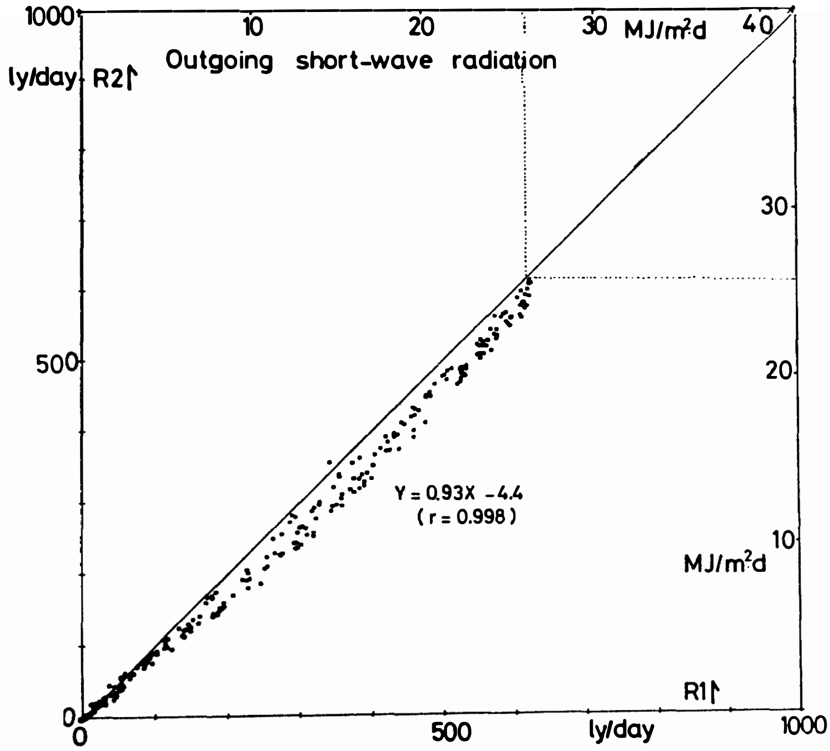

Fig. 7b. Same as Fig. 7a but for outgoing short-wave radiation.

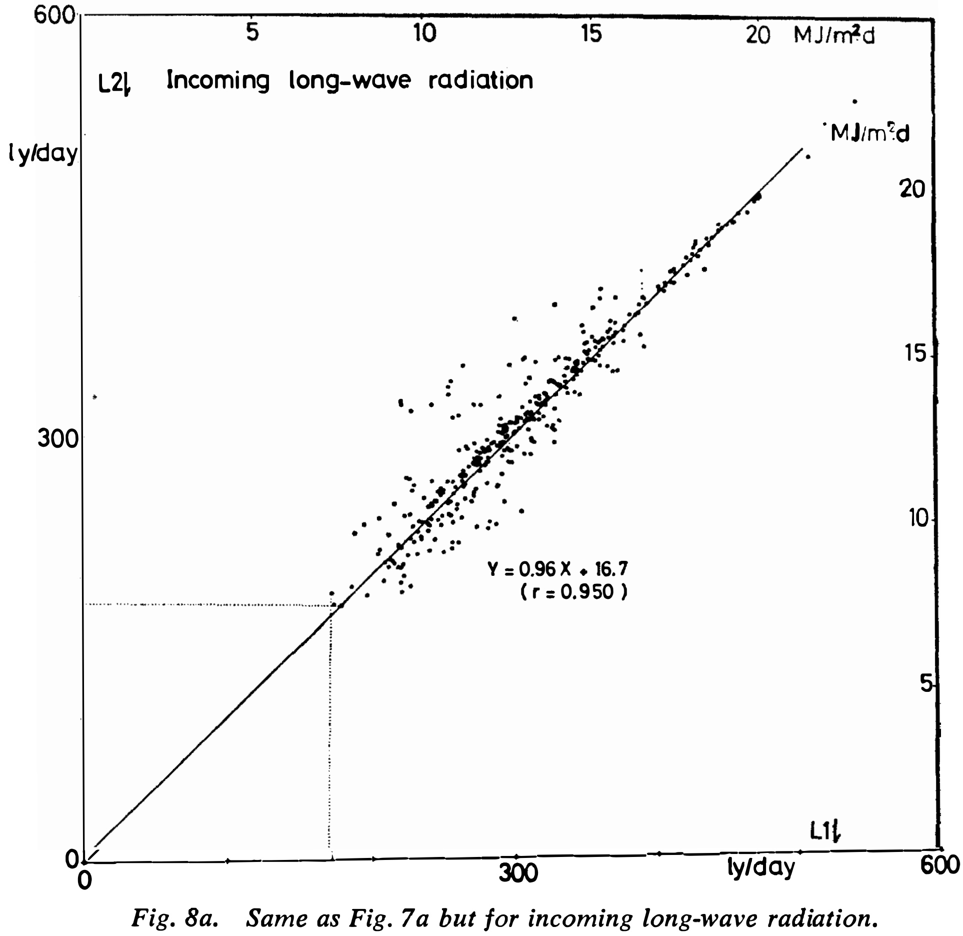

Fig. 8a. Same as Fig. 7a but for incoming long-wave radiation.

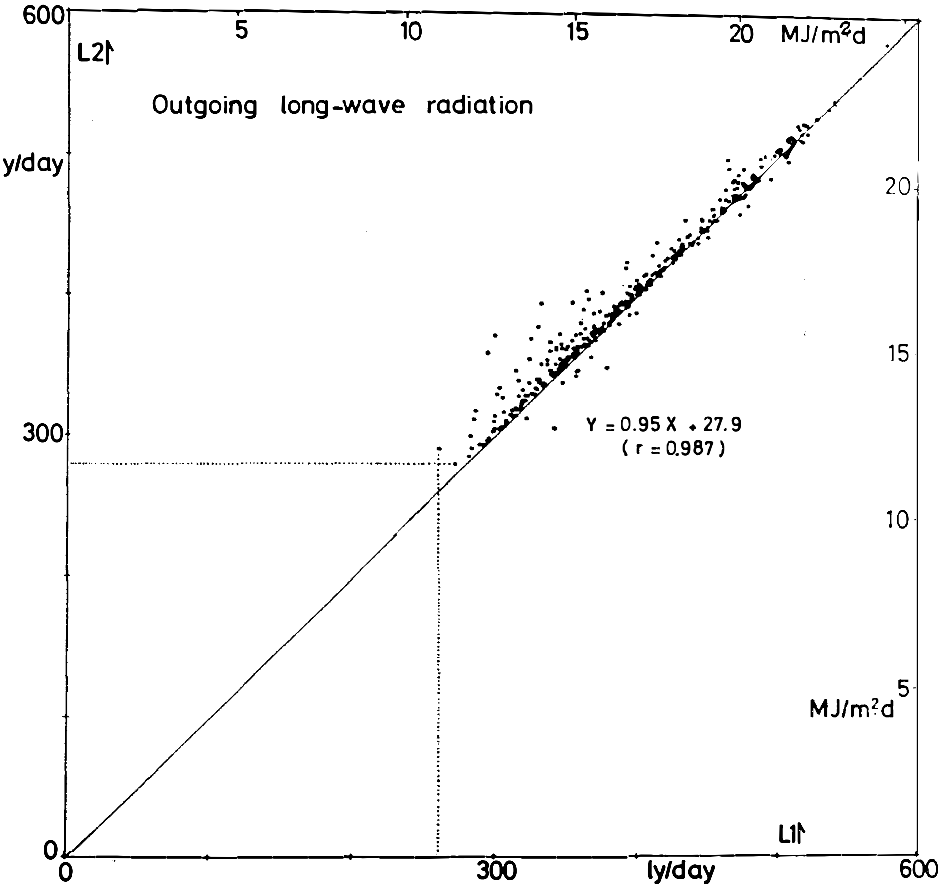

Fig. 8b. Same as Fig. 7a but for outgoing long-wave radiation.

sured at the surface, and large differences (ΔL) appear during the winter (from April to September).

Wind speed and air temperature are measured continuously at 7 different heights of the meteorological tower. Wind speed becomes stronger during winter, and the difference of wind speed between two heights (1.0 and 30 m) increases, especially from April to September. When wind speed exceeds about 10 m/s, low level drifting snow occurs at Mizuho Station. Surface temperature inversion also exists throughout the year and becomes dominant in winter. The differences of each component of long-wave radiation between two different heights becomes larger in winter, as shown in Fig. 9.

The correlation coefficients of all radiation components at two different heights are presented with meteorological elements as parameters in Fig. 10. In this figure T, C and V show the daily means of air temperature, cloud amount and wind speed, respectively, which were obtained by the surface meteorological observations in 1980. OHATA *et al.* (1981) reported these synoptic data in detail. The numbers at the right-hand side of each column mean the numbers of days which satisfied the conditions. For the short-wave radiation ($S1\downarrow$ and $S2\downarrow$, $R1\uparrow$ and $R2\uparrow$) good correlations hold at any time. For the outgoing long-wave radiation ($L1\uparrow$ and

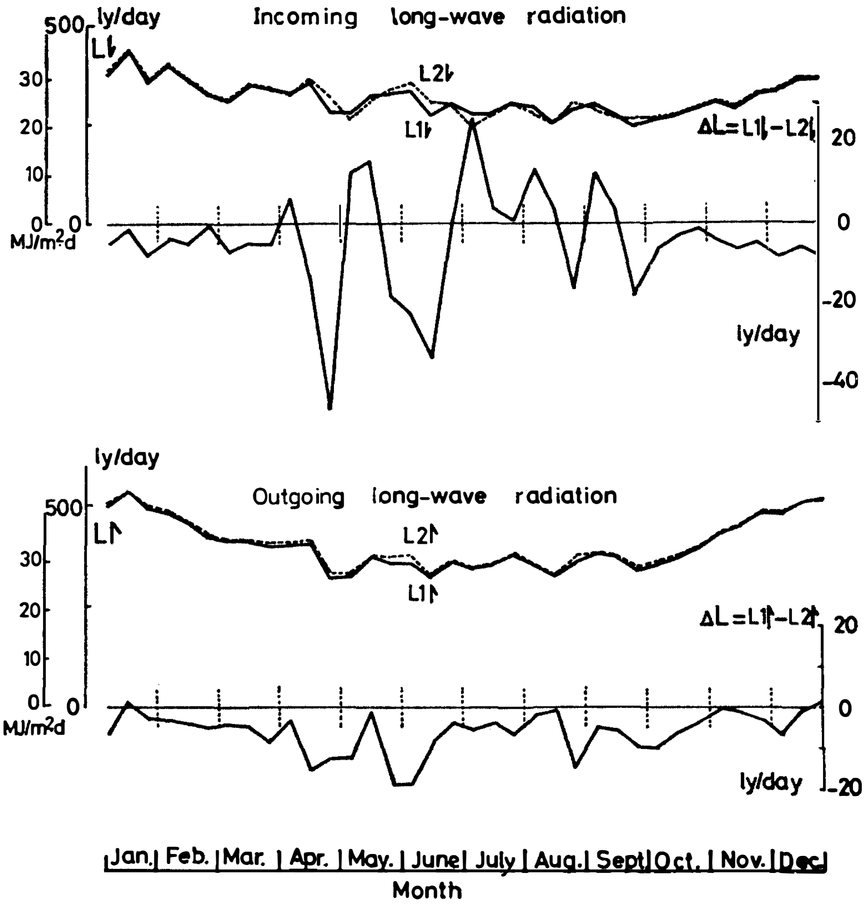

Fig. 9. Variations of long-wave radiation components and the difference of each component between the height of 1.0 and 30 m. Values are plotted for every 10 days means.

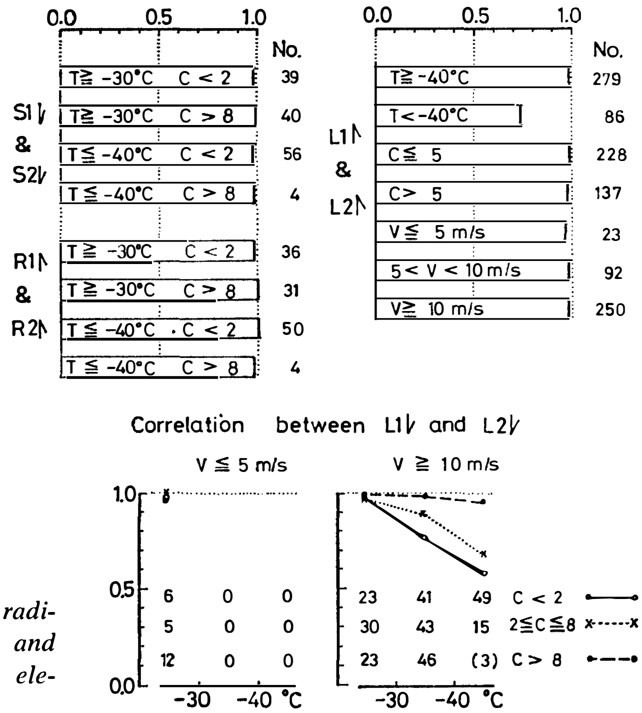

Fig. 10. Correlation coefficients of radiation components at 1.0 and 30 m with meteorological elements as parameters.

$L2\uparrow$) poor correlations appear at low temperatures ($T<-40°C$). For the incoming long-wave radiation, correlation coefficients are calculated under the condition which satisfies the three different terms simultaneously. Under the conditions of low wind speed (less than 5 m/s) and high air temperature (above $-30°C$), the coefficients become high in spite of the cloud amount. At this case no drifting snow and weak temperature inversion are observed. No data are taken under the conditions $T<-30°C$ and $V\leqq 5$ m/s.

At wind speeds of more than 10 m/s or at temperatures above $-30°C$, a good correlation appears on overcast days. In this case the surface temperature inversion becomes very weak or extinct, but drifting snow is observed. Under the condition of low temperature and fine weather ($C<2$) the correlation becomes fairly poor. At this time drifting snow and the strong temperature inversion become dominant.

From these figures it is obvious that the surface temperature inversions have great influence on the long-wave radiation at two heights.

The present paper describes only the preliminary results concerning radiation properties at Mizuho Station in 1980. More detailed analyses of the effects of drifting snow and surface temperature inversion will be described in future papers.

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