CLIMATOLOGICAL FEATURES OF MIZUHO STATION IN KATABATIC WIND ZONE, EAST ANTARCTICA

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***Abstract*:** Climatological features of Mizuho Station are described using seasonal variations in, and frequency distributions of meteorological elements for individual months as well as the periodicities of the individual variations and cross-correlations obtained by spectral analyses on the basis of data collected in 1980. The findings follow: Air pressure obtained at Mizuho Station decreases and takes its minimum in winter. On the other hand, it keeps the almost constant value at Syowa Station during the year; therefore, the pressure difference between Mizuho and Syowa increases in winter. Air temperature shows a remarkable daily variation in summer. In winter this short-time periodic variation disappears and the semi-long periodicity of about five days comes about. A strong wind blows constantly almost throughout the year, the annual mean being about 11 m/s. A significant cross-correlation is shown between air temperature at Mizuho and air pressure at Syowa in winter.

1. Introduction

Meteorological observations have been carried out since 1970 at Mizuho Station (44.3°E, 70.7°S, 2230 m above sea level) with some of the results as follows: YAMADA (1974) and SASAKI (1974, 1979) described the surface meteorological conditions. INOUE *et al.* (1978) found that variations in wind speed and air temperature at this station had good correlations with variations in air temperature at Syowa Station (39.6°E, 69.0°S, 21 m above sea level) with the periodicity of about four days. NAKAJIMA *et al.* (1981) pointed out the periodicity of 15 days in variations in air temperature at both stations and in wind speed only at Syowa Station, which corresponded to the periodicity of synoptic scale disturbances. The present paper uses the abbreviations of M.S. and S.S. for Mizuho Station and Syowa Station, respectively, hereinafter.

The JARE-21 wintering party to which the present authors belonged intended to obtain an accurate heat balance at the snow surface and seasonal variations in meteorological elements in the katabatic wind zone of East Antarctica. Thus, the party conducted surface meteorological observations and aerological soundings using low-level radiosondes and the acoustic sounder at M.S. in 1980 under the POLEX-South Program. As a result, KOBAYASHI *et al.* (1981) reported the details of the program and meteorological instrumentations. Meanwhile, ISHIKAWA *et al.* (1982a), KAWAGUCHI *et al.* (1982) and KOBAYASHI *et al.* (1982a, b) published, respectively, the preliminary results on radiation, radiosondes, and the structure of the surface boundary layer.

The present paper reports climatological features of M.S. for comparing seasonal variations in meteorological elements obtained at M.S. with those at S.S. from January to December in 1980, using the following data to clarify the climatological features: the 3-hourly data on air temperature, wind speed, and air pressure published by OHATA *et al.* (1981) for M.S. and by JAPAN METEOROLOGICAL AGENCY (JMA) (1982) for S.S.; including data on cloud amounts observed three times a day at M.S. and four times a day at S.S.; hourly radiation data at M.S. published by ISHIKAWA *et al.* (1982b); data from 63 flights of radiosondes at M.S.; aerological data twice a day at S.S. published by JMA (1982).

2. Seasonal Variations in Meteorological Elements

2.1. Air temperature

Figure 1 gives the monthly means of daily air temperature ranges at M.S. and S.S. and the long-term monthly means of air temperature at S.S. (JARE-1 ~-21). It follows from this figure that the annual mean of air temperature at S.S. in 1980 is abnormally higher than the long-term mean especially from March to September.

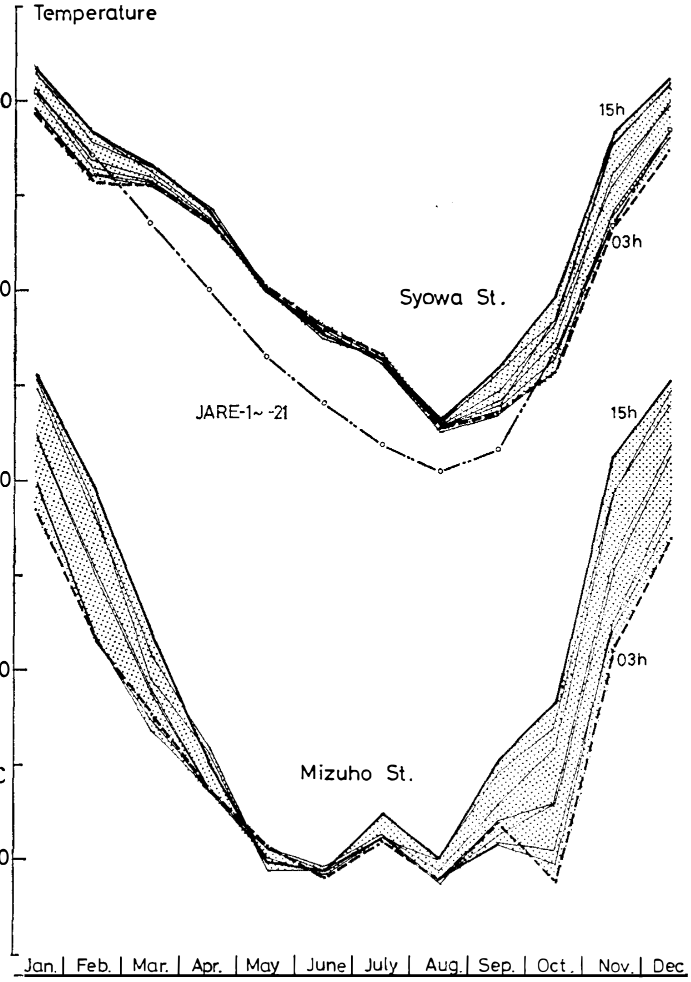

Fig. 1. Monthly means of daily ranges of air temperature at Mizuho and Syowa Stations in 1980

Unfortunately the reason of this high temperature is not clear yet, but some possibilities are considered; namely, the sea ice free period lasted longer and the strong surface inversion was not observed during the autumn in 1980; in winter the temperature at the higher altitude of S.S. was also higher than the long-term mean, which might be caused by the macro-scale circulation of air. At S.S. air temperature reaches its maximum in January and falls monotonously till it reaches the single minimum value in August. The annual range is about 18°C. On the other hand at M.S. air temperature which has its maximum in January falls very rapidly from March to April. During the winter it has no single minimum temperature, but keeps the nearly constant low value from May to August. This winter pattern is so-called coreless winter. The annual range, which is about 25°C, is much larger than at S.S.

Air temperature rises very rapidly from October to November at both stations. Variations in daily ranges at both stations show different aspects; namely, the wide daily ranges appear at M.S. from October to March with the maximum of about 10°C in November and they are reduced to small values from April to September. The daily ranges are also shown at S.S. from October to February with the maximum of about 5°C in November, but they are not so large as those at M.S. The difference in cloud amount (see Fig. 2b) between the two stations is one of the main causes of the different daily ranges between M.S. and S.S. in summer. Syowa Station is located

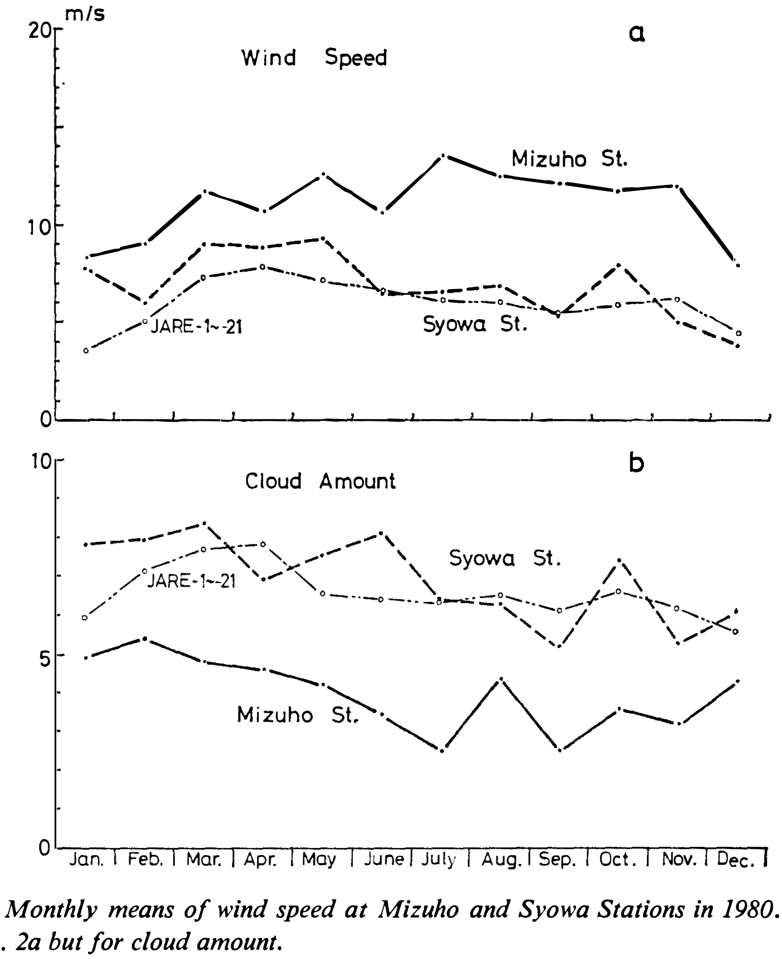

Fig. 2. (a) Monthly means of wind speed at Mizuho and Syowa Stations in 1980. (b) Same as Fig. 2a but for cloud amount.

on the island near the coast, therefore it is considered that the daily variation in air temperature becomes moderate.

NAKAJIMA *et al.* (1981) divided a year into three seasons, namely summer (November to February), winter (May to August) and the intermediate. In this paper a year is simply divided into two periods; summer (from October to March) and winter (from April to September) as a matter of convenience.

2.2. *Wind speed and cloud amount*

Monthly means of wind speed and cloud amount at both stations are plotted on Figs. 2a and 2b, in which long-term means of the two elements (JARE-1 ~ -21) measured at S.S. are shown. Wind speed at M.S. is reduced to below 10 m/s for a short time in summer (from December to February), but a strong wind more than 10 m/s blows always in the other period (the annual mean is about 11.2 m/s). Wind speed at S.S. is much smaller than at M.S. and it has no such predominant seasonal variation as at M.S.

Monthly mean of cloud amount at M.S. is smaller than at S.S. during the whole year. This means fine weather lasts longer at M.S., especially in winter.

2.3. *Air pressure*

Variations in air pressure at both stations are shown in Figs. 3a and 3b. Monthly means of sea level pressure at S.S. are gathering around 990 mb during the year except in June and October. The station pressure at M.S. is much lower (the annual mean is 732.9 mb in 1980) than at S.S., because of a difference in altitude between the two stations (about 2230 m). A remarkable variation in air pressure is seen at M.S. It takes a low value in winter and high in summer, and the annual range is about 17.5 mb at M.S. (9.8 mb at S.S.).

The relation of air pressure between the two stations is shown in Fig. 3b, in which air pressure at M.S. is given by the ordinate and that at S.S. by the abscissas on the left- and the right-hand side, respectively, for air pressure corrected to mean sea level

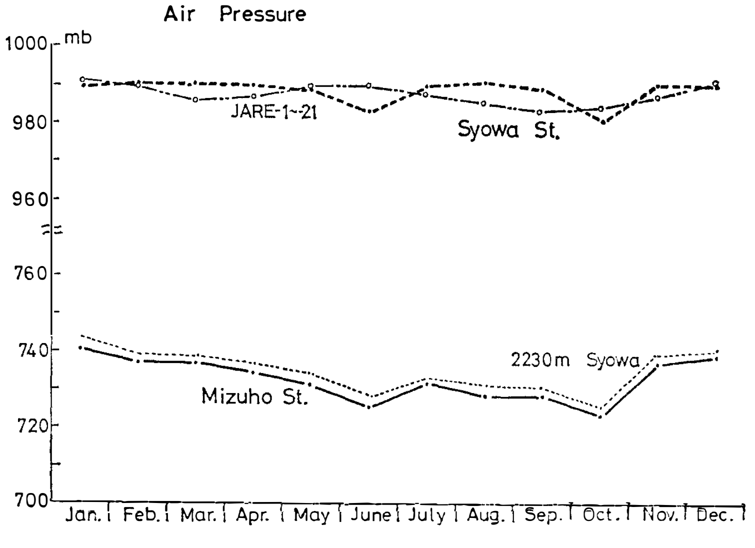

Fig. 3a. Same as Fig. 2a but for air pressure.

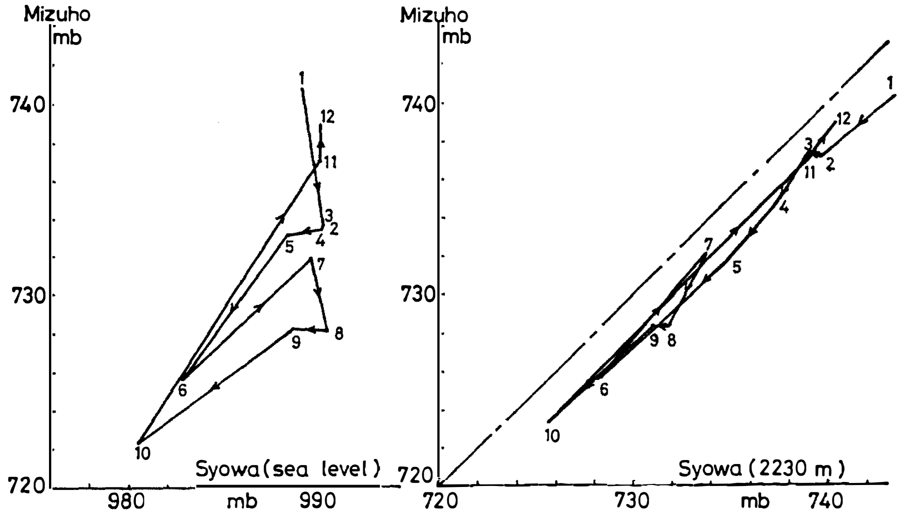

Fig. 3b. Relations of monthly means of air pressure at the two stations (Mizuho and Syowa) in 1980. Left: Mizuho and Syowa at the sea level, right: Mizuho and Syowa at the altitude of 2230 m.

and for that at the altitude of 2230 m. Compared with air pressure at S.S. 2230 m in altitude, that at M.S. has a similar pattern in spite of slightly lower values. Meanwhile, there are no simple relations between air pressure at M.S. and that at S.S. which was corrected to sea level.

2.4. Radiation

Radiation properties at M.S. have already been described (YAMANOUCHI *et al.*, 1981; ISHIKAWA *et al.*, 1982a). Therefore, variations in radiation components at M.S. are described briefly in this paper (Fig. 4). The amount of shortwave radiation varies in the range of 0–850 ly/day (0–35.6 MJ/m^2·day) for solar radiation and of 0–610 ly/day (0–25.6 MJ/m^2·day) for reflected radiation. The surface albedos gather around the value of 0.8, but they slightly decrease during the summer. The amount of long-wave radiation does not vary so large as the shortwave; namely, terrestrial radiation takes the value in the range of 350–500 ly/day (14.7–21.0 MJ/m^2·day) and atmospheric radiation in 270–400 ly/day (11.3–16.8 MJ/m^2·day). Therefore, net radiation is negative except a short time in summer, and the annual mean is −25.9 ly/day (−1.1 MJ/m^2·day). This value is nearly the same as at Pionerskaya in another katabatic wind zone (ISHIKAWA *et al.*, 1982a).

3. Variations in Meteorological Elements Averaged for a 10-day Period

It is considered that variation patterns of meteorological elements take other aspects, if the averaging period is changed. Variations in meteorological elements (air temperature, wind speed and air pressure) averaged for every 10 days are shown in Figs. 5a–c, where $T_S(S)$ and $T_S(U)$ represent the temperature at S.S., the former near the surface (1.5 m) and the latter at 2230 m, $T_M(S)$ near the snow surface (1.7 m) at M.S.; $V_S(S)$ shows wind speed at S.S., $V_M(S)$ at M.S.; $P_S(S)$ and $P_S(U)$ show air pressure at S.S., the former at sea level and the latter at 2230 m, $P_M(S)$ at M.S.

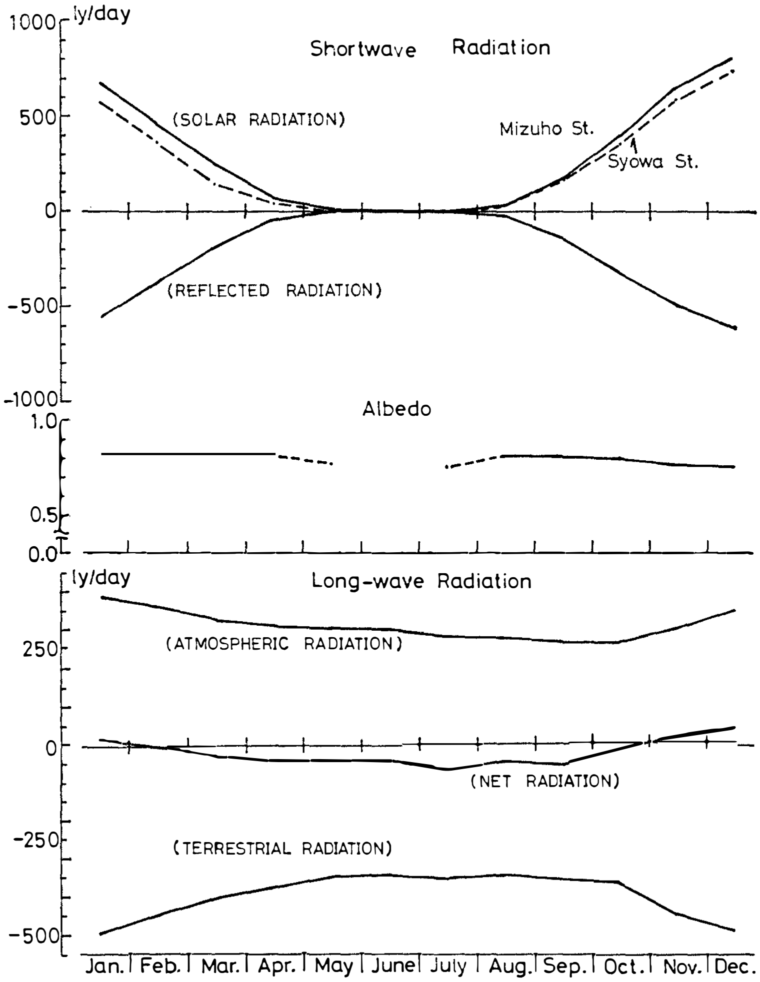

Fig. 4. Monthly variations in radiation components at Mizuho Station in 1980.

No periodic variation in air temperature appears at either of the stations in summer (from October to March), but the predominant variations with semi-long periods (10–30 days) are seen at M.S. during the winter (from April to September) when the short-time (daily) ranges diminish completely. The same patterns are seen at S.S. both at sea level and at 2230 m in winter though with longer periods.

Variations in wind speed at the two stations had different patterns; namely, a strong wind over 10 m/s blows continuously at M.S. throughout the year except two months in summer (December to January), and the wind at S.S. does not show a typical seasonal variation but shows a semi-long periodicity owing to the snowstorm (blizzard).

As for air pressure it shows a seasonal variation at M.S. and does not at S.S.; but fluctuations with the semi-long period (once a month) are seen at both stations. Differences in meteorological elements at M.S. and S.S. are also plotted in this figure with notations of ΔT, ΔV and ΔP. The difference in air temperature between the two stations increases till June with its maximum value around April, and decreases slowly toward its minimum in January except in September and October when it increases again. The difference in air pressure increases during the winter with its

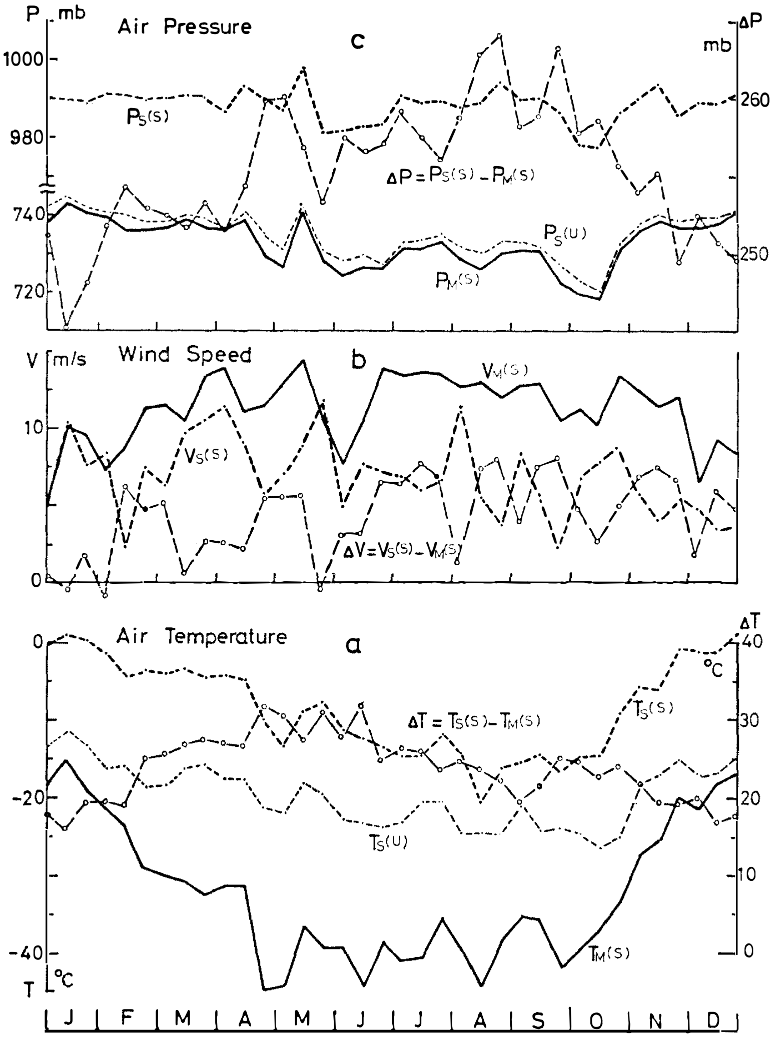

Fig. 5. (a) Variations in air temperature averaged for a 10-day period at Mizuho and Syowa Stations in 1980. (b) Same as (a) but for wind speed. (c) Same as (a) but for air pressure.

maximum in August. The difference in wind speed is usually large from February to November. But in the case of a strong wind at S.S. (snowstorm) the difference is reduced to a small value obtained several times during the season.

4. Frequency Distributions of Meteorological Elements at Mizuho Station in 1980

In order to clarify climatological features at M.S., frequency distributions of meteorological elements (temperature, pressure and wind speed) were obtained for every three months and for the whole year by using daily means (Fig. 6a). All of individual data are divided into a number of groups by every 5°C of air temperature, 5 mb of air pressure and 1 m/s of wind speed. Then, the number of individual data belonging to a group is divided by the total number of individual data, which gives the percentage of the group. This percentage is called frequency distribution in this paper.

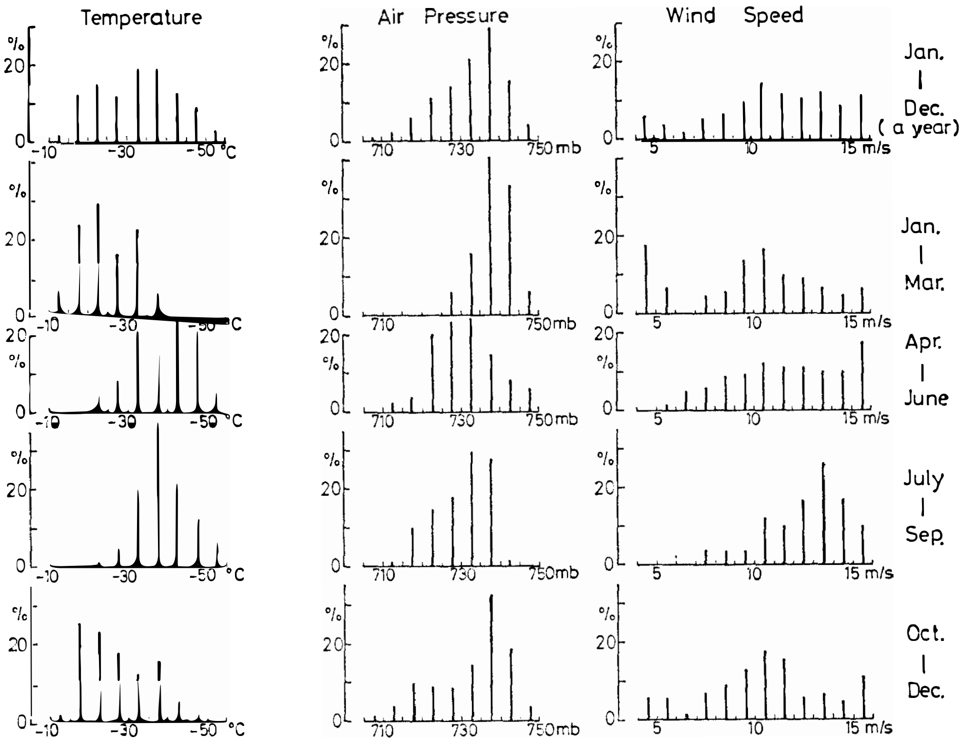

Fig. 6a. Annual and seasonal frequency distributions of air temperature, air pressure and wind speed at Mizuho Station in 1980.

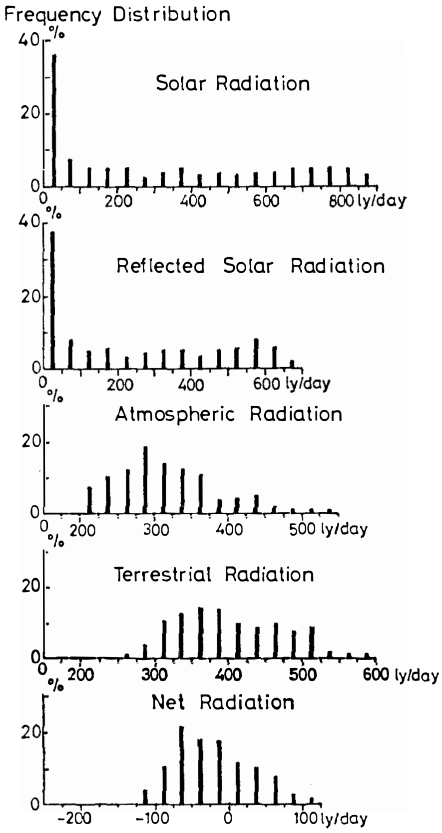

Fig. 6b. Annual frequency distributions of radiation components at Mizuho Station in 1980.

The following shows the maxima of frequency distributions: Air temperature −35 ~ −45°C in winter (April to September), −15 ~ −25°C in summer (October to March), −30 ~ −35°C in the whole year. Air pressure 730 ~ 735 mb in winter, 735 ~ 740 mb in summer, 735 ~ 740 mb in the whole year. Wind speed 13 ~ 16 m/s in winter, 10 ~ 11 m/s in summer, 10 ~ 11 m/s in the whole year. A weak wind less than 5 m/s has never been found at M.S. during the winter.

Frequency distributions of radiation components were obtained throughout the whole year (Fig. 6b). All data are classified into several parts by every 50 ly/day (2.1 MJ/m^2·day) for shortwave radiation and 25 ly/day (1.1 MJ/m^2·day) for longwave and all-wave net radiation. Shortwave radiation (solar and reflected) has even distributions, except the specific case, with the value below 50 ly/day in which about 70 polar nights are included. Extreme values appear in the range of 275 ~ 300 ly/day (11.6 ~ 12.6 MJ/m^2·day) for atmospheric radiation, 350 ~ 375 ly/day (14.7 ~ 15.7 MJ/m^2·day) for terrestrial radiation and −75 ~ −50 ly/day (−3.1 ~ −2.1 MJ/m^2·day) for all-wave net radiation.

5. Variations in Temperature Lapse Rate

YAMADA (1974) reported on lapse rates of air temperature along the ice sheet between Mizuho and Syowa Stations by using snow temperatures at the depth of 10 m below the surface. He presented the value of 0.7°C/100 m in summer, 1.1 ~ 1.2°C/100 m in winter and the annual mean of 1.1°C/100 m. Figure 7 shows seasonal variations in air temperature lapse rate between M.S. and S.S., which are averaged for every 10 days and for one month. The lapse rate between the altitude of 2230 m and near the surface at S.S. is also plotted in this figure.

The seasonal variation in lapse rate between M.S. and S.S. shows the same tendency which appears in Fig. 5a; namely, it increases very rapidly from February to April and decreases slowly toward January. It takes the lowest value of 0.7°C/100 m for 10-day mean (0.8°C/100 m in the monthly mean) in January and the highest value of 1.5°C/100 m for 10-day mean (1.3°C/100 m in monthly mean) in April.

This comes about from the following reasons: The air temperature at M.S. falls

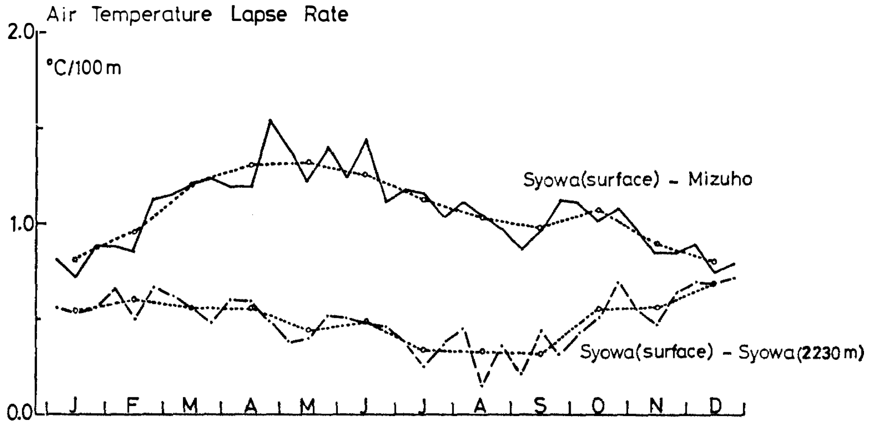

Fig. 7. Variations in temperature lapse rate between Mizuho and Syowa Stations in 1980.

very rapidly from February to May, but at S.S. it falls slowly during this period. Therefore, the temperature difference between the two stations becomes larger. During the midwinter (May to August) the temperature at M.S. hardly falls, and keeps the lowest value of the year (coreless winter). The temperature at S.S. continues to fall and reaches its minimum in August. It results in reducing the temperature difference between the two stations (see Fig. 1). On the other hand, the lapse rate in the atmosphere has the opposite tendency; namely, it takes the highest value of 0.7°C/100 m in December and decreases monotonously till August when the lowest value of 0.15°C/100 m in 10-day mean (0.3°C/100 m in monthly mean) appears. This variation pattern is caused by surface inversion at S.S.

6. Surface Inversion at Mizuho Station in 1980

The climate of the interior parts of Antarctica is characterized by the strong surface inversion (DALRYMPLE *et al.*, 1963; SCHWERDTFEGER, 1970). Japanese aerological soundings in the windy regions of East Antarctica were carried out for the first time by KOBAYASHI and YOKOYAMA (1976). They made the observations only a few times, but they found the existence of a strong surface inversion in the katabatic wind zone. In 1980 the members of JARE-21 carried out aerological soundings frequently (twice or once a week) by using low-level radiosonde at M.S. during the whole year in order to obtain a seasonal variation in surface inversion. The details were reported by KAWAGUCHI *et al.* (1982); so, the frequency distributions of surface inversion's height and strength are presented by using the data obtained by 63 flights of radiosonde (Fig. 8). The frequency distributions were obtained for winter (April to September) and for summer (October to March). All the data obtained from 30 flights in winter show the existence of surface inversion. The prevailing heights and strengths appear in a range of 350~500 m and 6~24°C, respectively.

In summer as much as 42% of 33 flights showed no occurrence of surface inversion. Even if it occurred, the strength was weak and the height was lower.

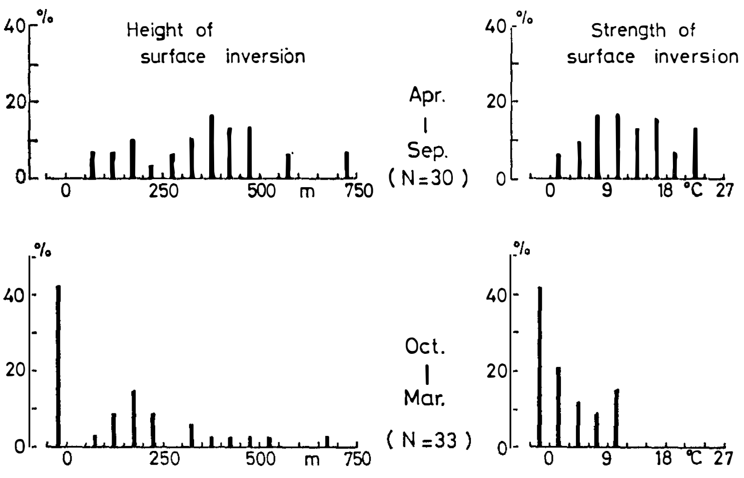

Fig. 8. Frequency distributions of inversion strength and height at Mizuho Station in winter and summer 1980.

7. Periodic Variations in Air Temperature, Air Pressure and Wind Speed at Mizuho and Syowa Stations

NAKAJIMA *et al.* (1981) conducted the spectral analysis of meteorological elements by using the 3-hourly data obtained in 1977 in order to find out the periodicity of their variations. As for the air temperature they showed the distinct periodicities of about 4 and 9 days at M.S. and of about 2.4, 3.7 and 15 days at S.S.; as for the wind speed they showed periodicities of about 3, 7 and 15 days at M.S. and of about 4.5, 9 and 15 days at S.S. They reported that the common period of 15 days for the wind speed at both stations was due to the synoptic scale disturbances. The present authors obtained seasonal changes in semi-long (within a week) periodicities for individual months, and calculated cross-correlations among different meteorological elements at M.S. or at both stations. The spectral analysis of the data was conducted by using a computer program with the FFT-method, which was developed by ISHIDA (1981).

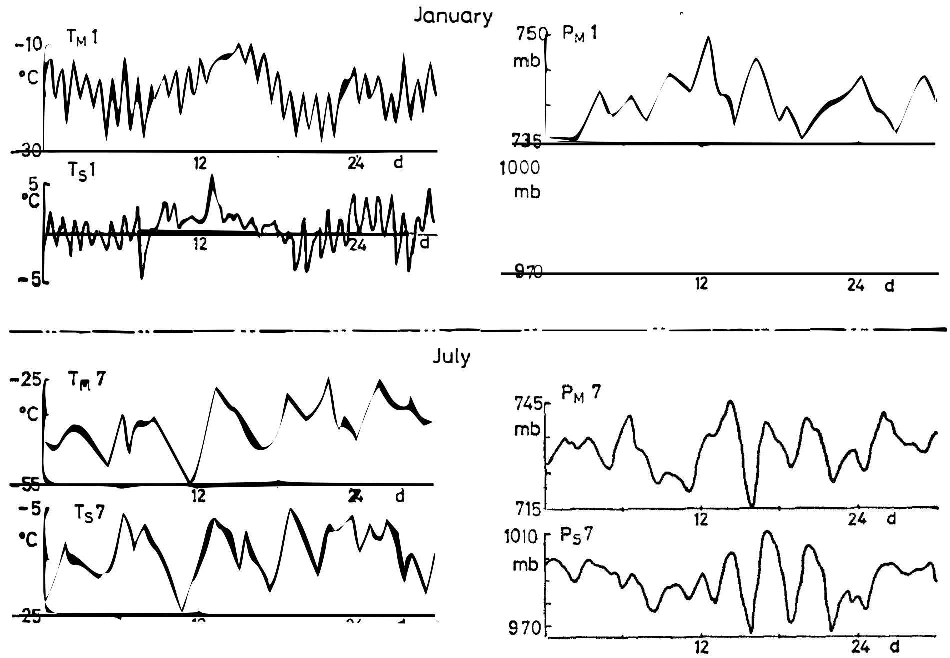

Fig. 9. Variations in 3-hourly air temperature and air pressure at Mizuho and Syowa Stations in January and July 1980.

Figure 9 shows variations in (T), air temperature (left), and (P), air pressure (right), at the two stations (M: Mizuho; S: Syowa) for January (higher column) and July (lower column), in which 3-hourly data are plotted. The typical daily variations in air temperature are clearly shown at both stations in January, but they disappear completely in July and semi-long variations with the periodicity of several days appear, as mentioned before.

By using the 3-hourly data, spectral analysis was carried out at both stations for individual months. The power spectrum of air temperature at M.S. is shown in Fig. 10. One can see several peaks in this figure, but the remarkable one is at the

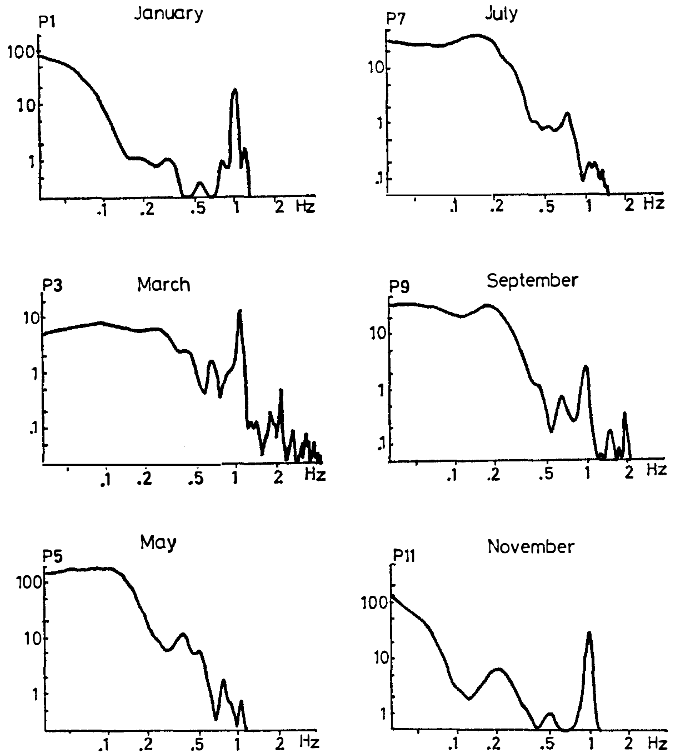

Fig. 10. Power spectra of air temperature at Mizuho Station in 1980 (Δh: 3 hours).

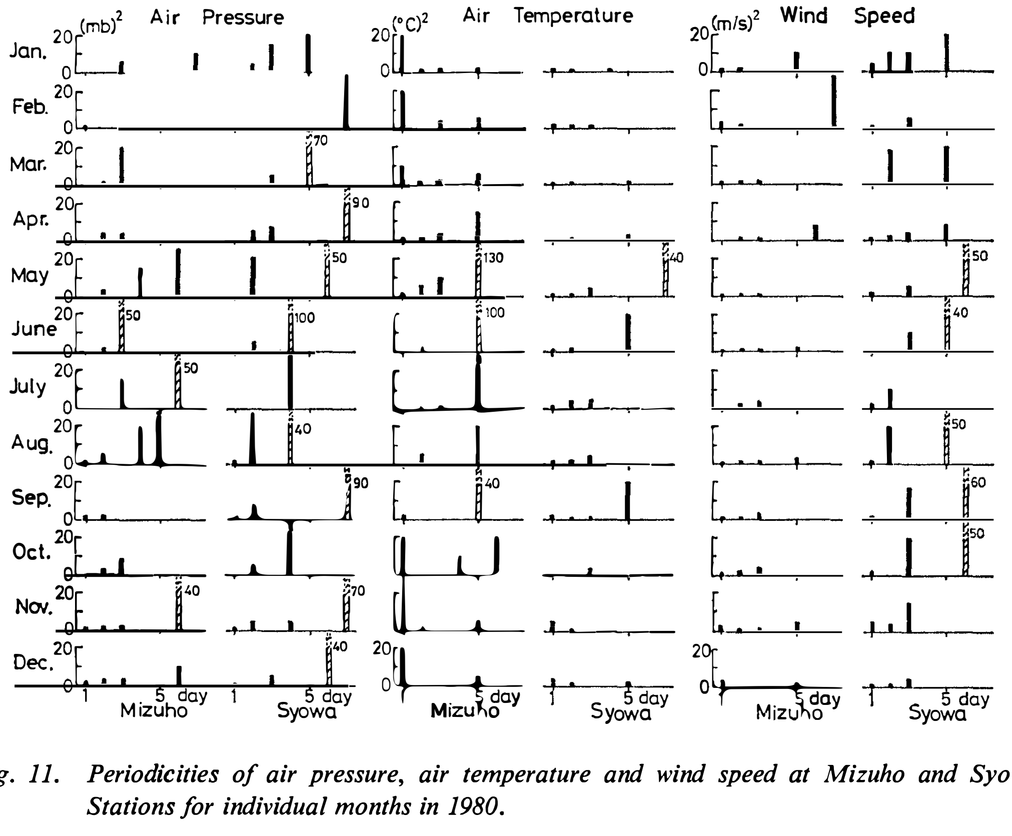

Fig. 11. Periodicities of air pressure, air temperature and wind speed at Mizuho and Syowa Stations for individual months in 1980.

frequency of 1 Hz (1 day) in summer and 0.2 Hz (5 days) in winter. The power spectra of other meteorological elements were obtained by the same spectral analyses against air temperature.

Figure 11 shows predominant periodicities of air pressure, air temperature and wind speed at both stations for individual months. Semi-long periodicities within 7 days are presented in this figure. A dramatic change in periodicity of air temperature at M.S. described in Figs. 9 and 10 is clearly shown; namely, daily variations prevail in summer and 5-day variations in winter. At S.S., however, such a remarkable periodicity of temperature variation is not seen.

Periodic variations in air pressure at both stations are also clear but not so remarkable as those in air temperature at M.S. The periodicities of about 3, 4 and 6 days were obtained at M.S. and those of about 2, 4 and 7 days at S.S. Variations in wind speed have no periodicity at M.S., but the periodicities of about 2, 3, 5 and 6 days are seen at S.S.

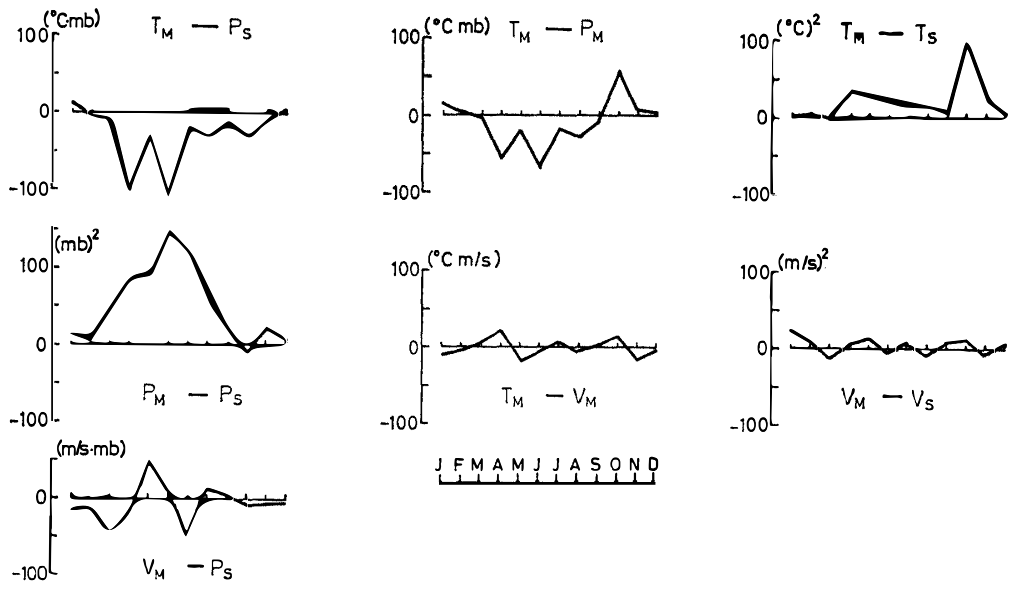

Fig. 12. Cross-correlations of two meteorological elements at Mizuho and Syowa Stations for individual months in 1980.

Cross-correlations of the meteorological elements at both stations were obtained for individual months in order to clarify the main causes of the periodic variations at M.S. (Fig. 12). The notations in this figure are as follows: T: air temperature, P: air pressure, V: wind speed, M: Mizuho, S: Syowa. The ordinate has not been normalized but the dimensions.

As for the air temperature at M.S. (T_M), one can see the negative correlations with air pressure at M.S. (P_M) and at S. S. (P_S) in winter, and the weak positive in summer. This means that the temperature rise at M.S. in winter occurs when air pressure at both stations drops (synoptic scale disturbances). But taking the year-long means, the air temperature and air pressure at M.S. show almost the same variation patterns (positive correlation). The correlation of air temperature between the two stations (T_M and T_S) is positive during the year.

A strong positive cross-correlation of air pressure was obtained between the two stations (P_M and P_S) during the winter (April to August), and it became weak in summer.

Wind speed at M. S. (V_M) has the negative correlation with air pressure at S.S. (P_S) except in May, June and August. No cross-correlation is seen between air temperature and wind speed at M.S. (T_M–V_M) and between wind speeds at M.S. and that at S.S. (V_M–V_S) during the whole year.

8. Concluding Remarks

Climatological features of Mizuho are described by showing seasonal variations in, frequency distributions and periodicities of meteorological elements. The most significant features are seen in the following items: 1) Air temperature has a wide daily range of variation in summer, but in winter instead of daily changes it shows a semi-long periodic variation of about five days. 2) A strong wind more than 10 m/s in speed blows constantly throughout the whole year except for a short period in summer, having no periodicity. 3) Air pressure decreases and a pressure difference between Mizuho and Syowa increases in winter. 4) A strong negative cross-correlation is seen between air temperature and air pressure.

This paper shows climatological features of Mizuho Station by using only the whole year data of 1980, but does not describe the relation of meteorological conditions to large scale circulations. In the future a more detailed analysis would be done to clarify the effect of synoptic scale disturbances on periodic variations of meteorological elements.

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