—研 究 論 文—
Scientific Papers

Statistical Studies of Snow Accumulation and Snowfall in the Coastal and Katabatic Areas of Antarctica —Observations at Syowa and Mizuho Stations in 1979 and 1980—

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南極沿岸部およびカタバ風帯の積雪量の変化 ——1979・80年の昭和基地・みずほ基地の観測——

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要旨：南極域気水圏観測 (POLEX-South) の期間 (1979-1981年)，沿岸基地である昭和基地と内陸に位置しカタバ風帯のみずほ基地との気象・雪氷観測から，両基地の積雪量と気象要素（雲量，雪日数，可降水量，ブリザード日数，気圧の分散値）との関係について解析を行った．

積雪量は昭和基地では，夏季後半，冬季および10月に増加を示した．一方みずほ基地では，夏季後半，冬季に増加している．夏季後半の増加は，可降水量が夏に多いことが主な原因であり，冬季の増加は，強い低気圧の接近が主な原因となっている．また10月の昭和基地での増加は，可降水量，低気圧の両方の影響のためと考えられる．可降水量は夏と冬で大きな違いがあるため，特にみずほ基地では，夏に積雪量の増加が著しい．

***Abstract*:** The snow accumulation at Syowa and Mizuho Stations was recorded from the observations during the POLEX-South period and the monthly and seasonal variations of it were discussed using the data of the cloud amount, the number of days with snowfall, precipitable water, the number of days with blizzard and the pressure-variance.

The accumulation generally increased in late summer, winter and October at Syowa Station, and in late summer and winter at Mizuho Station. Its increase in late summer relies on the content of precipitable water and the increase in winter depends on the cyclones that approached the region. The increase in October at Syowa Station relies on the both factors. There is a large difference in the content of precipitable water between summer and winter, so the summer season plays an important role in snow accumulation at Mizuho Station rather than the winter season.

1. Introduction

The water vapor and the precipitation in Antarctica are of desert properties on account of the low temperature environment and the presence of the large continent. From the mean meridional cross section of the mixing ratio in January by BRYAN (1966), it is found that the mixing ratio at every height decreases with increasing latitude. RUSIN (1964) reviewed the vapor pressure and the cloudiness at some sta-

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tions in Antarctica. The values of them are shown to be smaller at the inland stations than at other stations.

Some authors (RUSIN, 1964; SCHWERDTFEGER, 1969; ORVIG, 1970) collected and analyzed the data of the period of the IGY which started in 1957. In the katabatic area observations have been made only for a short period so that the data are insufficient.

RADOK and LILE (1977) discussed the snow accumulation at Plateau Station and described the relationship between the snow accumulation and the temperature. Some reports of the observations at the Japanese stations have been published. YAMADA (1974) described the cloudiness and some meteorological elements but the data were taken only in the summer season. NARUSE *et al.* (1971) described the snow accumulation at Syowa Station but not at Mizuho Station.

This paper firstly deals with the snow accumulation at Syowa and Mizuho Stations in 1979 and 1980 of the POLEX-South period. Then, the cloud amount, the number of days with snowfall, precipitable water, the pressure-variance and the number of days with blizzard are analyzed, and relationships between the variation of these data and the snow accumulation are investigated.

Syowa Station is located in the coastal area, where the water vapor is supplied easily, but Mizuho Station is situated in the katabatic area, which is about 300 km inland and the water vapor is not so rich as at Syowa Station. The difference in the snow accumulation rate between the coastal area and the katabatic area is described. These results would be useful for investigating the precipitation and accumulation processes in an area where the water vapor is poor.

2. Data

Many meteorological elements were observed at Syowa and Mizuho Stations during the POLEX-South period, 1979–1981. Especially, many observations with new sensors and systems were made at Mizuho Station in 1979 and 1980. In this paper the data of the temperature and the atmospheric pressure at Mizuho Station are referred to WADA *et al.* (1980) and OHATA *et al.* (1981), and the data of snow accumulation at Mizuho Station to WADA *et al.* (1981) and KOBAYASHI *et al.* (1982). The data of the temperature and the atmospheric pressure at Syowa Station are according to JAPAN METEOROLOGICAL AGENCY (1981, 1982). For the data of snow accumulation at Syowa Station, the observational note of the JARE-20, of which the author was a member, and the report of the JARE-21 wintering party are referred to.

3. Monthly Variations of Some Meteorological Elements at Syowa and Mizuho Stations in 1979 and 1980

3.1. Snow accumulation

As shown in Fig. 1, Syowa Station is located in the coastal area and Mizuho Station is in the katabatic wind area. Monthly variations of the snow accumulation rate at Syowa and Mizuho Stations in 1979 and 1980 are shown in Fig. 2. From February to June 1980 observation was not carried out since the observation site on the sea ice

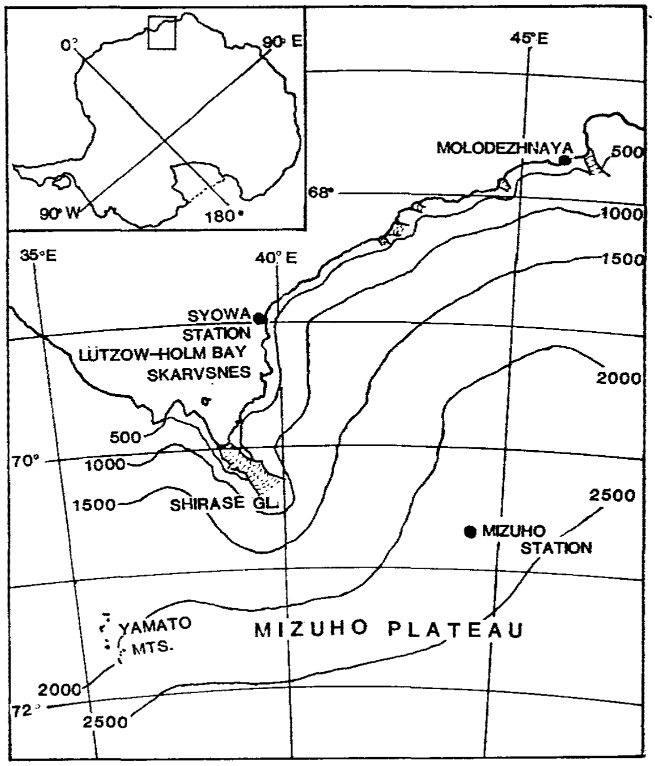

Fig. 1. Location of Mizuho and Syowa Stations.

was swept away. The snow accumulation stands for the net amount of snow by drifting, falling and sublimation.

As shown in Fig. 2, the snow accumulation at Syowa Station became large in March, July and October, and it became markedly negative in summer (November, December, January, February) in both 1979 and 1980. At Mizuho Station it showed large values in late summer (January, February, March) and in winter (July, August), but negative values in summer (November, December) in both years.

At both stations, the accumulation took large values in late summer (around February) and in winter (around July) but at Mizuho Station it was much larger in late summer than in winter, whereas at Syowa Station it was quite smaller in late summer or nearly equal between in late summer and in winter. Although in October the increase of the accumulation was large at Syowa Station, it was nearly zero at Mizuho Station.

3.2. The cloud amount and the number of days with snowfall

The monthly means of the cloud amount and the number of days with snowfall at Syowa and Mizuho Stations in 1979 and 1980 are shown in Fig. 3. The values are larger at Syowa Station than at Mizuho Station except the cloud amount in December 1979. This result is in good agreement with RUSIN's result (1964) who described that the cloud amount was larger in the coastal area than in the inland area.

At Syowa Station, the number of days with snowfall was large in late summer (March) and winter (July, August) of 1979, and large in February, May, August and October of 1980. In both years the cloud amount was nearly the same. At Mizuho Station both the cloud amount and the snowfall in 1979 showed similar variations, that is, the values were large in late summer (February and/or March), in summer (August

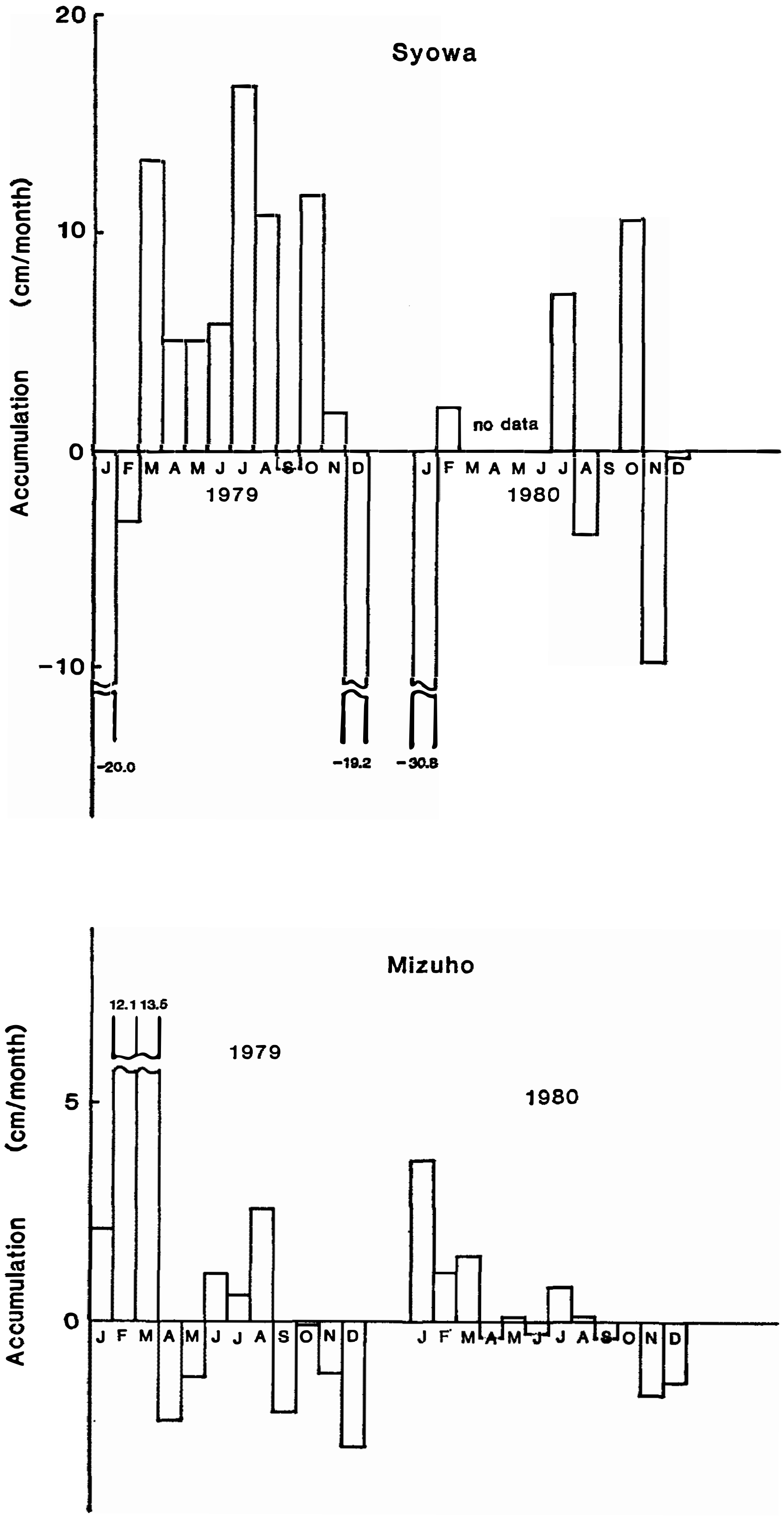

Fig. 2. Snow accumulation at Syowa and Mizuho Stations in 1979 and 1980.

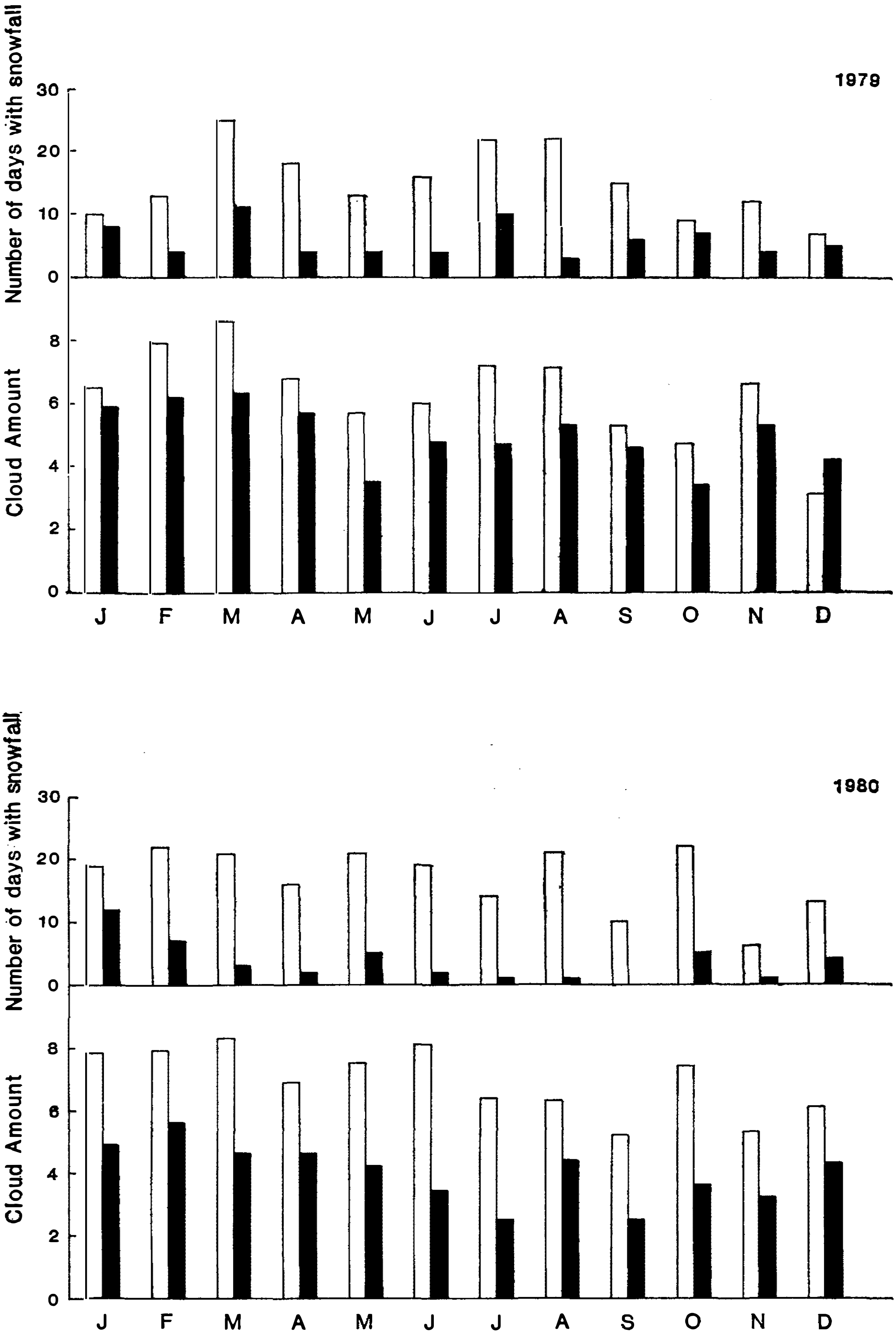

Fig. 3. Monthly variations of the cloud amount and the number of days at Syowa (open bar) and Mizuho (solid bar) Stations in 1979 and 1980.

or July) and in autumn (October or November). In 1980, however, the cloud amount took large values only in February and August and the number of days with snowfall was large in January, May and October. Especially the number of days with snowfall at Mizuho Station in winter of 1980 was very small.

3.3. Precipitable water

The monthly variation of precipitable water between the surface and the level of −40°C temperature at Syowa Station in 1979 and 1980 is shown in Fig. 4. The value of the precipitable water was large in January and February and small in July, August and September. Namely, the precipitable water increased in summer and decreased in winter, as shown in Fig. 4, due to the fact that the value of the saturated water vapor pressure becomes high in summer because of high temperature and became small in

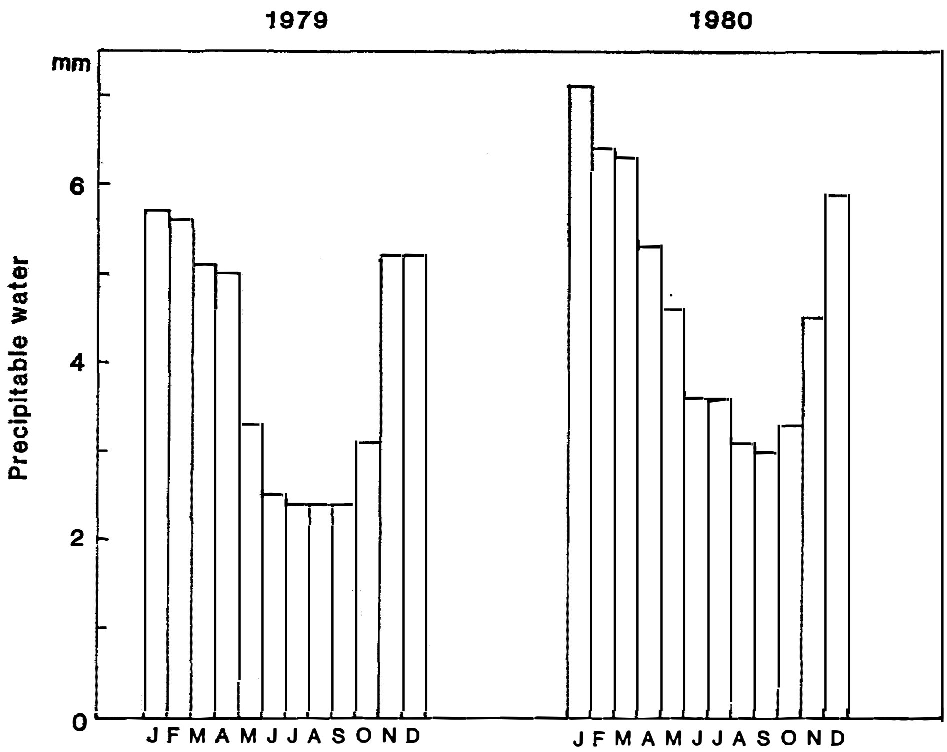

Fig. 4. Monthly variation of the precipitable water at Syowa Station in 1979 and 1980.

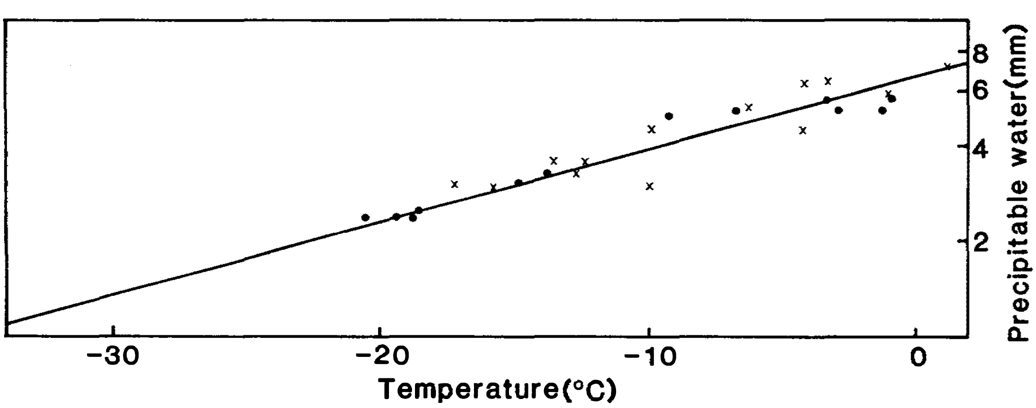

Fig. 5. The relationship between the air temperature and the precipitable water.

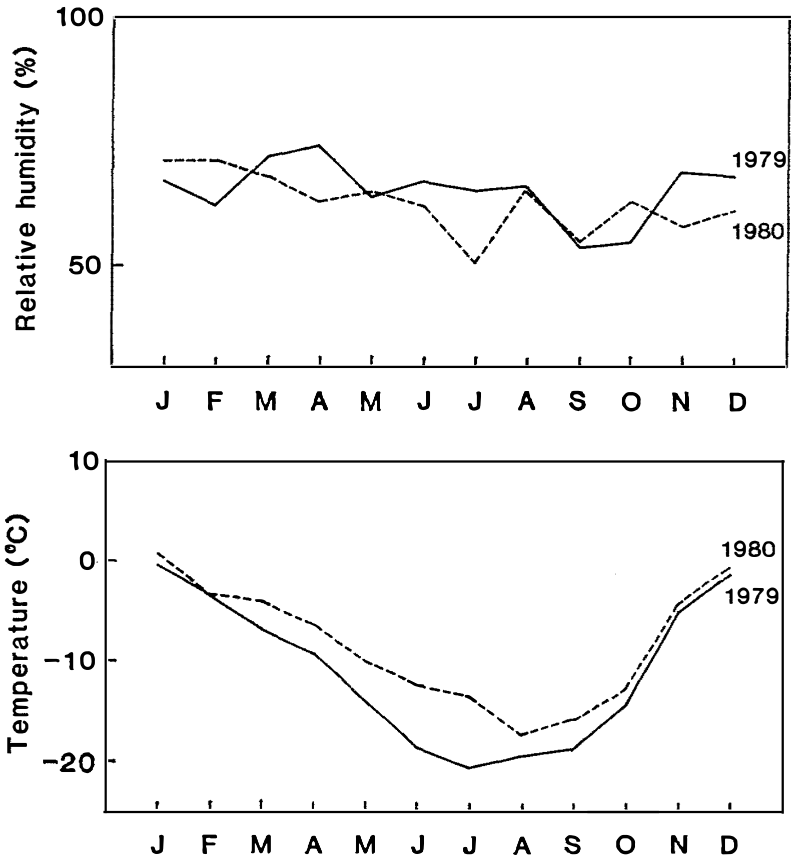

Fig. 6. Monthly variations of the temperature and the humidity at Syowa Station in 1979 and 1980.

winter because of low temperature. The relationship between the air temperature and the precipitable water is shown in Fig. 5. The vertical axis is the total precipitable water and the horizontal one is the mean air temperature of each month. The crosses in the graph show the data in 1980 and the circles show the data in 1979 at Syowa Station. The following empirical formula can be made from the relationship,

$$t = 44.1 \log_{10} Pw - 36.2 \qquad (1)$$

where t is the air temperature (°C) and Pw (mm) is the precipitable water. The value of the precipitable water of each month is larger in 1980 than in 1979 except in November.

The result that the monthly temperature was higher in 1980 than in 1979 and the relative humidity of every month was about 60% in both 1979 and 1980, as shown in Fig. 6, would account for the higher precipitable water in 1980 than in 1979.

3.4. The monthly pressure-variance and the number of days with blizzard

Two phenomena which seemed to be connected with cyclone will be described in this section. One is the pressure-variance and the other is the number of days with blizzard. The pressure-variance is defined in the following equation:

$$[\text{Pressure-variance}] = \frac{(p-\bar{p})^2}{n} \qquad (2)$$

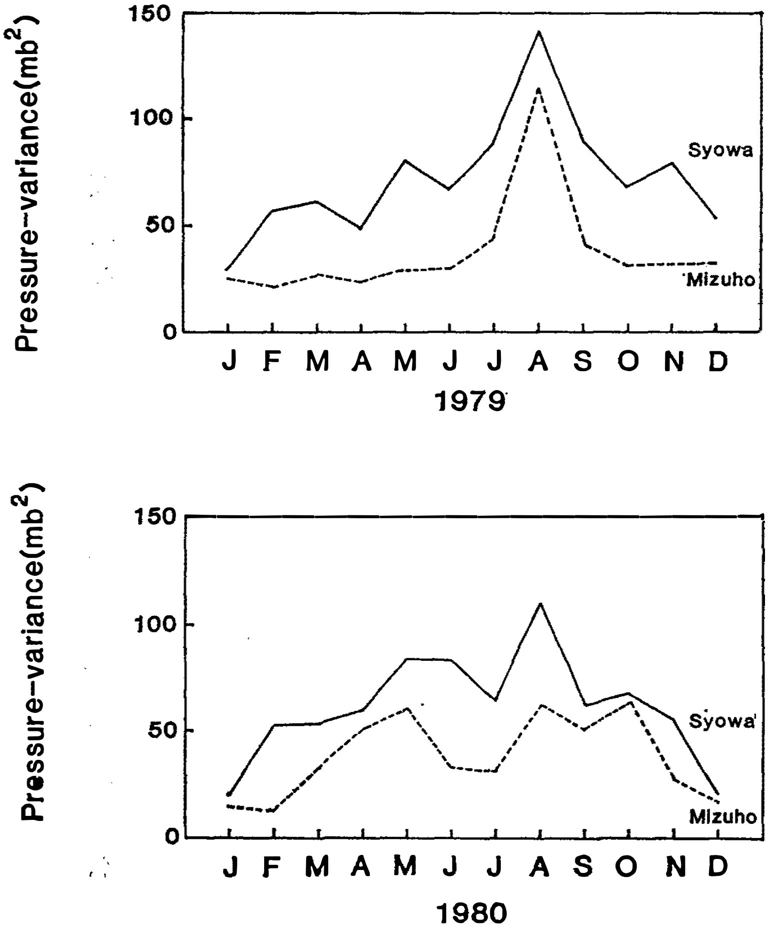

Fig. 7. Monthly variation of the pressure-variance at Syowa and Mizuho Stations in 1979 and 1980.

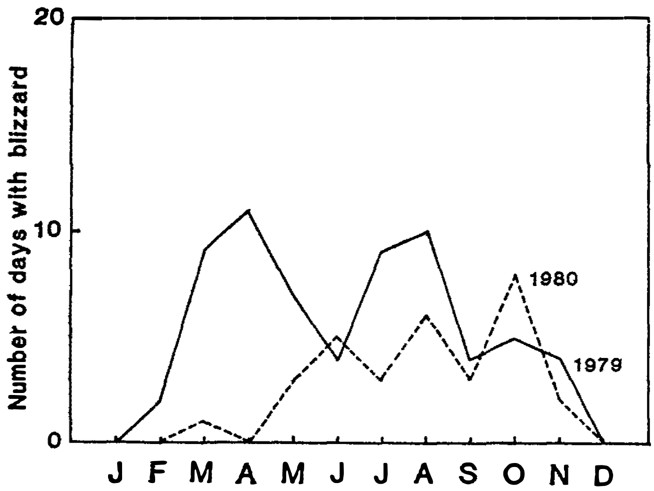

Fig. 8. Monthly variation of the number of days with blizzard at Syowa Station in 1979 and 1980.

where $\bar{p}$ is the monthly mean pressure (mb), p is the daily mean pressure (mb), and n is the number of days in each month. A blizzard has been defined as the condition when the wind speed is more than 10 m/s and the visibility is less than 1 km for a period longer than 6 hours.

The monthly pressure-variance in 1979 and 1980 is shown in Fig. 7. At Syowa Station the pressure-variance was large in May, Augst and November in 1979, and showed the same variation in 1980. In both years the value was the largest in August. At Mizuho Station the variation was similar in 1980, but in 1979 it took large values only in winter (July, August, September).

Figure 8 shows the number of days with blizzard at Syowa Station. The value was large in April and August of 1979, and in June, August and October of 1980.

4. Discussion

The monthly variations of meteorological elements in 1979 and 1980 were de-

Table 1. Months which took large values in the monthly variation at Syowa Station (×: No data).

Syowa Station, 1979

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Snow accumulation			+				+	+		+		
Cloud amount			+				+	+				
Snowfall			+				+	+				
Precipitable water	+	+										
Blizzard				+				+				
Pressure-variance								+				

Syowa Station, 1980

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Snow accumulation			×	×	×	×	+			+		
Cloud amount			+							+		
Snowfall		+	+							+		
Precipitable water	+	+										
Blizzard						+		+		+		
Pressure-variance					+			+		+		

Table 2. Months which took large values in the monthly variation at Mizuho Station.

Mizuho Station, 1979

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Snow accumulation		+	+			+	+					
Cloud amount		+	+					+			+	
Snowfall			+				+			+		
Pressure-variance								+				

Mizuho Station, 1980

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Snow accumulation	+	+	+				+					
Cloud amount		+						+				
Snowfall	+				+					+		
Pressure-variance					+			+		+		

scribed in the former section. These elements are closely related with water vapor and they are important for the antarctic clouds to be formed in Antarctica. The months in which the meteorological elements took large values are arranged as plus symbol in Tables 1 and 2 from the results of the former section.

Firstly the data at Syowa Station are discussed. The snow accumulation increased in late summer, in winter and in October in both 1979 and 1980, though the observation was not carried out in late summer of 1980. Since the snow accumulation is the net amount of falling, drifting and so on, the accumulation cannot rely directly on the number of days with snowfall or the cloud amount. However, the number of days with snowfall and the cloud amount increased in late summer in both years, in winter in 1979 and in October in 1980. Since the precipitable water was the largest in summer and was smallest in winter, the accumulation would be larger in summer than in winter, if the other meteorological conditions (*e.g.* the strength of cyclone) were the same. The monthly variation of accumulation has actually three peaks and does not coincide with that of the precipitable water except in summer. Namely, the precipitable water is important for the accumulation rate in summer, but the other elements will be important in winter.

Although the number of days with blizzard and the pressure-variance took large values in winter, the increase was not recognized in late summer of both years and was not distinguished in October of 1979. These values seem to be connected with the strength of cyclones which approached Syowa, and this will verify the increase of snow accumulation in winter. The increase of accumulation in October depends on both the precipitable water and the cyclone. When the cyclone approaches Syowa Station, the accumulation takes large values as the precipitable water is fairly large in October despite of the fact that the cyclone is not stronger in October than in winter.

Next, the accumulation at Mizuho Station is discussed. The accumulation took large values in late summer and in winter, but the increase in October is not clear. Since the precipitable water is nearly proportional to the temperature as shown in Fig. 5, it is expected that the value is large in summer. The precipitable water is a very important factor for the variation of accumulation at Mizuho due to the fact that the accumulation was much larger in late summer than in winter. The pressure-variance took large values in August of 1979 and in May, August and October of 1980, as at Syowa Station. One of the reasons for the small increase of the accumulation in winter is the large value of the pressure-variance in winter. However, since the value of the pressure-variance is smaller at Mizuho Station than at Syowa Station, the influence of the cyclone was not stronger at Mizuho Station than at Syowa Station. The reason why the accumulation is not so large in October of 1980 is that the precipitable water is much less in October than in summer despite of large pressure-variance in October.

5. Concluding Remarks

The following results were obtained by analyzing the snow accumulation, the cloud amount, the number of days with snowfall, the precipitable water and the number of days with blizzard. The accumulation increased in late summer (February, March), winter (July, August) and October. The increment in winter depends on the influence of strong cyclones and the increment in late summer relies on the large value of precipitable water which is much more in summer than in winter, though a few strong cyclone approached Syowa or Mizuho Stations in summer. The increment in October depends on both of the strong cyclone and precipitable water.

The snow accumulation depends not only on strong cyclone but also precipitable water in each month. As the value of the precipitable water in winter was smaller at Mizuho Station than at Syowa Station, increment of snow accumulation in winter at Mizuho Station was small even if a fairly strong cyclone approached Mizuho Station. Therefore, the snow accumulation at Mizuho Station is much larger in summer than in winter.

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