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Article

Climate and weather at the Advance Camp in East Queen Maud Land, Antarctica

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Abstract

In spite of the high altitude of the new Advance Camp (74° 12'S, 34° 59'E, 3198 m above sea level) in East Queen Maud Land, climate is more like the Cold Katabatic rather than the Cold Interior. The wind directional constancy reaches 0.93 and is comparable to the Mizuho value, 0.96. The annual mean air temperature is estimated to be −43.2°C, which is considerably higher than the 10−m depth snow temperature of the same altitude in the Enderby Land area. The daily and synoptic variations of the air temperature and the surface wind are also described.

1. Introduction

As a part of the East Queen Maud Land Glaciological Project (EQGP), the Advance Camp (AC) was established at IM252 (74° 12'S, 34° 59'E, 3198 m above sea level) in February 1985 (Ageta *et al.*, 1987) by the 26-th Japanese Antarctic Research Expeditions (JARE−26). Meteorological observations were carried out during the periods from 7 to 28 February, 1985, and from 15 October, 1985, to 3 January, 1986. The camp was unoccupied during the period from 1 March to 14 October, 1985, although limited observations were made using a long-term weather recorder (Kikuchi and Makino, 1988). The observations carried out at AC are summarized in Table 1, while the details of the observations are given in a data report (Kikuchi and Ageta, 1987). This paper describes the basic results of the observations.

2. Climatological character

The climatological characterization of the various stations in the Antarctic plateau has been made through the mean annual temperature (Dalrymple, 1966) and the annual wind regime (Schwerdtfeger, 1984). Because the present data are insufficient to derive the annual statistics, some preprocesses are required to give the climatic values.

The monthly mean values of air temperature T_a and wind speed V are listed in Table 2. The number of data N_t and N_v used in deriving the mean values, T_a and V, respectively, are listed together to indicate the accuracy of the values ; basically, the observations were made every 3 hours, thus N_t and N_v should be compared with the number of days multiplied by 8, which is listed in the second column from the left. The monthly averages are also shown in Fig. 1 together with the records taken at two other Japanese stations : Syowa Station (69° 00'S, 39° 35'E ; Japan Meteorological Agency, 1986) and Mizuho Station (70° 42'S, 44° 20'E, 2230 m a.s.l. ; Kikuchi *et al.*, 1986).

A glance at the figure reveals that the correlations in the temperature of AC and Mizuho are extremely high. The amount of wind data from AC is limited, but the winds at both AC and at Mizuho show a monotonic increase from February to May and a minimum in November. The wind at Syowa seems to be rather poorly correlated to that of the other two inland stations.

The correlation coefficient was calculated using the data obtained from the periods when the AC values were available : 11 and 8 months for the temperature and the wind speed, respectively. The results, listed in Table 3, show that the data from AC

Table 1. Outline of the meteorological observations at AC.

Period / Item	7 − 27 Feb., 85	1 Mar.−14 Oct.	15 Oct. −3 Jan., 86
Surface observations :			
Atmospheric pressure	Aneroid	n.a.*	Aneroid+Recorder
Air temperature	Alcohol+Platinum	Platinum	Alcohol+Platinum
Wind direction	Magnetic compass	Wind vane	Sonic anemometer
Wind speed	Viram	3−cup anemometer	Sonic anemometer
Net radiation	n.a.	n.a.	differential
Weather	visual	n.a.	visual
Visibility	visual	n.a.	visual
Cloud amount	visual	n.a.	visual
Low level soundings :			
Temperature and Humidity	radiosonde	n.a.	radiosonde
Wind velocity	pilot balloon	n.a.	pilot balloon

* not available

Table 2. Monthly summary of the wind and air temperature data at Advance Camp, 1985.

month	days×8	T_a	N_t	V	N_v
Feb.	224	−37.1	106	6.1	106
Mar.	248	−43.4	247	8.3	244
Apr.	240	−47.0	240	9.2	240
May	248	−54.8	246	9.5	237
June	240	−48.6	236	9.1	178
July	248	−51.1	226	−	10
Aug.	248	−49.4	120	−	0
Sep.	240	−50.7	224	−	0
Oct.	248	−45.5	142	8.4	76
Nov.	240	−35.4	239	5.7	207
Dec.	248	−28.0	245	7.4	240

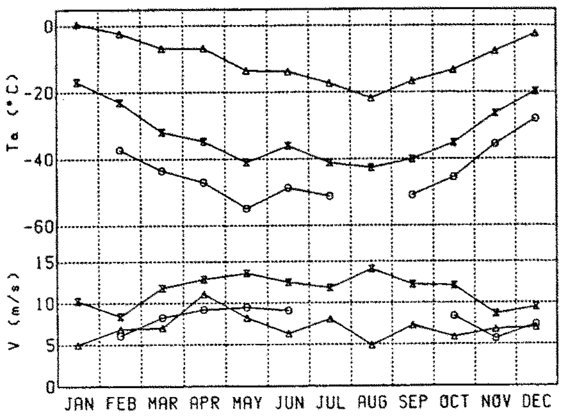


Fig. 1. Monthly averages of the air temperature and wind speed at Advance Camp (○), Mizuho Station (×) and Syowa Station (△), in 1985.

are well correlated with those from Mizuho. The data from Syowa are rather poorly correlated with those from both AC and Mizuho, although the correlation coefficient of the temperature appears to be high because of the predominance of the annual cycle. The low correlation between the coastal and the inland weather events is depicted better by the wind data.

The regression analysis is also carried out using the least squares method. The temperature T_{AC} and wind speed V_{AC} at AC can be calculated with

$$T_{AC}=0.99T_{MZ}-11.2 \quad (^{\circ}C) \qquad (1)$$

and

$$V_{AC}=0.69\ V_{MZ}+0.2 \qquad (m\ s^{-1}), \qquad (2)$$

where T_{MZ} and V_{MZ} are the values at Mizuho Station.

Although there are no observations in January and no wind data from July to September, the annual mean values can be calculated by using equations (1) and (2). The estimated average values are −43.2°C and 8.2 m s^{-1} for the temperature and wind, respectively. The estimated temperature agrees fairly well with the snow temperature, −44.5°C, measured at a depth of 10 m (Ageta *et al.*, 1986). These values are compared with the climate data from other Antarctic stations and are shown in Fig. 2. The data demonstrate clearly that AC is climatologically located between the South Pole and Pionerskaya Station.

The estimated annual mean values are compared with the criterion given in Table 2 by Dalrymple (1966). Although the temperature lies within the Cold

Table 3. Correlation coefficients of temperature and wind speed calculated from the monthly mean values.

Stations	Temperature	Wind speed
AC – Mizuho	0.96	0.97
AC – Syowa	0.78	0.38
Mizuho – Syowa	0.91	0.38

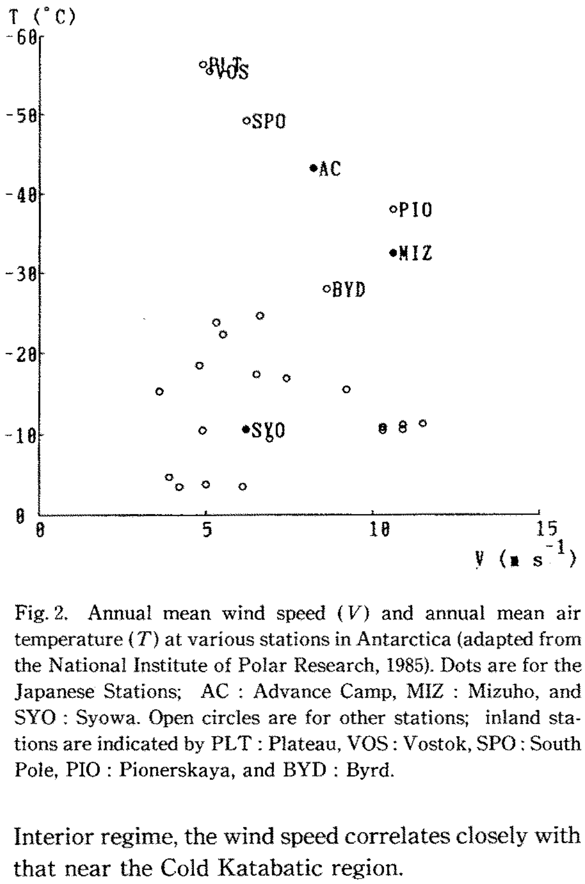


Fig. 2. Annual mean wind speed (V) and annual mean air temperature (T) at various stations in Antarctica (adapted from the National Institute of Polar Research, 1985). Dots are for the Japanese Stations; AC : Advance Camp, MIZ : Mizuho, and SYO : Syowa. Open circles are for other stations; inland stations are indicated by PLT : Plateau, VOS : Vostok, SPO : South Pole, PIO : Pionerskaya, and BYD : Byrd.

Interior regime, the wind speed correlates closely with that near the Cold Katabatic region.

Satow (1978) reports the distribution of 10−m depth snow temperature, which is presumably equal to the annual mean surface temperature, in the Enderby Land area (about 300 km east of AC). At the same level, the temperature varies from −46°C to −49°C and is considerably lower than the present estimate ; the 10−m snow temperature at AC is also higher than the above values.

Satow (1978) also reports a difference in the snow temperature gradient with the elevation along two traverse lines ; the typical value of gradient is −13 mK m^{-1} for the area of 1000 to 3000 m in elevation, while a transition to a larger absolute value of about −20 mK m^{-1} occurs at 3000 m along one route and at about 3200 m along another. The annual air temperature gradient between AC and Mizuho in 1985 was −11 mK m^{-1}, which is even smaller than that of the lower altitude value shown for the Enderby Land area. Ageta *et al.* (1986) pointed out that the transition to a larger temperature gradient occurs at a higher altitude of about 3400 m in the present study area.

Table 4 lists the parameters which characterize the katabatic wind ; these are the height above sea level (H), slope inclination, resultant (vector mean) wind speed (V_r) and direction (D_r), directional constancy (q) and the deviation angle from the slope (α). The directional constancy is the ratio of V_r to the scalar mean wind speed, and it is unity if the wind direction is constant throughout. The definitions of the parameters are described in detail in Schwerdtfeger (1984).

Earlier estimates of the slope inclination at Mizuho varied from 3×10^{-3} (Kobayashi, 1978), which is cited in Schwerdtfeger (1984), to 5×10^{-3} (Ohata *et al.*, 1985). A recent map compiled by Drewry (1983) indicates a moderate value of 3.8×10^{-3}, which is quoted in Table 4, on a horizontal scale of 50 to 100 km. The slope is in a 300° direction clockwise from the geographic north.

The slope at AC, 2.8×10^{-3} at 325°, is also estimated from the Drewry (1983) map. A preliminary estimate was made from a map based on measurements made by Japanese Antarctic Research Expeditions and by Levanon (1982) (National Institute of Polar Research, 1982). The slope direction thus estimated gave an α value of 54°, which was considerably larger than the value of Mizuho.

It is noteworthy that the q values at AC and Mizuho are significantly larger than those of the other three inland stations. Also, the temperature at AC is higher than that at the South Pole, as can be seen from Fig. 2, though the elevation of the former is higher than that of the latter.

It should also be noted that the wind vector averaged over the period from April to June (Fig. 4), 8.7 m s^{-1} at 108°, agrees fairly well with the windfield map made by Parish and Bromwich (1987) using a simple theoretical model. The model (Ball 1956 ; Parish and Bromwich 1986) predicts a wind of 9.2 m s^{-1} at 114°, with an inversion strength and height of 20 K and 200 m, respectively.

Table 4. Resultant wind vector (V_r : speed, D_r : direction), directional constancy (q) and deviation angle from the fall line (α) at inland stations

Station	Height (m a.s.l)	Slope (10^{-3})	V_r (m s^{-1})	D_r (°)	q	α (°)
Advance Camp (1985)	3200	2.8[1]	7.5[2]	106	.93	39
Mizuho (1985)	2230	3.8[1]	11.1	91	.96	29
South Pole[3]	2835	1.0	4.6	39	.79	61
Vostok[3]	3488	1.3	4.1	243	.81	42
Plateau[3]	3625	0.8	3.4	335	.67	55

1) based on the map by Drewry (1983).
2) only the available data are used.
3) adapted from Schwerdtfeger (1984).

3. Daily cycle variations in summer

Fig. 3 displays the three-hourly values of the cloud amount N, the air temperature T, the wind direction D, the wind speed V and the atmospheric pressure at the station level P measured at AC with solid lines and at Mizuho Station with broken lines. Only the data for March, May, July and December are shown for the sake of space capacity. The long-term recorder provided only T, D and V for AC in March, May and July.

The daily cycle variation of the air temperature is apparently predominant in March and December. The variation disappears in early April and does not prevail until mid September. These dates correspond to about a week after and a week before the autumn and spring equinoxes, respectively.

Fig. 4 shows the daily cycle variations of the surface wind vector in March, April-June, November and December. From April, the daily cycle wind variation disappears, like the variation of air temperature. The daily cycle wind variation is the largest in December.

The wind hodograph rotates counterclockwise and the wind speed maxima appear at about 9 to 12 LT. The behavior of the wind vector rotation may be explained within the framework of Ball's (1956) theory (van Meurs and Allison, 1986), but it should be noted that the pattern of the hodograph in December is considerably more distorted from that in November.

Fig. 5 shows the averages of 6 hourly upper wind observations which were made between the surface and the height of 1950 m in November and December. The data from these runs, in which the balloons were not fully tracked, are excluded because they may result in an unrealistic hodograph. The numbers of soundings averaged in Fig. 5 are 66 and 73 for November and December, respectively. It is clearly shown that the upper easterly wind was larger in December than in November. The association of the distorted surface wind hodograph and the strong easterly wind in December seems to indicate a strong interaction between the upper atmosphere and the surface boundary layer.

Fig. 6 shows the upper potential temperature profiles in the daytime (15 LT) and the nighttime (03 LT) averaged over 6 days in December. It is clearly shown that the daytime convection layer, which reaches about 400 m above the surface, is the cause of the strong interaction between the daytime surface wind and the upper wind.

Daytime strong winds are also observed at D80 in Adelie Land by Sorbjan *et al.* (1986 ; see also Wendler *et al.*, 1985), and the phenomena of coupling and decoupling during the daytime and nighttime, respectively, between the upper boundary layer and the lowest surface layer are noted. The upper wind or synoptic pressure gradient is sometimes neglected in descriptions of the winter wind pattern over Antarctica using theories of katabatic wind (*e.g.*, Schwerdtfeger, 1984) because the boundary layer is supposed to be decoupled from the upper layer in winter. But, these coupling and decoupling cycles and the synoptic pressure gradient should be taken into considerations for determining the windfield pattern in summer.

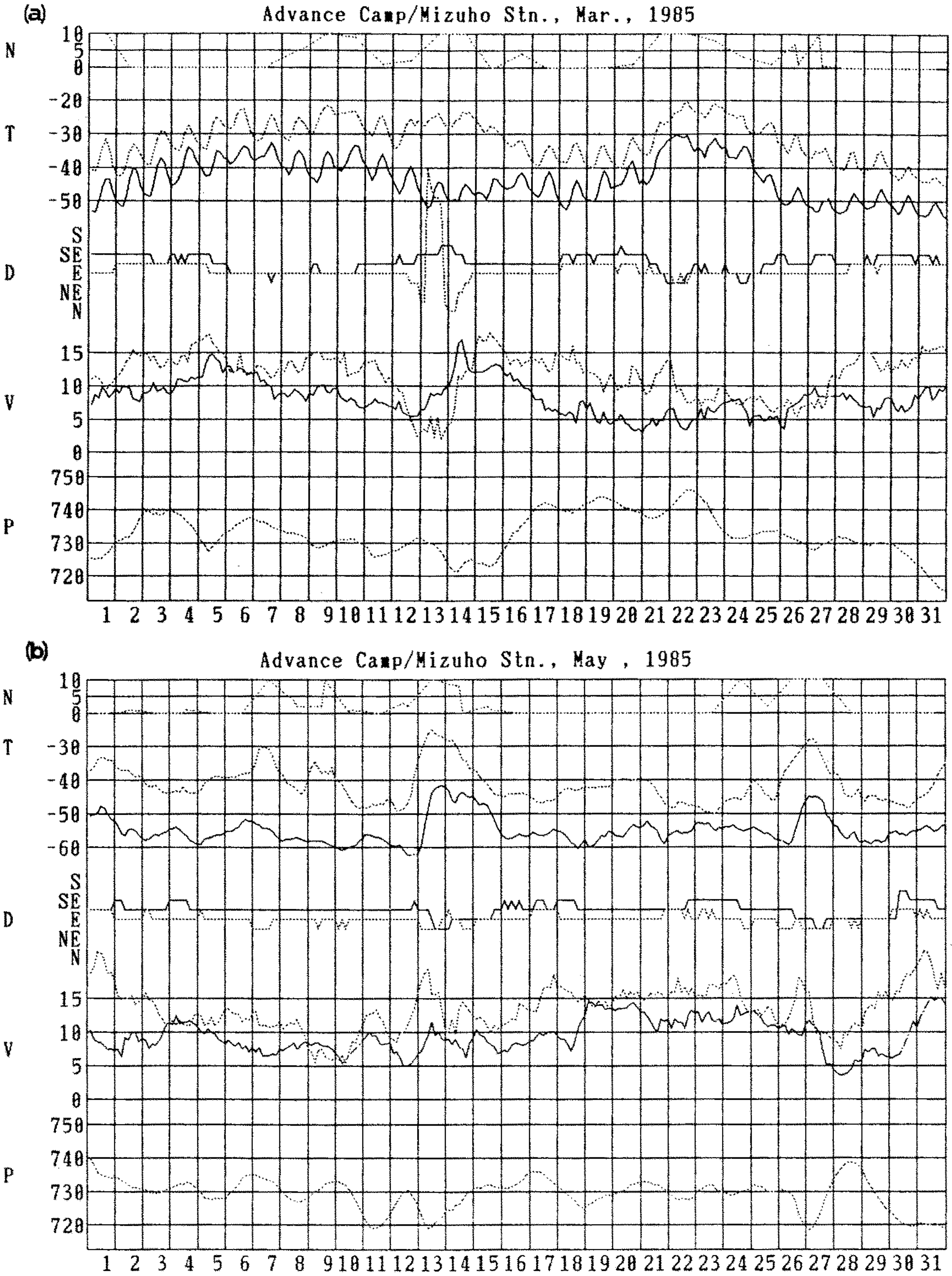
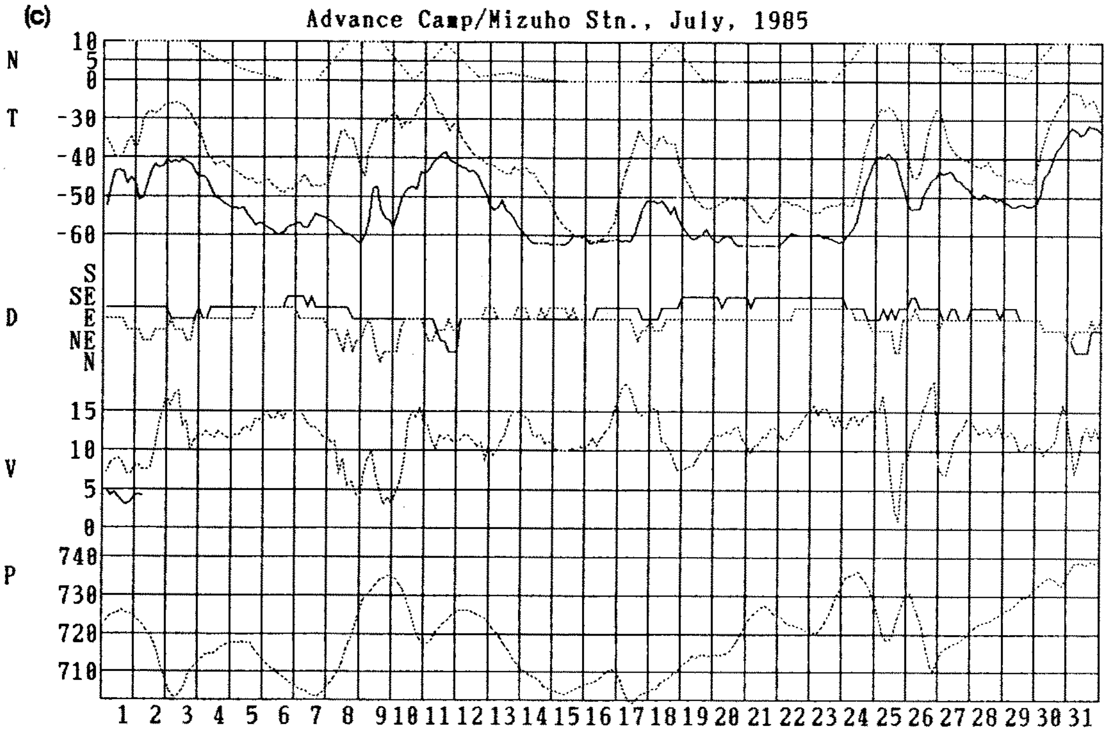
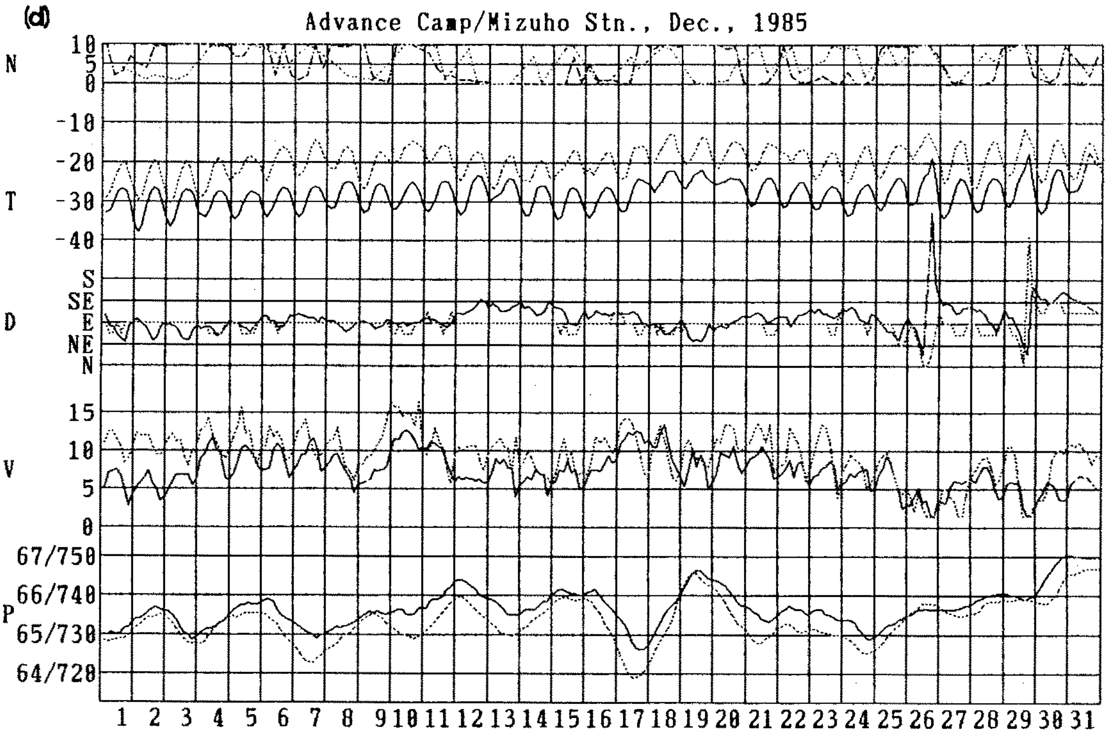


Fig. 3. Meteorological data from Advance Camp (solid lines) and Mizuho Station (dotted lines), (a) March, (b) May, (c) July, and (d) December, 1985. N is the cloud amount in the tenth scale, T the air temperature in ℃, D the wind direction, V the wind speed in m s^{-1} and P the atmospheric pressure at the station level in hPa.


(c)
Advance Camp/Mizuho Stn., July, 1985
N
T
D
V
P
10
5
0
-30
-40
-50
-60
S
SE
E
NE
N
15
10
5
0
740
730
720
710
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


(d)
Advance Camp/Mizuho Stn., Dec., 1985
N
T
D
V
P
10
5
0
-10
-20
-30
-40
S
SE
E
NE
N
15
10
5
0
67/750
66/740
65/730
64/720
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

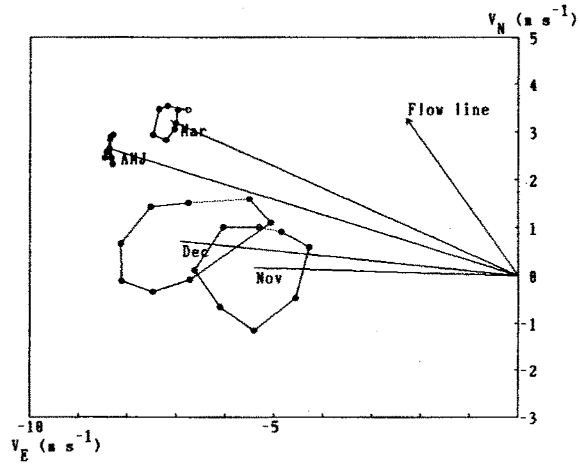


Fig. 4. Daily cycle wind vector variations at Advance Camp for March, April-May-June (combined), November and December, 1985. Open circles denote 3 LT data and dotted lines connect 24 to 3 LT. V_N and V_E denote northward and eastward components, respectively, of the wind vector. 'Flow line' indicates the surface slope direction.

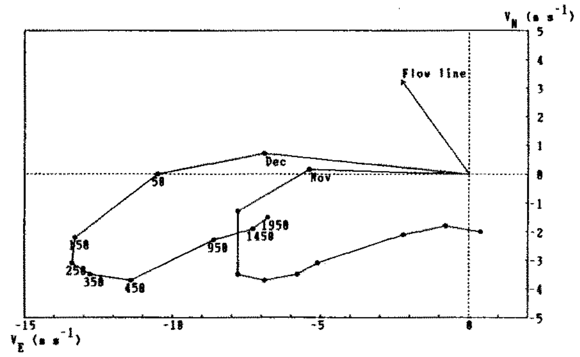


Fig. 5. Upper wind hodographs at Advance Camp for November and December, 1985. Open circles indicate the mean surface wind vector. Numbers associated with the December data dots are the height above the surface in m. Other notations are the same as in Fig. 4.

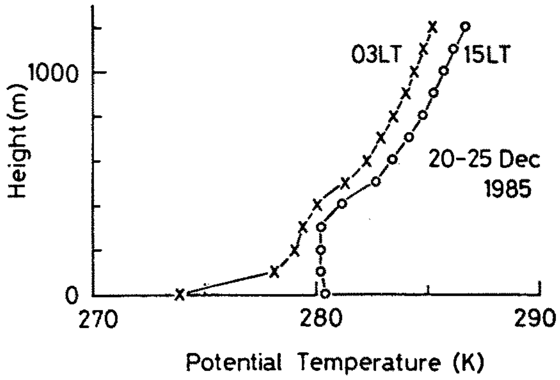


Fig. 6. The daytime (15LT) and nighttime (03LT) potential temperature profiles at Advance Camp averaged over the period 20–25 December, 1985.

4. Synoptic disturbances

In summer, the periods when the daily variation became small seemed to correspond to the arrival of synoptic disturbances ; the cloud amount and wind speed increased, as they did in 21–22 March and 17–20 December. The temperature also increased during those periods, although the variations were obscured by the diurnal ones.

On the other hand, the variations of temperature in winter seemed to be governed solely by synoptic disturbances. For example, the temperature increased suddenly from −60°C to −40°C in 24 h on 24 July. The cloud amount at Mizuho increased from 0 to 10 in the same period. Then, the air temperature decreased gradually after a cycle of sudden cooling and warming, which may be due to a disturbance of a shorter cycle, during the period from 27 to 29 July, until the next disturbance came on 30 July. Similar cycles of sudden warming and gradual cooling can also be observed in the May record. The gradual cooling may be related to the gradual retreat of cloud masses which is suggested by the Mizuho cloud amount.

The intervals of arrivals of the disturbances were about two weeks and 7 to 8 days in May and July, respectively. The above period seems to be considerably shorter than those given by Parish (1982) for the three Soviet Antarctic interior stations. The relative proximity of AC in the coastal region seems to be responsible for the shorter interval, although a sophisticated statistical analysis may be required for a precise comparison.

The traces of temperature in Fig. 3 indicate that synoptic disturbances arrive at both stations almost simultaneously, although there were some minor disturbances which did not affect AC. Endoh *et al.* (1987) found that the arrival of a synoptic disturbance at AC was about one day earlier than that at Mizuho from the data obtained in February and March, 1985. However, in some cases, the arrival was earlier at Mizuho than at AC in the other seasons. For example, a temperature maximum was observed at 03

LT on 11 July at Mizuho, while the related maximum at AC was at 15 LT on the same day. The time-lags in the arrivals of disturbances were quite variable from one case to another.

Bromwich (1987) pointed out that precipitations in the Antarctic region are caused by intrusions of warm moist ridges. The association between penetrating cloud masses and warm upper level ridges is illustrated schematically by Fauquet (1982). The largest blizzard encountered during the present summer observations occurred from 17 to 20 December. The wind shifted to the north and the temperature increased, and column or whisker type ice crystal precipitation was observed. These observations agree with the explanation given by Bromwich.

During the present blizzard, NOAA−9 satellite imageries revealed that a cyclone entered and stayed inside the Lambert Glacier region, 1000 km east from AC, becoming the center of the disturbance. The cloud mass associated with the cyclone traveled eastward on the plateau. This kind of synoptic situation was already noted by Kawaguchi (1982) in his study on the weather patterns at Mizuho. However, the cloud stayed over the AC region until 20 December, while a clear sky was observed at Mizuho a day earlier, the 19. The NOAA imageries suggested that the cloud mass merged with another disturbance as the blizzard reached the end of the plateau. Further studies on individual disturbances may be required to construct a refined model of the synoptic disturbances affecting the plateau.

5. Concluding remarks

From the meteorological data obtained from AC and Mizuho Station, new information on the climate and weather of the Antarctic plateau was revealed.

The climate of AC is characterized by a higher wind directional constancy and a higher temperature than those of the other study areas situated on the 3000−m high plateau. Overall appearance of the climatic conditions at AC seemed to be rather close to that at Mizuho. It was suggested that the steep slope is responsible for the climatic characteristics, but other factors such as the distance from the coast may be relevant.

In summer, the temperature and the wind vary with daily cycles. The wind variation is not only governed by the variation in the katabatic force but also by the development of a daytime convection layer. The upper wind caused by the synoptic system seems to be important in describing the surface wind during the summer.

Therefore, caution must be made in the interpretation of sastrugi orientations observed during oversnow traverses. The sastrugi orientations at AC (Ageta *et al.*, 1986) coincide well with the winter resultant wind directions. However, in a region of higher altitude, there seems to be a systematic deviation of the orientations to the upslope directions from the supposed katabatic direction. Similar observational results were also noted by Parish and Bromwich (1987) over gently sloping parts of the Antarctic ice sheet. The strong daytime wind coupled with the effects of the synoptic system may affect the orientations in the regions where the katabatic winds are not strong enough to create sastrugi. Synoptic disturbances may also be important in winter because they are accompanied by strong winds.

The synoptic conditions of AC resemble those of Mizuho Station ; the disturbances reach both stations almost simultaneously and seem to be associated with warm ridges. Details of individual disturbances require further study.

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