—研究論文—
Scientific Papers

Observations of the Stationary Katabatic Winds in Mizuho Plateau, East Antarctica

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みずほ高原における定常的なカタバティック風の観測

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要旨: 第14次南極地域観測隊における研究観測の気象部門は，内陸調査旅行中みずほ高原で，ラジオゾンデとパイロットバルーンによりカタバティック風の垂直構造について調べた．観測した回数は充分多くはなかったが，みずほ高原におけるカタバティック風の厚さは接地逆転層に一致していることが結論された．

逆転層の厚さは夏 (250 m) より冬 (600 m) 厚く，逆転層の強さ (温度差 ΔT) は，夏 ($\Delta T \approx 5°C$) より冬 ($\Delta T \approx 15 \sim 20°C$) 強かった．

Abstract: This paper describes the study on the thickness and intensities of surface inversions and vertical wind profiles in a katabatic wind layer existing semipermanently in the Mizuho Plateau. Observations of vertical temperature and wind profiles in lower layer were carried out ten times by means of radio sondes, and five times by pilot balloons to know upper wind directions, at mainly Mizuho Camp (70°42.6′S, 44°18.9′E, 2,200 m) in 1973.

From results obtained, it was found that the thickness of the surface inversion layer were about 600 m in winter and 250 m in summer, and temperature difference between the top and the bottom of the surface inversion layer (intensity) were in the range from 15 to 20°C in winter and about 5°C in summer.

1. Introduction

The studies of katabatic winds have been made by many investigators since IGY. A theoretical study of katabatic wind was first published by BALL (1956, 1960), who derived that various characteristics of the flow can predicted, including the intensity of the hydrauric jump, that will occur near the coast, and the deviation of the wind from lines of greatest slope caused by the Earth's rotation. However, the stationary katabatic winds blow in the vicinity of the Mizuho Camp and did

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not occur the hydrauric jump in there. But, MORITA (1968) reported some characteristics of katabatic winds at Syowa Station (69°00′ S, 39°35′ E, on East Ongul Island), and the effect of katabatic winds reach to Syowa Station only when the katabatic flow "type 2" in BALL's theory which the jump occurs inland. AGETA (1971) deduced the flow lines of katabatic winds in the vicinity of the Mizuho Plateau from the orientations of sastrugi and pitted patterns.

The present authors were the members of 14th Japanese Antarctic Research Expedition in 1973–1974, and measured vertical profiles of temperature and wind by using radio-sondes and pilot balloons at three sites in Mizuho Plateau in 1973. This observations were incidentally carried out on the way the glaciological traverse (NARUSE, 1975), so that the data collected were not sufficient and could not exhaustive survey of katabatic winds. However, it was found on the structure and seasonal variations of katabatic wind layer which predominates on the Mizuho Plateau.

2. Measurements and Results

The radio-sonde used for the present study consisted of an aneroid barometer, a thermister and carbon hygrometer, but in many cases the carbon hygrometer was replaced by a thermister in order to get more accurate temperature values. The trajectory of the rubber balloon inflated with helium gas, slinging a sonde, was obtained by using a theodolite every 15 seconds. The signals received by a Yagi antenna were recorded on paper charts. Radio-sondes were released at Mizuho Camp, Station C98 and Yamato Mountains as shown in Fig. 1, and pilot balloon observations were made only at Mizuho Camp.

The positions, elevations and slope of these three observation stations are given in Table 1. Surface meteorological conditions during the observations by radio-sondes and pilot balloons are shown in Tables 2 and 3, respectively. As shown in Table 2, the observations of radio-sondes were made in clear-sky conditions. When weather conditions were cloudy, the observations using the pilot balloons made to know the upper wind direction. Runs P2, P3 and P4 in Table 3, examples in winter, show that upper wind directions are roughly easterly. Run P4 in Table 3 is an example that cloud height of altostratus was about 2,800 m M.S.L. (600 m above snow surface at Mizuho Camp) measured by pilot balloon.

2.1. Lower layer temperature profiles above Mizuho Plateau

The surface temperature inversion above Mizuho Plateau is closely connected with katabatic winds. Although the annual mean speed of wind at Mizuho Camp is as high as 11 m/s (SASAKI, 1974), the inversion can develop there, and the turbulence

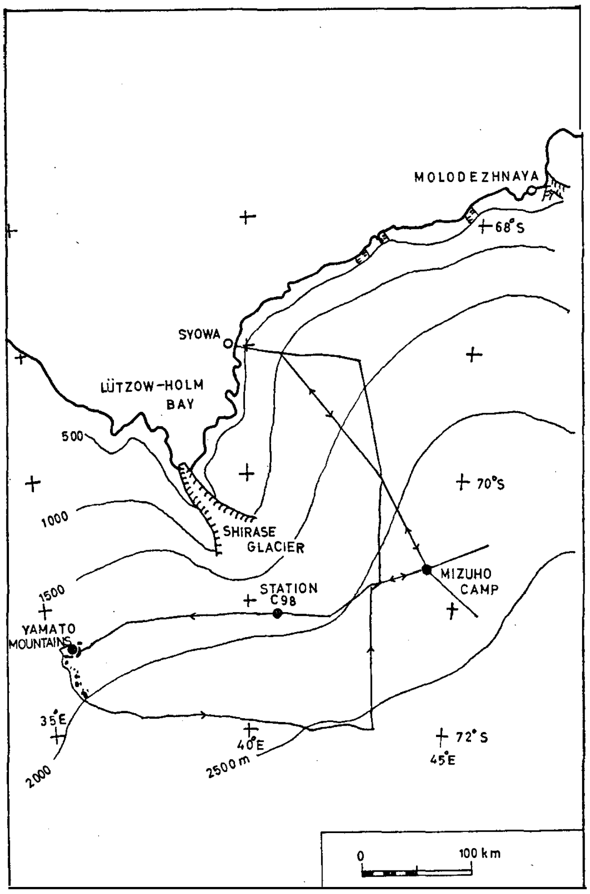


Fig. 1. A map of three observation points, Mizuho Camp, Station C98, Yamato Mountains, and the routes of the over-snow traverse.

Table 1. The position, elevation and slope of observation stations.

Observation stations	Latitude (S)	Longitude (E)	Elevation (meters)	Mean surface slope
Mizuho Camp	70°41′53″	44°19′54″	2230	4×10^{-3}
Station C98	71°06′00″	40°45′30″	1824	8×10^{-3}
Yamato Mountains	71°19′10″	35°39′28″	1678	5×10^{-3}

created by cyclonic strong winds more than 20 m/s can only destroy the inversion in a relatively short period, however, reform quickly when the wind speed decreased less than about 10 m/s and the sky becomes clear.

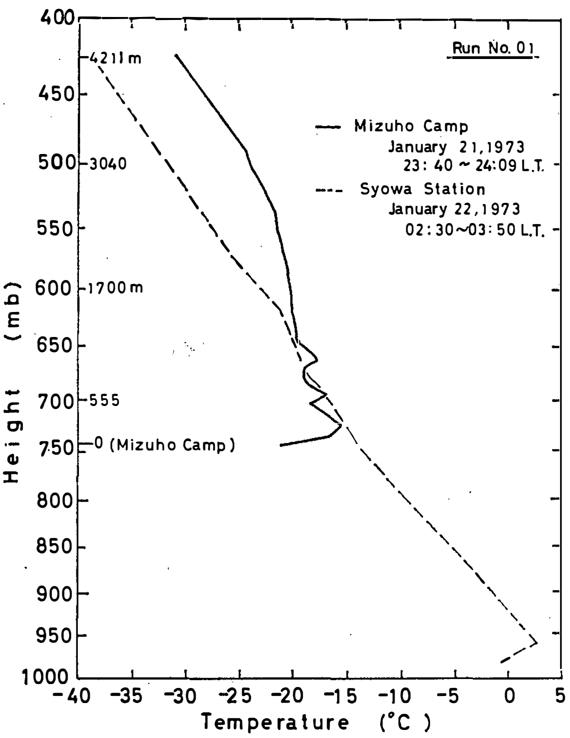
Temperature profiles at Mizuho Camp, Station C98 and Yamato Mountains in summer are shown in Figs. 2 (a), (b), (c), represented as solid lines in the figures. The dashed lines in the figures show the temperature profiles at Syowa Station about 250 km away from Mizuho Camp. From Figs. 2 (a), (b), (c), it found that in summer the temperatures above about 750 mb at Mizuho Plateau are higher than those at Syowa Station by 3 to 5 degrees. This may be explained by the predominant descending air flow in the upper layer at Mizuho Plateau under the Antarctic anticyclone

Table 2. Surface meteorological conditions during the radiosonde observations in Mizuho Plateau, 1973.

Run	Date	Local time	Location	Wind speed (m/s)	Wind direction in true (N: 360°)	Pressure (mb)	Temperature (°C)	Amount of cloud (in tenths)	Weather
01	Jan. 21	24h00	Mizuho Camp	9	110°	743	−21	0	Fine, drifting snow
02	Apr. 20	15 00	〃	10	90°	733	−36	8	Cloudy, blowing snow
03	Apr. 23	14 20	〃	11	120°	737	−42	3	Fine, blowing snow
04	Aug. 25	15 00	〃	11	95°	708	−52	0	Fine, drifting snow
05	Aug. 31	11 20	〃	11	135°	730	−43	0	Fine, drifting snow
06	Sep. 15	15 40	〃	11	90°	717	−43	0	Fine, drifting snow
07	Sep. 26	17 30	〃	3	45°	721	−33	1	Fine, halo
08	Nov. 21	13 00	C98	5	100°	764	−17	3	Fine
09	Nov. 21	18 00	C98	7.5	95°	765	−24	2	Fine
10	Dec. 12	12 30	Yamato Mts. D0	13	65°	784	−12	0	Fine, drifting snow

Table 3. Surface meteorological conditions during the pilot balloon observations and result of upper wind direction at Mizuho Camp, 1973.

Run	Date	Local time	Upper wind direction in true (N : 360°)	Surface wind speed (m/s)	Surface wind direction in true (N : 360°)	Pressure (mb)	Temperature (°C)	Amount of cloud (in tenths)	Weather
P1	Jan. 21	16h00	90°	7	110°	743	−15	2	Fine
P2	Aug. 29	12 20	90°	12	115°	716	−39	5	Cloudy, blowing snow
P3	Sep. 12	11 40	73°	7	110°	714	−32	7	Cloudy, drifting snow
P4	Sep. 12	12 00	73°	7	110°	714	−32	7	Cloudy (As), drifting snow, cloud height ≒2,800 m M.S.L.
P5	Sep. 23	17 00	270°	7	90°	732	−42	0	Fine



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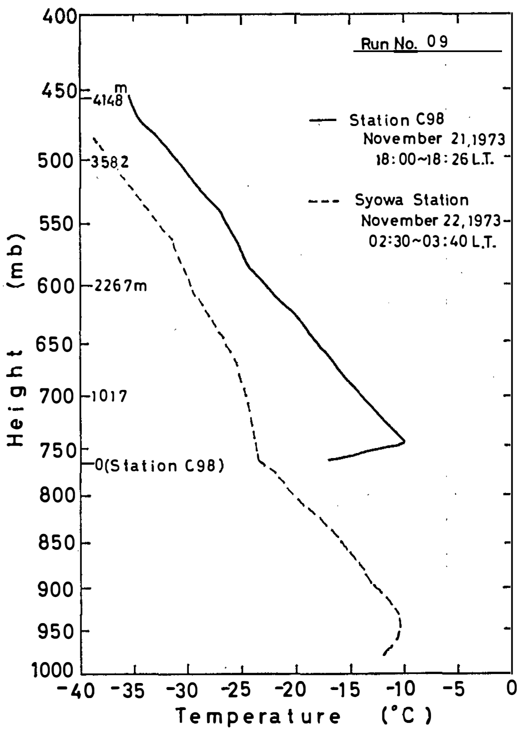

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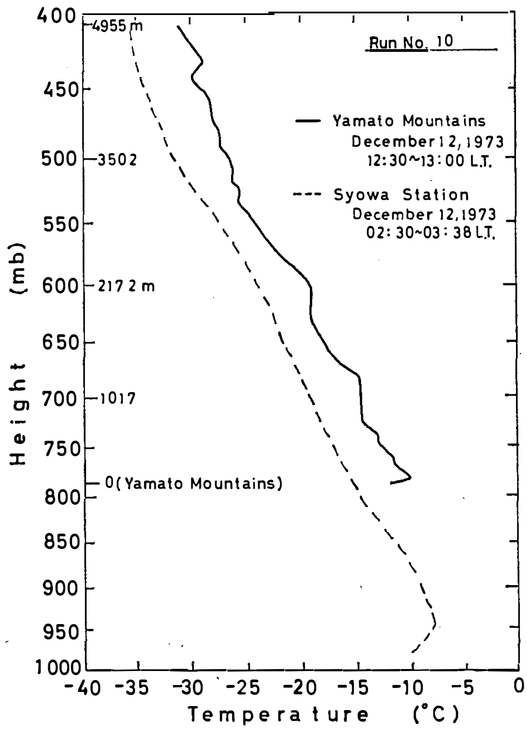

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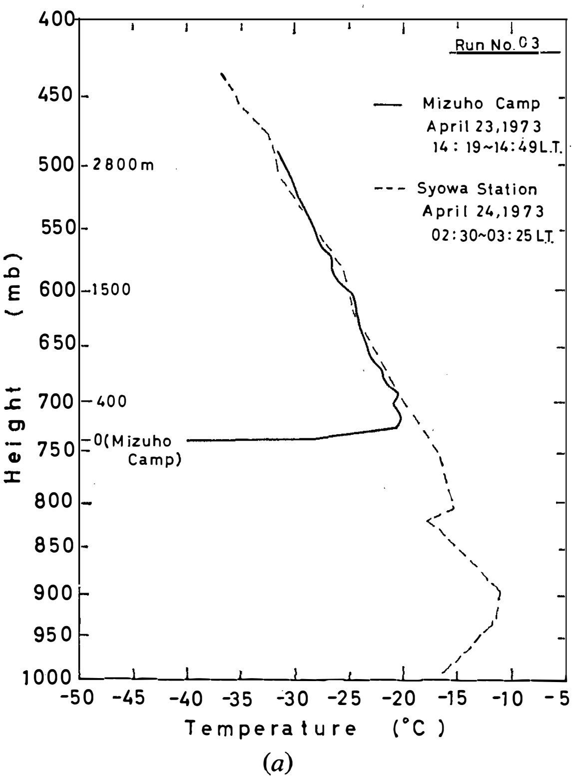
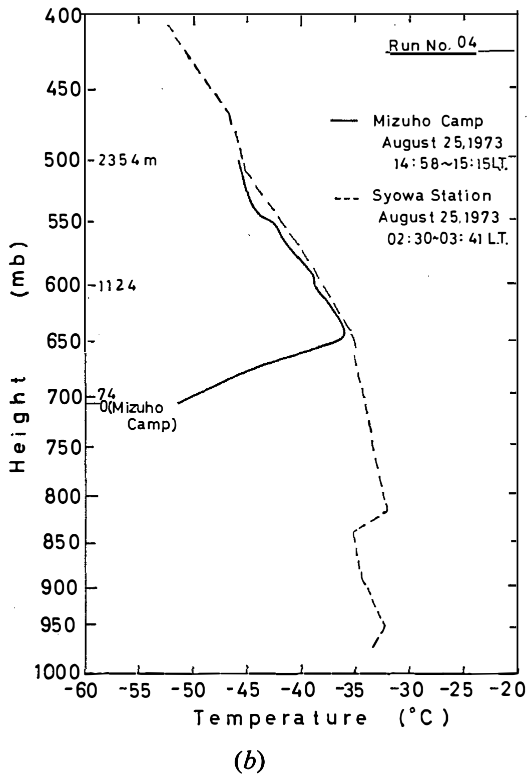
Fig. 2 (a). Temperature profiles in the austral summer at Mizuho Camp (solid line) and Syowa Station (dashed line).

(b). Temperature profiles in the austral summer at Station C98 (solid line) and Syowa Station (dashed line).

(c). Temperature profiles in the austral summer at Yamato Mountains (solid line) and Syowa Station (dashed line).





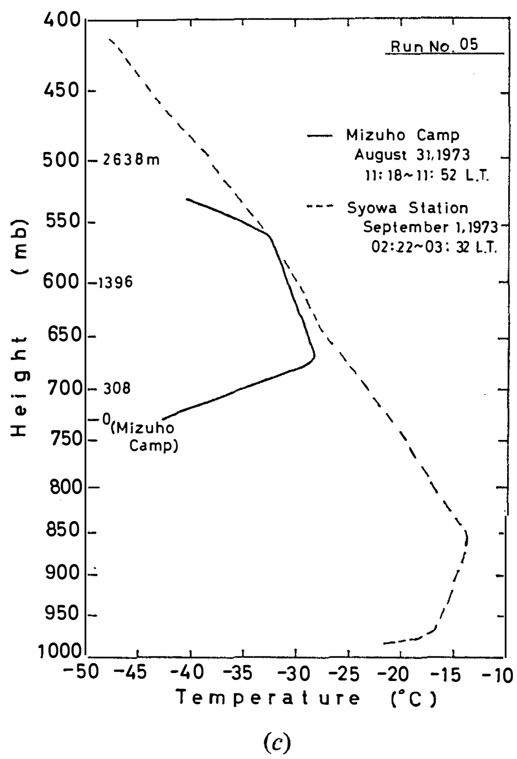


Fig. 3 (a~c). Temperature profiles in the austral autumn and winter at Mizuho Camp (solid line) and Syowa Station (dashed line).

(COURT, 1951), in which the air is warmed dry-adiabatically in comparison with Syowa Station. Although data are not sufficient, they show that the thickness of surface inversion in summer were about 250 meters, and the difference in temperature between the top and bottom of the layer (intensity) in summer were about 5 degrees. However, the intensity of inversion obtained at Yamato Mountains (Fig. 2 c) is smaller than those at Mizuho Camp (Fig. 2 a) and Station C98 (Fig. 2 b), because of the effect caused by nunataks.

On the other hand, temperature profiles at Mizuho Camp in autumn and winter are shown in Figs. 3 (a), (b), (c). The dashed lines at Syowa Station in the figures seem to coincide with the solid lines at Mizuho Camp above the surface inversion layer in autumn and winter season. The thickness of surface inversion in winter were about 600 m, but 250 m in autumn, and the intensity of inversion were in the range from 15 to 20°C.

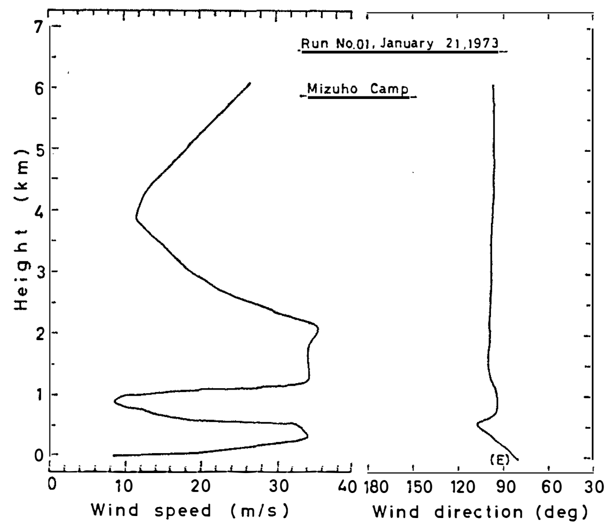
The largest intensity of surface inversion, about 20°C, was observed in April, while the deepest thickness of inversion of about 600 m in August.

2.2. Wind speed and wind direction profiles above Mizuho Plateau

Profiles of wind speed and wind direction above Mizuho Plateau in summer are shown in Figs. 4 (a), (b), (c). As shown in Figs. 4 (a), (b) the wind direction above katabatic wind layer (nearly equal to the inversion layer) agreed with that at the surface: directions of surface wind and upper wind are roughly easterly. Fig. 4 (c) shows the result obtained at Yamato Mountains, and the wind direction above katabatic wind layer was southly different from surface wind of easterly. In summer season the katabatic wind speed showed a minimum at 0300 LT and a maximum at 1500 LT once a day, which correspond to the maximum and minimum of the air temperature, respectively (YAMADA, 1974). Fig. 4 (b) shows an example of a change in the katabatic wind within five hours, from 1300 LT to 1800 LT, November 21, 1973. In this figure the solid line shows a gentle katabatic wind observed at noon, and the dashed line shows a strong one developed after five hours. This strong katabatic wind was nearly the same as that in winter season in spite of weaker surface wind of around 10 m/s in summer than that in winter season.

On the other hand, profiles of wind speed and wind direction at Mizuho Camp in autumn and winter are shown in Figs. 5 (a), (b), (c), (d). In the cases of Figs. 5 (a), (b) and (d), the wind direction in the upper layer were roughly westerly, which is considered to be the compensating current against surface wind in easterly. But, an example of Fig. 5 (c) showed that the wind direction in upper layer was southly. In Fig. 5 (a), (b), examples of autumn, the wind speed in upper layer were weaker than that in winter season (Fig. 5 c, d).

In the inversion layer the wind profiles have a maximum speed at lower part of inversion and a minimum speed at upper part, and the shape of wind profiles are similar to the shape of the so-called "wall jet". The wall jet is a jet of fluid impinging tangentially on a solid boundary. From Figs. 4 and 5, the values of maximum speed were in the range from 15 to 20 m/s at the height of 100 m. The levels of the minimum speed coincided roughly with the top of the inversion, suggesting that katabatic winds blow only in the inversion layer.



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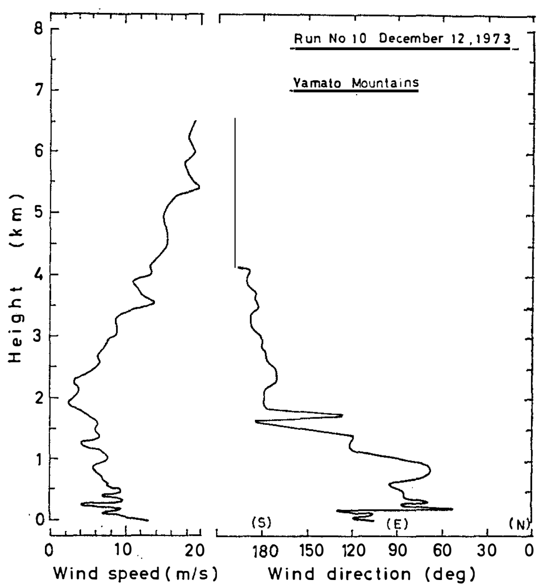

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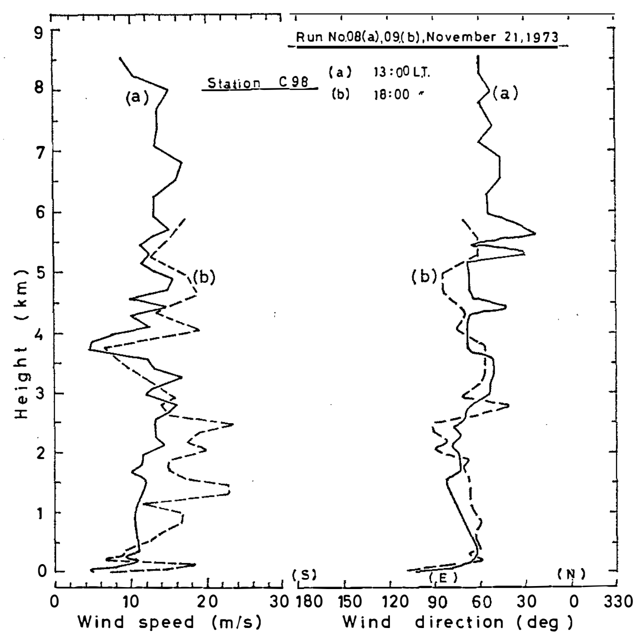

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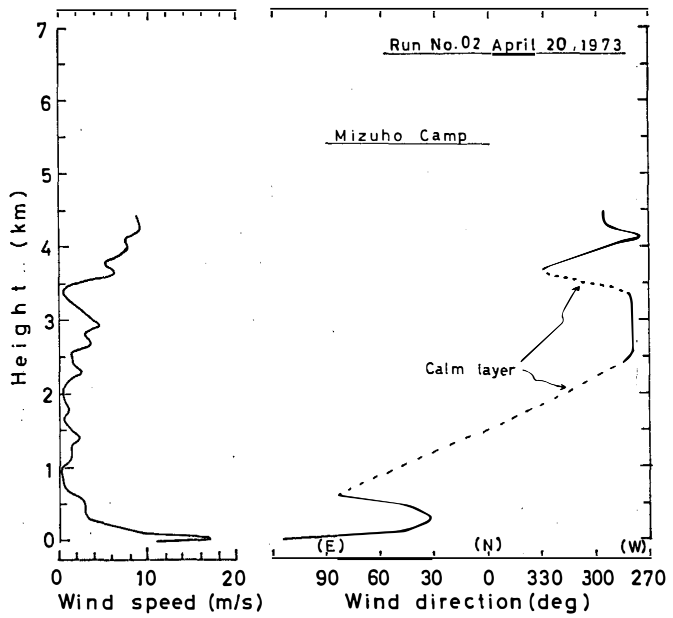
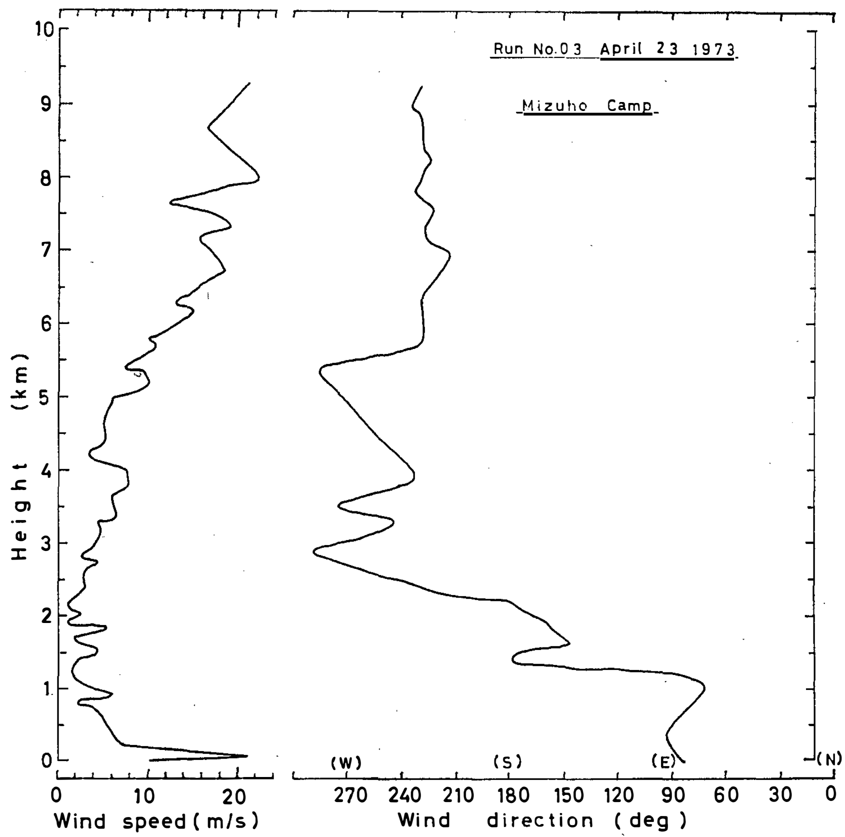
Fig. 4 (a). Profiles of wind speed and direction in the austral summer at Mizuho Camp.

(b). Profiles of wind speed and direction in the austral summer at Station C98. The solid line shows the result at 1300 LT and dashed line at 1800 LT.

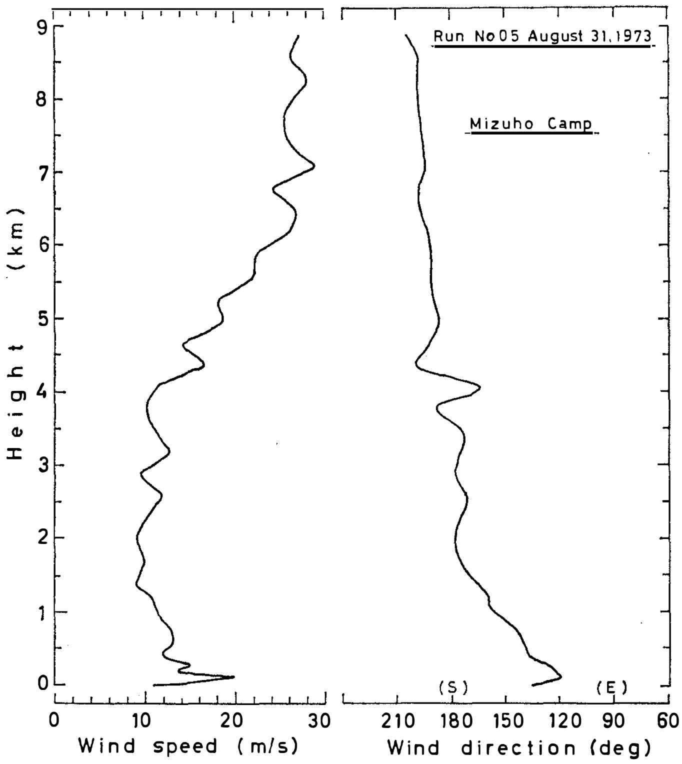
(c). Profiles of wind speed and direction in the austral summer at Yamato Mountains.


Run No. 02 April 20, 1973
Mizuho Camp
Height (km)
Calm layer
(E)
(N)
(W)
Wind speed (m/s)
Wind direction (deg)

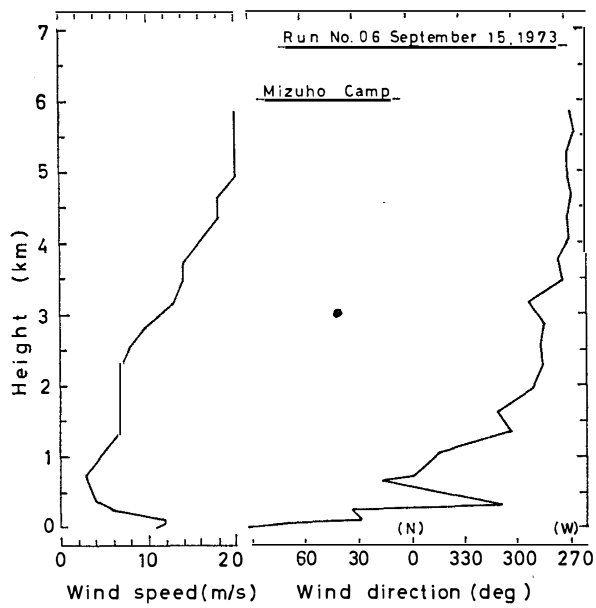
(*a*)


Run No. 03 April 23 1973
Mizuho Camp
Height (km)
(W)
(S)
(E)
(N)
Wind speed (m/s)
Wind direction (deg)

(*b*)



(c)



(d)

Fig. 5 (a~d). Profiles of wind speed and direction in the austral autumn and winter at Mizuho Camp.

2.3. Influence of a cyclone on the katabatic wind

It was already mentioned that the katabatic wind is affected by cyclonic activities. An example of such an influence of a cyclone passing over the ocean in the vicinity of Syowa Station was observed and the variations of the temperature and wind speed at Mizuho Camp are shown in Fig. 6. When the cyclone approached near the coast, the katabatic wind was strengthened and the air temperature was raised at Mizuho Camp; conversely when the cyclone went away from the coast the wind speed decreased even to about 1 m/s. It took about 15 hours before the stationary katabatic wind regime was restored. When the wind speed decreased, the air temperature also decreased at the rate of −1.7°C/hr. After the pass of this cyclone, profiles of wind speed and wind direction were observed and shown in Fig. 7, which clearly the destruction of katabatic wind layer by the strong turbulent wind. Namely, as shown in Fig. 7 the shape of wall jet at lower part of wind profile is extinguished.

3. Discussion

Six temperature profiles and nine wind profiles in the atmospheric surface

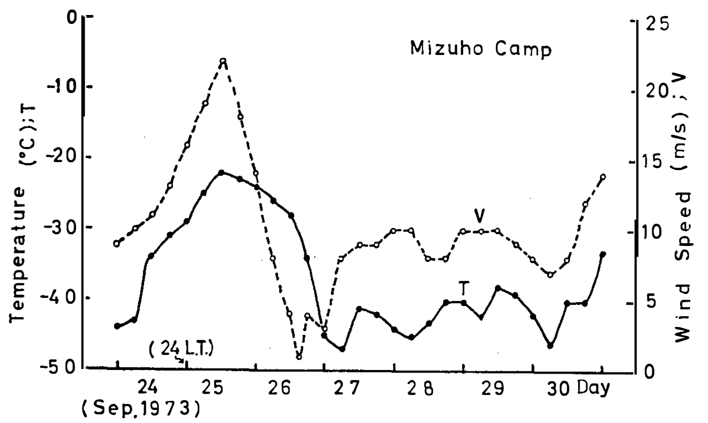


Fig. 6. Variations of temperature (T) and wind speed (V) at Mizuho Camp when a cyclone were passing nearly.

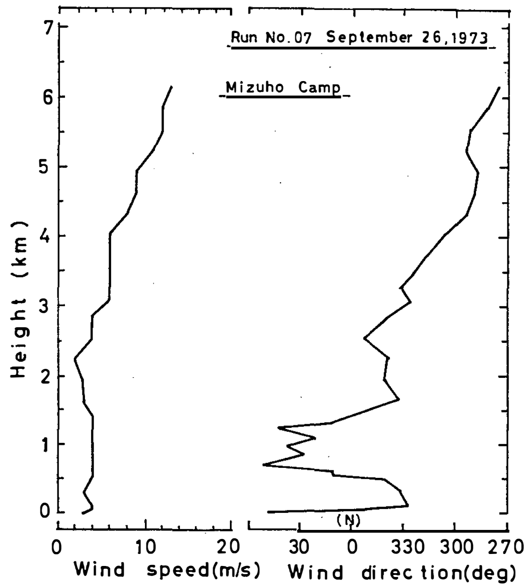


Fig. 7. Profiles of wind speed and direction after a cyclone passed, 26 September 1973. An example of the destruction of katabatic wind layer by the strong wind.

boundary layer were obtained by means of radio-sondes above Mizuho Plateau, East Antarctica. The results are summarized as follows:

(1) The thickness of the surface inversion in winter, 600 m, is much deeper than that in summer, 250 m, and the intensity of inversion is much greater in winter (15～20°C) than in summer (about 5°C).

(2) The katabatic winds showed a maximum speed of 15 to 20 m/s around the height of 100 m. The height of the minimum speed of the katabatic winds coincided with the top of the surface inversion layer, suggesting that the katabatic wind layer is roughly identical to the surface inversion layer.

(3) The katabatic winds were influenced by cyclonic activities: when a cyclone passed over the ocean in the vicinity of the coast, the katabatic winds were strengthened; conversely as the cyclone left away from the coast the katabatic winds ceased in a few hours.

(4) Temperature of the air above the surface inversion layer in Mizuho Plateau were warmer by 3 to 5°C than those at Syowa Station in summer. On the other hand, the temperature above the surface inversion layer in Mizuho Plateau coincided with those of Syowa Station in winter.

To explaine the above results of (1) to (4), we assumed a meridional air circulation over Antarctica: this shows that air circulation with south and east components at the surface layer, and with north and west components at the upper layer, agree qualitatively with concept of the outward drainage of cold air at the surface and a compensating inflow at the upper layer. The results obtained in Mizuho Plateau support the meridional air circulation over Antarctica in winter reported by WHITE and BRYSON (1967). Katabatic winds which flow outward to the periphery of the continent is greatly weakened at day time in summer because of decreasing in the intensity of radiative cooling. In summer season upper air with south and east components observed at Mizuho Plateau will have descending component, so that the air is warmed according to the adiabatic compression in comparison with Syowa Station. Under this anticyclonic condition, the weather is always clear sky. On the other hand, katabatic winds are enhanced in winter by increasing intensity of surface inversion which caused by radiative cooling. Therefore, the compensated current in the upper layer above katabatic wind layer is also increased, and the wind directions of upper layer are roughly in the range between west and north in Mizuho Plateau and Syowa Station.

BALL's (1960) nomogram for determining the katabatic force in terms of inversion strength and surface slope shows that katabatic force exceed pressure gradient force when the slope exceed 2×10^{-3}. The surface slope of Mizuho Camp is approximately 4×10^{-3}, i.e. 400 meters in 100 kilometers. Therefore, the katabatic force will dominate in comparison with the pressure gradient force in the vicinity of Mizuho Camp. The wind vector at the top of the inversion will be referred to as "inversion wind". Thermal wind persists in the inversion layer. This thermal wind effects that low-level winds tending to be cross-slope. The data shown in Figs. 4 and 5, the prevailing surface winds are cross-slope (east direction) rather than down-slope (south-east direction). The angle between the wind vector at the surface and the top of the inversion lies in the range of 40 to 70 degrees.

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References

AGETA, Y. (1971) : Higashi nankyoku Mizuho Kogen fukin no kisho jotai ni tsuite (Some aspects of the weather conditions in the vicinity of the Mizuho Plateau, East Antarctica). Antarct. Rec., **41**, 42–61.

BALL, F. K. (1956) : The theory of strong katabatic winds. Aust. J. Phys., **9**, 373–386.

BALL, F. K. (1960) : Winds on the ice slopes of Antarctica. Antarctic Meteorology, Oxford, Pergamon Press, 9–16.

COURT, A. (1951) : Antarctic atmospheric circulation. Compendium of Meteorology, ed. by T. F. MALONE, Am. Met. Soc. Boston, Massachusetts, 917–941.

MORITA, Y. (1968) : Syowa Kiti de kansoku sareru katabatic-fu ni tsuite (1) (Winds of katabatic origin observed at Syowa Station (1)). Antarct. Rec., **31**, 21–32.

NARUSE, R. (1975) : Dai-14-ji nankyoku chiiki kansokutai nairiku chosa gaiho 1973–1974 (Preliminary report of the oversnow traverse of the 14th Japanese Antarctic Research Expedition 1973–1974). Antarct. Rec., **53**, 127–140.

SASAKI, H. (1974) : Higashi nankyoku Mizuho Kansokukyoten ni okeru chijo kisho kansoku (Surface meteorological observations at Mizuho Camp, East Antarctica). Antarct. Rec., **50**, 21–28.

WHITE, F. D., Jr. and R. A. BRYSON (1967) : The radiative factor in the mean meridional circulation of the Antarctic atmosphere during the polar night. Polar Meteorology, WMO Tech. Note, **87**, 225–248.

YAMADA, T. (1974) : Syowa Kiti engan kara Mizuho Kansokukyoten ni itaru chiiki no kishio jotai ni tsuite (Surface meteorological condition in the region between Syowa Station and Mizuho Camp, Mizuho Plateau, East Antarctica). Antarct. Rec., **50**, 1–20.

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