Distribution of Firn Temperatures in Mizuho Plateau and West Enderby Land, East Antarctica

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東南極みずほ高原および西エンダービーランドにおける雪温分布について

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要旨：日本南極地域観測隊による9次隊の昭和基地—南極点往復調査旅行（1968－1969年），10次隊のやまと山脈方面への内陸調査旅行（1969－1970年），および11次隊のサンダーコック方面への内陸調査旅行（1970－1971年）の際，観測された10m深の雪温（その場所の表面の年平均気温にほぼ等しい）をまとめ，東南極みずほ高原，エンダービーランド地域，および極点旅行ルートにおける年平均気温分布について報告する．

内陸に入るほど大陸氷床の表面高度は増し，10m雪温は低温になるが，S16～みずほ観測拠点～Y200のルートについて，沿岸から内陸に沿ってみると，高度，氷床の表面地形との関係から，雪温の分布の傾向は，S122（高度1,850m）から，みずほ観測拠点（高度2,170m）付近を境にして，沿岸性地域と内陸性地域とに気候学的に分けられる．

10m雪温の表面高度に対する勾配は，場所によって－0.26～－2.11°C/100mと異なるが，氷床表面の斜面傾斜が小さい所では大きく，傾斜の大きい所では，乾燥断熱減率に近い．また内陸ほど，その値は大きい．

10m雪温の分布は，氷床の表面地形の影響をよく反映しているが，この地域における katabatic wind の方向と強さ，および海洋性低気圧の内陸への進入と密接な関係にあることを示している．

2m深の夏の雪温分布から，昭和基地に近い氷床の dry snow line は，高度700～950m付近にあると思われる．また，夏の表面雪温分布の高度に対する勾配は，高度950～1,450mにおいては，年平均値のほぼ半分になる．

1. Introduction

The Japanese Antarctic Research Expedition (JARE) carried out oversnow

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traverses in 1968–1971 in the region of Mizuho Plateau and West Enderby Land. During these traverses, measurements of firn temperatures at 10 m and 2 m depths were made. This report attempts to examine the relationships between the mean annual surface temperature (based on the 10 m firn temperatures) and the topographical environments, and to elucidate the climatological features of this region.

2. Data of Firn Temperatures

The inland traverse of 1968–1969 (by the 9th JARE) is a return trip between Syowa Station and the South Pole via Plateau Station along 43°E (S-route) (MURAYAMA, 1971). The traverse of 1969–1970 (by the 10th JARE) covered the west side of 43°E to the Yamato Mountains, and that of 1970–1971 (by the 11th JARE) covered the east side of 43°E to the Sandercock Nunataks (ISHIDA, 1972). These routes are shown in Fig. 1. Thus the area to be discussed in this paper is between 68°30′ S and 72°S, between 35°E and 52°E (Mizuho Plateau and West Enderby Land), and includes the route from Syowa Station to the South Pole.

All the firn temperatures were measured with thermistors and the overall accuracy of the measurements was within ±0.1°C. Measurements of the 10 m firn temperature were made at 45 stations. Data of the 10 m firn temperatures are given in Table 1 and those of the 2 m firn temperatures in Table 2 (See Fig. 1).

3. Meaning of 10 m Firn Temperature

As is known from the heat conduction theory in a semi-infinite medium without a heat source, the annual variation of firn temperature at a given depth depends on that at the surface and the value of the thermal diffusivity. When the amplitude at the surface and the diffusivity are large, the annual variation of firn temperature at the given depth becomes large. For example, when we assume the thermal diffusivity to be 7×10^{-3} cm^2/s for the snow density of 0.5 g/cm^3, the amplitude of the annual temperature variation at 10 m is reduced to about 2.3% of that at the surface (Table 3). Calculated amplitude of temperature at 10 m, 15 m and 20 m is given in Table 3, for reference, in the cases of three different themal diffusivities for the firn densities of 0.3, 0.7 and 0.92 g/cm^3 (ice).

The annual temperature variation at a depth of 10 m is 0.5°C at the South Pole and 0.8°C at Byrd Station (PHILLPOT, 1967). At Mizuho Camp in Mizuho Plateau the amplitude of air temperature was about 17°C (ÔNO, SATOMI and JOBASHI, 1971), so the amplitude at 10 m may be about 0.39°C (17°C×2.3%) if the thermal diffusivity is assumed to be 7×10^{-3} cm^2/s. Other measurements in Antarctica and

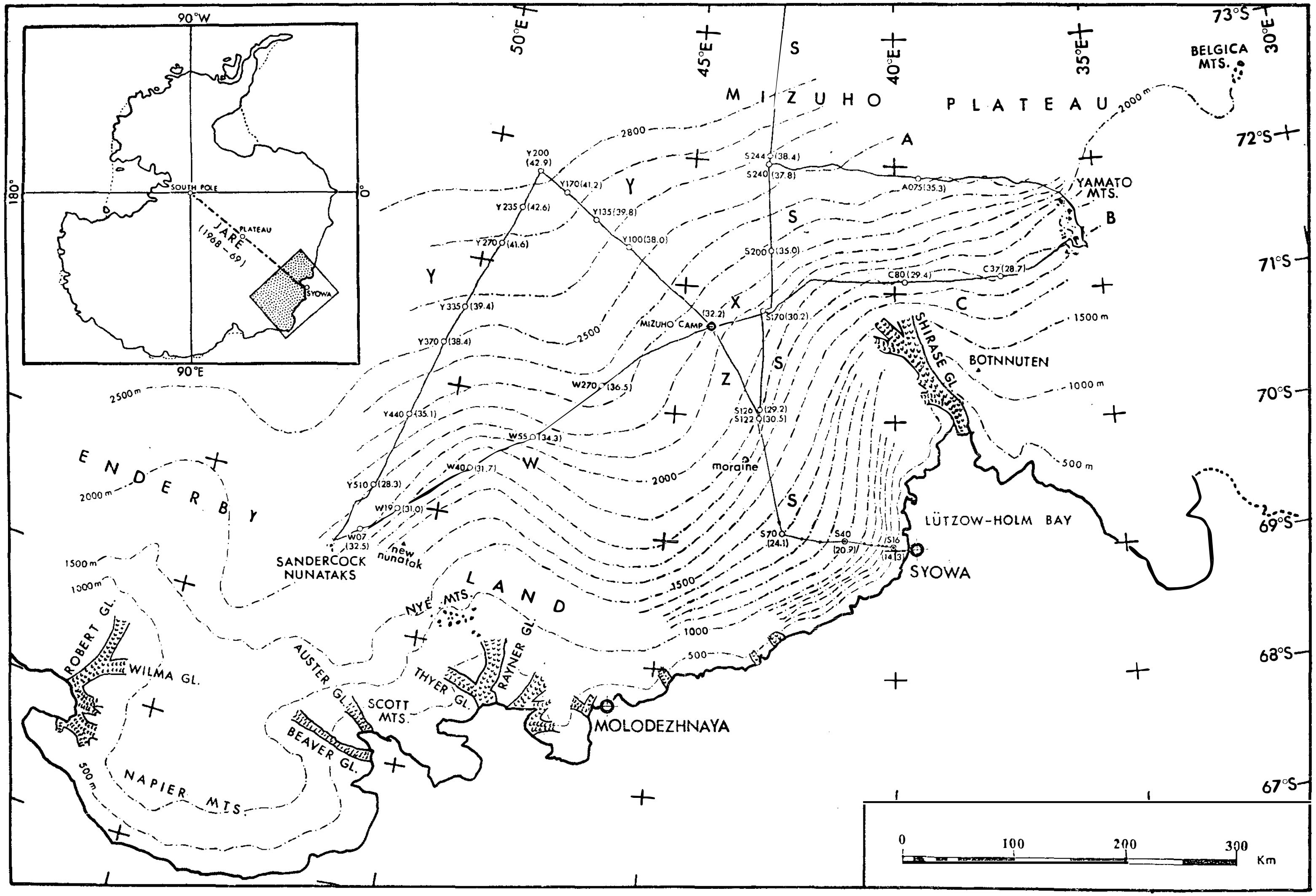

Fig. 1. Routes of JARE traverses in Mizuho Plateau and West Enderby Land.

Circle represents observation station of 10 m firn temperature. The numeral in the parenthesis is the temperature in °C. Small black dot near the coast represents observation station of 2 m firn temperature. The traverse route (S-route) from Syowa Station to the South Pole in 1968–1969 is inserted.

Table 1. Firn temperature at 10 m depth.

Station	Temperature (−°C)	Elevation (m)	Date	Latitude (S)	Longitude (E)
Part 1					
S 16	14.3	553	1968. 4.20	69°02.′0	40°02.′8
S 70	24.1	1388	1969. 2.12	06. 9	42 29
S 126	29.2	1883	1968. 4.26	70 05. 2	43 07
S 170	30.2	2034	1969. 2. 7	50. 6	11. 5
S 244	38.4	2617	1968.10.17	72 04. 2	09
S 330	46.0	3177	1969. 2. 4	73 32. 5	42 55
S 400	52.2	3478	1968.10.25	74 45. 2	51
S 414	51.6	3519	1969. 1.31	59. 7	50
S 470	54.6	3613	1968.10.31	75 57. 4	23
〃	54.0	〃	1969. 1.28	〃	〃
S 556	57.1	3717	1.24	77 26. 0	41 32
Plateau St.	60.5*	3624		79 14. 8	40 30
S 687	55.5	3563	1968.11.18	80 01. 1	39
S 747	51.2	3407	11.24	82 00. 1	37
S 777	50.5	3362	11.26	83 00. 4	31
S 807	50.3	3291	11.30	84 02. 0	37
S 837	49.9	3194	12. 4	85 03. 3	31
S 867	49.4	3116	12. 7	86 05. 0	00
S 897	49.3	2945	12.10	87 08. 4	39 37
S 927	49.1	2859	12.12	88 08. 4	40 53
S 957	49.2	2816	12.15	89 08. 8	41 08
S 975	49.8	2801	12.18	45. 4	42 14
South Pole	50.8**	2800		59. 9	
Part 2					
S 40	20.9	1112	1969.11. 3	69°04.′7	41°07′
S 170	31.2	2034	9.19	70 50. 6	43 11. 5
S 200	35.0	2261	11.18	71 19. 4	00
S 240	37.8	2591	11.23	72 00. 1	09. 9
A 075	35.3	2412	12.12	71 55. 4	39 23. 8
C 37	28.7	1805	1970. 1.16	07. 9	37 27. 5
C 80	29.4	1767	1.19	05. 7	39 43. 9
Part 3					
S 122	30.5	1853	1971. 1.17	70°01.′1	43°06.′5
Mizuho Camp	32.2***	2169	1970. 7.25	42. 1	44 17. 5
Y 100	38.0	2545	11.21	71 15. 9	46 32. 2
Y 135	39.8	2644	11.24	26. 8	47 21. 8

Station	Temperature (−°C)	Elevation (m)	Date	Latitude (S)	Longitude (E)
Y 170	41.2	2720	11.25	37. 4	48 12. 0
Y 200	42.9	2819	11.26	46. 2	56. 0
Y 235	42.6	2764	11.29	28. 2	49 13. 9
Y 270	41.6	2676	11.30	10 0	34. 3
Y 335	39.4	2577	12. 2	70 36. 9	50 13. 4
Y 370	38.4	2503	12. 3	18. 8	32. 8
Y 440	35.1	2306	12. 7	69 41. 9	51 00. 9
Y 510	28.3	2108	12. 9	05. 3	30. 1
W07	32.5	2051	12.17	68 45. 1	36
W19	31.0	1943	12.19	58. 7	50 51
W40	31.7	1840	12.26	69 23. 3	49 28
W55	34.3	2107	12.30	41. 4	48 10. 3
W270	36.5	2339	1971. 1. 6	70 09. 4	46 46. 0

Part 1 was measured by JARE 9 in 1968−1969 (FUJIWARA and ENDO, 1971), Part 2 by JARE 10 in 1969−1970 and Part 3 by JARE 11 in 1970−1971 (SHIMIZU *et al.*, 1972).

* WELLER and SCHWERDTFEGER, 1970

** DALRYMPLE, LETTAU and WOLLASTON, 1966

*** WATANABE and YOSHIMURA, 1972

Table 2. Firn temperature at 2 m depth (WATANABE, O., 1972).

Station	Temperature (−°C)	Elevation (m)	Date January, 1971
S 16	9.1	553	27
19	11.2	634	26
21	10.8	699	25
23	11.3	771	26
26	13.8	870	26
30	15.2	961	25
40	15.6	1112	22
50	16.3	1215	21
60	16.7	1332	21
75	18.0	1435	20

Table 3. Calculated amplitude of temperature at depths when a sinusoidal temperature change was given at the surface of semi-infinite ice sheet. (Unit: percent)

Depth (m)	Diffusivity (cm^2/s)		
	4.0×10^{-3} ($0.3 g/cm^3$)	7.0×10^{-3} ($0.7 g/cm^3$)	12×10^{-3} ($0.92 g/cm^3$)
10	0.68	2.31	5.61
15	0.06	0.35	1.33
20	0.00	0.05	0.32

Greenland have also confirmed that the amplitude at 10 m is very small (KOTLYAKOV, 1961; MELLOR, 1961; BENSON, 1961; MELLOR, 1964; DALRYMPLE, LETTAU and WOLLASTON, 1966; WELLER and SCHWERDTFEGER, 1970). Consequently, we may find from Table 3 that seasonal temperature changes are little below a depth of 15 m or 20 m, and that the uncertainty at 10 m can be neglected. Thus we can say that the 10 m firn temperature is nearly equal to the mean annual "surface temperature".

Such an area that the 10 m firn temperature represents the mean annual surface temperature is where the summer temperature is not so high as to produce substantial snow melting near the surface and non-conductive heat transfer downwards by infiltration and refreezing of melt water in the deeper layers. This area corresponds to "dry snow facies" (where the average temperature in melt season does not rise above −5°C) and to a part of "percolation facies" defined by BENSON (1962). As an example of an area warmer than percolation facies, CAMERON (1964) reported the situation near Wilkes Station: the deviation between the 10 m firn temperature and the mean annual surface temperature begins near the saturation line (500 m above sea level) where the surface temperature is lower by 0.2°C than the 10 m firn temperature; the difference is greatest in the area of the firn line (300 m above sea level) where the surface temperature is lower by 2.6°C than the 10 m firn temperature; then it decreases toward the sea level (at an elevation of 39 m, the difference is 0.3°C).

It is generally accepted that in high polar regions the 10 m firn temperature representing the mean annual "surface temperature" can be regarded also as an approximation of the mean annual "air temperature at screen level" at that location. LOEWE (1970), however, concluded as follows, summarizing the available data of eleven stations in Antarctica:

"On the Antarctic ice sheet and the ice shelves down to a mean annual temperature of −30°C, the temperature at a depth of 10 m is close to the annual mean at the surface and the level of the meteorological shelter. In colder regions the 10 m firn temperature is systematically colder than the air at 2 m height. The difference increases by 1°C for a drop of the mean annual temperature of 10°C." LOEWE attributed the reason of the difference that the inversions of temperature from 2 m upwards get stronger with lower temperature and the same is likely to occur between the surface and 2 m also.

DALRYMPLE (1966) attributed also the difference between the 10 m firn temperature and the mean annual air temperature to the existence of air temperature inversion during most of the year.

We can now conclude that the "10 m firn temperature" gives a fairly good approximation to the mean annual "surface temperature" in dry snow facies and the major part of percolation facies near the saturation line, and the 10 m firn temperature is also close to the mean annual "air screen temperature" in the regions warmer than −30°C.

4. Discussions

4.1. Relation between Mean Annual Surface Temperature and Continentality

As a representation of continentality, the shortest distance from the coast is adopted. The relation between the mean annual surface temperature and the distance from the coast is illustrated in Fig. 2 (a) and 2 (b).

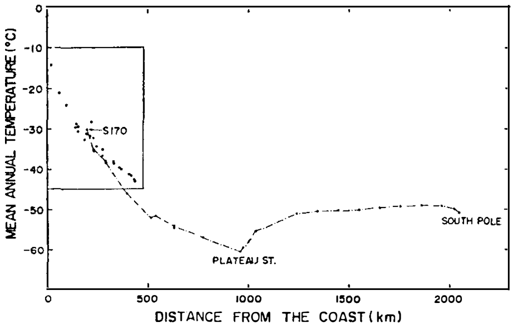

Fig. 2 (a). Relation between mean annual surface temperature and distance from the coast. The dot-and-dash line is along the S-route (South Pole Traverse by JARE-9). The left rectangular part is magnified in Fig. 2 (b).

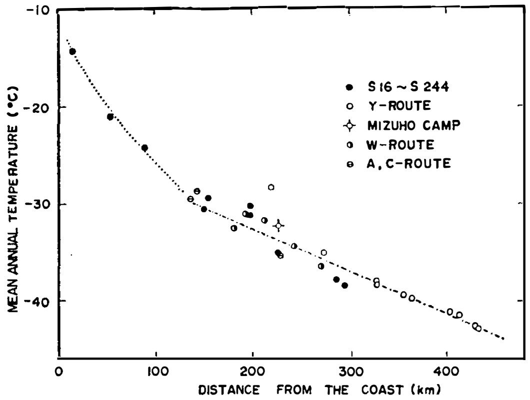

Fig. 2 (b). Relation between mean annual surface temperature and distance from the coast in Mizuho Plateau and West Enderby Land.

In the region of Mizuho Plateau and West Enderby Land, the mean annual surface temperature decreases rapidly from −10°C to −30°C within an area of about 140 km from the coast (Fig. 2 b), whereas the temperature in the inland decreases at a rate of 4.5°C/100 km.

Along 43°E (S-route) (Fig. 2 a), the temperature decreases towards Plateau Station from where to the South Pole the temperature increases. This temperature distribution is related to the surface elevations.

4.2. Relation between Mean Annual Surface Temperature and Elevation

It is considered that the temperature is most effectively controlled by the elevation, so the plots of temperature against elevation are shown in Fig. 3.

From 0 m to 3,100 m, the mean annual surface temperature decreases from −10°C to −45°C, which indicates the average elevation gradient of −1.22°C/100m.

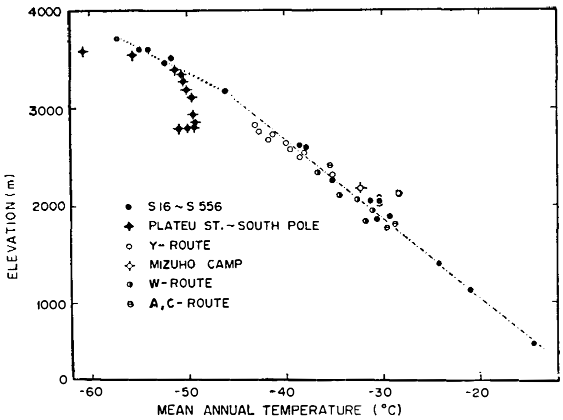

Fig. 3. Relation between mean annual surface temperature and surface elevation.

Table 4. Elevation gradients of mean annual surface temperatures in East Antarctica.

Investigator	Station	Longitude (°E)	Elevation (m)	Gradient (−°C/100 m)
Lorius (after Cameron, 1964)	Dumont d'Urville	140	0−2400	1.04
Cameron, 1964	Wilkes	110	0−1206	1.02
Bogoslovski, 1958	Mirny	93−94	0−2000	1.05
			2000−3500	1.27
Mellor, 1960	Mawson	63	0−1000	0.9
			1000−2000	1.1
			2000−	1.3
This paper (Satow, Watanabe and Nakajima)	Syowa	37−52	0−3100	1.22
			3100−3700	2.11

This elevation gradient is sometimes called "lapse rate" of mean annual surface temperature. The elevation gradient of −1.22°C/100 m is in close agreement with the values obtained in other parts of East Antarctica (Table 4).

From 3,100 m to 3,700 m (the highest elevation along 43°E), the temperature drops more rapidly (elevation gradient is −2.11°C/100 m), and the lowest temperature of −60.5°C was recorded in the vicinity of Plateau Station (3,624 m), which was situated farther south from the highest point. Elevation gradient of −2.11°C/100 m is an exceptionally large value, almost twice the values in other parts of East Antarctica (Table 4). The area with large elevation gradient has a horizontal distance of 440 km (from 73°30′ to 77°30′) and a fairly gentle slope as compared with the region near the coast.

From Plateau Station to the South Pole, the surface elevation decreases gradually while the mean annual temperature increases, and the elevation gradient in this portion is small, being −0.26°C/100 m.

It has been already mentioned that the mean annual surface temperature decreases with the increases of surface elevation and the distance from the coast (See Fig. 2 a, 2 b and Fig. 3). But it is a complex problem to separately evaluate the contribution of elevation and distance to the distribution of mean annual surface temperatures.

4. 3. Map of Mean Annual Isotherms in Mizuho Plateau and West Enderby Land

The isotherm contour map of mean annual surface temperature is shown in Fig. 4. In drawing this figure, linear interpolation of temperatures between two observed stations was not adopted automatically, but the relations between the mean annual surface temperature and the geographical conditions along various routes were examined to estimate the temperature in blank area. For example, Fig. 5 shows the relations among the temperature, the surface profile and the elevation along the route between Sandercock Nunataks and C 37, via Mizuho Camp. This route with a distance of about 600 km is roughly parallel to the coastline. Fig. 5 shows a good correspondence of the temperature distribution to the surface profile, so the temperatures between observed stations were easily estimated. It is also noted that three stations of W 40, W 55 and W 270 are on a

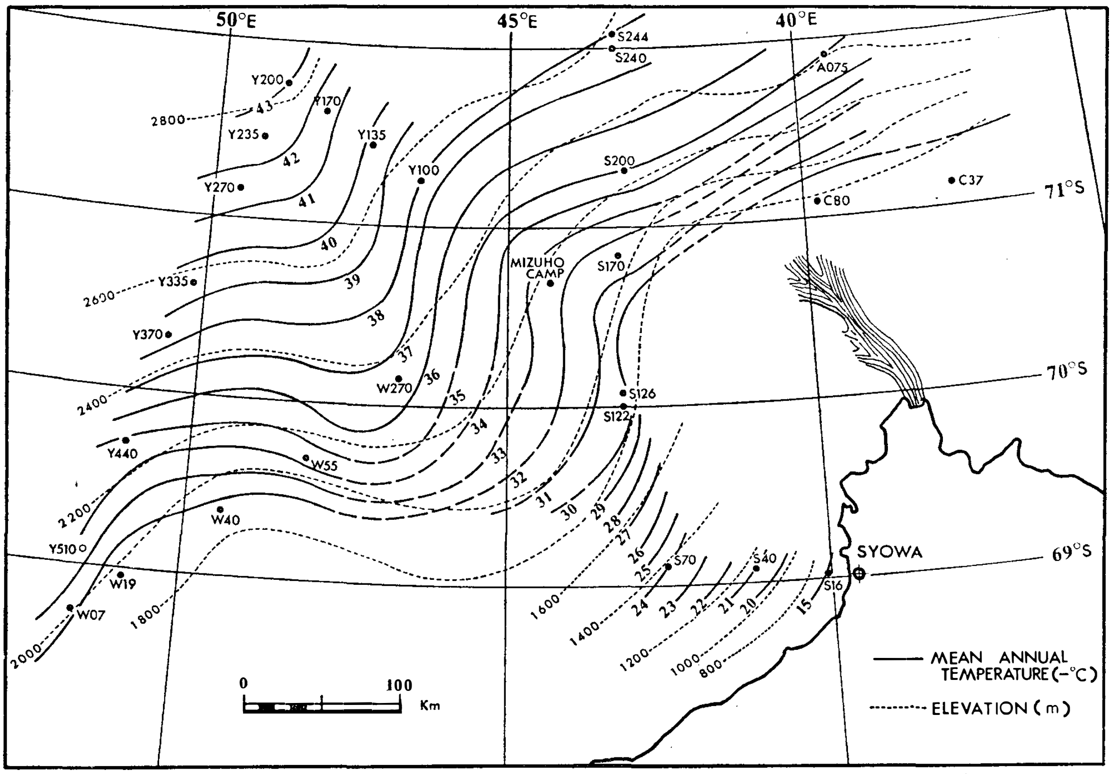

Fig. 4. Isotherm contour map of the Mizuho Plateau and West Enderby Land showing the mean annual surface temperature based on the 10 m firn temperature.

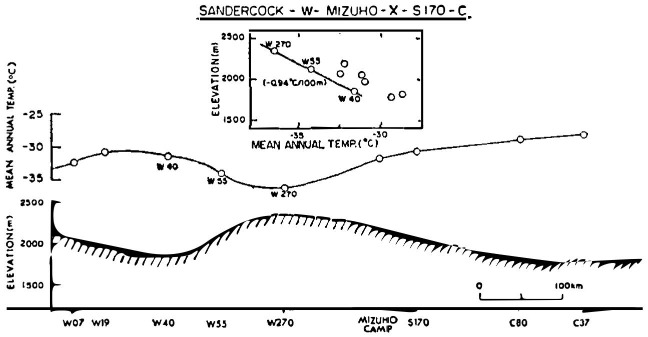

Fig. 5. Mean annual surface temperature and surface elevation along the route from Sandercock Nunataks to C 37 via Mizuho Camp.

The abscissa stands for the position of each station projected on the straight line connecting Sandercock Nunataks and Mizuho Camp.

straight line with the elevation gradient of −0.94°C/100 m, so that the temperatures between W 40 and W 270 were obtained with linear interpolation. Estimation of temperature in other areas was also made, the areas such as between S 16 and Y 200 via Mizuho Camp, between Y 200 and Sandercock Nunataks, and so on.

In compiling Fig. 4, the value of −28.3°C at Y 510 (2,108 m above sea level) was excluded. This was exceptionally higher than the values at neighboring low-elevation stations, like −32.5°C at W 07 (2,051 m), −31.0°C at W 19 (1,943 m) and −31.7°C at W 40 (1,840 m). It is not known whether this anomalously high value is due to some error in measurement or to any other reason.

Fig. 4 shows that the mean annual isotherms generally reflect the influence of topography; the lower temperature domain stretches out on the ridge of ice sheet and the warmer temperature domain occupies the troughs. It must be pointed out that the isotherms are not parallel to elevation contour lines in every part of the Mizuho-Enderby region; that is, the area on the east side of trough is warmer than on the west side, or the east side of the ridge is colder than the west side.

From the observations of the surface relief, or the orientations of sastrugis and other features, AGETA (1971), WATANABE and AGETA (1972) reported that the direction of the prevailing wind in this area is dominantly east. According to the theory of katabatic wind by BALL (1956, 1960), flow lines of prevailing winds (katabatic winds) have a tendency to concentrate towards the east side of the ridge. Thus the distribution of the mean annual surface temperature in this region seems to be largely influenced by the katabatic winds.

4.4. Distribution of Mean Annual Surface Temperature along the Longitudinal Section

An analysis will be made on the relation of the mean annual surface temperature to the surface elevation and profile along the longitudinal section from the coast to inland in the region of Mizuho Plateau and West Enderby Land.

The route between S 16 and Y 200 via Mizuho Camp is about 450 km from the coast. Fig. 6 (a) shows the relation between the distribution of the mean annual surface temperature and the surface profile, showing no appreciable change of temperature between S 122 and Mizuho Camp. Each station's elevation and distance from the coast are as follows; S 16 (553 m, 14 km), S 122 (1,853 m, 150 km), Mizuho Camp (2,169 m, 225 km), Y 200 (2,819 m, 435 km). The situation of uniform temperature distribution between S 122 and Mizuho Camp is also shown in Fig. 6 (b) representing the elevation gradients; the elevation gradient is −1. 18 °C /100 m near the coast between S 16 and S 122, and −1. 81 °C/100 m between Mizuho Camp and Y 200.

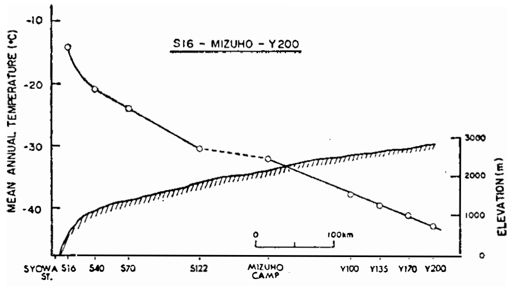

Fig. 6 (a). Mean annual surface temperature and surface profile along the route from S 16 to Y 200, via Mizuho Camp.

The three points, Syowa Station, Mizuho Camp and Y 200, are nearly on a straight line as shown in Fig. 1. The position of other stations are projected on this line.

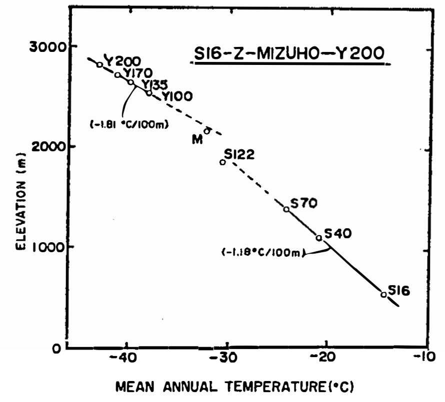

Fig. 6 (b). Relation between mean annual surface temperature and surface elevation along the route from S 16 to Y 200 via Mizuho Camp.

From snow stratigraphy studies, WATANABE (1973), one of the present authors, suggested the presence of a transition zone in the area between S 122 and Mizuho Camp. Analysing the data of the snow accumulation, YAMADA (1972) revealed that the accumulation changed also between S 122 and Mizuho Camp.

It may be concluded that the area of S 16 - S 122 belongs to the coastal zone in climatological aspects, and the area of Mizuho Camp-Y 200 to the continental zone. It may also be said that the Mizuho Plateau and the West Enderby Land are influenced by the katabatic winds and the penetration of moisture-rich cyclonic storms from the ocean onto the ice sheet.

4. 5. Two-meter Firn Temperature

Using the data of the 2 m firn temperatures measured by JARE 11 (Table 2), the elevation of dry snow line will be discussed. The surface temperatures were also measured, but the values were not used in the present discussion, because the solar radiation might have warmed the thermistor thermometer. According to the measurements of the radiation transmission and extinction in the snow at Plateau Station, only 1 percent of solar radiation at the surface reached below 1 m depth (WELLER and SCHWERDTFEGER, 1970). In the measurement of the 2 m firn temperature, therefore, the effect of the solar radiation might be neglected. The measurements of the 2 m firn temperatures at 10 stations along the route from S 16 to S 75 were made for a week from January 20 to 27, 1971 (See Fig. 1). Seasonal variation of the 2 m firn temperatures will not be detected within such a short period of 7 days.

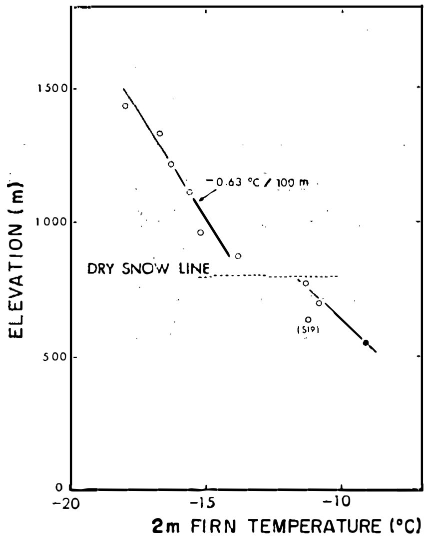

Fig. 7. Relation between 2 m firn temperature and surface elevation along the route from S 16 to S 75.

Fig. 7 shows the relation between the 2 m firn temperature and the surface elevation. The relations are different in two areas where the 2 m firn temperature are above −11 °C or below −15°C. Fig. 7 also indicates that the area up to 700 m above sea level is somewhat influenced by "melting", the area between 700 m–950 m is a transition zone, and the area higher than 950 m is a non-melting zone. About 100 m change in elevation of the dry snow line will be expected for both area and time. In considering the saturation line at 500 m on the ice sheet near Wilkes Station (CAMERON, 1964), the elevation of dry snow line near Syowa Station at 700 m–950 m appears to be reasonable. The stratigraphic observations of the surface snow cover down to 2 m deep revealed the evidence of melting up to station S 21 (699 m elevation) (WATANABE, 1972).

In Fig. 7, it is noted that the elevation gradient of 2 m firn temperatures from

950 m to 1,450 m was -0.63°C/100 m, which was about a half of the elevation gradient of mean annual surface temperature in this area. This small value is considered to represent the distribution of the mean surface temperature in the middle of December, 1970 (if the thermal diffusivity for firn is assumed to be 7×10^{-3} cm^2/s, the temperature variation at 2 m occurs with a time lag of about 44 days later than that at the surface). In summer, the inversion strength of air temperature on the ice sheet becomes small, thus the katabatic wind force is weakened. The warmer air mass with a smaller lapse rate of temperature from the ocean would easily invade inland.

4.6. Elevation Gradient of Mean Annual Surface Temperature

A preliminary discussion on the average elevation gradient of mean annual surface temperature was given in section 4. 2. In Table 5, the elevation gradient

*Table 5. Elevation gradient of mean annual surface temperature and surface slope.**

Area	G (−°C/100 m)	S (m/km)	T (−°C)	E (m)	D (km)	H (km)
S 40-S 122	1. 18	5. 18	21-31	1110-1850	50-150	130
Mizuho-Y 200	1. 81	2. 76	32-43	2170-2820	230-430	210
Y 200-Y 440	1. 58	3. 00	35-43	2310-2820	270-430	250
W 40-W 270	0. 94	8. 53	32-37	1840-2340	210-270	140
S 170-S 330	1. 36	3. 86	31-46	2030-3180	200-390	280
S 330-S 556	2. 11	0. 90	46-57	3180-3720	390-770	400
S 777-S 957	0. 26	1. 50	49-51	2820-3360	1340-1960	620

* G : elevation gradient
S : surface slope
T : mean annual surface temperature based on 10 m firn temperature
E : surface elevation
D : distance from the coast
H : horizontal distance

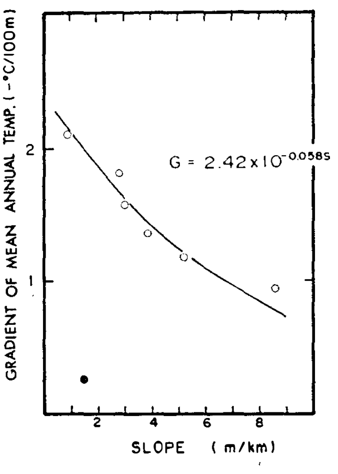

Fig. 8. Relation between elevation gradient and slope. Black cirle is the value between S 777 and S 957.

of mean annual surface temperature in several section is given with surface slope, firn temperature, elevation, distance from the coast and horizontal distance in the sections. In Fig. 8, the elevation gradient of temperature is plotted against the slope. The graph shows the following empirical relationship:

$$G=2.42\times 10^{-0.058S}$$

where G (°C/100 m) is the elevation gradient and S (m/km) the surface slope. With the exception of a very small value of -0.26°C/100 m in central Antarctic plateau (St. S 777 and S 957), when the surface slope increases, the elevation gradient approaches the value of the meteorological adiabatic lapse rate, -1.0°C/100 m.

The elevation gradients can be related to processes in the atmosphere by assuming that the snow surface has the same temperature as the air it contacts. But it is important to note that the elevation gradient refers to the rate of change of 10 m firn temperature measured along the surface of the ice sheet, and should not be confused with the meteorological "lapse rate" which refers only to the gradient of vertical free air temperature. The meteorological lapse rate is not generally applicable to the different air mass at different elevations along the surface of the earth.

In Antarctica, a strong inversion of air commonly takes place because the ground is severely cooled by net out-going radiation. An air mass with high density covers the ice sheet and flows down along the slope under the influence of gravity. At the same time, by the action of the Coriolis force, the direction of the wind is turned counterclockwise from that of slope. This is the commonly observed katabatic wind on Antarctic slopes; the steeper the surface slope, the larger the velocity of this wind. The katabatic wind is warmed up with the dry adiabatic lapse rate as it descends along the surface of the ice sheet.

Under such circumstances were the katabatic winds prevail throughout the year, the elevation gradient of the 10 m firn temperature representing the mean annual surface temperature is expected to be almost equal to the adiabatic lapse rate. Fig. 8 seems to indicate a close relation between mean annual surface temperature and katabatic wind.

KANE (1970) stated that two types of slope-influenced flows are possible: (1) katabatic air flow, and (2) air flow modified by a thermal wind. According to a multiple regression analysis of the data collected at 46 traverse stations in the central East Antarctic Plateau, he obtained the following equation:

$$T_P=-26.94-0.893(E)\times 10^{-2}+2.16(S)\quad {}^{\circ}\mathrm{C}$$

where T_P = the predicted mean annual temperature, E = elevation in meters, and

S=slope in meters/km. This equation indicates that the temperature increases 2.16°C for 1 m/km increases in slope. KANE concluded that the mechanism of this warming appears to result from turbulent mixing of the inversion layer caused by slope-induced thermal winds. His idea of the slope-induced thermal wind may not be simply applicable to the case of the Mizuho Plateau-West Enderby Land region.

On the basis of the weather observations made during the traverse by JARE 10 (1969-1970) and the previous traverses by JARE 4, 5, 8 and 9, in the area between the coast and 72°S, AGETA (1971) estimated that the mean wind speed from September to January is about 8–10 m/s.

5. Conclusion

We have discussed the distribution of the 10 m firn temperature (mean annual surface temperatures) and the 2 m firn temperatures in the region of Mizuho Plateau and West Enderby Land, and along 43°E from Syowa Station to the South Pole, East Antarctica. The results may be summarized as follows:

(1) The relation between the mean annual surface temperature and the distance from the coast showed the existence of a transition zone at about 140 km from the coast, from where to inland the temperature decreases at a rate of 4.5°C/100 km.

(2) Along 43°E, the lowest temperature of −60.5°C was observed at Plateau Station (3,624 m), while −57.1°C at the highest point (3,717 m). In general, the temperature shows a good correlation with the change of surface elevation.

(3) An average elevation gradient of mean annual surface temperature −1.22 °C/100 m was obtained in a area with temperatures between −10°C and −45°C (0 m to 3,100 m). This value of elevation gradient is in close agreement with the values obtained in other parts of East Antarctica.

An exceptionally large value of −2.11°C/100 m was obtained in a portion between 73°30′ and 77°30′ (3,100 m to 3,700 m). And an extremely small value of −0.26°C/100 m was obtained between Plateau Station and the South Pole.

(4) A map of mean annual isotherms in the region of Mizuho Plateau and West Enderby Land indicates a close relationship between the isotherms and the elevation contours. The deviation of isotherms from elevation contours was explained in terms of the influence of the katabatic winds.

(5) It is concluded that the coastal climate zone and the continental climate zone are separated in the vicinity of S 122–Mizuho Camp. Snow stratigraphy and snow accumulation measurements also support this conclusion.

(6) Analysis of the 2 m firn temperature near Syowa Station, with supplementary data of snow stratigraphy, indicated the existence of dry snow line at about 700 m–950 m above sea level. From 950 m to 1,450 m, the elevation gradient of summer surface temperatures, given by the 2 m firn temperatures, was −0.63°C /100 m, which is about a half of the mean annual surface temperature. This small value indicates the intrusion of an air mass with a small lapse rate into this area.

The elucidation of the phenomenon of katabatic wind and the relation between the stratigraphic structure of snow cover and the weather condition are important problems for a future study. For the study of these problems, comprehensive and continuous surface and aerological meteorological observations and glaciological researches in the inland area of the ice sheet are required. Furthermore, in connection with the dynamics of Antarctic Ice Sheet, it is very important to measure the vertical temperature distribution within the ice sheet together with deep core analysis, from the surface to the bottom.

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