DISTRIBUTION OF 10 M SNOW TEMPERATURES IN MIZUHO PLATEAU

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Abstract: Measurements were made of snow temperature at a depth of 10 m beneath the surface during the oversnow traverses in 1968–1975 in the region of Mizuho Plateau. The mean annual surface temperature estimated from the 10 m snow temperature decreases gradually from the coast to the inland, which mean temperature gradient with elevation is close to the dry adiabatic lapse rate in the area between 0 m and 3000 m and its value in the area between 3000 m and 3800 m is larger than $-2°C/100$ m. A map of mean annual isotherms shows that the isotherms are similar to elevation contours, especially in the area lower than 3000 m.

1. Introduction

It is well known that 10 m snow temperature gives a fairly close approximation to the mean annual "surface temperature" in the dry snow facies (SATOW *et al.*, 1974), and is also close to the mean annual "screen air temperature" in the regions warmer than $-30°C$ (LOEWE, 1970). Examining the relationships between the mean annual surface temperature (based on the 10 m snow temperature) and the climate-controlling factors such as elevation, latitude, continentality, slope and so on, this report attempts to elucidate the climatological features in Mizuho Plateau.

All of the measurements of 10 m snow temperatures during the traverses were made with a thermister-thermometer in a hole bored with a SIPRE-type hand auger (1968–1973; 1974–1975) and a steam-operated drill (1973–1975). The data obtained were compiled by FUJIWARA and ENDO (1971), SHIMIZU *et al.* (1972), YAMADA and NARITA (1975), NARUSE and YOKOYAMA (1975) and SATOW (1977).

The 10 m snow temperature to be discussed in this paper is that observed in the area of 68°30′S–79°S in latitude and 35°E–52°E in longitude.

2. Relation between Mean Annual Surface Temperature and Surface Elevation

Elevation has close relations to many meteorological elements, but especially to the degree of coldness in the interior of Antarctica. Fig. 1 shows the relation between T_{10}, the mean annual surface temperature derived from the 10 m snow

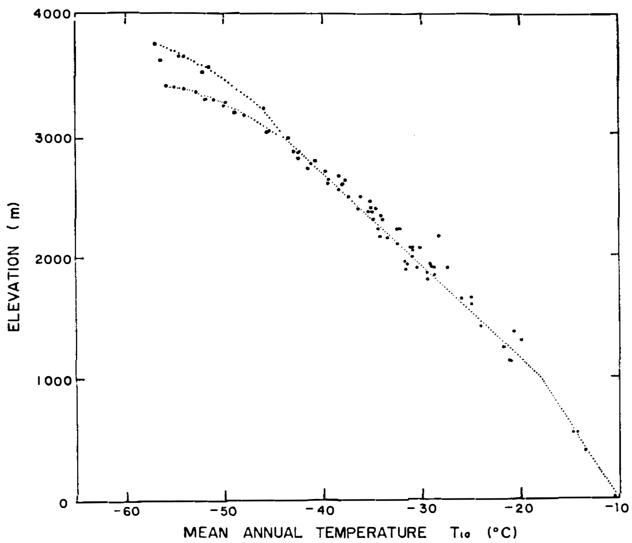

Fig. 1. Relation between mean annual surface temperature T_{10} and surface elevation.

temperature, and the surface elevation. At elevation from 0 m to 1000 m, the average temperature gradient with elevation is −0.8°C/100 m, considering that the mean annual air temperature at Syowa Station (near the sea level) is about −10.4°C in 1967–1974. At elevation from 1000 m to 3000 m, the temperature decreases from −18°C to −44°C, which indicates the average temperature gradient with elevation is −1.3°C/100 m. This value is slightly larger than those of other regions of Antarctica such as Mac-Robertson Land (MELLOR, 1960), Queen Mary Land (BOGOSLOVSKI, 1958), Wilkes Land (CAMERON, 1964), Adélie Land (CAMERON, 1964) and West Antarctica (SHIMIZU, 1964). At elevation from 3000 m to 3800 m, the temperature drops more rapidly with the increase of elevation, so the temperature gradient with elevation becomes larger than −2.0°C/100 m. In this area, two trends dependent on traverse route are shown along the longitude around 43°E and 48°E in the relation between temperature and elevation as in Fig. 1.

As to the change of the temperature gradient with elevation at about 1000 m, the reason is not known in detail, but it may be related with the fact that the amount of snow accumulation in Mizuho Plateau was largest in 1968–1974 at the elevation of 1000 m–1300 m (YAMADA *et al.*, 1978).

3. Relation between Mean Annual Surface Temperature and Continentality

3.1. The distance from the coast

Continentality can be defined as a numerical expression describing the contrast

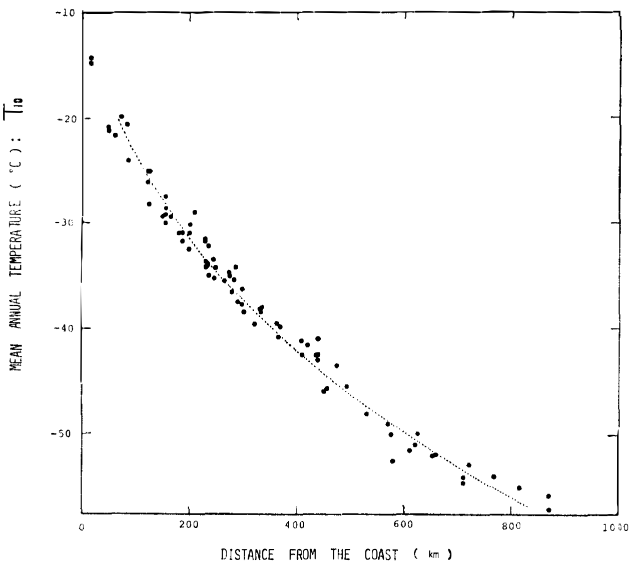

Fig. 2. Relation between mean annual surface temperature T_{10} and distance from the coast.
A dotted line is expressed as: $T_{10}=3.47\times L^{0.416}$, where
T_{10}: mean annual surface temperature (−°C), and
L: distance from the coast (km).

of continental and oceanic climates. The first index of continentality can be considered as the shortest distance from the coast. The relation between the mean annual surface temperature based on the 10 m snow temperature and the distance from the coast is illustrated in Fig. 2. In the region of Mizuho Plateau, the mean annual surface temperature decreases with the distance from the coast in the following relation,

$$T_{10}=3.47\times L^{0.416} \qquad (1)$$

where T_{10} (−°C) is the mean annual surface temperature and L (km) is the distance from the coast. KOTLYAKOV (1961) obtained the similar relation in the region from Mirny Station to Vostok Station, as follows,

$$T_{10}=3.80\times L^{0.400} \qquad (2)$$

The difference of T_{10} between equations (1) and (2) is less than 1°C where L does not exceed 1000 km.

3.2. Mean annual sea-level temperature in the Southern Hemisphere

In Fig. 2, T_{10} contains the effect of elevation. Therefore, sea-level temperature, T_0, was calculated from T_{10} on the assumption that the lapse rate is dry adiabatic, since the air on the ice sheet is very cold and dry. Fig. 3 shows the relation between T_0 and latitude. In order to know temperature gradient with latitude in the Southern Hemisphere, the mean annual temperature at the sea

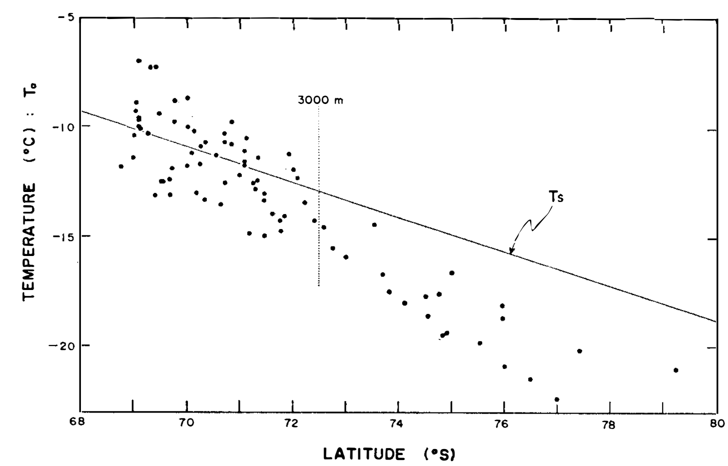

Fig. 3. Relation between sea-level temperature, T_0, and latitude in Mizuho Plateau.
A solid line is the extension of T_s in Fig. 4.

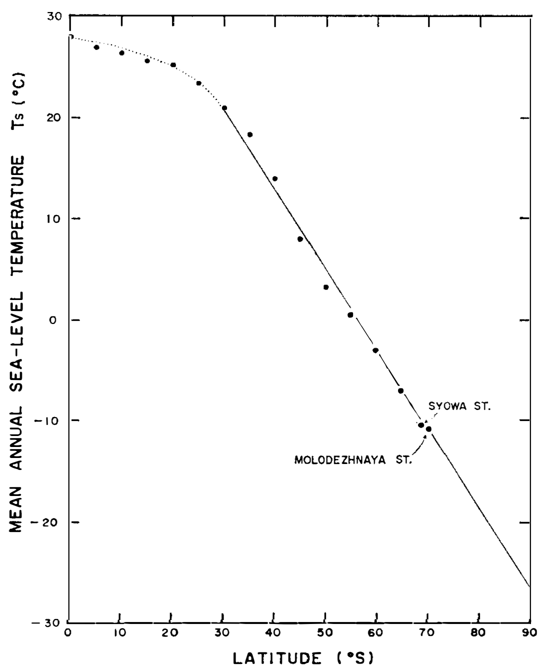

Fig. 4. Mean annual sea-level temperatures, T_s, between 30°E and 60°E in the Southern Hemisphere (based on data from TALJAARD *et al., 1969).*

level from the equator to 69°S in latitude between 30°E and 60°E in longitude, T_s, is calculated as the average of the mean annual sea-level temperature at intervals of every 5° latitude along 30°E, 40°E, 50°E and 60°E over the sea distant from continents, based on the data from TALJAARD *et al.* (1969). Fig. 4 shows the retation between T_s and latitude. As seen in this figure, the mean annual

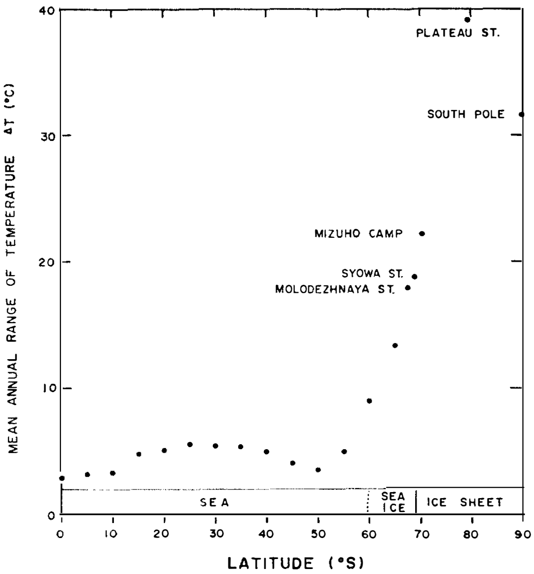

Fig. 5. *Mean annual range of temperature, ΔT, against latitude.*
Data between 0°S and 65°S: from TALJAARD *et al., 1969.*
Data at Syowa Station: from JAPAN METEOROLOGICAL AGENCY, *1969–1977.*
Data at Molodezhnaya Station and Plateau Station: from SCHWERDTFEGER, *1970.*
Data at South Pole; from DALRYMPLE, *1966.*
Data at Mizuho Camp: from YAMADA *et al., 1974 and* KAWAGUCHI, *1975.*

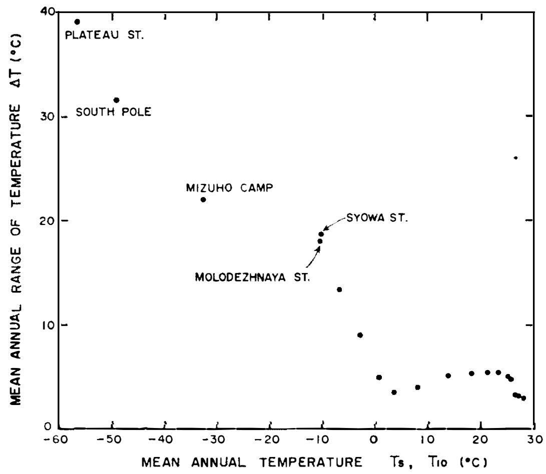

Fig. 6. *Mean annual range of temperature, ΔT, against mean annual temperature, T_s and T_{10}, between 30°E and 60°E in the Southern Hemisphere (from the same data in Fig. 5).*

temperatures of Syowa Station (69°00′S, 39°35′E) (JAPAN METEOROLOGICAL AGENCY, 1969–1977), 4 km far from the ice sheet, and of Molodezhnaya Station (67°40′S, 45°51′E) (SCHWERDTFEGER, 1970), at the periphery of the ice sheet, are on this curve. The rate of change of T_s with latitude is -0.8°C/deg latitude between 30°S and 69°S. This line is extrapolated as a solid line in Fig. 3. It can be seen from the comparison between T_0 and the T_s-line that T_0 is lower than T_s-line in the area between 72°30′S and 79°S. In this area, the mean decrease of T_0 with latitude is -1.6°C/deg latitude. The area around 72°30′S is about 3000 m in elevation and 450 km far from the coast.

3.3. *Mean annual range of temperature*

One of the most noticeable features of the continental climate is increase of the annual range of temperature. Therefore, the annual range of temperature can be taken as an index of continentality. The mean annual range of temperature, ΔT, is defined as the difference between the mean monthly temperature of the warmest month and that of the coldest month at a place. Fig. 5 shows the ΔT from the equator to Antarctica between 30°E and 60°E. Between 0°S and 57°S, the value of ΔT is 6°C. Between 57°S and 68°S or 69°S, it is 6°C–19°C in the area of sea ice. On the ice sheet, ΔT is 19°C–39°C.

In Fig. 6, ΔT is plotted against the mean annual temperature, T_s and T_{10}. As seen in Fig. 6, the change of ΔT with T_{10} is larger in the inland such as Plateau Station than that in the area between Mizuho Camp and Syowa Station. This tendency can be explained as follows. The area higher than 3000 m is extremely flat and is under weak influence of penetration of cyclonic disturbances that transport heat and moisture from the ocean. So the weather is very fine, and the intensity of the horizontal air-mixing is very weak, since the wind is weak. On the other hand, radiative cooling from snow surface will be more effective, since the water vapor content is low and the cloudiness associated with cyclonic disturbance is low. It can be concluded from the above situation that the change of ΔT with T_{10} is large in the inland area.

4. Distribution of Mean Annual Isotherms in Mizuho Plateau

An isotherm map of mean annual surface temperature, T_{10}, based on 10 m snow temperature is shown in Fig. 7, in which the elevation is also shown. It can be seen in this figure that the mean annual isotherms have a close relation to topography, especially in the area lower than 3000 m: the lower temperature area corresponds to the ridge of ice sheet and warmer temperature area to the troughs. It can be also seen that the area on the east side of the ridge is slightly colder than on the west side in some areas. Since the prevailing wind direction was E to ESE in the area between 69°S and 72°S (WATANABE, 1978), it would be reasonable to consider that the area on the east side of the ridge is colder than on the west side because of cooler air flow by katabatic wind from the higher altitude.

In the area higher than about 3000 m, the deviation of the isotherms from elevation contours becomes larger. This deviation is explained by the following reasons. This area is very flat and the wind is weak, so the horizontal air-mixing is small. There is a region of "cold central core", the coldest area in Antarctic Plateau, with the center around 82°S and 75°E (DALRYMPLE, 1966).

5. Concluding Remarks

From the observational results of the 10 m snow temperature in the region of Mizuho Plateau, the characteristics of temperature distribution are summarized as follows:

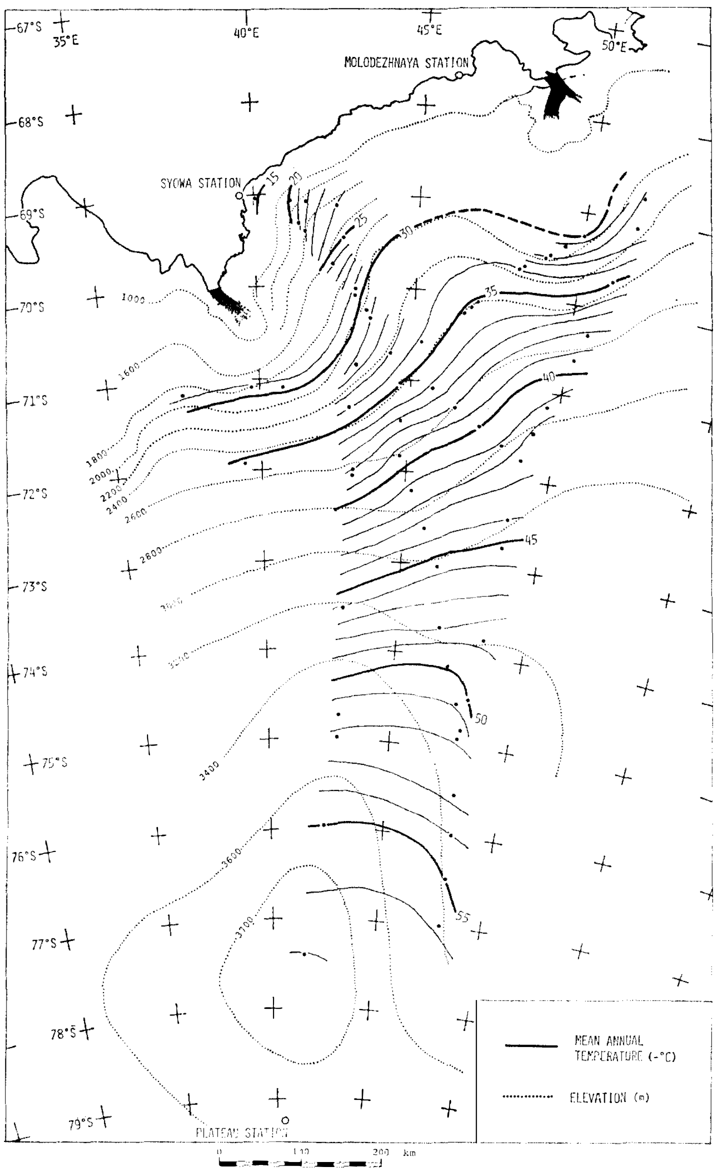

Fig. 7. Isotherm contour map of Mizuho Plateau showing the mean annual surface temperature T_{10}.
A black circle indicates an observation station where 10 m snow temperature was measured.

(1) An average gradient of mean annual surface temperature with elevation is $-0.8°C/100$ m in the area from 0 m to 1000 m where temperature is between $-10°C$ and $-18°C$. In the area between 1000 m and 3000 m ($-18°C$ to $-44°C$), this value is $-1.3°C/100$ m. In the area between 3000 m and 3800 m, the temperature decreases more rapidly with the increase of the elevation, as indicated by the fact that the temperature gradient with elevation is larger than

$-2.0°C/100$ m.

The mean of the temperature gradient with elevation is close to the dry adiabatic lapse rate, when averaged in the area between 0 m and 3000 m. This area has relatively high values of the surface slope as compared with those in the area higher than 3000 m, and might be strongly influenced by stationary katabatic winds throughout the year.

(2) The mean annual surface temperature, T_{10}, decreases gradually with the distance from the coast in the relation of T_{10} $(-°C)=3.47\times L^{0.416}$ where L (km) is the distance from the coast. This is similar to the relation in the area between Mirny Station and Vostok Station.

(3) The rate of change of the mean annual sea-level temperature, T_s and T_0, with latitude is approximately $-0.8°C$/deg latitude between 30°S to 72°30′S. Between 72°30′S and 79°S, the mean decrease of T_0 with latitude is about $-1.6°C$/deg latitude.

(4) The mean annual range of temperature between 30°E and 60°E, ΔT, is meanly 6°C between 0°S and 57°S. Between 57°S and 68°S or 69°S, ΔT is 6°C–19°C in the area of the sea ice. On the ice sheet, ΔT is 19°C–39°C. In the area between 3000 m and 3800 m, a high value of ΔT can be explained by weak winds and the effect of radiative cooling.

(5) A map of mean annual isotherms in the region of Mizuho Plateau indicates a close relation between the isotherms and the elevation contours, especially in the area lower than 3000 m.

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