# ANNUAL PRECIPITATION ESTIMATED BY BLOWING SNOW OBSERVATIONS AT MIZUHO STATION, EAST ANTARCTICA, 1980

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***Abstract:*** This paper describes annual precipitation estimated by blowing snow observations made on a strong katabatic wind slope at Mizuho Station (70°42'S, 44°20'E; 2230 m above mean sea level) in East Antarctica. Snowfall densities have been estimated from the asymptotes of the vertical profiles of snow drift density, *i.e.*, a method reported by FÖHN (J. Glaciol., **26**, 469, 1980) which separates the amount of snowfall from the drift density in a snowstorm.

Using the snowfall densities, fall velocity of blowing snow particles (0.5 m/s) and the distribution of number of days with snowfall, the value of annual precipitation in 1980 was estimated as about 140 mm in water.

## 1. Introduction

It is well known that Mizuho Station (70°42'S, 44°20'E; 2230 m above mean sea level) in East Antarctica is located in the cold katabatic wind zone accompanied by snowstorms. Here, a snowstorm is taken as the combination of blowing snow and snowfall. Therefore, it is important to separate the amount of snowfall and the flux rate of blowing snow. To date there is no data of annual precipitation at Mizuho Station, because it is difficult to measure only the amount of snowfall under conditions of strong wind.

According to FÖHN (1980), snowfall densities have been estimated from asymptotes of the vertical profiles of snow drift density by separating the amount of snowfall from the drift density in a snowstorm. So, we obtained an equation of the profile of drift density during the snowfall by consideration of a turbulent diffusion equation. Next, using the data of snow drift flux, and profiles of wind and air temperature obtained at Mizuho Station (KOBAYASHI *et al.*, 1983), the snowfall densities were estimated from the asymptotes of the vertical profile of drift density in the snowstorms.

## 2. An Equation of the Profile of Snow Drift Density during Snowfall

To illustrate the vertical profile of drift density under the condition of snowfall, a general turbulent diffusion equation was considered already by KOBAYASHI (1984) and KOBAYASHI *et al.* (1985). Namely, an equation of the profile of snow drift density during the snowfall is obtained as follows:

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$$n(z)=P/w+(n_0-P/w)\exp(-(w/K_s)\cdot z), \quad (1)$$

where $n(z)$ is the drift density at the height $z$, $w$ is the apparent fall velocity of snow particles, $K_s$ is the apparent diffusivity, $n_0$ is the drift density at the surface and $P$ is the vertical flux of snowfall. Equation (1) was obtained by using the assumptions that $K_s$ and $w$ are constant, and $P \fallingdotseq 0$. If $w \cdot n_0 > P > 0$, the asymptote of the profile in $z$-direction approaches the snowfall density: $P/w$. Figure 1 is a schematic representation of eq. (1).

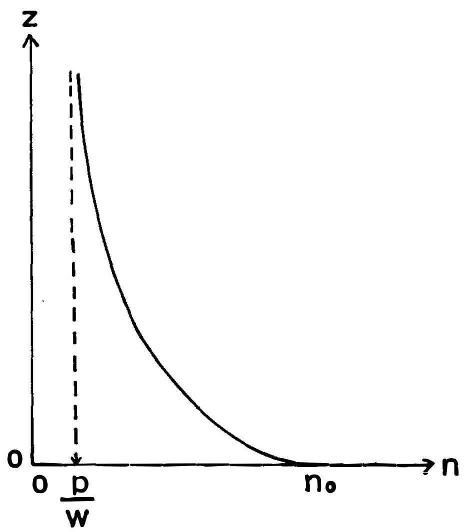


*Fig. 1. Schematic representation of the theoretical drift density profile, eq. (1), of turbulent diffusion under condition of snowfall.*

## 3. Results

The measurements of the snow drift flux and the profiles of wind speed and air temperature under conditions of strong wind and snowfall were made on a katabatic wind slope (mean surface slope $3 \times 10^{-3}$) at Mizuho Station in 1980. The data have been reported already by Kobayashi *et al.* (1983).

From the vertical profiles of the mean flux of blowing snow and wind speed up to 28 m above the snow surface under conditions of snowfall, the vertical profiles of drift density were calculated. Namely, the relation between the horizontal mass flux of snow $q(z)$ at any height $z$ and the drift density $n(z)$ is given by:

$$n(z)=q(z)/u(z), \quad (2)$$

where $u(z)$ is the wind speed at the height $z$.

Three examples of the vertical profile of drift density are plotted in Figs. 2 and 3. In the figures, the solid lines were drawn so as to fit the observed values, *i.e.*, the theoretical eq. (1) of turbulent diffusion during snowfall. In Fig. 2, two representative examples of drift density are shown, where the open circles and the solid circles denote the observed values in no snowfall and snowfall conditions respectively. According to the figure, the snowfall densities have been estimated from the asymptotes of the

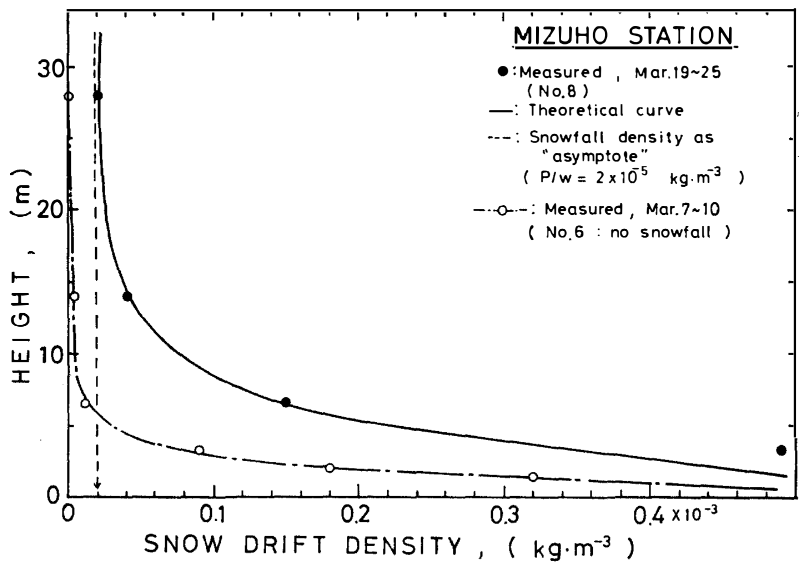


*Fig. 2. Examples of the profile of snow drift densities at Mizuho Station in 1980. The solid line shows a theoretical curve of eq. (1) to fit the observed values (solid circles) obtained during snowfall. The open circles and the dashed line show the observed values obtained during no snowfall.*

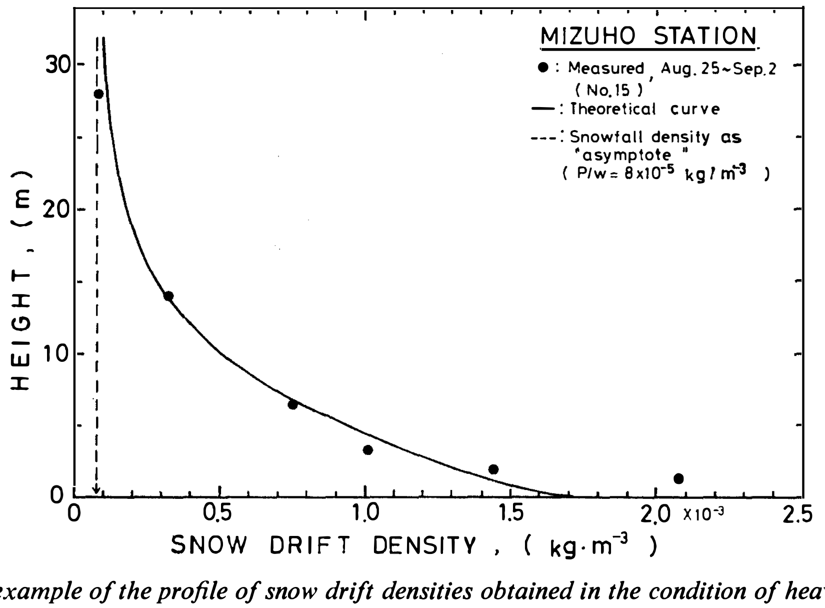


*Fig. 3. An example of the profile of snow drift densities obtained in the condition of heavier snowfall than the data in Fig. 2.*

profile of drift densities of blowing snow.

Here, if we assumed that $w$ is the fall velocity of snow particles, taken as 0.5 m/s according to TAKAHASHI *et al.* (1984), we can get the value of vertical flux of snowfall, *i.e.*, solid precipitation rate ($P$).

As the result, the precipitation rate, the apparent diffusivity, and other various parameters are given in Table 1. In Table 1, $K_m$ is the diffusivity calculated from the wind speed profiles. On the other hand, using the relative frequencies of occurrence

*Table 1. Various parameters derived from the theoretical eq. (1) by fitting the observed values.*

| Run | $P/w$ (kg/m$^3$) $\times 10^{-3}$ | $w/K_S$ (m$^{-1}$) | $n_0$ (kg/m$^3$) $\times 10^{-3}$ | $P$* (mm/h) | $K_s$* (m$^2$/s) | $K_m$** (m$^2$/s) |
|---|---|---|---|---|---|---|
| 4 | 0.012 | 0.999 | 0.084 | 0.02 | 5.1 | 4.6 |
| 7 | 0.005 | 0.129 | 0.121 | 0.01 | 3.9 | 5.2 |
| 8 | 0.020 | 0.250 | 0.640 | 0.04 | 2.0 | 5.5 |
| 10 | 0.008 | 0.121 | 0.117 | 0.01 | 4.1 | 2.0 |
| 11 | 0.016 | 0.138 | 0.271 | 0.03 | 3.6 | 3.2 |
| 12 | 0.008 | 0.125 | 0.060 | 0.01 | 4.0 | 2.9 |
| 13 | 0.032 | 0.137 | 0.223 | 0.06 | 3.6 | — |
| 15 | 0.080 | 0.137 | 1.720 | 0.14 | 3.6 | 4.5 |
| 17 | 0.018 | 0.167 | 0.142 | 0.03 | 3.0 | 6.4 |
| 20 | 0.025 | 0.133 | 0.250 | 0.05 | 3.8 | 4.8 |
| 21 | 0.040 | 0.123 | 0.180 | 0.07 | 4.1 | 5.0 |
| 23 | 0.010 | 0.412 | 3.210 | 0.02 | 1.2 | 5.4 |
| Mean | | | | 0.04 | 3.5 | 4.5 |

* In the case of $w=0.5$ m/s.

** Estimated from $K_m = kU_*Z$, where $k$ is von Karman constant (0.4) and $U_*$ is the friction velocity.

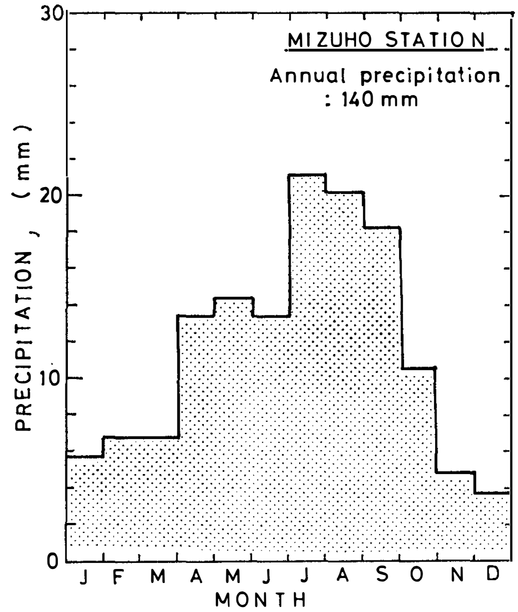


*Fig. 4. Distribution of monthly precipitation at Mizuho Station in 1980.*

of snowstorm and snowfall and a mean value of precipitation rate, the distribution of monthly precipitation was estimated as shown in Fig. 4. Therefore, the annual precipitation at Mizuho Station in 1980 was 140 mm in water.

## 4. Discussion

TAKAHASHI (1985) estimated the annual precipitation at Mizuho Station in 1982, using two methods of blowing snow, so that the values were 230 and 260 mm in water, respectively. To compare the value obtained here with others, the mean annual precipitations obtained at various stations are given in Table 2 (*e.g.*, SCHWERDTFEGER,

*Table 2. Mean annual precipitation at various Antarctic stations.*

| Station | Latitude | Longitude | Elevation m | Annual precipitation mm in water | Period | Reference |
|---|---|---|---|---|---|---|
| Mizuho | 70°42′S | 44°20′E | 2230 | 140 | 1980 | Present result |
| | | | | 230–260 | 1982 | TAKAHASHI, 1985 |
| Novolazarevskaya | 70°46′S | 11°50′E | 87 | 303 | 1961–1964 | SCHWERDTFEGER, 1970 |
| Molodezhnaya | 67°40′S | 45°51′E | 42 | 712 | 1963–1965 | 〃 |
| Mirny | 66°33′S | 93°01′E | 30 | 625 | 1956–1965 | 〃 |
| Melchior | 64°20′S | 62°59′W | 8 | 1189 | 1947–1956 | 〃 |
| Decepcion | 62°59′S | 60°43′W | 8 | 398 | 1948–1956 | 〃 |
| Orcadas | 60°45′S | 44°43′W | 4 | 404.8 | 1904–1906 | 〃 |
| | | | | | 1908–1956 | 〃 |

1970). However, it is distinct that the annual precipitation at Mizuho Station was smaller than the values of other stations, which are located along the periphery of the Antarctic Continent, whereas there are no data of precipitation at inland stations of Antarctica. Accordingly, we cannot make a comparison with the data of other inland stations.

NARITA and MAENO (1979) gave a value of mean annual accumulation, roughly 70 mm in water, at Mizuho Station, from the growth rate of crystal grains in the snow above 35 m.

TAKAHASHI (1985) proposed two methods of estimation of the amount of precipitation during blowing snow, *i.e.*, one is estimation from drift flux at 1 m height, and the other is based on the assumption that the drift density at 30 m height is equal to a value of precipitation. The latter corresponds to our method which revealed that the annual precipitation in 1982 was roughly two times the value in 1980.

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