DEPENDENCE OF OXYGEN ISOTOPIC COMPOSITION OF SURFACE SNOW ON DISTANCE FROM COAST IN MIZUHO PLATEAU

Keiji HIGUCHI

Water Research Institute, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464

Abstract: The dependency of the $\delta^{18}O$ values of drifting snow on distance from the coast was studied on the basis of the data obtained by the traverse of the 15th Japanese Antarctic Research Expedition in 1974. The rate of horizontal variation of the $\delta^{18}O$ value was 7.5 and 7.8‰/100 km in the coastal region, and 4.2 and 5.0‰/100 km in the inland region. On the basis of a simple model of the precipitation process, it can be said from the rate of horizontal variation of the $\delta^{18}O$ values that precipitation in the coastal region is from convective clouds with large vertical velocity and precipitation in the inland region is from clouds related to synoptic scale disturbances with small vertical velocity.

1. Introduction

Oxygen isotopic composition of surface snow on the Mizuho Plateau, East Antarctica, was studied by KATO *et al.* (1978). It was found in their work that the $\delta^{18}O$ values of drifting snow show a linear relationship with the elevations of the stations at elevations between 1000 and 2900 m, along the traverse route S-H-Z-Y-I of the 15th Japanese Antarctic Research Expedition (JARE-15) in October and November 1974. In addition, they found also a linear relationship between the $\delta^{18}O$ values of drifting snow and 10 m depth snow temperature at the sampling station.

However, it is also important to study the relation between the $\delta^{18}O$ value of snow and distance from the coast, in order to discuss the precipitation process depending on transportation of water vapor from the ocean. Therefore, such a relation was studied as described in this paper.

2. Results

On the basis of the same data (KATO, 1977) as used by KATO *et al.* (1978), the $\delta^{18}O$ values of drifting snow were plotted against distance between Syowa Station and the sampling station, as shown in Fig. 1. Distance was measured between Syowa Station and the projection of each station on a line from Syowa Station to the point 45°E, 72°S. This direction is reasonable for comparison between the stations along the traverse route which dog-legs along the S-H-Y route and the I route as seen on the map of Mizuho Plateau.

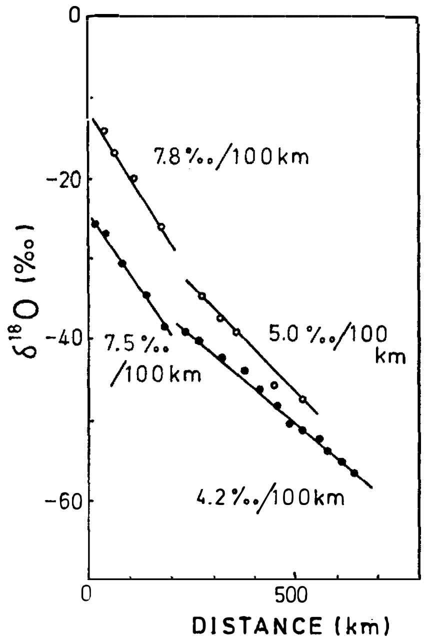

Fig. 1. Oxygen isotopic composition ($\delta^{18}O$) of drifting snow collected at the stations along the traverse route S-H-Y-I of JARE-15 in October and November 1974, and the distance from the coast. ● indicates the sample obtained on the way to I 240, and ○ does that on the way back from I 240.

It can be seen in Fig. 1 that the $\delta^{18}O$ values show a linear relationship with the distance, for the samples on the way to Station I 240 (solid circles) and from it (open circles). In each case, the rate of change is steeper in the coastal region within 200 km of the coast and lower than 2000 m in altitude. As shown in Fig. 1, the rate of horizontal variation of the $\delta^{18}O$ values was 7.5 and 7.8‰/100 km in the coastal region, and 4.2 and 5.0‰/100 km in the inland region.

3. Discussion

The relationship between the $\delta^{18}O$ values of precipitation particles and the temperature range in the corresponding cloud layer was discussed by KATO (1978) on the basis of samples of fallen snow collected at Syowa Station and also data obtained by the upper air soundings at Syowa Station. But, since precipitation particles will drift for a long distance during travel from the cloud to the ground (HIGUCHI, 1962), precipitation particles from the lower part of the cloud will fall nearly, but those from the upper part will fall far away. Therefore, the dependence of the $\delta^{18}O$ values of precipitation particles with distance from the cloud can be correlated with the conditions in the cloud in which the particles formed.

Such a relation was studied by the use of a simple model to combine the variation of $\delta^{18}O$ of precipitation particles in moist adiabatic cooling (DANSGAARD, 1964) with the trajectory of lifting of air parcels and drifting of particles, as shown in Fig. 2.

In Fig. 2, the fourth quadrant (IV) shows the upper air condition (temperature: T, wind speed: v, height: Z) at Syowa Station on September 17 (0331 LST), 1974 (JAPAN METEOROLOGICAL AGENCY, 1977), since these data were selected as typical when precipitation occurred before sampling. It can be clearly seen in the temperature profile (T) that a frontal surface was observed at a height between 1.5 and 2.5 km. In the air layer above the frontal surface, the wind direction

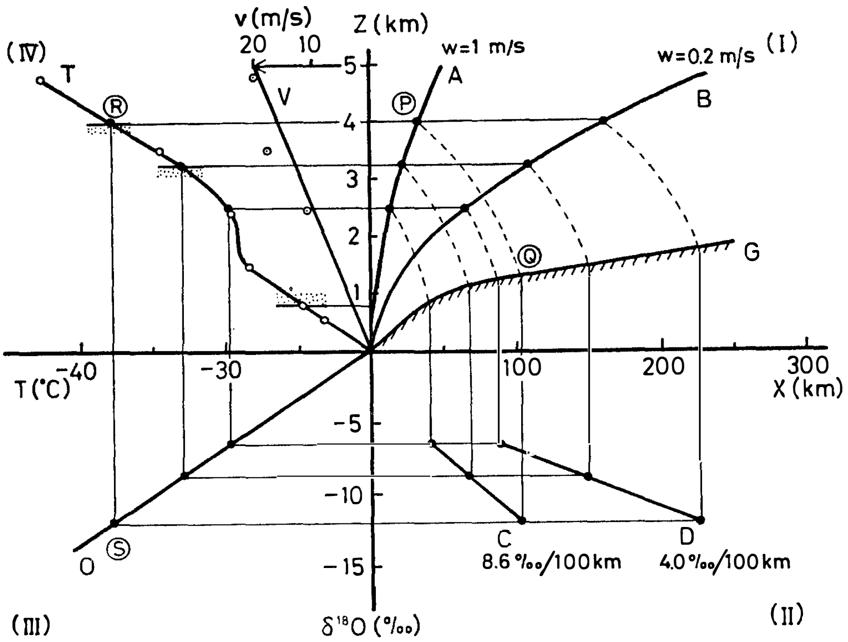

Fig. 2. Diagram to show trajectories of air parcels and precipitation particles (first quadrant), relation between the $\delta^{18}O$ values of precipitation particles and distance (X) (second quadrant), relation between the $\delta^{18}O$ values of precipitation particle and its condensation temperature (third quadrant), and the upper air conditions (temperature: T, wind speed: v, height: Z) at the Syowa Station on September 17 (0331 LST), 1974 (fourth quadrant).

was constant, near 270°, and the wind speed was as shown by ⊙. Therefore, the wind profile was assumed to increase linearly with height until 20 m/s at 5 km in height, as shown by line V. The air layer saturated with respect to water was between 0.8 and 3.2 km. Since the air layer below 4 km was saturated with respect to ice, the cloud top was estimated as 4 km.

In Fig. 2, the third quadrant (III) shows the relation between the $\delta^{18}O$ value of precipitation particles and their condensation temperature calculated by DANSGAARD (1964) for the case of moist adiabatic cooling at vapor-ice equilibrium. The $\delta^{18}O$ in this diagram indicates the relative value with respect to the $\delta^{18}O$ value of water vapor contained in an air parcel at the start of lifting.

In the first quadrant (I) of Fig. 2, the curves A and B indicate trajectories of air parcels, with the same horizontal velocity as the wind velocity shown in the fourth quadrant, and vertical velocities $w=1$ and 0.2 m/s respectively. It was assumed that the air parcels were saturated at the ground, so condensation of water vapor occurred during the lifting of air parcels. The broken lines indicate trajectories of precipitation particles falling from the air parcel along the lines A and B, the fall velocity being assumed to be 0.4 m/s. The line G indicates the profile of the ice sheet along the direction of the wind.

From the lines described above, it is possible to find the dependence of the $\delta^{18}O$ values of precipitation particles on distance in the second quadrant (II) of Fig. 2. For example, in the case of an air parcel with $w=1$ m/s, the particle at the cloud top started to fall from P on line A, to Q on the ground. The condensation temperature of this particle is given by R on line T, and its oxygen isotopic composition can be estimated from S on line O. From Q and S, it is possible to estimate the $\delta^{18}O$ value of a precipitation particle which has fallen on the ground.

By such a procedure as described above, the relation between the $\delta^{18}O$ values of precipitation particles and distance can be obtained as shown by lines C and D in the second quardrant of Fig. 2. It was found from these lines that the rate of variation of $\delta^{18}O$ is 8.6‰/100 km when the vertical velocity of an air parcel is 1 m/s, and 4.0‰/100 km when the vertical velocity is 0.2 m/s.

These rates can be compared with the rates obtained from the observations shown in Fig. 1, since the samples of drifting snow can be considered as new snow fallen during snowfall just before the sampling.

As seen in Figs. 1 and 2, the observed values of rate of variation of $\delta^{18}O$ in the coastal region agree with the estimated value for the vertical velocity of an air parcel, 1 m/s, and those in the inland region agree with the estimated value for the vertical velocity 0.2 m/s. The direction in which the distances are measured is not the same in the two cases, but such agreement as above can be said to be reasonable.

It can be concluded from these results that the precipitation process is different between the coastal region and the inland region, that is, precipitation in the former is mainly from a convective cloud with large vertical velocity, and precipitation in the latter is mainly from the clouds related to synoptic scale disturbances with small vertical velocity. This conclusion is in agreement with the observational result that the coastal region is strongly affected by cyclonic disturbances with high accumulation (YAMADA *et al.*, 1978; WATANABE, 1978). This is a first attempt to discuss types of precipitation process on the basis of the isotopic composition of precipitation particles. Research work along this line will be continued by the author, about precipitation not only in the Antarctica but also in Japan.

Acknowledgment

The author expresses his hearty thanks to Prof. T. TAKEDA, Water Research Institute, Nagoya University, for his discussions through the course of this work.

References

DANSGAARD, W. (1964): Stable isotopes in precipitation. Tellus, **16**, 436–468.

HIGUCHI, K. (1962): Experimental studies on drift and turbulent diffusion of paperlets emitted from aircraft as a model of snowflake. J. Meteorol. Soc. Jpn., **40**, 170–180.

JAPAN METEOROLOGICAL AGENCY (1977): Meteorological Data at the Syowa Station in 1974. Antarct. Meteorol. Data, **15**, 229 p.

KATO, K. (1977): Oxygen isotopic composition and gross β-radioactivity in firn. JARE Data Rep., **36** (Glaciol.), 156–167.

KATO, K. (1978): Factors controlling oxygen isotopic composition of fallen snow in Antarctica. Nature, **272**, 46–48.

KATO, K., WATANABE, O. and SATOW, K. (1978): Oxygen isotopic composition of the surface snow in Mizuho Plateau. Mem. Natl Inst. Polar Res., Spec. Issue, **7**, 245–254.

WATANABE, O. (1978): Distribution of surface features of snow cover in Mizuho Plateau.

Mem. Natl Inst. Polar Res., Spec. Issue, **7**, 44–62.
YAMADA, T., OKUHIRA, F., YOKOYAMA, K. and WATANABE, O. (1978): Distribution of accumulation measured by the snow stake method in Mizuho Plateau. Mem. Natl Inst. Polar Res., Spec. Issue, **7**, 125–139.

(Received May 19, 1982)