CORRELATION BETWEEN THE MONTHLY MEANS OF SURFACE AIR TEMPERATURE AND OXYGEN ISOTOPIC COMPOSITION OF FALLEN SNOW AT SYOWA STATION (EXTENDED ABSTRACT)

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The correlation between the isotopic composition and the temperature of formation of precipitation is theoretically determined by the cooling process, under equilibrium Rayleigh conditions (*i.e.* a slow process with immediate removal of the condensate or sublimate from the vapor after its formation in a closed system), as pointed out by FRIEDMAN *et al.* (1964) and DANSGAARD (1964). The formation of fallen snow around and in Antarctica is very suitable for equilibrium Rayleigh conditions, because of low temperature and ice- or snow-covered surface around and in Antarctica.

The oxygen isotopic composition ($\delta^{18}O$) was determined for the fallen snow samples collected at Syowa Station in 1974 (KATO, 1977, 1978, 1979; KATO and HIGHCHI, 1979; KATO *et al.*, 1977, 1978) and in 1977 (KATO and IWAI, 1982). KATO (1978) found that the transportation process of water vapor to the Antarctic ice sheet also largely controls the isotopic composition of fallen snow in Antarctica, which was related only to its temperature of formation in the previous studies (GONFIANTINI and PICCIOTTO, 1959; PICCIOTTO *et al.*, 1960; GONFIANTINI *et al.*, 1963; EPSTEIN *et al.*, 1963; ALDAZ and DEUTSCH, 1967). KATO and IWAI (1982) confirmed the results found by KATO (1978).

Taking into consideration the transportation process of water vapor, the theoretically developed correlation between the isotopic composition and the temperature of formation of precipitation was proved with the actual findings (KATO, 1979, 1982). The mean value of change of $\delta^{18}O$ per degree of cooling is nearly equal to 0.7‰ per °C for the fallen snow samples at Syowa Station.

The temperature of formation of precipitation (temperature range in the corresponding cloud layer in which precipitating clouds are formed) is not always available together with the isotopic composition of precipitation. If the mean surface air temperature varies directly with the mean temperature of formation of precipitation, the correlation between the mean isotopic composition of precipitation and the mean surface air temperature may also provide information about the cooling process for its formation.

Figure 1 shows the variations of unweighted monthly mean $\delta^{18}O$ of fallen snow samples, and monthly mean surface air temperature and atmospheric pressure

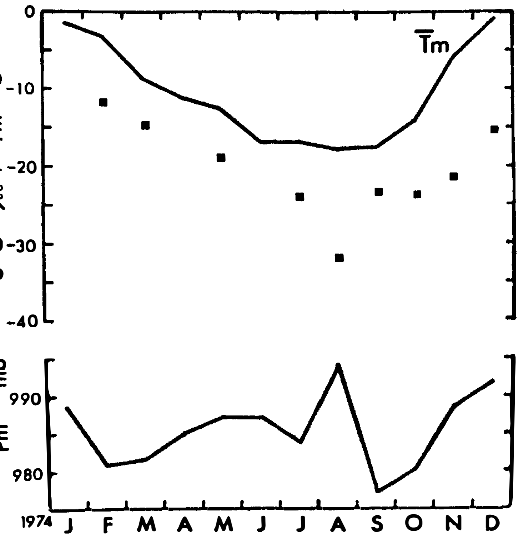

Fig. 1. Variations of unweighted monthly mean oxygen isotopic composition of fallen snow ($\bar{\delta}^{18}O$), monthly mean surface air temperature ($\bar{T}_m$) and monthly mean atmospheric pressure at station level ($\bar{P}_m$) during the course of 1974, at Syowa Station.

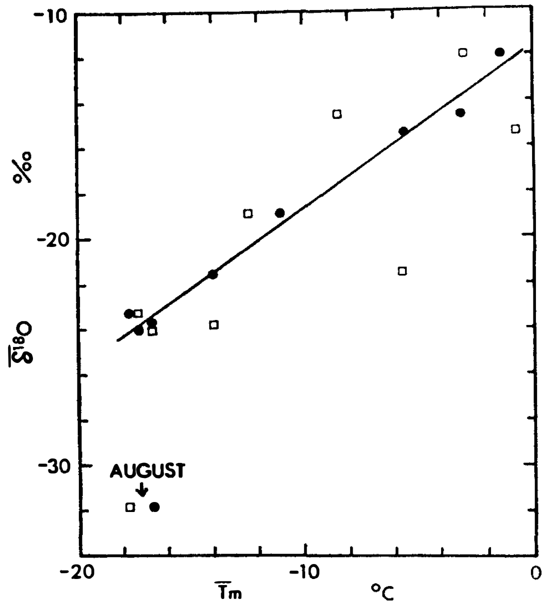

Fig. 2. Unweighted monthly mean oxygen isotopic composition of fallen snow ($\bar{\delta}^{18}O$) with respect to monthly mean surface air temperature ($\bar{T}_m$) in 1974, at Syowa Station. □, $\bar{T}_m$ and $\bar{\delta}^{18}O$ in the same month, ■, $\bar{T}_m$ and $\bar{\delta}^{18}O$ in the month following the month which $\bar{T}_m$ indicates.

(JAPAN METEOROLOGICAL AGENCY, 1977) at Syowa Station in 1974, due to the sparsity of the $\delta^{18}O$ determinations in 1977. The unweighted monthly mean $\delta^{18}O$ denotes the mean value of the unweighted 10 day mean $\delta^{18}O$, because samples of fallen snow were not collected every day.

The variation of the unweighted monthly mean $\delta^{18}O$ of fallen snow seems to follow more faithfully that of the preceding month's mean temperature than that of the same month's mean temperature, except for August. August had a very high atmospheric pressure, as shown in Fig. 1. Therefore the amount of ^{18}O-rich water vapor supplied by the circumpolar cyclone was smaller in August than in the other months. Hence it becomes understandable why the monthly mean $\delta^{18}O$ of fallen snow is so low in August.

Figure 2 shows the unweighted monthly mean $\delta^{18}O$ of fallen snow with respect to the monthly mean surface air temperature shown in Fig. 1. A linear correlation is seen between the monthly means of $\delta^{18}O$ of fallen snow and surface air temperature, except for August. Furthermore, the slope of the straight line is nearly equal to 0.7‰ per °C and exactly equal to that showing the correlation between the $\delta^{18}O$ of fallen snow and its temperature of formation (KATO, 1979, 1982). This shows that a linear correlation between the monthly means of isotopic composition of precipitation and surface air temperature also provides useful information about the cooling process for its formation.

In Fig. 2 it is seen that no remarkable correlation is found between the monthly

Table 1. Squared coefficients of correlation of monthly mean temperature ($\bar{T}_m$) variables with unweighted monthly mean of oxygen isotopic composition of fallen snow ($\bar{\delta}^{18}O$) and distance from the coast of open sea to the sampling station ($\bar{D}_m$), respectively, in 1974 at Syowa Station.

	Same month's $\bar{T}_m$		Preceding month's $\bar{T}_m$	
	$\bar{\delta}^{18}O$	$\bar{D}_m$	$\bar{\delta}^{18}O$	$\bar{D}_m$
$\bar{T}_m$ at surface	0.52	0.55	0.83	0.87
$\bar{T}_m$ at 800 mb level	0.50	0.50	0.77	0.80
$\bar{T}_m$ at 600 mb level	0.53	0.52	0.72	0.76

means of $\delta^{18}O$ of fallen snow and surface air temperature in the same month. However, a remarkable linear correlation is found between the monthly mean $\delta^{18}O$ of fallen snow and the preceding month's mean surface air temperature, except for August. This is an unexpected and very interesting result. The squared coefficients of correlation of monthly mean surface air temperature with monthly mean $\delta^{18}O$ are given in Table 1.

Table 1 also gives the squared coefficients of correlation of monthly mean air temperature at 800 and 600 mb levels, around which snow is formed, with monthly mean $\delta^{18}O$ of fallen snow. It is seen from this table that the linear correlation is better between the monthly means of air temperature at both levels and at surface in the same month. The mean surface air temperature may vary parallel to the mean temperature of formation of snow.

GONFIANTINI and PICCIOTTO (1959) and PICCIOTTO *et al.* (1960) determined the isotopic composition of fallen snow samples collected at Roi Baudouin Station near Syowa Station in 1958. The $\delta^{18}O$ values of fallen snow are grouped into 'isotopic summer' and 'isotopic winter' by abrupt jumps in the variation of $\delta^{18}O$. KATO (1978) found that the $\delta^{18}O$ of fallen snow is higher in December–May than that in July–November, even at the same temperature of formation of snow. This is because the water vapor supplied to the sampling station is richer in ^{18}O in December–May than in July–November, which results from two abrupt jumps between May and July and between November and December in the variation of the distance from the coast of open sea to the sampling station. The difference of transportation process of water vapor between the two above periods causes the appearance of 'isotopic summer' (December–May) and 'isotopic winter' (July–November).

Taking into consideration the transportation process of water vapor, the one month lag between the variations of monthly means of surface air temperature and $\delta^{18}O$ of fallen snow may be caused by the time lag between the variations of surface air temperature and distance from the coast of the open sea to the sampling station. This is because the sea ice response is delayed relative to the variation of air temperature, due to the large thermal capacity of sea water and sea ice.

The squared coefficients of correlation of unweighted monthly mean distance from the coast of the open sea to Syowa Station (KATO, 1978) with the monthly mean $\delta^{18}O$ of fallen snow are given in Table 1. From this table it is clearly seen that the one month lag between the variations of monthly means of surface air temperature and distance from the coast of the open sea to the sampling station causes the one month lag between those of surface air temperature and $\delta^{18}O$ of fallen snow. This fact also proves that the isotopic composition of precipitation is controlled not only by its temperature of formation but also by the transportation process of water vapor.

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