$^{18}O/^{16}O$, $^{2}H/^{1}H$ and ^{3}H measurements on precipitation and air moisture samples from the North Water area

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Abstract. From 1972 to 1974 a mesoclimatic study was conducted in the North Water area between north Greenland and Ellesmere Island, with the aim of assessing the influence of this polynya.

In support of the climatological and glaciological programme of the North Water Project an isotope study was carried out. At Coburg Island, Carey Island and Cape Herschel precipitation and air moisture were systematically collected.

The analysis of all samples collected from November 1972 to May 1973 on Coburg Island is complete. In the precipitation samples the $^{18}O/^{16}O$ and $^{2}H/^{1}H$ ratios as well as the tritium content were measured, for the air moisture samples the $^{18}O/^{16}O$ ratios were determined.

The data obtained from the precipitation and air moisture samples show remarkable correlation with the temperature; however, the air moisture samples may be affected by isotopic fractionation during collection.

The isotopic data suggest that approximately 25 per cent of the precipitation is of local origin.

Mesures de l'$^{18}O/^{16}O$, de l'$^{2}H/^{1}H$ et de l'^{3}H dans des échantillons de précipitations et des échantillons d'humidité atmosphérique dans la région du North Water

Résumé. De 1972 à 1974 des études mésoclimatiques ont été réalisées dans la région du North Water dans le but d'évaluer l'influence de cette polynya entre le nord du Groenland et l'île d'Ellesmere.

Pour compléter et confirmer les résultats climatologiques et glaciologiques, nous avons développé un programme isotopique, consistant à échantillonner systématiquement les précipitations et la vapeur d'eau atmosphérique à l'île de Coburg, à l'île de Carey et au cap d'Herschel.

Les échantillons recueillis à l'île de Coburg entre novembre 1972 et mai 1973 ont déjà été analysés de façon complète: rapport $^{18}O/^{16}O$, $^{2}H/^{1}H$ et teneur en T pour les échantillons de précipitation et rapport $^{18}O/^{16}O$ pour les échantillons de vapeur d'eau.

Les résultats montrent des corrélations remarquables avec la température, bien que les échantillons d'humidité atmosphérique soient affectés du fractionnement isotopique durant la collection. Selon les résultats environ 25 pour cent des précipitations sont d'origine locale.

INTRODUCTION

The isotopic composition of hydrogen and oxygen in water differs slightly in different water bodies. In newly formed air moisture the isotopic composition depends on that of the water of origin, on the temperature of the water, and on the evaporation kinetics. The isotopic composition of precipitation depends mainly on that of the air moisture from which it originates. These processes are discussed by Craig and Gordon (1965) and Dansgaard (1964). The changes in the isotopic composition of air moisture during its movement from the site of evaporation to the site of precipitation are very complex due to mixing. Dansgaard (1964) showed, however, that the mean isotopic composition of annual precipitation in polar regions is in a simple way related to the mean annual surface temperature.

The aim of the North Water Project is to assess the influence of the open water on its surroundings (Müller *et al.*, 1973). The analysis of air moisture and precipitation in this area may provide an important contribution. In the present report the results of isotopic analysis of air moisture and precipitation samples from the North Water area are compared with meteorological data.

SAMPLING METHODS

Precipitation
The snow samples were collected with big open tin cans, mounted 1.5 m above the snow surface to minimize contamination by drifting snow. To measure the ^{18}O, ^{2}H and ^{3}H content, the minimum sample amount had to be 20 cm^3. About 10 cans were needed to get enough material for precipitation down to 0.2 mm water equivalent. After each snowfall, samples from the surface were also collected (this snow is a mixture of precipitation and drifting snow). In some cases this sampling was repeated after some days to check the ageing of the snow. All samples were stored and transported in air-tight sealed tin cans.

Air moisture
To avoid fractionation the moisture of a given air mass must be extracted completely; various methods are described in the literature (Oestlund, 1967; Roether and Junghans, 1966; Steinberg and Rohrbough, 1962; Zimmermann, 1972), but they were all too difficult to be applied in the North Water region. Therefore, we developed a new system. A molecular sieve 3A (200 g) is placed between two steel grids in a plastic tube (12 cm diameter). A small ventilator sucks air at a rate of 2–4 m^3/h through the sieve. The molecular sieve was replaced each 24 h and the exposed sieve sealed in an air-tight tin can.

MEASURING TECHNIQUE

Oxygen-18 and deuterium content
The $^{18}O/^{16}O$ ratio is measured in CO_2 (Moser and Stichler, 1971) by a mass spectrometer GD 150 with a double collector. The air moisture samples first have to be extracted from the molecular sieves by heating up to 450°C and collecting the moisture in a cool trap at −190°C. There is some danger that the oxygen from the molecular sieve exchanges with the oxygen from the water. This does not, however, affect the deuterium and tritium results. The measurements of the deuterium content were made by the Geotechnical Institute, Vienna, and the Institut für Radiohydrometrie, Munich.

Tritium content
The tritium activity in the collected samples is too small to be measured directly in a liquid scintillator. It has to be enriched, or transferred into a counting gas (CH_4) and measured in a proportional counter. In our case all samples were measured in a proportional counter. The results are given in tritium units [TU]. 1 TU corresponds to the concentration of $T/H = 10^{-18}$, i.e. about 7.2 decays per min and per 10 cm^3 of water.

RESULTS AND DISCUSSION

Precipitation (Fig. 1)
In the first winter period (January to May 1973) only the heavier precipitation was collected, representing close to 90 per cent of the total precipitation. For the second period (November 1973 to April 1974) the 93 collected samples represent close to 100 per cent of the precipitation.

The correlation between the two isotope deviations $\delta(^{18}O)$ and $\delta(^{2}H)$ is

$$\delta(^{2}H) = 7.94\ \delta(^{18}O) + 17.93‰$$

with a correlation coefficient of 0.99. The relatively high value of the constant

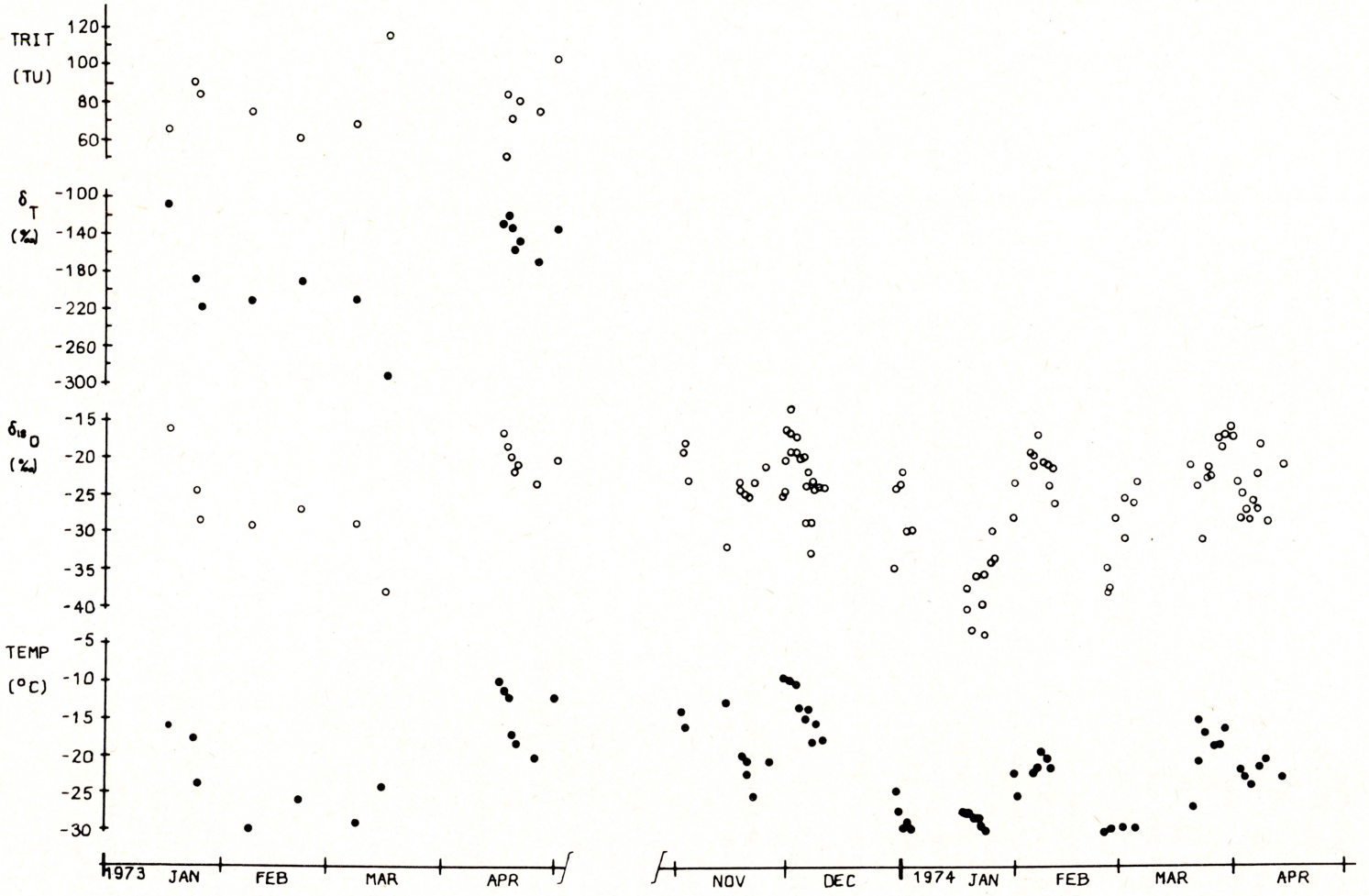

FIGURE 1. Precipitation from Coburg Island (winters 1972–1973 and 1973–1974). Correlation between isotopic concentrations and mean daily temperature.

($17.93^0/_{00}$) indicates the presence of kinetically evaporated water (Craig and Gordon, 1965; Dansgaard, 1964; Gat and Carmi, 1970). The tritium content also indicates the presence of local water as it is between the figure for the ocean water ($\simeq 30$ TU) and that for water vapour transported over a long distance in the atmosphere (expected to be approximately 200 TU in winter 1973 for this region).

There is no very good correlation between the $\delta(^{18}O)$ values of single precipitation events and the surface temperature. The linear regression line is given by

$$\delta(^{18}O) = 0.57t - 13.83^0/_{00}$$

(t = temperature in °C). The correlation coefficient is 0.55. Taking instead of the surface temperature the mean cloud temperature (calculated by A. Ohmura) the following regression line results:

$$\delta(^{18}O) = 0.64t - 9.93^0/_{00}$$

with a correlation coefficient of 0.57. It is assumed that the better single precipitation samples fit the regression line the better the assumptions for the model of an equilibrium evaporation and Rayleigh condensation are fulfilled (Dansgaard, 1964). The more they deviate, the more important are influences not included in the model (e.g. local water vapour).

Air moisture (Fig. 2)

A correlation between the $\delta(^{18}O)$ and the mean daily temperature is obvious. The linear regression line is given by the equation

$$\delta(^{18}O) = 0.65t - 12.67^0/_{00}$$

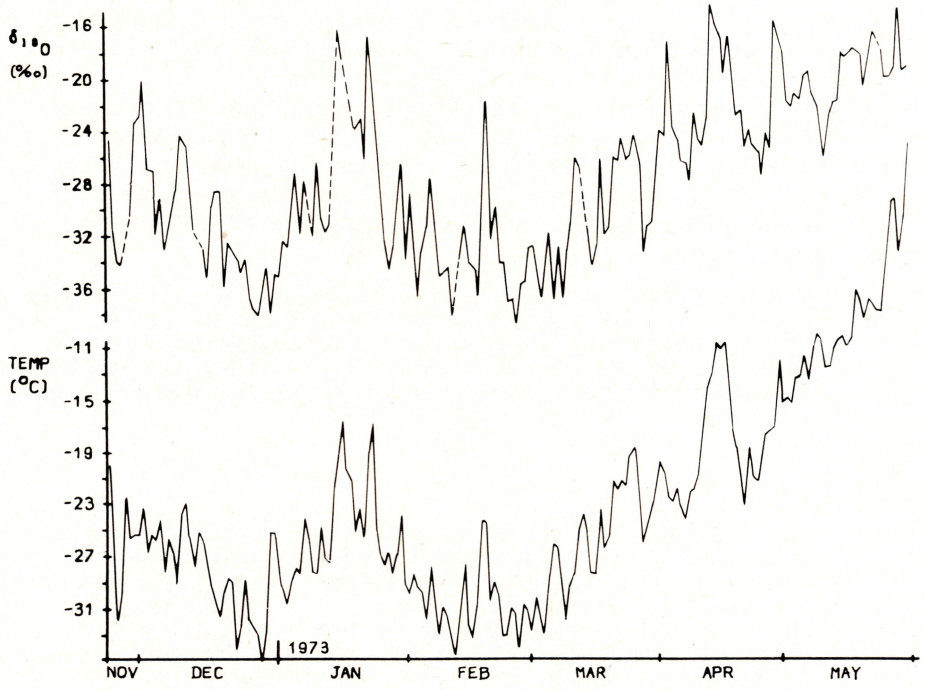

FIGURE 2. Air moisture from Coburg Island (winter 1972–1973). Correlation between ^{18}O content and mean daily temperature.

The correlation coefficient is 0.84. This regression line deviates only little from the Dansgaard line [$\delta(^{18}O) = 0.70t - 13.6‰$], which is surprising because his relation is valid for precipitation. For air moisture values approximately $10‰$ lower would be expected. The anomaly is probably due to an isotopic fractionation process during sampling on the molecular sieve. Therefore, the data have to be looked at critically. Nevertheless an interpretation of the results is given assuming that the isotopic fractionation resulted in a constant shift for all samples.

Many small deviations considered together with the tritium measurements show that besides temperature other parameters connected with the presence of much local water vapour influence the ^{18}O content. Although it is not yet possible to draw definite conclusions from these results, the following tendencies can be observed: if there is an anticorrelation between relative humidity and temperature, which is an exception, the $\delta(^{18}O)$ varies proportionally to the relative humidity. Wind from southern directions often leads to a decrease and strong wind from northern directions to an increase of the $\delta(^{18}O)$. Haze or fog seems to cause a decrease of the tritium content in the air moisture. These observations require further investigation.

ESTIMATION OF THE PERCENTAGE OF LOCAL WATER VAPOUR IN PRECIPITATION

In Dansgaard's model it is assumed that the moisture contained in a given air mass originates mainly in subtropical waters and is transported along with the air mass to the northern regions. As the air mass cools on its poleward course, moisture is precipitated continuously. The average temperature for the winter half year 1972–1973 in the North Water area is $-25°C$. According to the model the $\delta(^{18}O)$ in the precipitation in this area can be calculated to be $-29‰$.

In a model which takes into account the moisture exchange at the surface of the open North Water, the precipitation originating from this open water would have a $\delta(^{18}O)$ value of $-11‰$ (Schriber, 1974).

The measured value of $-26‰$ lies between the two model values, suggesting a contribution of 17 per cent of local water. Similar estimations with ^{2}H and ^{3}H give 28 and 22 per cent for the contribution from local moisture.

Based on ^{2}H, ^{3}H and ^{18}O measurements we can estimate that 20–25 per cent of all the precipitation on Coburg Island during winter 1972–1973 must have been of local origin.

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