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PRELIMINARY INVESTIGATIONS ON ACCUMULATION AT THE FILCHNER/RONNE ICE SHELVES AND ATKA BAY

by

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ABSTRACT

In January 1980, the accumulation rates on the Filchner/Ronne ice shelves and at Atka Bay were determined by snow-pit stratigraphy (at Filchner station) and isotope analyses using a snow pit and a hand-drilled core down to about 12 m from the surface. At Filchner station a mean annual net accumulation of 51 cm a^{-1} of snow representing a water equivalent of 20 g cm^{-2} was found by stratigraphic measurements. ^{2}H, ^{18}O and ^{3}H analyses led to a value of 55 cm a^{-1} of snow for the last two decades. At Atka Bay a mean annual accumulation rate of 75 cm a^{-1} of snow resulted from ^{2}H and ^{18}O analyses.

1. INTRODUCTION

The main task of the German pre-site survey expedition 1979-80 was a reconnaissance of the marginal zone of the Filchner/Ronne ice shelves for a suitable site for the German research station which was to be built in the following year. In the late summer season of 1981 the station, designated as Georg von Neumayer station, was installed further north in the vicinity of Atka Bay and is meanwhile operating as a wintering-over station.

In addition to a general reconnaissance investigating the accessibility of the ice shelves and the inland crevasse situation, basic information on the absolute ice movement and the strain-rate as well as on climatological features and the accumulation rates were required.

In this paper accumulation measurements at the field camp Filchner station on the Ronne Ice Shelf (77°08'S, 50°38'W, about 20 km inland) will be discussed and compared with data from Atka Bay (70°37'S, 08°22'W, about 3 km inland). The sites of the investigations are shown in Figure 1.

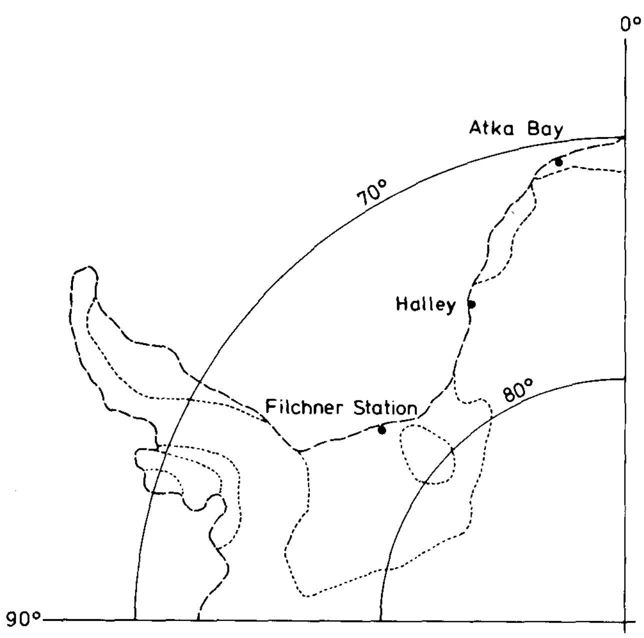

Fig.1. Weddell Sea sector of Antarctica with place names mentioned in text.

2. GLACIOLOGICAL MEASUREMENTS AT FILCHNER STATION

Snow-pit analysis was applied to determine annual net accumulation in the field, taking density, and grain size and shape down to 3.5 m depth, and ram hardness to 3 m. Whereas the variation of density and ram hardness with depth as shown in Figure 2 did not allow a definite limitation of annual layering, the analyses of the stratigraphic sequences, clearly visible in the transparent light penetrating through a thin slice of snow taken over the entire depth of the snow pit proved suitable for a reliable interpretation of annual strata. In particular the marked boundaries between the highly transparent, coarse-grained summer material and the overlying opaque, fine, dense winter accumulation were used for determination of annual rates. As a result seven summer layers could be identified within 3.6 m depth. With a total water equivalent of 135 g cm^{-2}, the mean annual accumulation amounts to 51 cm a^{-1} of snow representing a water equivalent of 20 g cm^{-2}.

A check of the site in January 1981 proved that an additional amount of 13 cm of snow has to be added in order to cover seven complete budget years, thus raising the mean value to 53 cm of snow accumulation which is not a noticeable change in the water equivalent. The mean density is 0.38 g cm^{-3}. For the

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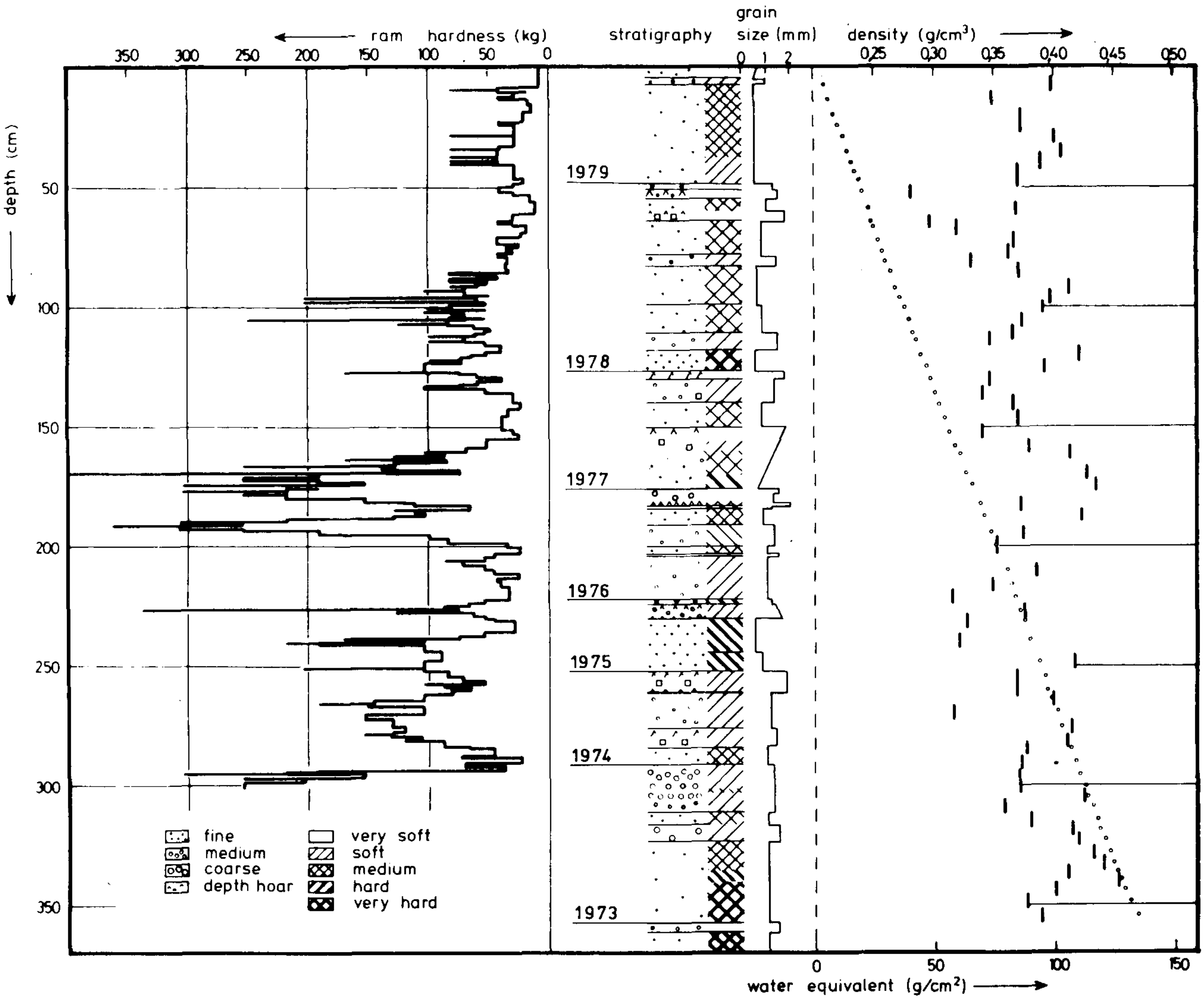

Fig.2. Snow pit at Filchner station: depth profiles of ram hardness, stratigraphic parameters, density, and water equivalent. The inserted years indicate the beginning of the winter season.

upper 2 m the density value of 0.37 g cm^{-3} is identical with that found during the Ellsworth traverse 1957-58 for the marginal region of Filchner Ice Shelf (Kojima 1964).

In order to obtain more representative accumulation data, firn samples were taken down to 10.8 m using lightweight coring equipment designed for glacier fieldwork, which also proved very suitable under Arctic conditions. The cores were cut into pieces of 7 to 12 cm length, melted and bottled, and later on analysed with respect to isotope contents (^{2}H, ^{3}H and ^{18}O).

3. ^{2}H AND ^{18}O ANALYSES

^{2}H and ^{18}O contents are given in $\delta^{2}H$°/oo or $\delta^{18}O$°/oo with respect to standard mean ocean water (SMOW). Accuracies (95% confidence level) are 1 $\delta^{2}H$°/oo or 0.15 $\delta^{18}O$°/oo respectively.

The basis of dating snow layers by ^{2}H and ^{18}O analyses is the seasonal variation of the ^{2}H and ^{18}O contents in precipitation displaying a summer maximum and a winter minimum due to temperature dependent isotope fractionation. The $\delta^{2}H$-$\delta^{18}O$ relation is generally given by the equation $\delta^{2}H = 8\ \delta^{18}O + d$, where d is the so-called deuterium excess which depends on climatic factors such as air humidity, temperature during evaporation and condensation (e.g. Merlivat and Jouzel 1979), and on air-mass characteristics. Possibly also isotope fractionation processes at the snow surface may play a role.

Figure 3 shows the $\delta^{2}H$- and d-values along the depth profile at Filchner station. The $\delta^{2}H$ values vary periodically between -260 and -130°/oo. Counting of cyclic peaks leads to the assumed time scale given in the figure. For the depth also covered by the snow pit this scale is in complete agreement with the accumulation values determined from stratigraphic analyses. As a consequence the mean annual accumulation is 55 cm a^{-1} of snow between 1960 and 1980. With a mean density of 0.4 g cm^{-3}, this value corresponds to 22 cm water equivalent and differs only a little from the amount derived from the pit studies. This value fits quite well to the accumulation distribution given by Bull (1971). The $\delta^{2}H$-$\delta^{18}O$ relation calculated by linear regression is given by $\delta^{2}H = 8.1\ \delta^{18}O + 8.2$ ($r = 0.99$). The d values show also quasi-periodical variations lying between 2 and 12°/oo correlated with the variations of $\delta^{2}H$ values at least in the upper few meters. An explanation of the d variations requires long-term parallel meteorological and isotopic observations which are not yet available.

Figure 4 gives corresponding results for Atka Bay.

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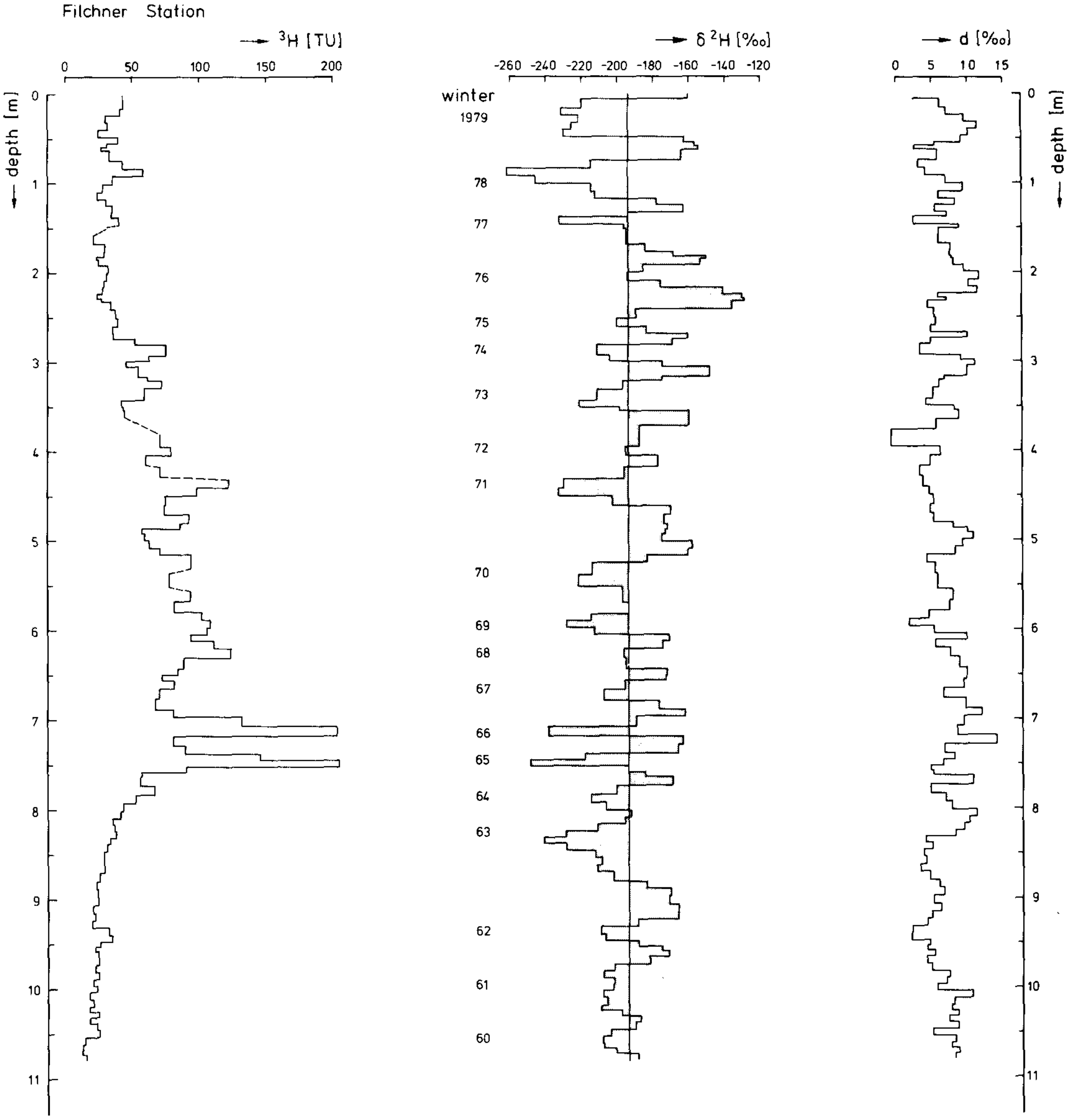

Fig.3. Dating of the snow profile at Filchner station by means of ^2H and ^3H measurements. The mean δ^2H value is indicated by a straight line. In addition the deuterium excess $d = \delta^2H - 8\ \delta^{18}O$ is shown.

Here the δ^2H values vary between -220 and -100°/oo and the d values between 4 and 14°/oo . The δ^2H-$\delta^{18}O$ relation is given by $\delta^2H = 8.1\ \delta^{18}O + 9.5$ ($r = 0.99$). The mean annual accumulation rate 1964 to 1979, derived from the time scale in Figure 4, leads to 75 cm a^{-1} of snow or 32 g cm^{-2} water equivalent, respectively. The difference of δ-values between Filchner station and Atka Bay can be attributed to the dissimilar geographical situations and meteorological conditions of the sites (e.g. latitude, distance from coast, sea-ice cover, mean temperature, and wind regime).

The δ-values at both places are in the same range as the values for monthly precipitation at Halley (International Atomic Energy Agency 1969-1979).

4. ^3H ANALYSES

The tritium contents are given in tritium units (1 TU represents 3.2 picocurie ^3H per litre of water) and referred to the date of sampling (January 1980). The tritium analyses of samples taken from depths between 3.8 and 7.6 m at Filchner station were carried out on 10 g of water each by direct liquid scintillation counting the errors (95% accuracy) being 9 to 13 TU (depending on the ^3H content). In all other cases electrolytic enrichment of ^3H prior to counting was applied to 100 g samples of water, the resulting errors being 2 to 6 TU.

^3H dating of snow, firn, and ice layers is based on increased ^3H concentration in precipitation mainly due to ^3H production by thermonuclear weapon tests. In middle latitudes of the northern hemisphere the maximum ^3H contents appeared in the summer precipitations of the years around 1963 and were also found in snow cores taken in the Alps (e.g. Oeschger and others 1977, Behrens and others 1979). In pits located near the South Pole, Jouzel and others (1979) found pronounced peaks of ^3H content in snow layers the deposition of which were attributed to the Antarctic winter mainly during August and September of the years 1965 and 1966. This indicates an increased interhemispheric transit time of the fallout after the 1961-62 bomb tests, compared with the two-year

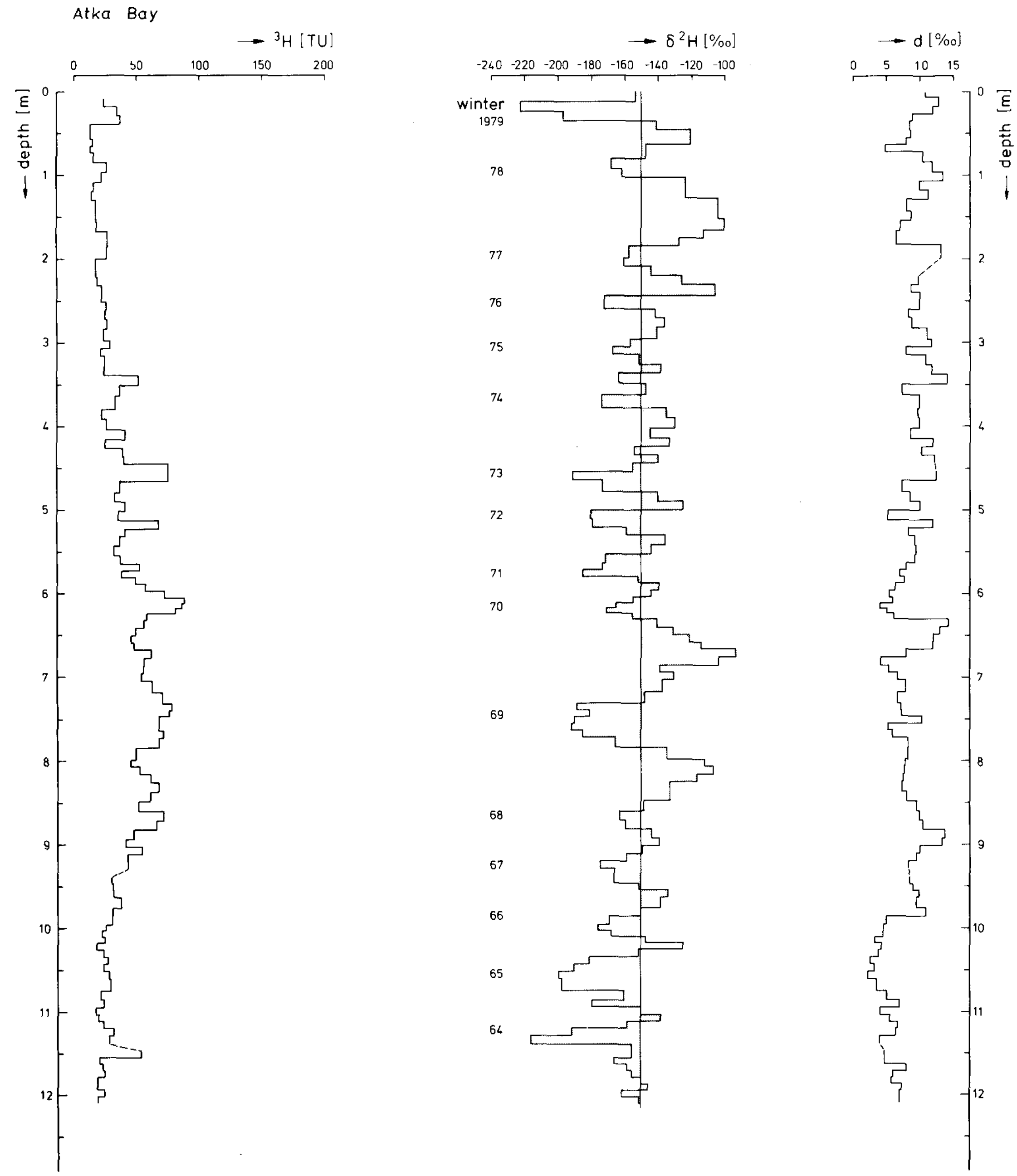

Fig.4. Dating of the snow profile at Atka Bay by means of ^2H measurements. The mean δ^2H value is indicated by a straight line. Additionally the results of the ^3H measurements and the deuterium excess d = δ^2H-8 $\delta^{18}O$ is inserted.

delay between explosions and fallout found for the period 1958 to 1960.

If we, too, ascribe the highest ^3H contents which were measured to 1965 and 1966, the snow-layer chronology at Filchner station, as tentatively derived from ^2H measurements and seasonal stratification of snow in the upper layers, is strongly supported (Fig.3). In this connection, we note that correction for decay gives a maximum ^3H content of 458 ± 28 TU at the assumed time of deposition (August-September 1965).

The values of ^3H contents in accumulated snow are comparable to those of precipitation measured at the nearshore station Halley, which are available for 1967 to 1978 (International Atomic Energy Agency 1969 ff., 1981). The seasonal variations of the ^3H content however, clearly visible in the precipitation at Halley, cannot be used, with the exception of 1965 and 1966, for establishing a snow-layer chronology even if some indication of such variations appears to be left. The smoothing effect can have several causes, one being the insufficient layer resolution of sampling.

The annual means of ^3H contents in the snow layers at Filchner station are much lower than at the South Pole (Jouzel and others 1979). This may be due, at least partially, to the higher portion of air humidity derived from ^3H deficient sea-water reaching the nearshore Filchner station compared to that reaching South Pole station, situated far inland. In the snow layers at Atka Bay a general trend of increase and subsequent decrease of ^3H content with growing depth exists too, which is similar but less pronounced to that found at Filchner station. However, no distinct ^3H peaks which on the basis of ^2H and

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^{18}O analyses could be expected to represent 1965-66 precipitation, appear in the ^{3}H depth profile thus prohibiting the possibility of ^{3}H dating. The lack of the ^{3}H peaks could be caused by insufficient analytical resolution of the snow layers, in addition to the fact that the ^{3}H contents at Atka Bay are generally lower (by approximately one-third) than those found at Filchner station. This might be due to the nearshore situation of the Atka Bay measuring site. The pit stratigraphy of Atka Bay shows that ^{3}H peaks were certainly not removed by percolation although some thin ice layers exist in the upper metres.

5. CONCLUSION

The results show that in both areas under investigation annual accumulation rates of at least 20 a can be determined by means of ^{2}H and/or ^{18}O measurements ^{3}H measurements are of additional value for the determination of mean accumulation rate. The correlation of d values with climatic factors needs further investigation.

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