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E. PICCIOTTO, S. DEUTSCH and L. ALDAZ

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THE SUMMER 1957-1958 AT THE SOUTH POLE AN EXAMPLE OF AN UNUSUAL METEOROLOGICAL EVENT RECORDED BY THE OXYGEN ISOTOPE RATIOS IN THE FIRN

E. PICCIOTTO and S. DEUTSCH *
Service de Géologie et Géochimie Nucléaires, Université Libre de Bruxelles, Belgium

L. ALDAZ
Department of Physics and Astronomy, University of New Mexico, Albuquerque, USA

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Climatological records from the Amundsen-Scott Station, South Pole, show the summer 1957-1958 to be characterised by periods of exceptionally warm air temperature and above normal snow accumulation. The firn layer deposited during this summer displays an exceptionally high oxygen-18 content, as revealed by $^{18}O/^{16}O$ ratio profiles obtained by Epstein et al. [6, 7] and by us in five pits dug alongside accumulation stakes.

It is generally known that the oxygen and hydrogen isotopic composition of precipitations depends, among other variables, on their temperature of formation [1-4]. This dependence appears reflected on the so-called latitude, altitude and seasonal effects (see bibliography in [3]). These relationships suggest the possibility of finding out climatic changes which took place in the past by analysing the isotopic composition of ancient precipitations. The most likely places where it is possible that such precipitations might be found are within the Arctic and Antarctic ice-sheets.

The interest in the subject in question is enhanced by the present proposals of deep drillings on the Antarctic ice sheet.

The interpretation of the isotope ratio variations with depth, is far from being straightforward, even in the case of polar glaciers where no melting occurs; it depends on a number of variables, meteorological, physico-chemical and glaciological in character. Included in the last class are the vertical and horizontal motions of the ice (see for example [5]).

The purpose of the present paper is to present an example of a clear correspondence between the meteorological conditions and the concentrations of ^{18}O in the firn in recent times, namely from 1957 to 1964, at Amundsen-Scott Station (South Pole). It is believed that this case is the only one for which both the $^{18}O/^{16}O$ ratio in the various layers of firn and the air temperature at the time of deposition are known by direct observations.

Considering the small accumulation (6 cm water-equivalent per year) and the irregularities attending the snow deposition in this part of the Antarctic Plateau, it is necessary to have several isotopic profiles to obtain meaningful conclusions.

Within a radius of a few kilometers around the Amundsen-Scott Station, five glaciological pits were dug and sampled on various occasions and by different workers with the purpose of measuring oxygen isotope ratios [6, 7]. The dates for the various layers are firmly ascertained because pits numbers 1, 2, 3, 4 in fig. 1 were dug alongside snow stakes erected in January 1958 and since, measured twice a year. The dating for pit number 5 is less straightforward, but it was dug in 1959 and its stratigraphy leaves little doubt as to where the 1957-1958 summer surface is located.

The air temperatures during the time interval covered by the five profiles (1957-1966) have been measured by radiosonde, twice a day routinely by U.S. Weather Bureau personnel. The monthly

* Chercheur à l'Institut Interuniversitaire des Sciences Nucléaires, Belgique.

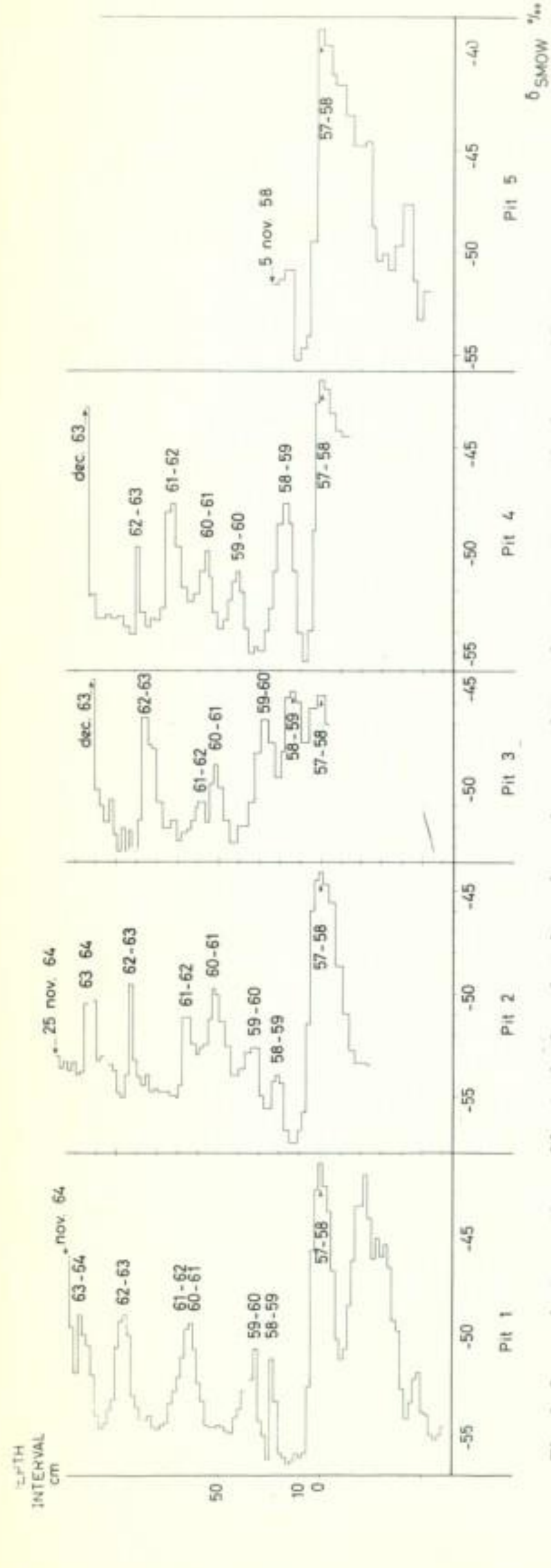

Fig. 1. Oxygen isotope ratio profiles in the five glaciological pits dug around Amundsen-Scott Station. The five profiles have been arbitrarily aligned on the summer 1957-1958 maximum. Profiles of pits 3 and 4 from [7]. profile number 5 from [6].

means of the air surface temperature are published in the Climatological Data for Antarctic Stations (U.S. Department of Commerce, Washington D.C.). In addition, air temperatures on a daily basis have been obtained from the local climatological records of the Amundsen-Scott Station itself.

In fig. 1, the results of the $^{18}O/^{16}O$ ratio measurements are given, following the customary practice, in per mil relative deviation from "Standard Mean Ocean Water" (∂ SMOW) together with the position of the summer layers. Profiles corresponding to pits 3, 4 and 5 are taken from Epstein et al. [6, 7].

Pits 1 and 2 have been sampled and described by Cameron et al. [8] and the corresponding isotopic profiles were obtained by techniques similar to the ones described by Epstein and Mayeda [1].

These profiles show the well known seasonal ∂ variations. The relationships between the stratigraphic and isotopic profiles will not be discussed here. As far as pits 3, 4, 5 are concerned a detailed study has already been published by the above mentioned authors. Our results from pits 1 and 2 only confirm their conclusions.

We want here to call attention to the maximum taking place during the summer 1957-1958 which appears in the five profiles. The snow accumulation during that summer is characterised by its considerable thickness and by the exceptionally high value of its ^{18}O content. The mean ∂ value for the summer 1957-1958 maxima is -42.5‰ while the other summer maxima vary little about their overall mean of -49.5‰.

Epstein et al. [7], in connection with their discussion of pit 5, had already noted this peculiarity and did suggest that it was due to unusually warm precipitations during the summer 1957-1958. A perusal of the meteorological observations confirms their conjecture. The other four profiles, obtained later, rule out the possibility that this maximum was due to a localized singularity in one of the pits.

Fig. 2, based on the values obtained from the climatological records, shows a striking correspondence between the average of the ∂ maxima for each summer on the one hand and the surface air temperature on the other. During the summer season, the surface inversion is very often absent. A constant decrease of temperature with height is present, the slope of which changes little from day to day. Therefore, during summer, the surface temperature reflects valuably the air temperature aloft, while during winter,

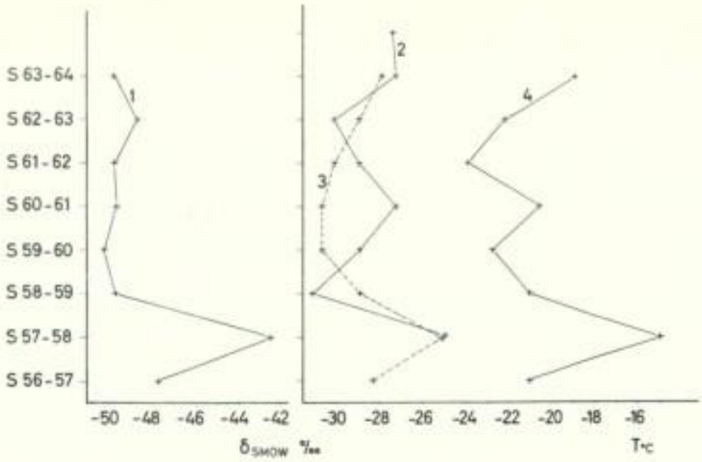

Fig. 2. Curve 1: average of the ∂ maxima for each summer.
Curve 2: mean monthly surface air temperature for each December.
Curve 3: mean monthly surface air temperature for each January.
Curve 4: maximum recorded surface air temperature for each summer.

due to the surface inversion, there is no correlation at all between ground temperature and upper air temperature.

The mean monthly surface air temperatures, for each December and January, are shown by curves 2 and 3, fig. 2. In addition, curve 4 gives, for the same years, the maximum recorded surface air temperature.

Data on December and January precipitations for 1957-1964 show that the thickness of deposited snow was too slight to be measured, except during summer 1957-1958. These latter accumulations took place during two, three to four days long storms with exceptionally high air temperatures, one in December and one in January. So is explained the formation of this continuous firn layer yielding a true isotopic horizon. The study of its geographical extension would be of interest.

The correspondence between curves 1 and 4 is a striking evidence that the isotopic composition of the firn has recorded and preserved an unusual meteorological event.

Moreover, thanks to the successive samplings after 1959, we know that the isotopic composition of this layer has not undergone any noticeable change after its deposition. Although the interval of time elapsed is merely six years, nevertheless it covers that depth interval of the firn in which isotopic changes are most likely to occur. It is in these first two meters where the temperature gradients and their seasonal changes are most marked and where strong exchange by water vapour transport could be expected.

This tentative exploration of recent past meteorological conditions is considered as an encouragement to progressively extend in time and in space this type of studies.

Acknowledgements

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