CORRESPONDENCE

SIR,   *Temperature measurements on the Barnes Ice Cap, Baffin Island, Canada,*
and on Sukkertoppen Iskappe, Greenland

During reconnaissance studies on Sukkertoppen Iskappe, Greenland, and on the north (or main) dome of the Barnes Ice Cap, Canada, temperature measurements were made in three bore holes. The holes were bored with a 50 mm electrical hot point (Hooke, 1976[b]) and cased with a 32 mm O.D. aluminum tube filled with diesel fuel. Measurements were made with a VECO thermistor probe and Data Precision 245 multimeter. The system was calibrated against a standard thermistor at the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, U.S.A. Because the calibration was done in a non-circulating fluid bath, no further correction for self-heating of the probe, which amounted to about 0.09 deg, was necessary. The system is capable of resolving temperature differences (gradients) of 0.003 deg but the uncertainty in measured temperatures, resulting largely from calibration errors, is estimated to be 0.05 deg.
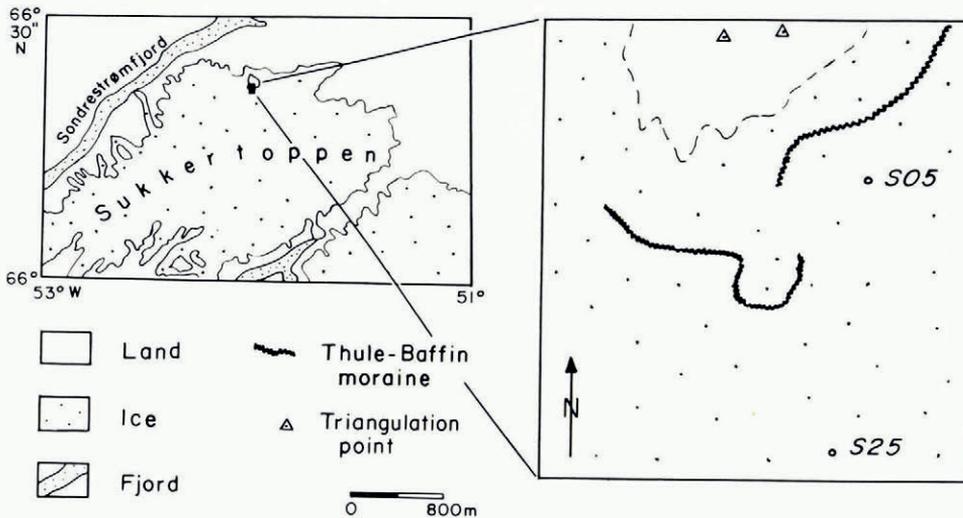
Fig. *1. Index map showing location of bore holes on Sukkertoppen. Positions of holes relative to moraine and to each other were established by theodolite survey from triangulation points shown.*

Two of the holes were drilled in the ablation zone on Sukkertoppen. Hole S05 was at an elevation of about 1 170 m, whereas hole S25, 2.3 km up-glacier from S05, was about 60 m higher (Fig. 1). Measurements were made 2–3 d after drilling so thermal equilibrium had not been re-established, but repeated measurements in hole S05 24 h apart allow tentative extrapolation to equilibrium. The measured temperatures at 19 m after 2 d were −7.3 and −6.3°C in S05 and S25, respectively (Fig. 2); the equilibrium temperatures are estimated to be 0.1 to 0.2 deg colder than this. The down-glacier decrease in temperature is attributed to differences in snow cover and melt regime. The snow insulates the ice in the fall and winter but allows percolating melt water to reach the snow–ice interface early in the spring (Hooke, 1976[a]).

The thermal gradient between 19 and 23 m in S25 is 0.14 deg m^{-1} (Fig. 2), which corresponds to a heat flux of about 1.8 μJ cm^{-2} s^{-1}. Measurements near the southern tip of Greenland (Sass and others, 1972) suggest that the geothermal contribution to this flux is about 0.24 μJ cm^{-2} s^{-1}. The unusually high gradient can be attributed to lack of thermal equilibrium in the hole, to a high upward hole-parallel velocity, or to refreezing of melt water at the base of the glacier. Although the hole had not reached thermal equilibrium, departures from equilibrium should not be strongly depth-dependent over this interval; thus the temperature gradient should not be greatly in error. The vertical velocity

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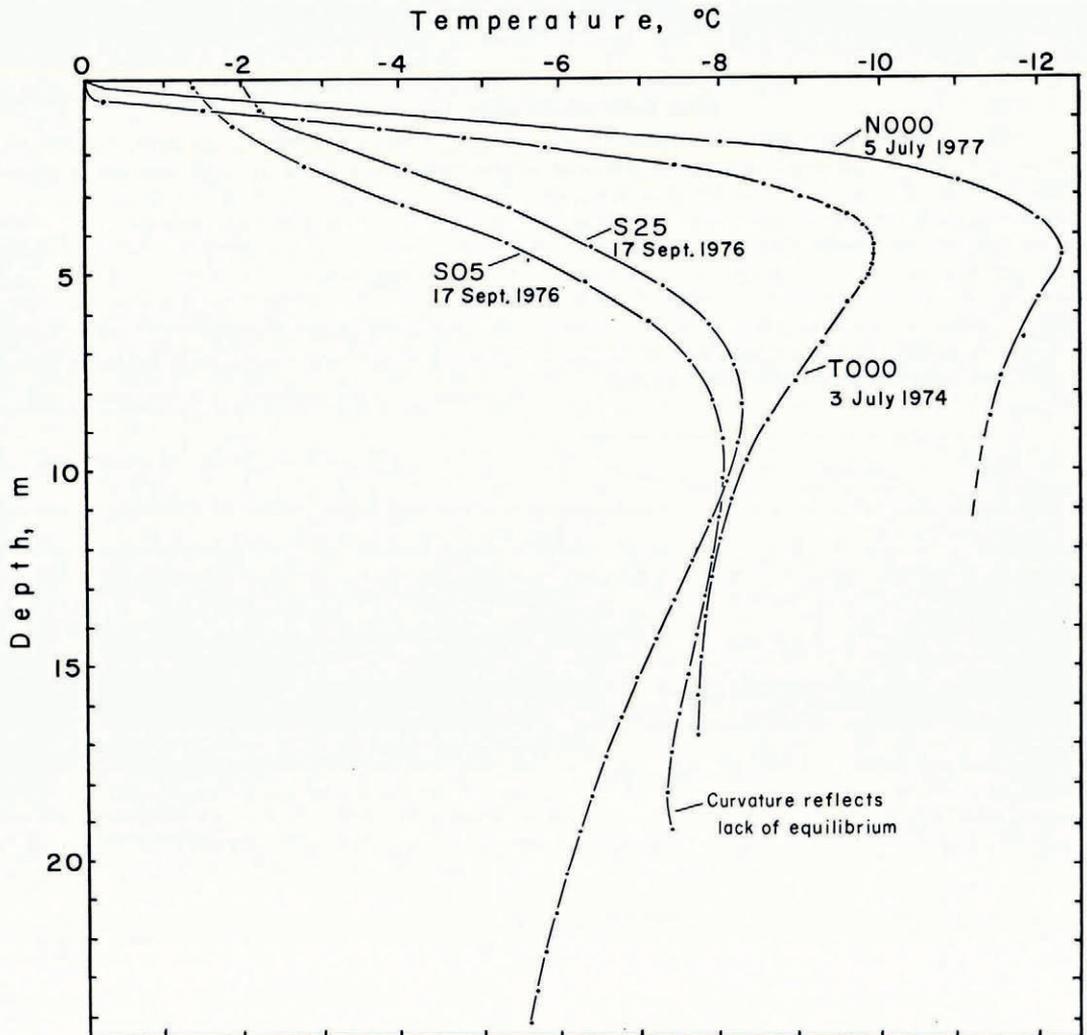
Fig. 2. *Temperature profiles in bore holes discussed herein. Dots represent actual measurements.*

required to produce such a gradient is of the order of $1-2$ m year^{-1}, depending on ice thickness. As such a high flow rate is unlikely, at least some refreezing of melt water at the base of the glacier is inferred.

Other temperature measurements on Sukkertoppen are sparse. Bull (1963) obtained measurements at depths of $3-4$ m at four locations above 1 500 m in the accumulation area and none of his measurements was lower than $-0.5°C$. He concluded that the deeper ice is probably temperate. Henry and White (1964), however, found temperatures substantially lower than $0°C$ at depths "below the winter cold wave" near the margin of Sukkertoppen. Their holes were in the ablation area at an elevation of about 500 m. This down-glacier decrease in temperature is due to the effect of refreezing of percolating melt water in the accumulation zone (Loewe, 1966; Hooke, 1976[a]).

On the inland ice, Colbeck and Gow (1974) measured temperatures in two deep holes at Isua, about 165 km south-east of our holes on Sukkertoppen. The tops of both holes were at approximately 1 170 m and the holes were 97 and 265 m deep. The 20 m temperatures were between -4 and $-5°C$ in both holes and deeper measurements suggested that melt water would be present at the base in both locations.

Our measurement on the north dome of the Barnes Ice Cap was made in hole Nooo at lat. 70° 01′ N., long. 73° 25′ W. at an elevation of approximately 1 115 m. Due to problems with the drill and to approaching bad weather, the hole reached a depth of only 8.6 m and measurements had to be made within 3 h of the time the hole was completed. Thus, thermal equilibrium clearly had not been re-established but measurements over a period of nearly 2 h at the bottom of the hole again provide a basis for extrapolating to equilibrium. The equilibrium temperature at 8.6 m is estimated to be $-11.7 \pm 0.3°C$ (Fig. 2). For comparison, the temperature at a depth of 17 m in hole Tooo at an elevation of 892 m on the south dome of the ice cap is $-7.67°C$. Tooo was drilled in July 1973 and was measured 1 year later. Hole Nooo penetrated highly permeable firn containing scattered ice lenses, indicating that this hole was in the percolation zone of the accumulation area. In contrast, at depths greater than 2–3 m, hole Tooo was in superimposed ice with scattered firn layers characteristic of the soaked zone. The amount of percolating melt water at Tooo is thus greater than at Nooo, and heat released by refreezing of this water is responsible for most of the temperature difference between these two sites. Based on numerical modeling of temperature profiles in Tooo and five additional holes at lower elevations on the south dome, the mean annual temperature at Tooo is estimated to be about $-13.0 \pm 0.5°C$ (Hooke, 1976[a]; unpublished data). The mean annual temperature at Nooo is probably only a degree or so colder.

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SIR,   *On the non-linearity of glacier length response to climatic changes:*
                                     comments on a paper by H. W. Posamentier

IN a recent paper in the *Journal of Glaciology*, Posamentier (1977) speaks of a new climatic model for glacier behaviour. This is indeed a title that will attract the attention of the scientific community and it nourishes the hope that, at least for the Eastern Alps, there is now a way of modelling or predicting the intricate relations linking glaciers and climate.

When reading the paper, however, one becomes aware that it does not deal with the physical interaction of the atmosphere with glaciers and their dynamic response, nor with glacier behaviour in the complex sense but with a linear regression of the percentage of Austrian glaciers advancing or