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Temperature Measurements on Black Rapids Glacier, Alaska, 1973*

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Abstract

As part of reconnaissance work on Black Rapids Glacier, we measured near-surface temperatures in early April and July, 1973, at three sites. The highest site is at 1860 m altitude in the accumulation area. In April the 0 C isotherm was found at a depth of 9 m below the 1972 summer surface; by July the snow and firn were isothermal at 0 C at all depths of temperature measurement. It is fairly likely that this condition is typical of the entire accumulation area. The second site is at an altitude of 1550 m, about 7 km below the equilibrium line. There the April and July temperatures were, respectively, −1.0 and −1.7 C at 10 m below the 1972 summer surface. The third site is at 1140 m in the ablation area and the temperatures were −0.6 and −1.2 C.

Our measurements favor the classification of Black Rapids Glacier as temperate, except for the colder surface layer. In this case its surge behavior would not be due to thermal instability associated with alternation between freezing and melting conditions at the bed.

Several hundred glaciers in Alaska periodically flow at speeds 10 to 100 times greater than their "normal" flow rate; these are called surging glaciers. To date no satisfactory explanation of this surging behavior exists. A leading hypothesis (Robin, 1955; Hoffman and Clarke, 1972) states that a surging glacier is normally frozen to its bed and that surging recurs periodically when the bed is warmed to 0 C as the ice in the "ice reservoir" area gradually thickens while the glacier recovers from its previous surge. The inference is that no temperate glacier, one that is at 0 C throughout except for a thin surface layer subject to seasonal temperature fluctuations, may surge, at least by this mechanism.

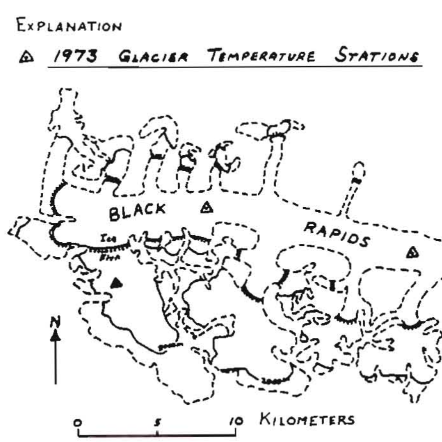

FIG. 1. Map of Black Rapids Glacier showing the location of temperature measurement stations and the average firn edge.

Black Rapids is a famous surging glacier in the central Alaska Range. The glacier has surged periodically in the past; the last surge was in 1936–37. The Richardson Highway is built over moraines associated with earlier, somewhat larger surges which blocked the Delta River. A joint project on the Black Rapids Glacier by the U. S. Geological Survey, Water Resources Division, the University of Alaska and the University of Washington is designed to study the mechanism of surging. As part of our work we are attempting to determine the thermal regime.

Three holes were steam drilled in firn and ice on October 18–19, 1972 (Fig. 1). An array of three thermocouples spaced at 4 m intervals was placed in each hole. The temperature at each thermocouple was measured in April and July, 1973; the uncertainty is about ±0.15 C. Overlying snow temperatures were obtained at the same time using a bimetallic dial thermometer in the walls of snow pits; the uncertainty is about ±0.4 C for temperatures in the snow and somewhat greater for the snow surface temperatures.

Temperature data from the highest altitude station, at 1860 m, near the center of the accumulation area are presented in Fig. 2. The April 3 measurements revealed that the winter cold wave had penetrated about 9 m below the summer surface. By July 19,

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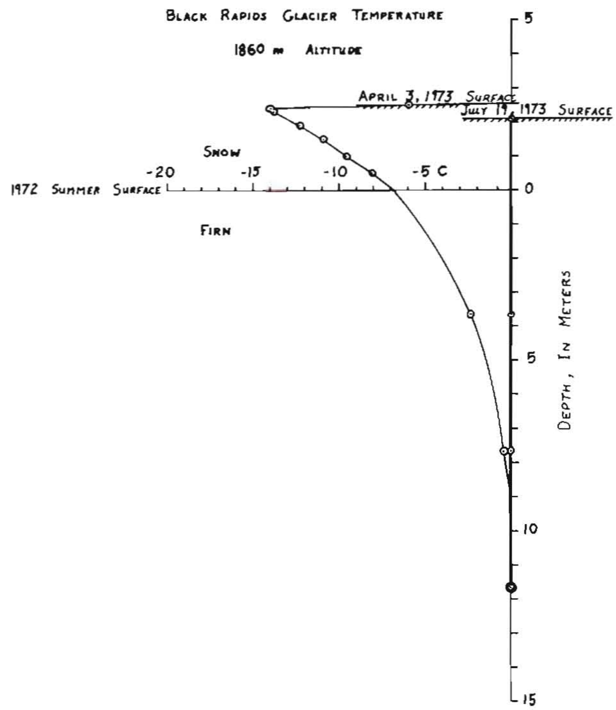

FIG. 2. Temperature of Black Rapids Glacier at 1860 m altitude in the accumulation area. The snow depths at the times of measurement are also shown.

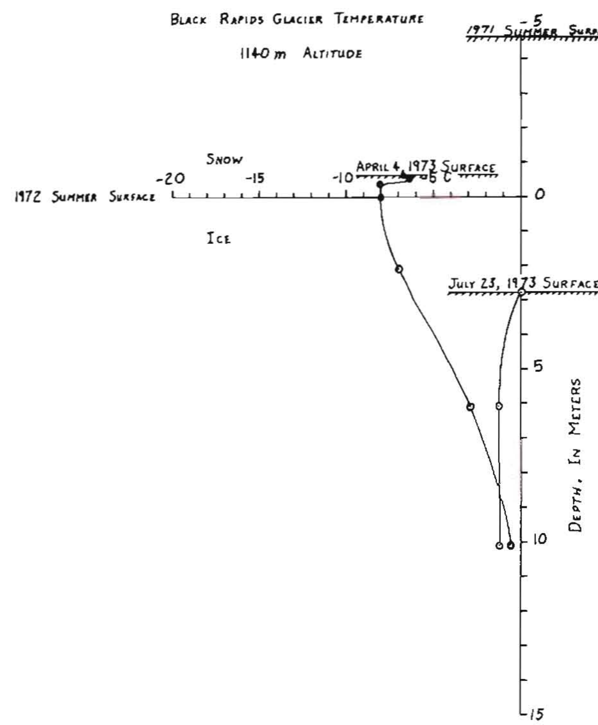

FIG. 4. Temperature of Black Rapids Glacier at 1140 m altitude, low in the ablation area. The April snow depth and ice ablation by July are also shown.

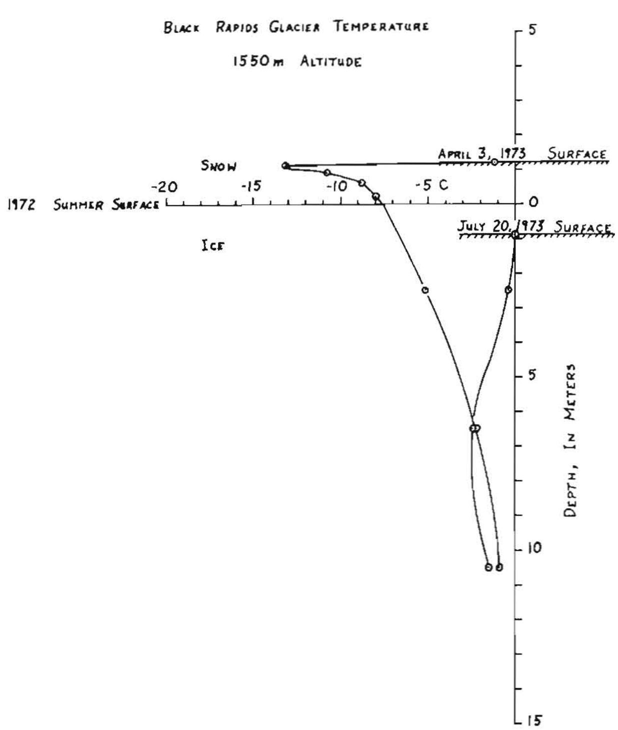

FIG. 3. Temperature of Black Rapids Glacier at 1550 m altitude, high in the ablation area. The April snow depth and ice ablation by July are also shown.

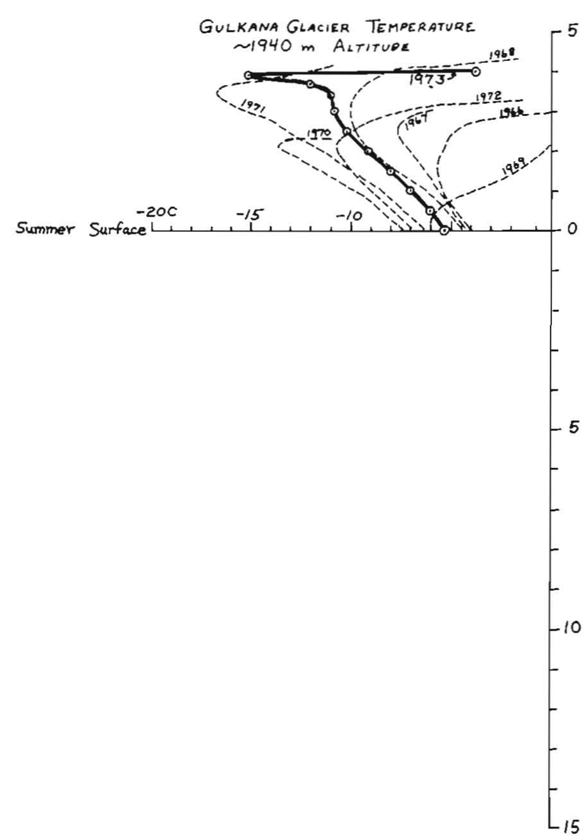

FIG. 5. Eight years of Gulkana Glacier spring snow cover temperatures. The 1973 spring temperatures were not extreme.

and probably earlier, it had been completely eliminated. Therefore, the temperature below the level of seasonal fluctuations is 0 C at this site, and by inference over most of the accumulation basin.

Ice temperatures from the upper part of the ablation area, 7 km below the equilibrium line and at an altitude of 1550 m, are shown in Fig. 3. Seasonal temperature fluctuations appear to be nearly damped out at 10 m depth, where the temperature is between −1.0 and −1.7 C. Note that depths have been referenced to the 1972 summer surface rather than the actual snow or ice surface at the time of measurement.

The lowest site is at 1140 m altitude, somewhat below the center of the ablation area. Here the April and July temperatures are −0.6 and −1.2 C, respectively, 10 m below the 1972 summer surface (Fig. 4). Annual ablation removes 3 to 5 m of ice here, and it is possible that 10 m below the ice surface at any time of year the temperature is continuously higher than −1 C.

The question arises as to whether these data are typical or, for example, the result of an exceptionally warm winter. Snow temperature measurements have been made for 8 years at Gulkana Glacier, 30 km southeast of Black Rapids Glacier. Temperatures from March through May, at approximately 1940 m altitude (Fig. 5) were compared with the April 1973 Black Rapids temperatures. The snowpack base, or summer surface, has varied from −4 to −7.4 C. On March 31, 1973, the snowpack base was −5.4 C and the temperature gradient in the lower part of the snow was similar to all previous years. From this information, the 1973 Black Rapids Glacier temperatures are judged to be near normal.

Black Rapids is typical of many glaciers in that its ablation area is cooler than its accumulation area. This is because the impermeable ice in the ablation area cannot be warmed by the freezing of downward percolating water. Both the 10 m temperatures and the annual ice loss in the ablation area are similar to those of Athabasca Glacier in Canada's Jasper National Park, which is temperate in the ablation area below a depth of roughly 15 m (Paterson 1971, 1972). It is likely that Black Rapids Glacier is similar. In this situation, probably typical of many glaciers, latent heat is released at the lower boundary of the cool surface layer by the freezing of small amounts of liquid water contained in the upward moving ice. We have not yet measured deep temperatures, and it is possible that the temperature structure here is complicated by the slow freezing of water trapped in deep crevasses during the 1936–37 surge (Jarvis and Clarke, 1974).

In summary, the near-surface temperature measurements we have made to date favor the classification of Black Rapids as a temperate glacier, in which case its surge behavior could not be thermally controlled.

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