The Editor,
The Journal of Glaciology

SIR,

Air Temperature and Solar Radiation

It is not unusual to come across misconceptions in glaciological literature about the part played by direct solar radiation in the melting of snow and ice. For example, when discussing the processes causing ablation, O. Rogstad states on page 554, line 16, of the October 1951 *Journal of Glaciology*, that the amount of radiation is independent of the air temperature. Other examples of this type of misconception, although usually of a much less specific character, often occur in the literature.

In fact, the solar radiation which remains available for melting snow and ice is highly dependent upon the temperature of the free air above. This dependence is most easily appreciated from a few typical figures such as those given in the table below.

For these the solar heating was taken as averaging 60 calories per cm.^{2}/hour on a horizontal surface, for a few hours round mid-day with clear sky in May to August, at about 60° N latitude. Owing to reflection only one-fifth of this would be available for heating the firn surface, leaving 12 calories to supply the outgoing radiation and cause melting. The values of atmospheric radiation used here are in accordance with recent observations.*

Free air temperature ° C.	−5°	0°	+5°	+10°
Down radiation from atmosphere, cal./cm.^{2}/hr. .	15·8	18·0	20·3	22·7
Radiation loss from surface at 0° ,, ,, .	11·3	9·1	6·8	4·4
Solar radiation available for melting ,, ,, .	0·7	2·9	5·2	7·6
Radiation melting in 5 hours as mm. water . .	—	1·8	3·2	4·8

When the free air temperature is several degrees below freezing convection will tend to cool the snow and prevent the small surplus of solar heat from being effective for melting, but for air temperatures above freezing convection is mainly dependent on the wind.

Although low clouds may greatly reduce the radiation in both directions, they do not always diminish the surplus available for melting. Here again the latter is highly dependent on air temperature.

Ministry of Supply,
London
23 *November* 1951

G. S. CALLENDAR

SIR,

Glacier Tunnel Observations in Alaska

In view of the recent emphasis on glacier tunnelling and englacial studies of the mechanics of ice movement, the following notes which I gathered in 1941 while returning by steamer from Alaska may be of interest. They represent descriptive information, without alteration, which I wrote down during a lengthy discussion with Dr. John Reed, who at that time was Chief of the Alaskan Branch of the U.S. Geological Survey. Dr. Reed had obtained this information a few weeks earlier in conversation with one L. Thornton, a prospector and miner, who had occasion to do a considerable amount of tunnelling into an unnamed glacier near Hyder, Alaska. The location is near the head of Portland Canal, on the extreme south-eastern boundary between Alaska and British Columbia, and lies approximately at lat. 56° N., long. 130° W. Unfortunately many details which would be of further interest to the glaciologist are lacking.

Intermittently between 1931 and 1941, Mr. Thornton had driven about 1830 m. of tunnels, adits, caves and pits into a small "ice cap" glacier south of Texas Glacier. The bulk of this work was distributed between 10 to 15 different tunnels, some of which were driven horizontally south-eastward from the steeply sloping face of the glacier, and upstream in a direction roughly parallel to the movement of ice. The tunnels penetrated to bedrock. According to Dr. Reed, Mr. Thornton, although not a trained observer, is a reliable person and one keenly interested in the scientific significance of what he saw. He therefore made a point of noting whatever aspects of interest he could. Since he was cut-

* Robinson, G. D. *Quarterly Journal of the Royal Meteorological Society*, Vol. 76, No. 327, 1950, p. 37–51.

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ting these tunnels in search of ore minerals in a lode beneath the glacier, some of his observations were of practical value to his own operations. He worked in these tunnels throughout all seasons of the year. The cutting was done by pick and shovel.

Concerning temperature conditions within the longer and deeper tunnels, he noted that temperatures were the same both in summer and winter. (It is assumed that his tunnels were therefore far enough in so that the surrounding ice was little affected by surface atmospheric influences in winter. Since this is in a relatively temperate section of Alaska, this observation does not seem out of line.) He further reports that on many occasions cracked ice in buckets left in the tunnels developed no water but slowly evaporated. He also noted that running water and water trapped in caverns—and in the bottom of crevasses in summer—did not freeze. The floors of larger openings or caverns were dry. There was, however, considerably more water in the glacier in the summer months than in winter.

Regarding glacial motion, his observations are of further interest, especially those made at some distance along the tunnels and at depths well beneath that reached by crevasses. He saw that irregularities in the rock floor caused disturbance of ice flow. For example, a bedrock hump would "gouge" a deep groove in the base of the overriding ice mass. And after "moving for a distance above the floor in the lee of the hump, the ice would again impinge on the rock floor, and with particular pressure if the bedrock surface happened to be flatter." This left basal caverns down-glacier from these hummocks. "Loose blocks of rock held in the ice at these places would be given a rolling or rotational movement."

Occasionally the glacier roofs of such caverns would fall off and the resulting chunks of ice would eventually disappear, both by melting and evaporation. Some of the larger chunks, after falling into such a cavern would themselves seem to "flow plastically," just as this portion of the main glacier did. (At least, after many weeks of observation, Thornton had this impression.)

Huge caverns within and at the base of the glacier apparently impounded quantities of water. One of these "holes" when punctured by Thornton created such a flood of water that it washed him clear out of the tunnel in which he was working.

The basal ice in the glacier was observed to penetrate "plastically" as much as two feet into bedrock wherever there were open fractures in the rock or other narrow or confined openings. Sometimes actual "ice veins" were formed in this way.

Those tunnels driven into the glacier parallel to its flow, would "fill" within several months time. His observations indicated that at first the bottom would begin to bulge up, then the sides, and then the back. The effect would decrease toward the portals.

Ice tunnels driven across the glacier's down-valley flow were seen to close much more rapidly. This closure was largely accomplished by "bulging" from the upstream side. On one occasion, when Thornton had been ill for some weeks, he found it difficult to resume his work in places due to such obstruction within the tunnel.

Some light was seen to penetrate through the glacier—an estimated distance of 30 m. into solid ice. Only the blue rays would get through.

It was Thornton's impression that the lower portion of the glacier seemed to move farther (faster?) than the upper layers, as estimated from the displacement of his workings in relation to rocks on the surface of the glacier. (Perhaps this was an impression due simply to a mass rotation of ice on its bed or to some other factor not clear in this case since there is no dimensional and quantitative record.)

Along the walls of several adits and tunnels, he observed that loose material (debris) was picked up from the rock floor by the ice as it moved down slope. This debris did not move along the lower layers of the glacier but migrated slowly upward to higher levels along distinct lines. Dense and bubble-free ice could be seen at the very bottom of the glacier between the zone of transported debris and the bedrock floor below. Similar detritus appeared at the surface of the glacier nearer its edge and down-glacier from the point of tunnel observations.

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