# Runoff studies from the Mitdluagkat Gletcher in SE-Greenland during the late summer 1958.

By Hans Valeur Larsen.

Since 1956, glaciological investigations have been carried out in Greenland under the leadership of *Børge Fristrup.* The expeditions have been sent out from the *Geographical Institute* at the *University of Copenhagen* and are part of the Danish IGY work. In 1958 an expedition worked on the Mitdluagkat Gletscher (gletscher = glacier) on the island Angmagssalik Ø, East Greenland. The main object of this expedition was studies of the glacier variations in relation to change of climate; in addition, some special glacial-meteorological research-work was carried out and, in connection with these studies, an investigation of the runoff from the glacier.

I wish to express my gratitude for all the help and advices given to me in my studies, first of all to the leader of the expedition, *Børge Fristrup,* who made it possible for me to carry out my investigations, and a special thank to *Jens Fabricius,* who assisted me in the field. I also wish to thank the other members of the expedition for their valuable help. Further, I take this opportunity to express my gratitude to the *Danish Technical Highschool,* the *Hydrological Laboratory,* to which I am much indebted for having lent the necessary instruments and for the advices which I got there from amanuensis *B. A. Christensen.*

The glacier which had been chosen was called the Mitdluagkat Gletscher after the peak Mitdluagkat (973 m.). The landscape is alpine (fig. 1), and the glacier may be classified as a transection glacier (Ahlmann's classification system). Its total area is *about* 30 sq. km. The greater branch is a tongue towards west, narrowing in the approach to the front. The latter is situated at a distance of about 0,8 km. from the sea (Sermilik Fjord). Most of this tongue is drained off to the front, in the bottom of which a stream emerges through a gate. The water level at this point was on the

6th of August computed (by levelling) to 4,10 m. above mean sea level. From there the stream runs meandering in a flat-bottomed valley, which has a width of about 200 m. (fig. 1).

For the investigation of such a glacial river several methods are useful; however, the chemical ones may be preferable, *Sögnen* (1954). The principle of these is to add an indifferent saline solution to the river above violent stream turbulences and to measure the time required for the »saltwave« to pass a point further down and the concentration of the latter. This method is preferable when the stream is very turbulent, which is generally the case of glacial rivers; however, its application offers rather great difficulties to unexperienced persons. Furthermore, as it was possible for me to borrow the necessary instruments for the following method this was adopted:

It is a well-known fact that there is a certain relation between the discharge and the water level of a watercourse. By means of a self-recording river-gauge (fig. 2) the water level was automatically recorded. The type of instrument was A. W. 1. R. Fuess no. 1033; it was fixed upon a triangular wooden tube. Inside this a float was hanging, following the water movements up and down. The movements were drawn on a recording paper, wrapped round a rotating cylinder driven by a clockwork.

In plate I the thinner curve (H) indicates the water level at any time from 4th August to 17th September, copied directly (after the necessary corrections) from the above mentioned recording paper, while the thicker curve (Q) indicates the discharge, computed from fig. 3 (see below).

The position of the river-gauge is 250 m. from the outlet, as shown by »H« in fig. 1; the difference of the water level between the two points is about 1 m. Part of the stream does not pass this place, but forms a separate branch. However, the size of this is comparatively small, and, as it was evident that its slope was nearly the same as that of the main stream, the error brought in by recording the level only at »H« is bound to be insignificant. From time to time the position of the river-gauge had to be controlled by levelling to a point on the solid rock; however, the deviations from the mean instrument height were small — less than 16 mm. difference between the highest and the lowest position. Also the relative position of the pen had to be controlled at least twice a week.

For the determination of the velocity of the current it is necessary to find a place where the stream is smooth, deep and undivided

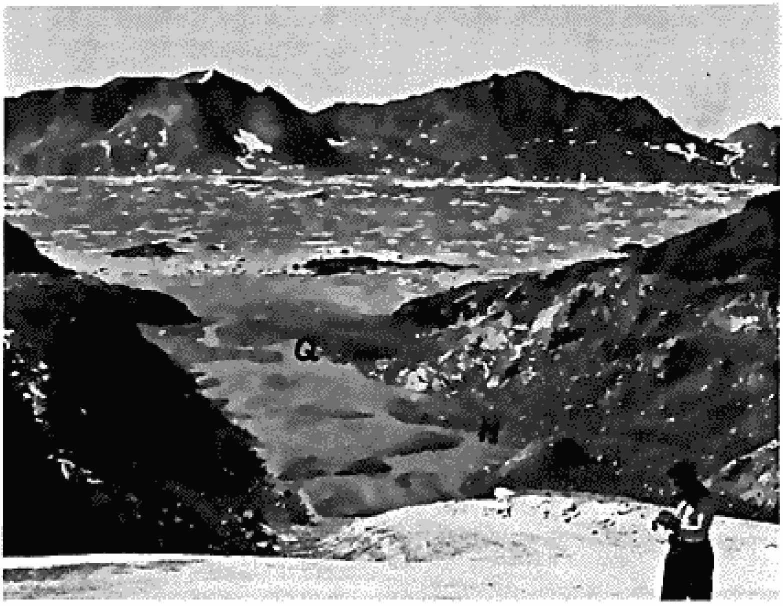

*Fig. 1. The glacial river, seen from the glacier.*

and the place so far upstream that the changes in the sea level will not affect the current (the tidal amplitude was 2,5–3,5 m.). The chosen point is indicated by »Q« in fig. 1 about 420 m. downstream from »H«, 2,40—2,45 m. above mean sea level. The distance along the stream from »Q« to the sea is about 360 m. at high tide and about 200 m. longer at mean sea level. The type of instrument was »Flügel Lüth 4251« current-meter; a signal is given every time a propeller has rotated 20 times. The discharge was measured 5 times at different water levels, and a diagram of the water level as a function of the discharge (log. scale) was drawn (fig. 3). The five values are shown to be situated approximately on a straight line. The upper (dotted) part of this could not be determined in this way; however, the tapping-off from an ice-dammed lake on the 2nd of September made the extension possible:

The quantities of water tapped off could be calculated, and they are clearly represented by the area »A« in plate I (cf.: *Brüchner* (1895)); the dotted line below »A« indicates the probable values of the water level if no tapping took place. The curve in fig. 3 was extended in a way to satisfy the different water-level values by differentiating the area »A«; however, the extended part of the curve is, of course, given with far less accuracy.

About 50 per cent of the drainage area concerned is glacier-covered; consequently, the conditions of the glacier, especially in

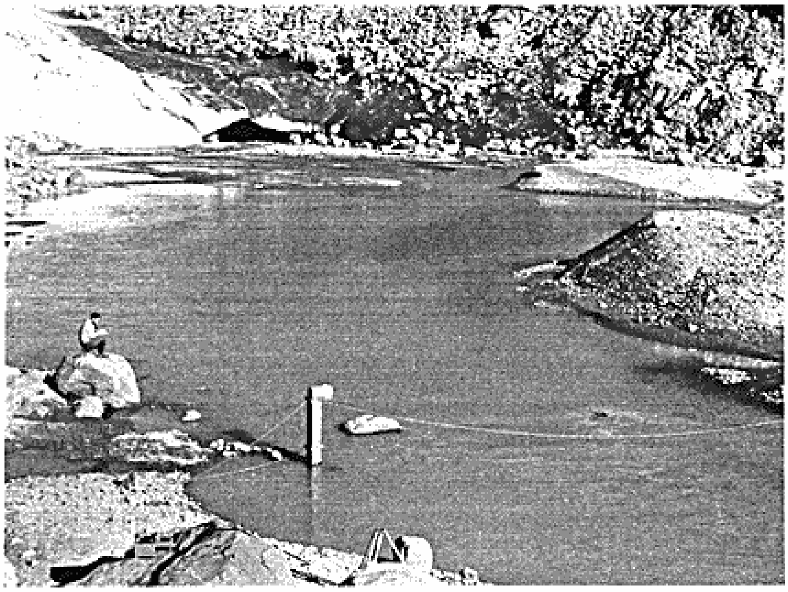

*Fig. 2. The river gauge in position. In the background: the glacier outlet, the height of which is 4 m.*

dry periods, dominate the discharge. This is rather uniform (plate I) — although slightly diminishing — from the beginning of the investigation period until about the 29th of August. The amplitude is big and very regular (the high discharge values on the 23rd of August are probably caused by tapping from a certain reservoir in the glacier). Later, the amplitude is diminishing, and from the 2nd of September the discharge is extremely irregular, and the daily variation has almost disappeared.

In the period with pronounced daily rythm the high water occurred at about 5 or 6 p. m. and the low water at about 10 (or 9) a. m. The corresponding discharge values were about 4 cu. m./sec. and 2 cu. m./sec. — i.e. a very big amplitude (67 per cent of the mean discharge) and only a small delay of the dicharge maximum, compared with the probable hour for the daily maximum of melting on the glacier.

This short delay of the discharge might go to show that only a small and local area is drained off to the stream in question; however, a comparison between the total discharge in a certain precipitation-free period and the readings of the ablation poles, shows that the intake area is not less than 5,6 sq. km. and not more than 19,6 sq. km. with a most probable value of 8 sq. km. Consequently, the area drained off to the river is not inconsiderable, when the total size of the glacier and the narrowness of the (lower part of the) glacier tongue are taken into consideration. Consequently, the pronounced daily variation in August and the short delay of maximum and of minimum must be due to an effective draining from the glacier surface; the great number of (small) crevasses in the upper part and of wells in the lower part seems to confirm this; so does the fact that but few slush accumulations existed and that the extension of the firn was very small, as the greater part of the glacier surface was bare ice or firn ice.

No doubt, the daily amplitude was much smaller earlier in the year and the delay of discharge much bigger owing to the greater extension of firn and snow.

The radiation and the meteorological conditions are often clearly reflected in the curve of discharge; and as the temperature of the glacier at all depths, according to *Fristrup*'s investigations from the uppermost 15 m., was about the melting point the refreezing of melt-water must be insignificant. The month of August was mostly radiation-dominated — great incoming radiation in daytime and great outgoing radiation at night — while September was dominated by the precipitation and by the ice-dammed lakes.

Fig. 4 illustrates the influence of the radiation and of the meteorological conditions. In this figure 6 days have been given as samples. As stated above, the curves called »Q« indicate the discharge, »t« indicates the temperatures at the coast-camp, 25 m. above sea-level, read on an Assman aspiration psychrometer; the temperatures on the glacier were lower according to the difference of altitude. The greater part of the glacier, drained off to the stream, is situated at about 300—500 m. above sea-level. The cloudiness is indicated by a fat, black gurtle near the top of the figures; a width of 8 units means 8/8 cloudiness. The letters »H«, »M« and »L« refer to the cloud base »high«, »middle« and »low«. »Weak, »middle« and »strong« refer to the winds, but are only to be understood relatively, as »strong« merely means force 4 or more (Beaufort scale). Finally, the actinograms have been copied to give an idea of the incoming radiation (it should be noticed that in reality the ordinate-axis is slightly bent). The actinagraph was placed on a nunatak on the outlet of the glacier, and, therefore, the undoubtedly rather big multible reflex between the sky and the glacier higher up cannot fully be read from the actinagrams; partly for this reason, and partly because no zero-point correction of the actinagrams has yet been made, no ordinate-scale has been put in.

The period with daily rythm is seen clearly to reflect the radia-

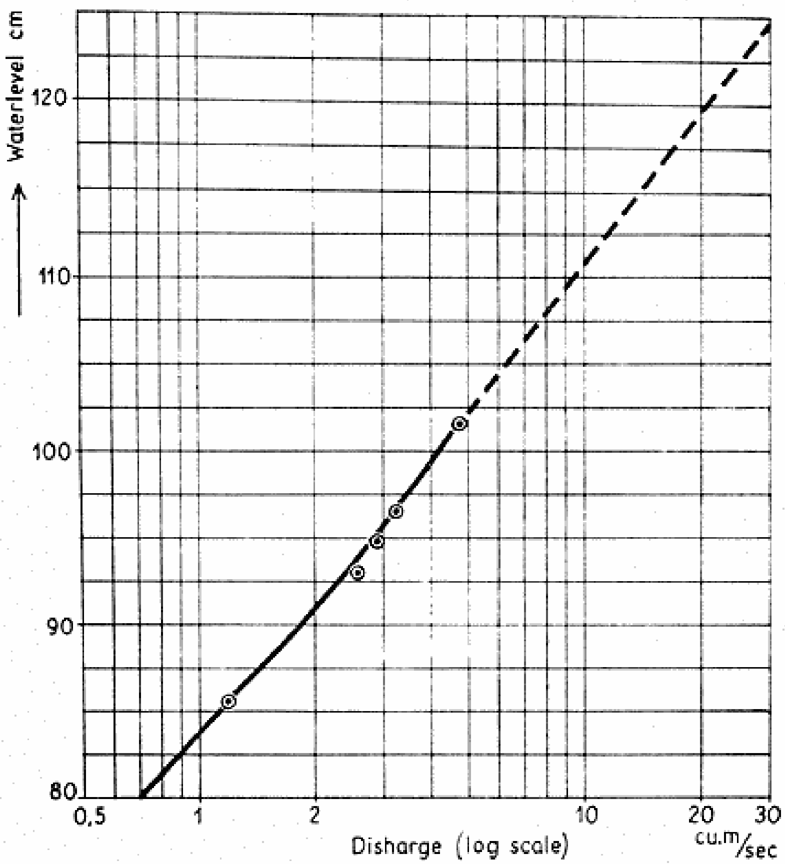


*Fig. 3. The water level at point II as a function of the discharge.*

tion conditions and, in addition, the temperature conditions. The 20th of August was cloudless, and the temperature maximum occurred at about 11 a.m.; the discharge maximum occurred at 5 p.m. (3,4 cu. m./sec.), the discharge minimum at about 10 a.m. (1,5 cu. m./sec.); consequently, the amplitude was 78 per cent, and the delay of maximum in relation to the incoming radiation and to the temperature maximum was about 5—6 hours. It should here be remembered that at a negative radiation equilibrium the surface temperature of the glacier may be several degrees lower than that of the overlying air.

The 11th of August shows similar conditions; however, a cloud layer has reduced the loss of radiation during the night, causing high discharge values the following day; the minimum of these were 2,6 cu. m./sec. (at 10 a.m.) and maximum 5,3 cu. m./sec. (at 5 p.m.). The high maximum temperature can only be responsible for the high discharge values in the late afternoon and in the evening. The winds, being weak all the time, could not have any great influence on the discharge.

On the 9th of August the maximum of incoming radiation occurred at about noon or 1 p.m., at the same time as the occurrence of the temperature minimum. Nevertheless, the rythm of discharge is pronounced on this date too, the maximum being only an hour later than normally. The discharge amplitude was 72 per cent of the mean value, i.e. only slightly less than that of the 20th of August.

On the 26th of August a rather dense cloud layer caused a small insolation in day-time and a small loss of radiation by night; furthermore, the temperature variations were insignificant; the discharge amplitude was only 33 per cent.

During the last third of the investigation period the discharge is completely dominated by rain and by tapping from ice-dammed lakes, the latter causing the flood values on the 2nd and on the 5th of September (see below). The daily rythm of discharge was insignificant. In plate I the curve composed by black steps illustrates the recorded precipitation at the coast; the figures above the single steps indicate the precipitation (mm. water) in the periods in question. The precipitation on the upper parts of the glacier was undoubtedly bigger — how much is not known. The increase of the discharge on the 14th of September is no doubt due to the abundant precipitation just before, although part of this appeared in the form of snow — especially on the upper parts of the glacier — and, consequently, hampered the runoff. The delay was only 4—6 hours, probably because the mountain slopes already were waterlogged, causing an instant runoff. On the 10th and 11th of September, however, the discharge was delayed considerably more, partly because the slopes were not saturated at that time, and partly because most of the precipitation was snow, except for the lower parts of the glacier.

### Tapping from ice-dammed lakes

On the 2nd of September a flood was observed in the glacial river. The water poured down along the southern edge of the glacier tongue, making a cascade when passing the front. Fig. 5 has been photographed from the glacier at nearly the same point as fig. 1 and shows how the stream flooded the river-bed. At about 4 p.m. the flood suddenly decreased, and after a few minutes stopped totally. At the southern edge of the glacier, at a distance of about

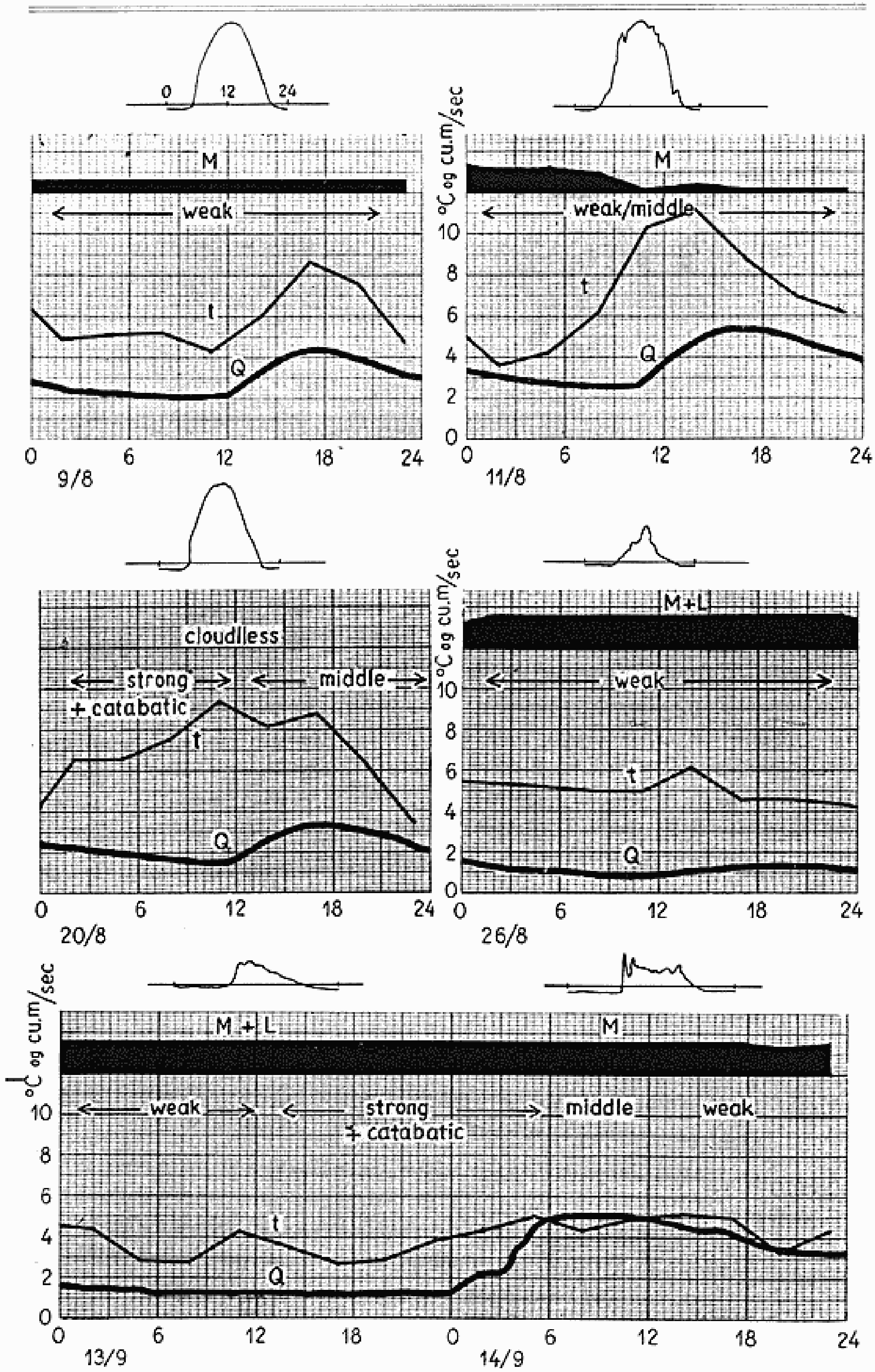


*Fig. 4. The influence of the radiation and the meteorological conditions on the discharge.*

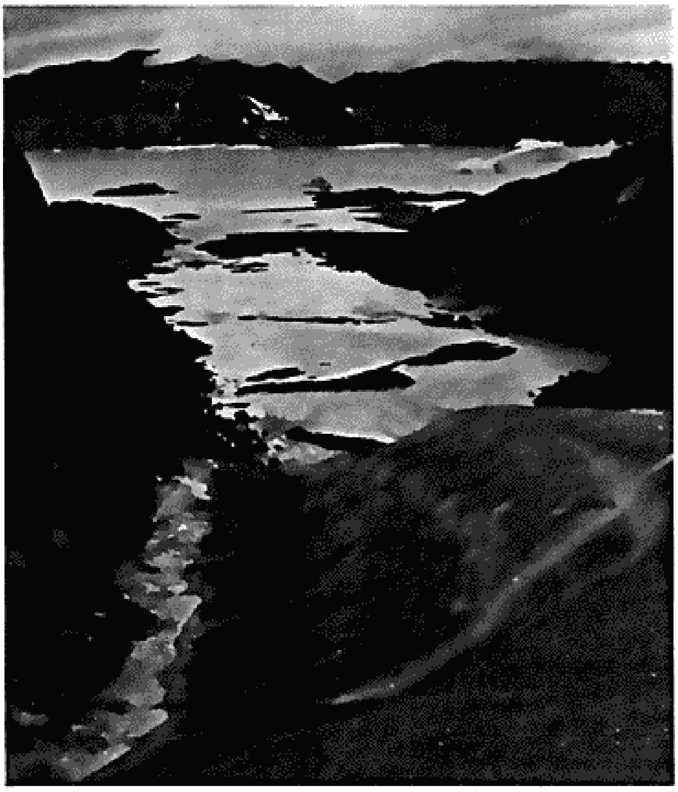

*Fig. 5. The flood on the 2nd of September. Water is running down from the lake being discharged in the lateral groove along the glacier, compare with fig. 1.*

4 km. from the front, we found an ice-dammed lake which, no doubt, had caused the sudden flood. At a height of about 5 m. above the water surface there was a mark showing the level of the water before the tapping. The total quantity of water tapped off was computed at about 400.000—450.000 cu.m.

On the 5th of September another tapping took place from a lake situated between the one mentioned above and the glacier front. This lake was totally emptied, as shown in fig. 6. The large discharge values around this date are difficult to explain, the precipitation being too small to cause them. It is possibly a question of a series of small tappings from the numerous ice-dammed lakes along the glacier-edges.

It is easy to reconstruct the emptying of the latter lake, the distance from this to the lateral groove, shown in fig. 5, being very short. In fig. 6 is shown the gate-hole, through which the water had undoubtedly forced its way down. I may have used an old subglacial tunnel, as the hydrostatic pressure grew to become high enough.

*Fig. 6. The dry bottom of the lake, tapped off on the 5th of September. Notice the person and the gatehole.*
(Fabricius fot.).

The explanation of the tapping on the 2nd of September is much more complicated. It is impossible to say whether a certain syphonic mechanism has acted, or whether the hydrostatic pressure had become high enough to enable the water — in lifting part of the ice — to force its way under the ice through a sub-glacial channel already used; it may be a combination of both processes, cf.: *Glen* (1954); however, the syphone theory explains probably in the best way the sudden cease of the flood.

Of course, the tapping-off from these small lakes must be interpreted in another way than that from the big ice-dammed lakes, well known from Iceland, *Arnborg* (1955), *Okko* (1956), *Thorarinsson* (1939, 1957); however, it is interesting to observe that both types show the typical tapping-profile in the curve of discharge: a relatively gentle increase until the maximum value, and then a sudden drop.

## Conclusion

This rather superficial treatment of the material leads to the result that in the month of *August* the *discharge* was primarily *determined by the radiation,* whereas the winds were mostly so weak that the temperature and the humidity had no appreciable effect on the discharge. In *September* the discharge shows great variations, in the first place due to *tappings from ice-dammed lakes.*

secondly because in this month the discharge is dominated by *precipitation* (and the somewhat more powerful winds). Further, it appears that periods with big daily variations of the radiation equilibrium also have big amplitudes of discharge; inversely, on a day and night with small radiation variations the amplitude of the discharge is insignificant.

As will be seen from the above, a small glacier like the Midtluagkat Gletscher is excellent for making studies of the runoff and, thereby, for getting an impression of the magnitude of the melting at different hours of the day and of the night. Especially in summer, when the extension of snow and firn is small, it is possible in this way to study the influence of radiation and of meteorological factors. Our interpretation possibilities were additionally favoured by the fact that the glacier in question is in recession and that, consequently, the firn cover has a small extension. A further study of the material will undoubtedly give a more exact picture of the relation between the melting, on one side, and the radiation and the meteorological factors, on the other side.

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**RESUMÉ**

Siden 1956 er glaciologiske ekspeditioner under ledelse af *Børge Fristrup* blevet udsendt af *Universitetets Geografiske Laboratorium* som led i det danske forskningsprogram for *Det Internationale Geofysiske År*. I sommeren 1958 udsendtes en ekspedition til Mitdluagkat Gletscher på Angmagssalik Ø, Østgrønland. Foruden opmåling af gletcheren og glacioklimatiske undersøgelser, der var ekspeditionens hovedformål, udførtes nogle bestemmeser af vandføringen i en elv fra denne gletscher.

Gletscheren – en transection gletscher – er ca. 30 km², hvoraf ca. 8 km² afvandes til den pågældende elv (fig. 1), der strømmer ud fra gletscheren af en 4 m høj port (fig. 2) i fronten af dennes hovedudløb mod VSV.

Ved hjælp af en selvregistrerende vandstandsmåler (fig. 2) og en vingestrømmåler måltes vandstand (»H« i tavle I) og vandføring (»Q« i tavle I), idet sidstnævnte bestemtes 5 gange og indlagdes på et semi-logaritmisk diagram med vandstanden som ordinat (fig. 3), hvorved vandføringen ved de øvrige vandstandsværdier kunne interpoleres.

I august måned iagttoges en tydelig døgnrytme, som navnlig var strålings-betinget, idet de daglige vandførings-svingninger var næsten lige store, hvad enten temperatur-maximet faldt samtidig med indstrålings-maximet eller modsat dette (fig. 4 den 9/8, 11/8 og 20/8). De store døgn-variationer i strålings-balancen bevirkede denne måneds tilsvarende store variationer i vandføringen, yderligere fremhævet af den ringe forsinkelse, smeltevandet fik på den i denne måned næsten overalt firnfri gletscher-overflade.

I september måned var vandføringen ganske uregelmæssig og stærkt afhængig af nedbørsforholdene og i anden række af vindforholdene, mens afsmeltningen grundet på en ringe strålings-omsætning og de ringe temperatur-variationer sandsynligvis var ret uafhængig af tidspunktet på døgnet, og vandføringen derfor næsten mangler døgnrytme.

De meget høje værdier den 2/9 og 5/9 skyldes aftapning fra isdæmmede søer (fig. 5–6). Ved den første af disse blev en søs vandspejl sænket 5 m, hvilket betød, at den mistede omtrent en halv million $m^3$ vand (denne tapning muliggjorde en extrapolation af kurven fig. 3). Ved den anden tørlagdes en sø fuldstændigt.

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## LITTERATUR

*Arnborg, Lennart* (1955): Hydrology of the glacial river Austurfljot. Geogr. Ann. 37.

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*Klebelsberg, R. v.* (1913): Die Wasserführung des Suldenbaches. Zeitschr. f. Gletscherkde., 7.

*Okko, Veikko* (1956): Glacial drift in Iceland. Acta Geographica 15.

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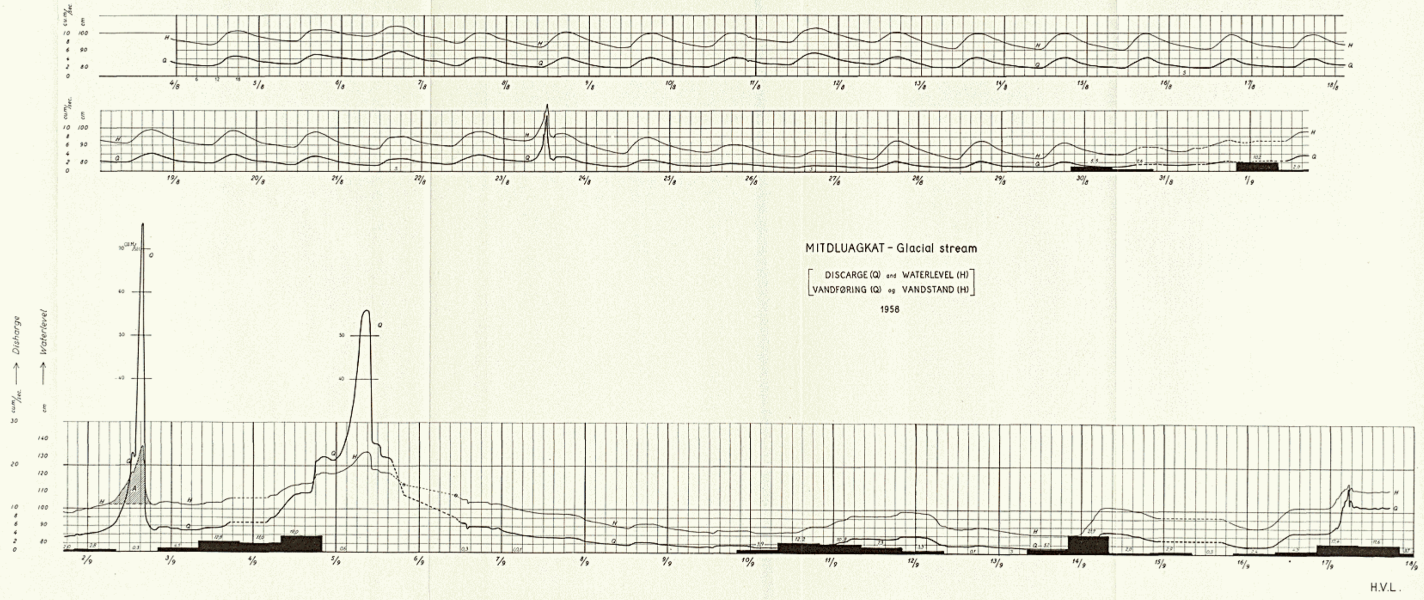
MITDLUAGKAT – Glacial stream
DISCARGE (Q) and WATERLEVEL (H)
VANDFØRING (Q) og VANDSTAND (H)
1958
Discharge
Waterlevel
H.V.L.

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