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RECENT CHANGES OF NORDBOGLETSCHER AND NORDGLETSCHER, JOHAN DAHL LAND, SOUTH GREENLAND

by

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ABSTRACT

Generally, outlet glaciers from the Inland Ice in South Greenland have retreated and thinned considerably since the 19th century. A sector in Johan Dahl Land, comprising the glaciers Nordbogletscher, Nordgletscher, and Eqalorutsit kangigdlît sermiat, has no trim-line zones. These glaciers have probably reached their most advanced position in historical time and are advancing further.

Marginal and surface changes of the glaciers, over the last 30 years, are determined, using topographic maps based on aerial photographs taken in 1953, 1977, and 1981 and compared with ablation and surface movement of ice measured at stakes, established in 1978 at Nordbogletscher.

The conclusion, made on the basis of the observations, is that the advance is the result of a higher transport rate of ice from the accumulation area than can ablate during the summers in the ablation area, under prevailing climatic conditions.

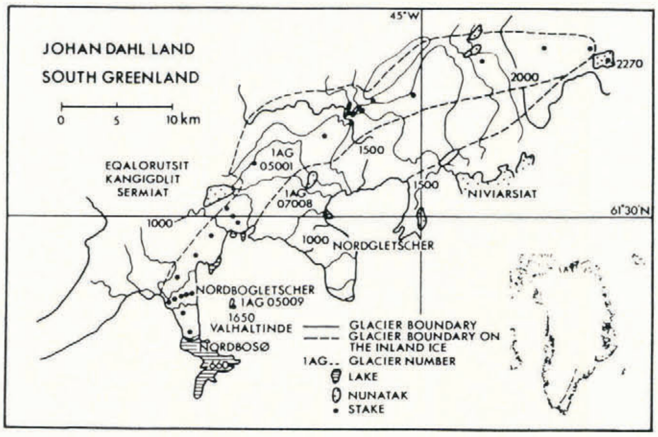

Fig.1. The glaciers Nordbogletscher and Nordgletscher, in Johan Dahl Land, South Greenland. Also shown are positions of the inserted stakes.

INTRODUCTION

The present study deals with Nordbogletscher and Nordgletscher, two outlet glaciers from the Inland Ice in South Greenland, that, during the last 30 years or more, have experienced considerable advance. They are characterized by their lack of trim-line zones. The glaciers are advancing into vegetated areas and are in their most advanced position in historical time (Clement 1982). Local glaciers in the area are retreating, exposing areas covered by ground moraine and leaving terminal and marginal moraines behind.

LOCATION AND PREVIOUS OBSERVATIONS

Nordbogletscher (1 AG 05001; 61°27'N, 45°24'W) is situated in Johan Dahl Land in South Greenland (Fig.1.). The ELA varies between about 1400 and 1600 m and the accumulation area reaches 2150 m. (Olesen and Weidick 1978). Since it is part of the Inland Ice, the area is uncertain, if based completely on surface topography. The glacier terminates in Nordbosø (at about 660 m). Water depths in front of the glacier vary between 50 and 150 m (Larsen 1981) and the low rate of calving suggests that the marginal area is grounded. The glacier surface is broken by minor crevasses and has a general slope of 2–3°.

Nordgletscher (1AG 07008; 61°30'N 45°10'W) is situated about 15 km east of Nordbogletscher. The glacier is situated between about 600 and 2200 m. The area extent is uncertain. The slope of the glacier, below the ELA, is about 5°. The frontal area is very steep and shows the radial crevasse pattern or claw form, typical of advancing glaciers.

PROCEDURES

Ablation was determined as the change in stake length, projecting out of the glacier, between subsequent surveys. Data used here cover the period 1979–82.

Ice velocity was determined, using intersection from survey points, established on bedrock around the periphery of the glacier, to stakes drilled into ice. Angle measurements were performed with a Carl Zeiss, Jena, "Theo 010A", theodolite, allowing readings to 0.0002^g and an accuracy for double readings of ±0.0003^g. No measurements of vertical angles were made. Only yearly values, based on September to September measurements, are used.

Maps from 1953, 1977, and 1981 are based on vertical aerial photographs. All photographs were taken during August. The original maps were drawn on a scale of 1:20 000, with 10 m contour intervals, using a Jena Topocart. The geodetic material, used for orientation of the stereoscopic models, was provided from a triangulation network established in the area around Valhaltinde (n=12). The mean error in horizontal direction does not exceed ±0.5 m, those of the absolute altitude being within ±0.2 m. Maps covering Nordbogletscher, Nordgletscher, and a local, cirque glacier (1 AG 05009) were produced. The maps showing surface change were produced by direct comparisons between maps, using a grid net, and the change was then determined at each coordinate point. Lines showing equal increase (or loss) were drawn using linear interpolation.

RESULTS

NORDBOGLETSCHER

Marginal and surface change

Change of surface height and marginal advance were determined during the period 1953–81 (Fig.2a). Along a 1.5 km-wide terminus in Nordbosø, advances between 300 and 700 m were measured. Along the sides, advances were less, being of the order of 50–100 m. Surface change took place over the entire area covered. A maximum increase of 45 m was measured at the 1953 position of the terminus, but fell to 30 m, 2 km behind the present margin. It corresponds to a net gain of the order of 1.0 m/y. Surface change along the centre line (Fig.3a) shows the same pattern. The figure incorporates data from the period 1977–81. It shows that, in the first kilometer behind the margin, no surface increase was measured during 1977–81,

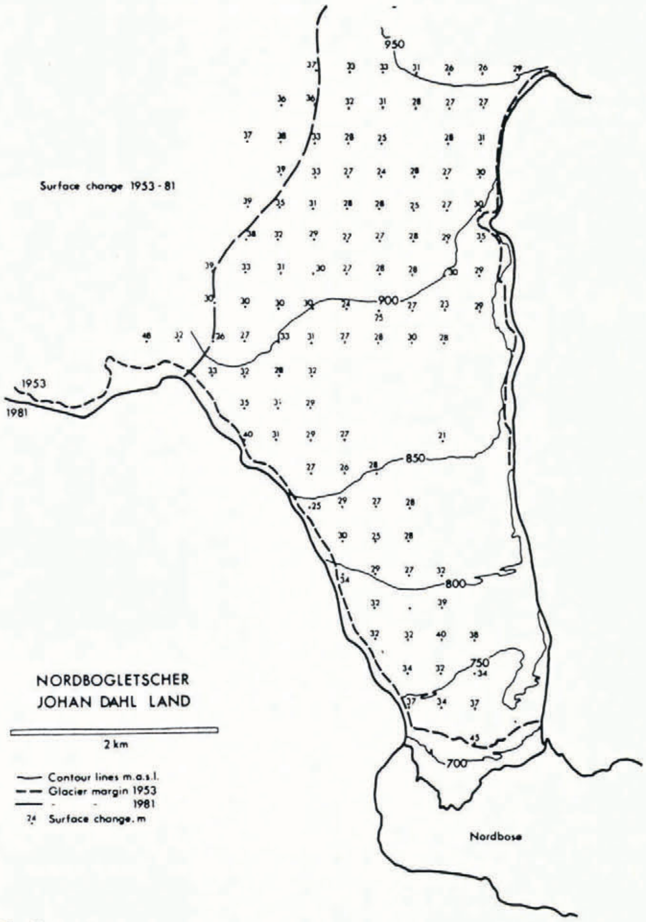

Fig.2a. Changes of surface elevation at Nordbogletscher between 1953 and 1981. Net increases of ice thickness are indicated as point values in metres.

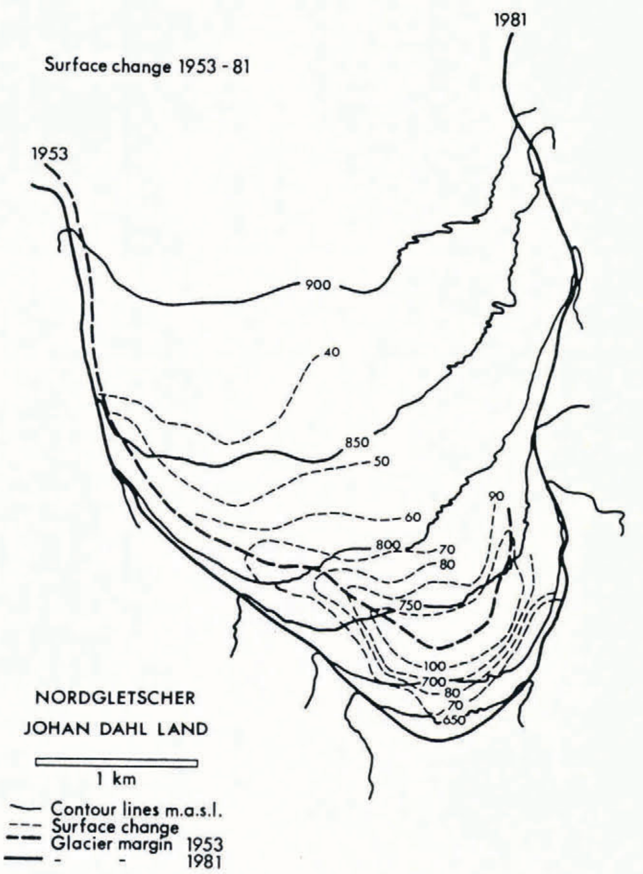

Fig.2b. Changes of surface elevation at Nordgletscher between 1953 and 1981. Net increases of ice thickness are indicated by isolines of 10 m.

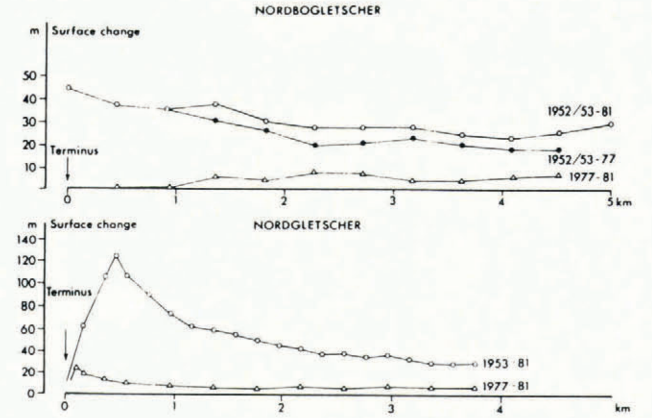

Fig.3a and b. Changes of centre line surface elevation, based on mapping from aerial photographs (1952/53, 1977, 1981). At Nordbogletscher and Nordgletscher, the surface elevation increased, showing a maximum towards the terminus.

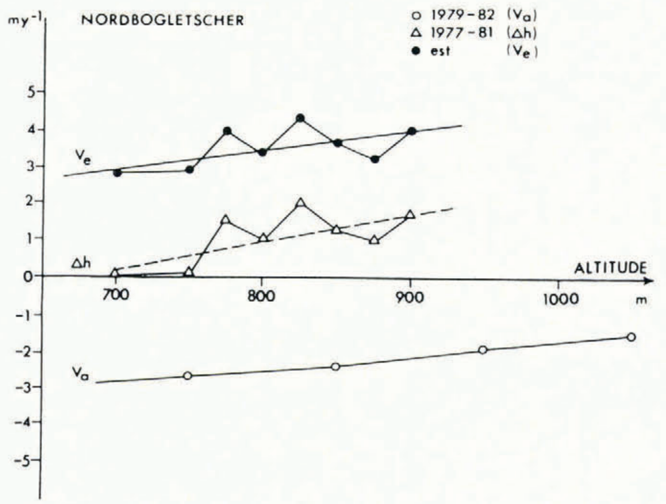

Fig.4. Vertical ice velocity (V_e), annual net ablation (V_a) and surface change (Δh) along the central line of ice movement on Nordbogletscher, during 1977–81.

but, further behind the terminus, increase varied between 1 and 1.5 m/y.

Ablation and net balance

At 800–900 m, ablation during 6 years (1978–83) of observation showed a mean value of 2.4 ± 0.3 m/y (Clement 1983b). Net accumulation varied between 0.2 and 0.3 m/y. The net balance below 1100 m, based on three years measurements (1979–82), is shown in Table I.

Horizontal ice velocity

The spatial variation of horizontal ice velocity (Us), along two cross profiles at 865 m and 1050 m, is shown in Fig.5. Velocity data and calculations of internal deformation and basal sliding are given in Table II. Both presentations comprise data collected during the period 1978–83. In Figure 5, cross profiles of the glacier bed are drawn from thickness measurements, based on radio echo-soundings (Clement 1983b). As the surface slope is known, it is possible to calculate basal sliding and determine mean velocity and discharge of ice through the profiles.

The highest velocities were measured at stakes on the 1050 m profile and were about 370 m/y at the centre line. Calculation of internal deformation, using a surface slope of 2° and an ice thickness of 200 m. gave values of a few metres a year, indicating that almost the entire ice velocity consists of basal sliding.

On the lower glacier, at about 800–900 m, the ice velocity at the centre line is about 90 m/y, with a regular

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TABLE I. AREA DISTRIBUTION AND NET BALANCE AT NORDBOGLETSCHER DURING 1979–82 BELOW 1100 m

Height m asl.	Area km^2	1971–80 $BNx10^6m^3$	1971–80 bn m	1980–81 $BNx10^6m^3$	1980–81 bn m	1981–82 $BNx10^6m^3$	1981–82 bn m
1000–1100	8.0	–9.9	–1.2	–15.4	–1.9	–11.1	–1.4
900–1000	10.6	–19.6	–1.9	–19.8	–1.9	–19.5	–1.8
800–900	4.8	–12.9	–2.7	–11.7	–2.4	–10.2	–2.1
700–800	5.2	–14.5	–2.8	–14.4	–2.8	–13.2	–2.5
600–700	0.3	–0.9	–2.8	– 1.0	–3.0	– 0.9	–2.8
600–1100	28.9	–57.8	–2.0	–62.3	–2.2	–54.9	–1.9

(from Clement 1981, 1982, 1983b)

decrease towards both margins. The velocity increases slightly to about 100 m/y at about 1.5 km from the terminus. This indicates a low value of longitudinal compression. A calculation of basal sliding, under the assumption of an ice thickness of 300 m and a surface slope of 2.5°, yields values of about 60 m/y (or 2/3 of the total velocity) close to the centre line.

Vertical ice velocity

The emergence-flow component, v_e, represents the component of movement that tends to compensate for the net gain or loss of ice from the surface (Meier, 1974). It is given by

$$\Delta h = V_e + V_a$$

where Δh is surface change and V_a is net gain or loss of ice/snow at the glacier surface,

A diagram showing variation in V_e, Δh, V_a along the central line of ice movement, during the period 1977(79)–1981(82), is presented as Fig.4. Values of emergence flow were positive; all stakes placed in the ablation area. Values increase slightly away from the terminus, with a mean value of about 3.5 m/y.

NORDGLETSCHER

Marginal and surface change

Change of surface height and marginal advance were determined during the period 1953–81 (Fig.2b). The advance, determined as the distance between the two most advanced positions in the two years, was 750 m. From there, it fell towards the sides, where it was of the order of 50–100 m. Surface increase took place in the entire area covered. Above 900 m, a value of about 30 m was found, corresponding to the value determined at Nordbogletscher. At lower levels, the surface gain increased and reached a maximum of about 120 m, at the position of the 1953 terminus.

Surface change along the centre line (Fig.3b) reveals the same pattern. The figure covers the periods 1953–81 and 1977–81. In general, the increase was of the order of 1 m/y, except in the terminal area, where it attained a value of about 5 m/y.

DISCUSSION AND CONCLUSIONS

Nordbogletscher advances into Nordbosø, which has diminished about 0.5 km^2 (4%) since 1942 (Clement 1983a). Surface change during the period 1953–81 attained a maximum towards the terminus, where values of 40–45 m of increase were recorded. Thickness change decreased steadily away from the terminus and attained a value of 25–30 m at about 700–900 m and 2–7 km behind the present margin. In recent years, 1977–81, the increase has remained at about 1–1.5 m/y.

The relation between ablation, ice discharge, and surface change at Nordbogletscher is shown in Table III. An evaluation of ablation, below the positions of ice-velocity, cross profiles, yields values of net, annual, mass loss, of respectively, 22.5 x 10^6 m^3 below 865 m, and 55–60 x 10^6 m^3, below 1050 m. The areas in question are 9 and 29 km^2. Using a value of about 1.25 m/y of surface increase gives a yearly surplus, transported into these areas, of 10 x 10^6 m^3 and 28 x 10^6 m^3. As for the lower profile, at 865 m, the sum of these volumes corresponds to

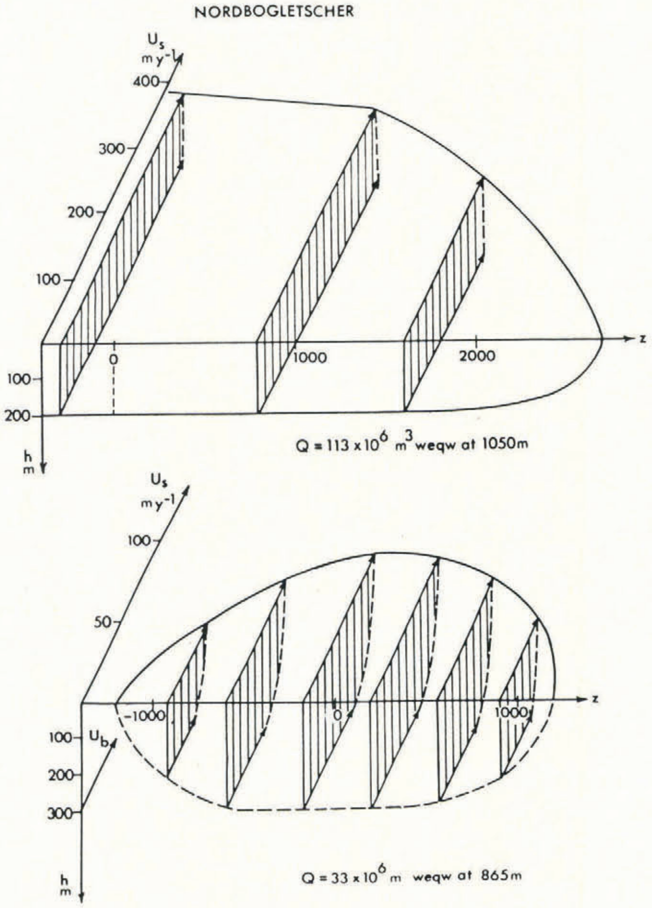

Fig.5. Horizontal ice velocity along cross profiles at 865 m and 1050 m on Nordbogletscher, during 1981–82. Also shown is assumed glacier bed and calculated values of basal sliding. Discharges through the cross profiles are given in m^3 H_2O/year.

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TABLE II ICE VELOCITY AND DISCHARGE THROUGH CROSS PROFILES AT 865 m AND 1050 m AT NORDBOGLETSCHER

STAKE	Us m/y	h m	α	Ud m/y	Ub m/y
43	48	220	2°.5	7.7	40
41	73	290	2°.5	23.5	50
04	89	300	2°.5	26.9	62
42	88	300	2°.5	26.9	61
44	72	290	2°.5	23.5	48
46	50	230	2°.5	9.3	40

STAKE	Us m/y	h m	α	Ud m/y	Ub m/y
1	245	200	2°	5	240
2	358	200	2°	5	353
3	385	200	2°	5	382

TABLE III RELATION BETWEEN ABLATION, ICE DISCHARGE AND SURFACE CHANGE AT NORDBOGLETSCHER

Below 865 m:	
Net ablation: (1979–82)	22.5×10^6 m^3 a^{-1}
Surface change:	9.8×10^6 m^3 a^{-1}
	32.3×10^6 m^3 a^{-1}
Ice discharge:	32.8×10^6 m^3 a^{-1}
Below 1050 m:	
Net ablation: (1979–82)	52.2×10^6 m^3 a^{-1}
Surface change:	28.1×10^6 m^3 a^{-1}
	80.3×10^6 m^3 a^{-1}
Ice discharge:	113×10^6 m^3 a^{-1}

the amount of ice transported through the profile: 32.8 x 10^6 m^3. At the upper profile, the discharge amounts to 113 x 10^6 m^3, which is somewhat higher than the sum of surface increase and ablation of about 87–92 x 10^6 m^3. The volume transported into the ablation area below 1050 m is rather sensitive to changes in position of the ice divide with Eqalorutsit kangigdlît sermiat. A change of 100 m corresponds to a change in discharge of 7.2 x 10^6 m^3. The discrepancy is thus removed by shifting the ice divide 400 m.

At Nordgletscher, the advance took place above older moraines and ice forced its way into old morainic deposits (Weidick 1963). The surface change is at a maximum along the central line of ice movement and at the position of the 1953 margin. Ice thickness decreases rapidly away from the present margin and attains a value of about 30 m at 1000 m. (Fig.2b and 3b). The increase at higher levels is equivalent to values measured at Nordbogletscher, indicating that a major portion of the Inland Ice marginal areas has experienced a general increase of about 1 m/y over a longer period. The tendency towards increasing thickness has continued during recent years, as a comparison between maps based on photographs taken in 1977 and 1981 reveals changes along the centre line of almost 1.5–2 m/y. As seen from Fig.4b, the maximum increase during 1953–81 was as much as 120 m. The appearance of the long profiles is as would be expected if they were to be explained by a sudden increase in mass balance, which created a kinematic wave. On the other hand, no signs of waves creating bulges, in the area covered by mapping, have been observed.

The conclusion that is made on the basis of observations is that the advance of Nordbogletscher and Nordgletscher is the result of a higher transport rate of ice from the accumulation area than, under prevailing climatic conditions, can ablate during the summers. To reach more definite conclusions as to what events in the past have created the present conditions needs further investigation into the specific relation between mass balance and the dynamic conditions of the glaciers.

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