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Glacier velocities from aerial photographs in North and North-East Greenland

A. K. Higgins

General descriptions of the glaciers of North and North-East Greenland have been given by Koch (1928), Davies & Krinsley (1962) and Weidick (1975). These descriptions, however, provide little in the way of quantitative data on glacier velocities, although Davies & Krinsley concluded that a large number of glaciers and

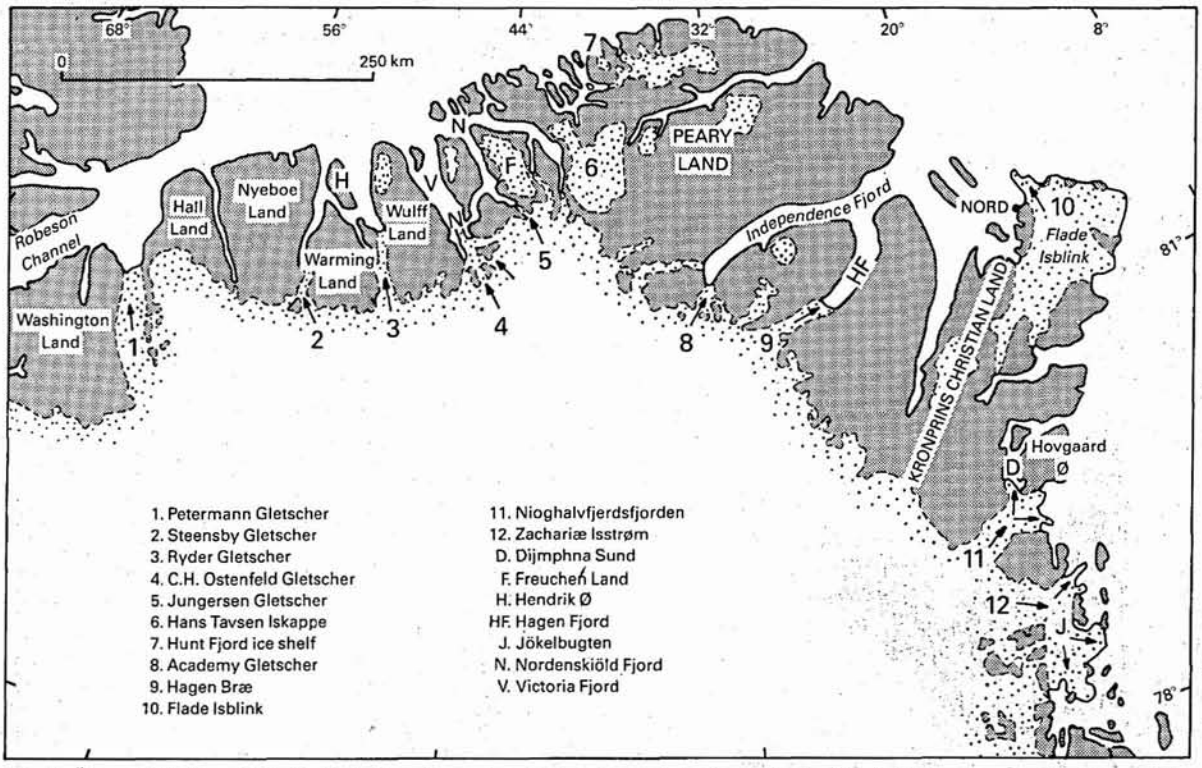

Fig. 1. Map of North and North-East Greenland showing location of glaciers described in text. Land areas are shaded. The marginal area of the Inland Ice and independent ice caps and glaciers have a dotted ornament.

small ice caps in North Greenland exhibited stable conditions, with a significant number showing evidence of recent retreat. Comparisons of vertical aerial photographs taken in 1959–63, 1971 and 1978 permit measurements of glacier velocity to be made on floating ice tongues which have preserved a distinctive surface pattern of meandering streams and crevasses. These show the largest glaciers draining the Inland Ice in North and North-East Greenland to have average velocities ranging from 300 to 900 m/year.

This study of vertical aerial photographs has also demonstrated that for floating glacier tongues the position of the glacier terminus is not a reliable indicator of advance or retreat. In the fjords of North Greenland semi-permanent sea ice often maintains the integrity of advancing floating glacier fronts for periods of ten to twenty years (Koch, 1928; Weidick, 1975); the break-up of the floating tongue in rare summers when the sea ice melts completely may give the impression of a sudden retreat, but this 'retreat' is unrelated to changes in the mass balance.

Petermann Gletscher (fig. 1: no. 1) is 110 km long and 15 km wide at its front, and occupies a deep cleft between Washington Land and Hall Land. At least the northern 40 km of the glacier is afloat, and matching of surface features on aerial photographs from 1959 and 1978 demonstrate that the central part of the glacier has moved 17 km in 19 years, an average velocity of 895 m/year.

The position of the glacier terminus is reported to have had a fairly stable position since 1876 (Koch, 1928; Davies & Krinsley, 1962), which indicates that large icebergs must regularly calve from the front and escape into Robeson Channel, where there is often open water in the summer.

Steensby Gletscher (fig. 1: no. 2) drains into the head of Sankt George Fjord, between Warming Land and Nyeboe Land. It is 62 km long, and about 3.5 km wide at the front where it characteristically breaks up into several floating lobes separated by aggregates of small icebergs (Ahnert, 1963). Aerial photographs from 1963, 1971 and 1978 demonstrate a velocity of 430 m/year. Ahnert's estimate of an annual advance of 5.4 to 8.7 km was based on an incorrect assumption. The semi-permanent sea ice has maintained the advancing front of Steensby Gletscher as an intact mass, and no large icebergs drifted away from the front between 1953 and 1978.

Ryder Gletscher (fig. 1: no. 3) is more than 80 km long and drains northwards between Wulff Land and Permin Land, where it is 8 km wide. Characteristic surface features on the frontal floating segment of the glacier demonstrate a movement of up to 8 km between 1963 and 1978, an average velocity of about 535 m/year.

Lauge Koch's observations in 1917 showed the floating glacier tongue to extend a considerable distance farther north than at present, into the fjord between Hendrik Ø and Wulff Land (Koch, 1928). Davies & Krinsley (1962) note that this tongue had broken up prior to 1947, and that the position of the glacier front withdrew a further 5 km from 1947 to 1956. Between 1971 and 1978 the front has advanced without drift of significant icebergs away from the front.

Break-up and dispersal of the floating glacier tongue clearly takes place only in rare summers when the sea ice melts completely. Oblique aerial photographs from 1953 show a collection of large icebergs off the front of Ryder Gletscher, which in an ice-free summer prior to 1963 had drifted 15 to 45 km northwards to positions between Hendrik Ø and Wulff Land. These tabular icebergs occupied virtually unchanged positions on 1963 and 1978 aerial photographs and in 1985 (personal observations), showing the sea ice had not melted completely for at least 22 years.

C. H. Ostenfeld Gletscher (fig. 1: no. 4). In May 1917 Lauge Koch encountered in the outer part of Victoria Fjord what he initially took to be glacier ice from the floating tongue of C. H. Ostenfeld Gletscher, but later concluded it might be old sea ice (Koch, 1928). His first impression was correct, and as shown by Davies & Krinsley (1962) the inner 75 km of Victoria Fjord is tightly packed by large and small icebergs derived from the glaciers at the head of the fjord. The position of the iceberg front is currently much the same as in 1917.

Six large glaciers merge at the head of Victoria Fjord, of which the most important is C. H. Ostenfeld Gletscher; it is up to 7 km wide and has a more or less connected floating segment projecting for 25 km into Victoria Fjord. Velocity measurements made on the basis of aerial photographs from 1963, 1971 and 1978 range from 750 to 815 m/year. Two glaciers west of C. H. Ostenfeld Gletscher are inactive, whereas the three glaciers to the east have velocities of 400–550 m/year.

Jungersen Gletscher (fig. 1: no. 5). This is not a large glacier filling Nordenskiöld Fjord as depicted by Koch (1928), but as shown on modern maps it is a relatively small glacier 2.5 km wide draining from the Inland Ice south of Freuchen Land into the head of the fjord. The measured velocity determined from 1963 and 1978 vertical aerial photographs is 350 m/year.

Hans Tavsen Iskappe (fig. 1: no. 6) is an independent ice cap about 70 km across. Three small outlet glaciers draining into the fjord to the west have measured velocities of 40–70 m/year, and a larger glacier draining northwards 100 m/year. A drilling operation was carried out on Hans Tavsen Iskappe during the 1975 Greenland Ice Sheet Programme (Langway *et al.*, 1985).

Hunt Fjord ice shelf (fig. 1: no. 7). Small ice shelves occur in northern Peary Land, one of which completely fills Hunt Fjord; a smaller ice shelf partially blocks the sound west of Hunt Fjord. These are the only ice shelves in North Greenland which bear comparison with the better known ice shelves fringing northern Ellesmere Island (Jeffries, 1987). Like them they appear to be very ancient features and exhibit a comparable surface pattern of undulating ridges and water-filled hollows. However, the North Greenland ice shelves are clearly fed by the alpine glaciers in north Peary Land, and while they generally show little sign of movement between 1963 and 1978 aerial photographs, a glacier feeding a portion of the west front of Hunt Fjord ice shelf is moving forward at 23 m/year.

Academy Gletscher (fig. 1: no. 8). Early observations of the 10 km wide glacier at the head of Independence Fjord indicate a floating frontal portion of hummocky ice and densely packed icebergs, extending about 12 km into the fjord (Peary, 1898; Freuchen, 1915; Koch, 1928). This floating portion of Academy Gletscher had dispersed by 1956 (Davies & Krinsley, 1962), and aerial photographs from 1962 and 1978 show no indication of re-establishment. It is inferred that since the 1950s the fjord ice has melted sufficiently frequently that floating segments of the glacier disintegrate and disperse before they can form substantial ice tongues. No velocity measurements are possible on aerial photographs of the present crevassed frontal portion.

Hagen Bræ (fig. 1: no. 9), at the head of Hagen Fjord, is 75 km long and about 10 km wide in its central part. Towards the front the glacier widens, and while the southern part is partially dammed by two islands and breaks up, the northern part of the front continues into the fjord as a floating segment 6 km wide and up to 18 km long. Davies & Krinsley (1962) describe the floating glacier tongue as stagnant with a surface of interlacing streams and large interconnecting ponds in parallel troughs. Aerial photographs from 1960 and 1978 show

that Academy Gletscher with its floating front is moving outwards at 540 m/year. Large tabular icebergs up to 5 km by 2 km in size, which formed the front of the glacier tongue in 1960, had broken free and drifted up to 45 km towards the outer part of Hagen Fjord by 1978.

Flade Isblink (fig. 1: no. 10). Northern Kronprins Christian Land supports a large independent ice cap, Flade Isblink. It is more than 100 km long and up to 75 km wide but has only a few outlet glaciers which reach the sea, the most important being that east of Station Nord where a floating glacier up to 25 km broad extends northwards into the sea for up to 15 km. The eastern lobe of this floating glacier moves at 175 m annually and the western lobe at 360 m annually. There was no significant loss from the advancing front between 1961 and 1978, although extensive open water leads were adjacent to the front on the 1978 aerial photographs.

Nioghalvfjerdsfjorden (fig. 1: no. 11). The interior of Nioghalvfjerdsfjorden is filled by an extensive floating glacier tongue, of which a northern branch projects into Dijmphna Sund west of Hovgaard Ø. The main glacier is 60 km long and 18 km wide at its narrowest point. It widens eastwards and the outer 30 km segment is afloat. A prominent system of undulating ridges and hollows, first described by Koch & Wegener (1911), is developed on the surface of the floating glacier.

The velocity of parts of the main glacier have been measured from 1962 and 1978 aerial photographs at 310–330 m/year. The main floating front of the glacier in Nioghalvfjerdsfjorden abuts against a series of small islands. On the north side of the fjord movements of only 35–40 m/year have been measured, whereas on the south side of the fjord tongues of ice projecting between islands move seawards at rates of up to 160 m/year. The branch of the glacier moving north into Dijmphna Sund has an average velocity of 210–230 m/year.

Zachariæ Isstrøm/Jökelbugten (fig. 1: no. 12). The largest area of floating glacier ice in Greenland is that filling Jökelbugten, which emanates from Zachariæ Isstrøm. This area of ice-covered sea was initially described by Koch & Wegener (1911) as 'Das schwimmende Indlandeis der Jökelbugt', and was classified by Koch (1928) as 'confluent ice'. The floating glacier ice cover a region 100 km from north to south and a maximum of 50 km from east to west.

Zachariæ Isstrøm has a minimum width of 20 km, and the central active stream has a velocity estimated from 1963 and 1978 vertical aerial photographs to be at least 470 m/year. The northern part of the floating glacier ice is a single intact mass whose outward expansion is hindered by large and small islands. Between the islands narrow tongues of shelf ice up to 15 km long move outwards at 220–280 m/year. The southern area of floating glacier ice filling Jökelbugten comprises tightly packed, broken, tabular icebergs. Movement of individual icebergs varies from 66 m to 600 m/year averaged over 15 years, the rate of movement being clearly related to the damming effect of islands, and large icebergs trapped between islands.

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