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A. W., Geological Survey of Greenland, Copenhagen.

Greenland glaciers and the 'greenhouse effect'

Roger J. Braithwaite

Glacier studies have been made in Greenland since the 1970s to plan hydro-electric power. However, there is also public concern about the extra melting from the Greenland ice sheet and local glaciers that may occur under a warmer climate due to the 'greenhouse effect' (Fenger & Laut, 1989). The increase in melting will cause a rapid retreat of glaciers over the next 100 years and could give serious problems for large hydro-electric power stations. More seriously, glacier retreat in Greenland will also cause a rise in world sea level. Greenland is therefore a possible hazard to all low-lying land, including Denmark!

The amount of future sea level rise due to thermal expansion of sea water, melting of local glaciers, and changes in the ice sheets of Greenland and the Antarctic is still debated (National Research Council, 1985; Hekstra, 1986; Robin, 1986). It is hoped that an authoritative assessment will be made in late 1990 by a working group of the Intergovernmental Panel on Climate Change which is chaired by J. Oerlemans (University of Utrecht, The Netherlands) and R. A. Warrick (University of East Anglia, UK) with participation of the present author. To anticipate the findings of this body, it can be said that a sea level rise of under a metre may occur in the next 100 years. Such assessments are good enough to show the potential threat of sea level rise but a precise forecast needs much more data. In particular, a better figure for Greenland's share of sea level rise can only be reached by more research in Greenland. GGU is encouraging this aim by helping foreign groups to plan projects and by its own research using the large amounts of data which have been collected to plan hydro-electric power.

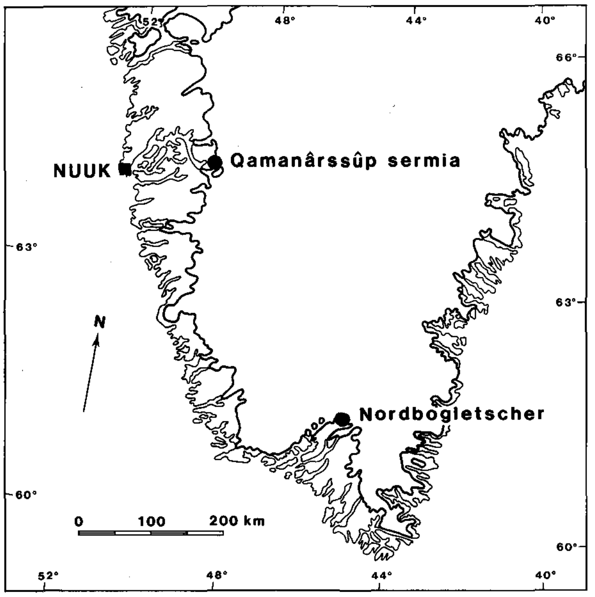

Fig. 1. Map showing location of Qamanârssûp sermia and Nordbogletscher. SS = Søndre Strømfjord.

Sea level rise from Greenland

A key point in the discussion of sea level rise is the assumption that glacier melting increases with higher temperatures. This is confirmed by analysis of data from Nordbogletscher and Qamanârssûp sermia (fig. 1) (Braithwaite & Olesen, 1989a). The empirical relation found between melting and temperature has already been used to model runoff under the present climate at Pâkitsoq (Braithwaite & Thomsen, 1989) and shows a rapid increase of melting with temperature. However, one cannot be sure that this relation is valid under greatly changed climatic conditions and greenhouse melting is therefore calculated with an energy balance model which includes the physics of the melting process (Braithwaite & Olesen, in press). The model describes ablation under present climate quite well, while a temperature rise of 5°C nearly doubles the melting at the ice sheet margin (fig. 2).

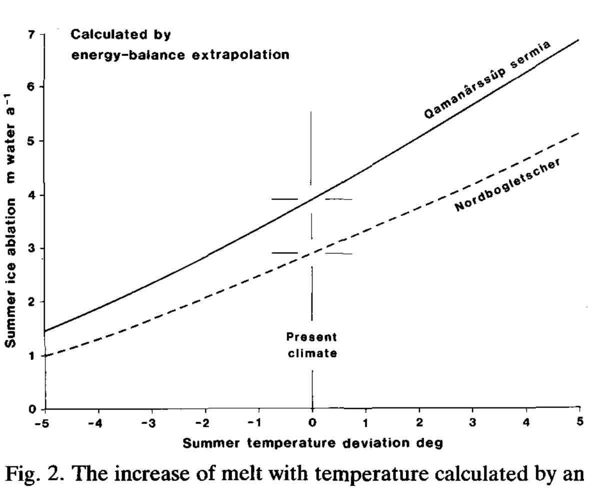

Fig. 2. The increase of melt with temperature calculated by an energy balance model. From Braithwaite & Olesen (in press).

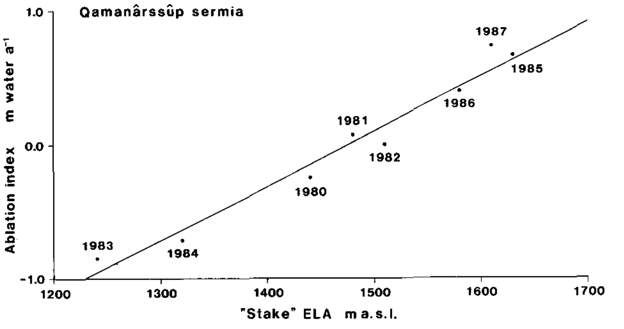

Fig. 3. Ablation index versus altitude of equilibrium line on Qamanârssûp sermia.

The curves in fig. 2 show a similar trend which, if applied to the whole ablation zone of the Greenland ice sheet, is equivalent to a sea level rise of about 4 cm/100 years for each 1°C rise in temperature. There are obvious deficiencies in this estimate. For example, both the area of the ablation zone, and the length of melting season, will increase with temperature. On the other hand, the melting in the higher parts of the ice sheet will be much lower than shown in fig. 2. These errors may partly offset each other.

Monitoring increased melting

There is no sign of a recent increase in glacier melting in Greenland aside from general retreat from the 'Little Ice Age' maximum of the last century. However, the design of future systems to monitor year-to-year changes in rate of melting and to detect trends is already being studied. The solution will probably be a blend of remote sensing from satellites and data collection in sparse stake nets.

Glaciers in many parts of the world show a general correlation between their mass balance and the equilibrium line altitude (ELA), i.e. altitude where runoff is equal to accumulation. A similar relation can now be shown for an 8-year data series from Qamanârssûp sermia (fig. 3). The data here are derived from stakes on the glacier, but the obvious next step is to estimate the ELA from satellite images. Mass balance data collected at various places in western Greenland by GGU since the 1970s would then be used as 'ground truth' for these estimates.

Data in Greenland are often measured with only a few stakes spread over a large area. It is not obvious that such sparse stake nets give reliable data on mass balance changes but Braithwaite & Olesen (1989b) show that one can detect the climate signal against a background of errors. The climate signal in this case has strong correlations with both summer temperature (positive correlation) and annual precipitation (negative correlation). From data at Qamanârssûp sermia, Braithwaite & Olesen (1989b) suggest that the 'greenhouse effect' may involve a trend of about + 0.6 m water a^{-1} deg^{-1} of increased melting which must be detected against a background of year-to-year changes with an amplitude of ± 0.6 m water a^{-1}.

Future work

GGU's studies on the 'greenhouse effect' will continue in western Greenland as a by-product of hydropower investigations. There will also be more activity by foreign agencies. For example, a long-term glacier-climate project was started in August 1989 at the ice sheet margin near Kangerlussuaq/Søndre Strømfjord by the University of Utrecht, The Netherlands. The Alfred Wegener Institute for Polar Research, West Germany, has completed the first summer of a new glacier-climate project in Germania Land, North-East Greenland (Reeh *et al.*, 1989; Henriksen, 1990) while a further project is planned at Pâkitsoq for 1990–1992 by the Swiss Federal Institute of Technology (ETH), Zürich.

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