Is 'Tipping Point' for the Greenland Ice Sheet approaching?

Once an ice sheet starts to have continuously negative surface mass balance, the ice surface gradually decreases in altitude and become warmer, leading to more melting in a positive feedback effect.

By Sebastian H. Mernild


Photo H. H. Thomsen, GEUS

The Greenland Ice Sheet 65 km north of Kangerlussuaq, W. Greenland.

Observations indicate that the most pronounced temperature increase occurs at higher northern latitudes, which have increased at almost twice the global average rate in the past 100 years. Since 1957, air temperature for the Arctic has increased on average more than 2°C. The warming was accompanied by an average increase in precipitation of ~1% per decade.

The Greenland Ice Sheet is the Northern Hemisphere's largest terrestrial permanent ice- and snow-covered area and represents a reservoir of water, containing between 7.0 and 7.4 m global sea level equivalent. This ice sheet is a useful indicator of ongoing climatic variations and changes, and it is suggested that the ice sheet responds more quickly to climate perturbations than previously thought. It is therefore essential to predict and assess the impact of future climate on the ice sheet. Variability in mass balance of the Greenland Ice Sheet closely follows climate fluctuations; the mass balance was close to equilibrium during the relatively cold 1970s and 1980s, and lost mass rapidly as climate warmed in the 1990s and 2000s with no indication of deceleration. A response to the altered climate has already been observed, manifested by a retreating ice sheet, increasing surface melt extent, decreasing permanent snow cover, and increasing freshwater runoff to the ocean.

Contributing to sea level

Recent research studies have shown that the present annual ice sheet mass loss is around 250 km^3, where nearly half of the loss originates from surface melting and subsequent freshwater runoff, and the other half from iceberg calving and geothermal melting. The mass loss affects the freshwater flux both to the West: Baffin Bay, Davis Strait, and Labrador Sea and to the East: Greenland–Iceland–Norwegian Seas. The freshwater flux plays an important role in determining ocean salinity, thermohaline circulation, sea ice dynamics, and the global sea-level rise. At local scale the freshwater increases the potential for hydro power in Greenland. At present the mass loss is equivalent to a net global sea-level rise of approximately 0.7 mm per year, or 25% of the global sea-level rise of approximately 3 mm per year.

Tipping point in the 2040s

A highly sophisticated surface snow, ice, runoff, and energy balance model (SnowModel), was used to simulate the Greenland Ice Sheet surface mass balance, and the surface freshwater flux to the ocean from 1950 through 2080. The simulations were based on input data from the Intergovernmental Panel on Climate Change (IPCC) scenario A1B modeled in a high resolution Regional Climate Model (HIRHAM4).

The projected climate data (1950–2080), air temperature and precipitation are shown in Figure 2. The greatest changes in mean annual air temperature of 5.6°C occurs in NE Greenland; this is likely due to the projected change in sea ice extent off the east coast of Greenland. The lowest warming, 3.6°C, occurs in SW Greenland, where sea surface temperatures are changing only slightly. Overall, the temperature is projected to increase by 4.8°C. Precipitation was found to increase by 80 mm on the ice sheet, with the lowest gain of 57 mm in NW Greenland and the greatest increase of 160 mm in SE Greenland, due to projected changes in cyclonic systems. The overall trend for the predicted climate (1950–2080) is a warmer and wetter climate.

The projected change in climate for Greenland will lead to an enhanced average ice sheet loss and runoff in the years approaching 2080. The annual surface mass balance changed from positive to negative values, displaying that continuously negative mass balance values will occur from the beginning of the 2040s. As the ice sheet also will continue to lose mass, partly through the dynamic production of calving icebergs, for example at Jakobshavn inWest Greenland, and at Helheim in East Greenland, and partly by geothermal melting and by melting at the interface between glacier ice and warmer ocean water, the ice will have no way to recover its volume, as long as the surface mass balance continues to be negative. Once an ice sheet has continuously negative surface mass balance, the surface gradually decreases in altitude and warms up, leading to further melting in a positive feedback loop. When this irreversible process takes over, the 'Tipping point' for the Greenland Ice Sheet has been exceeded.

A global rise of only 0.6°C can cause tipping point

The climate model used in SnowModel predicts that the tipping point for the Greenland Ice Sheet will be exceeded in the early 2040s following a warming of 1.2°C, compared to present temperatures. It is most realistic to assume that the early 2040s is the latest that tipping point may occur, since observations have in general evolved faster than the IPCC climate model scenarios. As the temperature increase in the Arctic, including Greenland, on average, probably will continue to be twice the global average rate, there is a reason to expect that the tipping point may be reached at a global average temperature increase of approximately 0.6°C. This is low, compared to temperature predictions based on simple climate models, like the positive degree day model. These degree day models predict that the tipping point will be reached at a global temperature increase of 3°C. The choice of model concept and framework conditions can obviously be important. The HIRHAM4-SnowModel concept is far more physically realistic than the degree day approach. Therefore, it seems more reasonable to expect the tipping point to be reached at a global temperature increase of 0.6°C, rather than an increase of 3°C from today's average global temperatures. ■

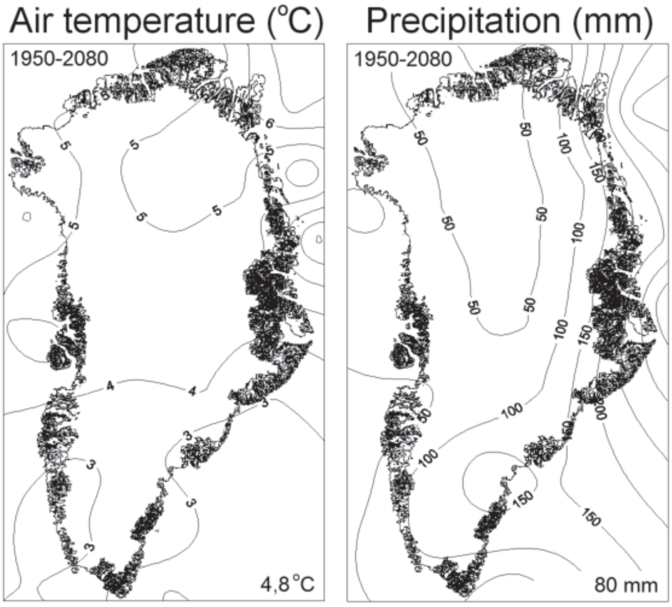

Figure 1: Greenland HIRHAM4 RCM average annual difference from 1950 through 2080 for the parameters air temperature and precipitation.

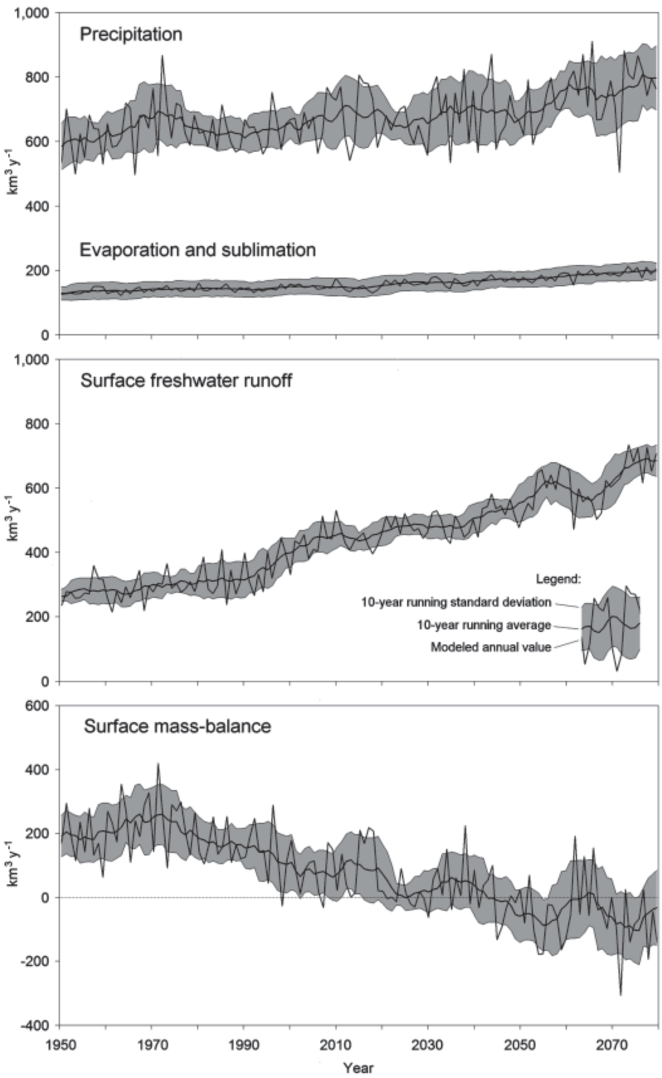

Figure 2: Time series for the simulated Greenland Ice Sheet precipitation, evaporation and sublimation, surface freshwater runoff, and surface mass-balance for the period 1950–2080.

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Further reading:

Definition of tipping point: Bamber, J. and others 2009. What is the tipping point for the Greenland Ice Sheet? IOP Conf. Ser.: Earth Environ. Sci. 6 062007, Pp 1. DOI: 10.1088/1755-1307/6/6/062007.

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