



A new indicator of Greenland Ice Sheet stability

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We use the regional energy-moisture balance model REMBO coupled to the ice sheet model SICOPOLIS to investigate the stability of the Greenland Ice Sheet (GIS) on long timescales. Using this approach, we are able to simulate the equilibrium response of the ice sheet to various levels of global warming for several model realizations. This provides the unique opportunity to evaluate criteria that can be used to estimate the long term stability of the ice sheet. For example, we find that the total surface mass balance (SMB) of the GIS is positively biased by high accumulation rates in the Southeast. Since this quantity has been used until now as the criterion for stability, the critical threshold in temperature leading to complete melting of the GIS has likely been overestimated by approximately 1°C.

Several useful alternatives exist that provide more accurate indicators of when the threshold will be crossed. These include the regional SMB, the equilibrium line altitude and the cumulative melt area. We focus here on the cumulative melt area (CMA, the sum of the melt area of each day over the year), because it is directly observable and reacts quickly to climatic forcing. A time series of this quantity is available for the period 1979-present based on satellite data. Furthermore, regional climate models (RCMs) have been used to extend the time series back to 1958. This allows a direct comparison of REMBO to the RCMs.

For the average from 1958-2001, we find very good agreement between the REMBO and RCM estimates of both the daily melt area throughout the melt season and the CMA. The estimate of the present-day CMA using REMBO is somewhat uncertain, depending on the model version used. However, we show that the threshold CMA value leading to complete melting of the GIS is largely invariant (i.e. independent of the model version) and, thus, it can be used as a reliable indicator of stability. Under global warming, a quadratic increase in CMA is predicted. Based on recent trends from the satellite data and RCMs, it is likely that Greenland will cross the threshold within the next 1-2 decades.