Geophysical Research Abstracts
Vol. 19, EGU2017-18915, 2017
EGU General Assembly 2017

What is important to get right when modelling the Greenland ice sheet?

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Ice sheet and glacier models need accurate surface mass balance inputs to accurately reproduce ice sheet extent and likely evolution. In recent years a number of different regional climate models (RCMs) have produced subtly different estimates of ice sheet surface mass balance (SMB) for the Greenland ice sheet. While the total ice sheet SMB number is often similar from these, there can be substantial differences spatially and in terms of the components of surface mass balance: precipitation, melt, runoff, retention and sublimation. The substantial increase in the amount of observational data available from Greenland allows us to compare not only models and data but also to optimize models to get the best SMB estimates.
Using carefully designed sensitivity experiments we explore the importance of albedo, retention and refreezing parameters choices, precipitation, model resolution and topography in HIRHAM5, a typical RCM run at 5km resolution over Greenland, to create the best possible representations of surface mass balance of the Greenland ice sheet.
Our analysis shows that the 5km resolution of HIRHAM more accurately captures precipitation over the ice sheet, compared with the old 25km resolution. Compared with 68 ice cores from the accumulation area the simulated mean annual net accumulation bias is -5% (correlation coefficient of 0.90).
The retention scheme of the model is able to reproduce the subsurface temperature structure and occurrence of perennial firn aquifers and perched ice layers. However, small differences in parameter choices, while important locally, are not significant over the whole ice sheet. Modelled SMB compares favourably with 1041 PROMICE observations. Varying parameter choices means that a regression slope of 0.95-0.97 can be obtained (depending on model configuration) with a correlation coefficient of 0.75-0.86 and mean bias -3%.
Our experiments clearly show that albedo choices are more important to modelled SMB than retention parameters. We use either an internally calculated or MODIS driven albedo in our experiments. These give biases in runoff in the ablation area between -5%, using MODIS, and -7% with the internal albedo scheme. However, comparison with observed melt day counts shows that patterns of spatial and temporal variability are realistically represented in both types of simulations.
Finally, a series of experiments where ice sheet topography is evolved according to SMB estimates imply that ice sheet models need to include feedbacks between topography and SMB when modelling the dynamical evolution of the Greenland ice sheet.