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The need for water vapor fluxes in long-term modeling of the Greenland ice sheet

Tobias Zolles (1,2) and Andreas Born (1,2)

(1) Department of Earth Science, University of Bergen, Bergen, Norway (tobias.zolles@uib.no), (2) Bjerknes Centre for Climate Research, Bergen, Norway

The surface mass balance is one of the main drivers altering the mass and shape of the Greenland ice sheet (GrIS). Conventional ice-models for studies on longer time scales, like glacial cycles, use rather simple temperature dependent melt models for simulation of the surface mass balance due to their low computational costs. For a better understanding and more accurate simulations a more complex model would be desirable. We present the Bergen Snow SImulator (BESSI), an efficient mass and energy balance firn model designed for such long-term simulations of the Greenland ice sheet. This type of models require calibration of the parameterizations often based on present-day observations. However, the invariance of the parametrizations on longer time scales is not guaranteed. Therefore, we conduct an extensive sensitivity analysis of various model variables including the surface mass balance, the turbulent latent heat flux and the surface albedo for 500 years of present day (PD) climate as well as for the last glacial maximum (LGM).

Our results show that the most important parameters in our model are related to albedo, the incoming longwave radiation and the turbulent latent heat flux. We observe an increasing importance of the latent heat flux in the cold and dry climate and the scarcity of precipitation during the LGM. The largest sensitivity was found within the parametrization of the longwave radiation and the latent heat flux. The model is also sensitive to the snow albedo and the associated parameters, but the incoming longwave radiation dominates. The albedo representation uses four different parameterizations and the choice thereof is most relevant during warmer periods.

The distinct variation in the sensitivity of the parametrizations and related energy components indicates a clear dependence on the climate. The turbulent water vapor flux has to be included to simulate the surface mass balance over longer time scales in cold climates. We identified the key uncertainties of our surface mass and energy balance model which lie in the incoming longwave radiation and the albedo parameterization. In the absence of sufficient calibration data the focus should be on those components.