Geophysical Research Abstracts
Vol. 13, EGU2011-2152, 2011
EGU General Assembly 2011

Spatial and temporal uncertainties in the surface mass balance of the Greenland ice sheet from a model intercomparison

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The surface mass balance (SMB) of the Greenland ice sheet has been determined for the last 50 years through a combination of observations and modelling. About 60 percent of the increase in loss from the ice sheet over the last decade was due to changes in SMB and the remainder to discharge. It has been suggested that processes controlling SMB are well constrained compared to discharge. Observational evidence to support this suggestion is limited, however. One approach to investigating uncertainties is through a model inter-comparison. Here, we compare four different simulations of the SMB of the ice sheet over the last five decades. Three use a regional climate model to downscale ECMWF re-analysis (ERA-40) and operational analysis data from 1958-present day, while the fourth uses the same inputs but an empirical downscaling approach and melt model.

In a previous study we compared time series of annual precipitation, melt, refreezing, runoff and net SMB to investigate the gross level of agreement between the reconstructions. There was good agreement, not surprisingly, in the phase of inter-annual variability in the various terms, as this is controlled largely by the common forcing (ERA-40). The amplitudes in inter-annual variability, however, differed by as much as a factor two, while the absolute magnitudes of the individual terms that contribute to the SMB show systematic differences as large as a factor 3. Inter-model differences in melt production, for example, deviated consistently by about 100%. Despite the very large differences in the individual terms, the SMB between models showed greater consistency and agreed to within the standard deviation of the temporal variability. This suggests that a cancellation of errors in one or more of the models may be responsible for the agreement in SMB. The results also indicate that the models would likely have significantly different sensitivities to a secular trend in climate forcing.

Lastly, we examine the spatial pattern of the SMB components and, in particular, runoff and precipitation. Marked differences exist in both the gradients and distribution of these components, which, in the case of precipitation are likely partly resolution related. In the case of runoff, the different methods for calculating this term appear to be responsible for the discrepancy in ablation area and gradients. We conclude that significant uncertainties exist in estimating components of the SMB of the ice sheet for the recent past, and near future.