The Cryosphere Discuss., 1, S122–S125, 2007
www.the-cryosphere-discuss.net/1/S122/2007/

The Cryosphere
Discussions

Interactive comment on "Reconstruction of the 1979–2006 Greenland ice sheet surface mass balance using the regional climate model MAR" *by* X. Fettweis

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Received and published: 14 August 2007

I want first to thanks the reviewer #3 for his constructive remarks and his propositions to extent this study.

- The reference of Tedesco (GRL, 2007) will be added in the introducing discussion.
- The reviewer asks a very interesting question about: "Why the model results for the SMB components are so different ?
  1. Firstly, each model has its own ice sheet mask. A too large ice sheet mask (i.e. with pixels, low in altitude, where there is no ice in reality) leads to

an overestimation of the runoff (as discussed in Section 3.1 for the MM5 results). A model with a too small ice sheet area will rather overestimate the SMB. In addition, due to the albedo feedback, biases in the ice sheet mask will also have an impact on the surface energy balance.

2. Secondly, the resolution (and then the topography) used in a model can have significant influence on the simulated SMB because the ablation zone where substantial seasonal melting occurs, is not wider than 100 km in Greenland. A too coarse resolution prevents to resolve adequately in the model the steep ice sheet margin and the ablation zone. (I plan to investigate with the MAR model these two points by varying the ice sheet mask and after the resolution with the same model setup.)

3. Thirdly, the modelled results are very sensitive to the spin-up time used in the snow model. At the beginning of a summer, the ice sheet and the tundra have to be covered with the winter snow accumulation. Either precipitation climatologies or reanalysis are used to initialize the snow model at the end of the spring, or the winter accumulation is simulated by the model itself by beginning the simulation at the end of the previous summer. Previous MAR simulations showed a very large sensitivity to the initial snow height and the snow properties above the tundra and the ablation zone given the albedo feedback (Lefebre et al., 2005). Too large a snow pack height at the beginning of the summer above the ablation zone puts back the appearance of bare ice (with a lower albedo) in the ablation zone and can considerably reduce the melt. That is why it is preferable to begin the simulation at the end of the previous summer (or several years before) to reduce the problem of the snow model initialization. Differences in the initialisation method could also explain disagreements between the models.

   With the MAR model, a spin-up of 3 years are needed to reduce at maximum the impact of the initialisation of the snow model. This was found by comparing/recovering simulations from different initialisation dates. These considerations allowed to launch in parallel (to save CPU time because MAR is not yet parallelized) a series of shorter simulations (with a spin-up of 3 years) beginning each time on different dates which I gathered to form the 28 years afterwards. Remote sensing data could be useful to reduce the spin-up by initializing the snow pack with conditions closer to the reality.

The surface in the MM5 model is reinitialised every day with a spin-up time of 6 hours because MM5 is used in a forecast mode (Box et al., JGR, 2004). To reduce the impacts of the reinitialisation, MM5 is however driven by data (SMB measurements for the GC-Net AWS's and remote sensing derived surface albedo) independent of the ECMWF atmospheric analyses used to force the model at its boundaries (Box et al., JofClim,2006).

4. Part of disagreement between the models come also from large differences in the processes resolved by the snow model and the coupling with the atmosphere. The MAR climate model has a complex snow model fully coupled with the atmospheric module running at the same resolution (i.e. 25km). The MM5 model is an atmospheric weather model running at a resolution of 24km coupled with a very simplified snow model (to my knowledge) but it is the only one taking into account the blowing snow erosion. The snow pack properties in MM5 comes mainly from direct measurements which drive the model during the simulation. The Hanna et al. (2007) estimations use a complex snow model running at a resolution of 5 km forced by monthly mean atmospheric fields from the ECMWF (re)analysis available at a resolution of 110km. The Mote (2003) estimations use a PDD model at a resolution of 25 km forced by the SSM/I brightness temperature and by the Bromwich et al. (2001) accumulation time series.

5. Finally, each model has biases. The MM5 model is recalibrated during the simulation and the estimations from Hanna et al. (2007) are recalibrated after the simulation. The MAR outputs are not recalibrated while this would improve our modelled results.

- The MAR albedo and the MAR melt extent had been successfully validated previously with remote sensing data in Fettweis et al. (2005, 2006). It would be very interesting to extent this validation with the last available remote sensing data i.e. accumulation (Thomas et al., 2006) and melt estimate (Tedesco, 2007) as suggested by the reviewer #3. We can also imagine to use these remote sensing observations during the simulation itself to improve our modelled SMB results. The remote data (albedo, liquid water content) can easily detect the presence or not of bare ice/fresh snow in the ablation zone in summer. If disagreement between MAR and remote data, the MAR snow pack would be updated knowing that an accurate apparition in time of the bare ice in the ablation zone in summer has a great impact on the simulated SMB. Applying these changes during the simulation (against after the simulation) allows to take directly into account in the model the feedback mechanisms of the bare ice apparition.

- In addition, as a future work, it should be wonderful to validate the MAR runoff with satellite derived observations (The runoff rate could be derived from changes in the LWC of the snow pack). The runoff rate is different for each model (see table 1 pg 147) and is a great uncertainty in the current SMB estimations because no observations are available to validate this flux. The sea level rise and perturbations of the THC depend of this flux. With the global warming, this flux could quickly increase but as it is still unknown currently, it is difficult to make accurate projections. The remote sensing could help us to have a better idea of the runoff rate independently from models. This can help to validate the models afterwards.

Interactive comment on The Cryosphere Discuss., 1, 123, 2007.