

Interactive comment on “Simulating melt, runoff and refreezing on Nordenskiöldbreen, Svalbard, using a coupled snow and energy balance model” by W. J. J. van Pelt et al.

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We are very grateful to the reviewer for giving useful and constructive comments. Our reply to the issues raised by the reviewer is given below:

General comments:

RC: An important weakness of the study is that no attempt has been made to incorporate ice dynamics in the calculation of glacier mass balance. This is recognised by the authors, however, and its difficulty is understandable without measurements of ice thickness. Potential changes to the hypsometry of Nordenskiöldbreen, however, either in the past or in the future may have a considerable effect on the cumulative surface

C351

mass balance of the glacier. It would strengthen the paper substantially if the authors could show that the reasonable magnitude of such changes likely to occur/have occurred within their study time period would not significantly impact their calculations.

AC: Our main intention with presenting the mass balance time-series was to give the reader an idea of the relevance of accounting for seasonality in climate change scenarios and to put the simulated mass balance for the period 1990-2010 into a longer term perspective. As the reviewer mentions, ice dynamical factors may lead to a significant uncertainty in mass balance estimates over longer periods of time. Estimating this uncertainty seems only possible when the mass balance model is coupled to an ice flow model, which is beyond the scope of this study. It is therefore hard to put an error bar on the presented mass balance time-series and mainly because of this (and after consulting the other reviews), we decided to leave out these longterm time-series and we applied a different approach to achieve the goals of demonstrating the relevance of accounting for seasonality and putting the simulated mass balance into perspective. The importance of accounting for seasonality in future climate change scenarios is clearly demonstrated in the climate sensitivity section and does not need much more explanation. Comments on the role of refreezing in a changing climate are added to this section. In order to put the simulated mass balance over the period 1990-2010 into a historical perspective, the final paragraph of the climate sensitivity section has now been extended and discusses trends in temperature and precipitation at a seasonal scale during the 20th century and discusses this in relation to the SSC (figure 14) to determine a trend in the mass balance and indicate seasonal variability in climate change. In addition, in this paragraph a discussion will be given of uncertainties in mass balance estimates over long periods of time and it will be motivated why not to present the time-series. Note that these changes hardly affect our main conclusions.

Specific comments:

RC: (212, 10-12) “a major impact on future mass balance and ELA estimates” – could the nature of the impact be stated more specifically in the abstract.

C352

AC: Reformulated to: "reduces the sensitivity of the mass balance and ELA estimates in a future climate"

RC: (214, 23) I would change the title of this section, the word "grid" seems out of place. The resolution of the DEM should also be stated somewhere in this section, presently I don't think this is given until the numerical set-up is discussed in section 4.3.

AC: We decided to leave out the word "grid" and rename the section to "Nordenskiöldbreen" and a statement about the grid resolution is included.

RC: (215, 2-5, 21-22) a reference should be given for this GPR work.

AC: It is now mentioned that this involves data gathered during fieldwork in 2010.

RC: (216, 5) The altitude of the AWS should be given here.

AC: This has been added.

RC: "The mean observed precipitation rate at Svalbard Airport (27 m a.s.l.) over the period 1989–2010 of 191 mm is used to compute a mean altitude of 971 m a.s.l. above which precipitation is constant." I think this sentence probably needs some more explanation.

AC: Agreed. It now reads: "The precipitation rate at 27 m a.s.l. is set equal to the precipitation rate at Svalbard Airport and above an altitude of 971 m a.s.l. the precipitation rate is assumed to be constant. The altitude of 971 m a.s.l. is chosen such that the parameterized mean maximum precipitation rate is equal to observed mean maximum precipitation of 540 mm per year found by Pälli et al. (2002) on Nordenskiöldbreen for the period 1963-1999."

RC: (216, 25-27) Could the RACMO grid resolution be given somewhere here.

AC: Included. (11 km resolution)

RC: (217, 24-25) "We therefore decided not to use RACMO data for those variables for

C353

further analysis." Could this sentence be replaced with a concise description of what was used instead?

AC: Reformulated to: "We therefore decided not to use RACMO data for those variables for further analysis and use the aforementioned Svalbard airport data instead"

RC: (219, 22) slope "aspect" and "gradient" should probably replace "orientation".

AC: Fixed.

RC: (220, 17-20) This sentence could do with re-writing.

AC: The sentence now reads: "Finally, the glacier heat flux, which depends on the conductivity of the medium and the vertical temperature gradient, is computed by extrapolation of subsurface heat transport in the two uppermost firn layers to the surface."

RC: (224, 3-8) I would like to be convinced here, or somewhere else, that dynamic changes to the glacier hypsometry do not have a substantial effect at the timescales which you are interested in.

AC: They might have a substantial effect and we therefore applied an alternative approach. For further details we refer to the earlier general comment.

RC: (224, 20-22) This sentence does not make sense in its current form.

AC: Reformulated to: "Fresh snow is added at the top of the snow model with a density ρ_{fs} of 300 kg per m³".

RC: (229, 19-21) This may be true, but the results are later used to extrapolate the mass balance right back to 1912, when calving would certainly have contributed significantly to the mass budget.

AC: Calving is indeed an uncertain component in the total mass budget of this glacier, especially further back in time. We therefore aim to present the surface mass balance rather than the total mass balance. The following sentences will be added here: "Al-

C354

though the glacier snout has partly retreated on land over the course of the simulation period, the mass loss by calving may still have been significant. Estimating the mass loss by calving is hindered by the absence of frontal velocity and ice thickness estimates during the active calving phase. Hence, in this study we will only discuss the surface mass balance of the glacier." As mentioned before the extrapolation to 1912 is no longer included in the paper.

RC: (237, 11-12 and 24-25) "The time-series are scaled to match the simulated gridded mean for Nordenskiöldbreen for 1990–2010." – What is the scaling factor? This sentence is a bit vague at present. It is also repeated later on but again without the relevant details.

AC: This approach is no longer used.

RC: (240, 1-5) These ice dynamic factors may be quite important, but are only very briefly mentioned. I appreciate that predicting the dynamic response of the glacier is a completely different study, but some estimates of the maximum/minimum effect of realistic hypsometric changes might be possible and would substantially improve the validity of Figure 16, for example.

AC: Agreed, A different approach is now used to avoid presenting uncertain time-series without being able to give error estimates (requires coupling to an ice flow model).

Technical corrections:

RC: The +/- symbol appears to have cropped up several times where it isn't supposed to be.

AC: This has been fixed. Some have been replaced by the tilde symbol, others were left out.

RC: You should always have a space between a number and its unit.

AC: This somehow went wrong during the production phase.

C355

RC: Figures with multiple parts should be described either before their identifying letter is given in the caption or after, currently there is a mixture of both.

AC: This has been corrected.

All additional suggested small technical corrections have been applied.

Interactive comment on The Cryosphere Discuss., 6, 211, 2012.

C356