Review of Rückamp et al. “The effect of overshooting 1.5C global warming on the mass loss of the Greenland Ice Sheet.”

General comments:

This manuscript presents future volume evolution scenarios of the Greenland Ice Sheet under three different surface mass balance forcings. Atmospheric forcing is provided by three global climate models and the surface mass balance is computed with a relatively simple surface energy balance model. The ice-sheet model employed, is the state-of-the art ISSM model with higher order ice physics. The sea-level rise projections from surface mass balance perturbation alone are between 46-71 mm by 2100 and 114-189 mm by 2300.

The topic of the manuscript is of interest to ice-sheet modellers as well as the wider cryospheric community. The overall structure of the paper is logical but some sections would benefit from a tidy-up and the language is hard to follow in some places. While the results are certainly not groundbreaking and omit any contributions from ice dynamics, I think the manuscript presents enough novelty and hence merits publication subject to consideration of my comments listed below.

Specific comments

The study’s strong point from an ice-sheet modelling perspective is the model initialisation which combines the two commonly employed spin-up and data assimilation techniques. The main focus is, however, on the surface mass balance forcing with the SEMIC model. In the light of this and the importance of the surface mass balance forcing, for someone that is not familiar with the SEMIC model, I am missing a succinct description of the model fundamentals and the configuration used in this manuscript. Furthermore, the entire manuscript would benefit from some reordering and substantial improvements to certain sections and improvements in readability of some figures (detailed below). My main concern is with the calculation of the surface mass balance anomaly for the projections. Please find below my main concerns, followed by specific comments.

Main concerns:

1. My main concern is the calculation of the surface mass balance anomalies. First of all, I understand that you account for the model drift by adding a synthetic SMB correction term (SMB_{corr} in Equation 3). But what dh/dt is applied – an average of your unforced relaxation run from 1960-2060 or the last or first time step of this relaxation simulation? How can this term be time-varying in your projections? On page 9 line 20 this time-varying SMB_{corr} term is used as an explanation for spatial differences in the SMB pattern. Maybe I missed it, but it would help if you clarified this.

2. The more critical point is how you compute your ΔSMB in Equation 3. The way I understand it and please correct me if I am wrong, Equation 3 states that SMB_RACMO plus your correction for the model drift should give you an SMB that keeps your ice sheet close to steady state (or at least present geometry). The applied perturbations are however calculated with respect to the SEMIC model baseline. If

you use your RACMO_SMB to keep your ice sheet in steady state, you should also calculate your anomalies with respect to your SMB_RACMO field. If not, your perturbations to the surface mass balance appear a bit arbitrary. Would it not be more consistent to use the SEMIC output? The argument that your model drift gets larger is rather weak, considering that you would just get a larger SMB_{corr} term from the unforced relaxation simulation.

3. I think the section "Input data" should be removed as this mostly repeats earlier statements (e.g. Greve 2005 dataset). The basal drag inversion should be moved to the "Initial state" section as this is where it is most appropriate. I would introduce a section "Results" which would start with the subheading "Forcing fields" and continue with "Present day elevation and velocities". The heading "Projections" followed by "Present day …" was confusing. I would suggest to add "projections" where appropriate e.g. Mass loss projections, Speed up projections etc.

4. Please provide a more complete description of the SEMIC model than the few lines provided on P6 L15-22. You also claim to have improved the albedo parameterisation, but to me it is not clear how or to what extent. Please expand on this.

5. I am certainly not an expert on ice temperature, but to me the following questions came up when looking at Table 2. Are there no temperatures from observations for EastGRIP? Why are there such large differences in basal temperatures between the Greve (2005) and Shapiro and Ritzwoller (2004) maps at the selected locations? Does this mean that temperature in these regions is dominated by the geothermal heat flux and that this heat flux is that different at these locations? Why do the simulated temperatures do not agree with GRIP temperature observations?

Technical corrections

Abstract

L2 "…sea-level change under different atmospheric forcing scenarios from …"
L11 Sentence starting with "Simulated an observed sea-level rise…" That makes no sense to me. Is it simulated or observed? I believe you are trying to say that your simulated sea-level rise for the period 2002-2014 matches sea-level rise from observations in magnitude? Please clarify.

P1L19 delete second "past decade"
P1L22 Delete "Obviously, …"
P2L1 „engaged"? Do you mean encouraged?
P2L20 "…provided by …"
P2L27 replace "." with ","
P2L27 Sentence starting with "ISSM is designed to … " Is this really important for the paper? Also while I welcome the fact that the authors kept the details of the ice-sheet model brief, I would appreciate if you could add what higher-order physics you used (Blatter-Pattyn, Stokes or SSA)? Please add to ice-flow model section. Also, can elements be either Stokes or SIA? Do you mean that for each element you can choose what force balance is solved?
P3L2 "…surface mass balance and climate forcing"
P3L19 "compensates"

P3L20-21 “…according to a sub-grid paramterization scheme,…”
P3L24 “… towards the base where vertical shearing becomes more important.”
P4L4 Delete sentence starting with “Furthermore, the themo-mechanically …” I think it is obvious that if you simulate ice temperatures that your simulations are sensitive to temperatures.
P4 L5-13 and Table 1 I do not completely understand when you start your mesh refinements? The way I understand your initialisation method is that you run your temperature spin-up with mesh sequence 1, then you do an inversion for basal friction parameters and run your temperature spin-up again with a refined mesh before you do another inversion on the refined mesh? Please describe this more clearly.
P5L4-7 Please reformulate this sentence. It is too long. Also please delete “aim” as this implies that you are not sure it is going to work. Your results show that it clearly does work.
P5L10 Could you explain why the three GCMs were selected as forcing? So far this choice appears a bit random.
P5L20 This sentence is unclear. It reads like Greenland warms above 1.5°C but you are talking about ΔT I believe. Also, could you state more clearly that you are comparing it to the global temperature increase in the GCMs..
P6L3 Sentence starting with “While HadGEM2 … “ makes no sense to me. Leading to similar factors? What factors?
P6L8 “reaches”
P6L8-9 This sentence has to come earlier as it is indeed very striking, but also expected.
P6L9 Please delete “Summarizing”
P6L17 Please delete “Due to the fact that Krapp et al. (2017) performed calibration over GrIS”
P6L28 “We follow …”
P7L4 Here and throughout “the ISSM”=”ISSM”
P7L5 very well = well
P7L14-16 This statement needs a citation. Is this true for Greenland? I doubt that every data assimilation initialization leads to a 3% ice volume gain.
P8L5 By doing so = This ensures that
P8L14-15 espectively=respectively
P9L4 “leads to an increase in temperatures …”
P9L5 “exceed 2°C of warming”
P9L6 and P9L8 Be more specific. By how much? Numbers please!
P9L13-15 Please explain this. Why is this the most plausible? It is not apparent to me.
P9L16 delete first “as”
P9L19 here and throughout vallies=valleys
P9L20-21 See main comment above. How can this be time-varying?
P9L27 “The magnitude of ΔSMB is far less in the period 2300-2000…”
P9L31 which pattern? Spatial or temporal or both?
P11L14 Again why is this the most plausible pattern? Please elaborate.
P11L33 “… experience acceleration across all simulations.”
P12L8 levelled out = balanced
P12L17 “…ice sheet loses contact with the ocean.”
P12L17 resolution = grid resolution
P12L28 “considerably large”. What does this mean? Be more specific!

Figures:

Figure 1: Can you make the line for 1.5°C bold to aid visibility when the models pass this threshold?
Figure 3: Question mark before “C” symbol in Figure. Colour bar is too small. As it is the same magnitude for all panels one big colour bar should suffice.
Figure 4: See comments for Figure 3
Figure 6: Again, use one colour bar per panel. Also, please have colour bar labels on the same side of the colour bar and avoid overlap of axes labels with main Figure. Please align top and bottom panels properly.
Figure 7: Again bigger axes labels and legends.
Figures 8 and 10: See comments for Figure 3

Sincerely, Clemens Schannwell