

## ***Interactive comment on “SEMIC: an efficient surface energy and mass balance model applied to the Greenland ice sheet” by Mario Krapp et al.***

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We thank Xavier Fettweis for his helpful comments and for the pointing out the clear distinction between MAR and its snowpack model. Xavier raised some valid points which we would like to address in our revised manuscript.

In the following we reply to each of the referee's comments. We highlight individual parts of the comments that we are going to address in italics. Our response is put below each comment together with our proposed changes to the manuscript; where these changes will appear in the revised manuscript is put in parentheses.

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## 0.0.1 1. Reference to MAR in the text

- [...] *SEMIC is comparable in fact to the snow model used in MAR [...] and [...] all the inter-comparisons of Surf Temp. and SMB components with MAR must refer to SISVAT (used in the MAR model) and not to MAR!*
  - We acknowledge that MAR is more than just the surface energy and mass balance model but we think that we already differentiate between SEMIC and MAR right in the beginning. For example, in the abstract we write that SEMIC is able *to reproduce surface characteristics and day-to-day variations similar to the regional climate model MAR* and that SEMIC is *in good agreement with the more sophisticated multi-layer snowpack model included in MAR*. For the sake of clarity and understanding we simply use the model name MAR whenever we refer to the surface snowpack model (i.e., SISVAT). However, to give reasonable credit to the MAR community should add a brief description what we exactly compare our model to.
  - We propose to add a brief description of SISVAT and its part in the MAR framework in Sect 2.5 (page 7). However, throughout the paper we are still simply referring to MAR output whenever a comparison to SEMIC is made.
- *Secondly, SEMIC does not allow to take into account the atmosphere-snowpack interactions. But, as it is forced by MAR, these feedbacks (and notably the albedo feedback) are taken into account here. This should be mentioned in the manuscript.*
  - That is true in the sense that atmospheric characteristics are prescribed and are not affected by surface properties simulated by SEMIC. This is because in this work we used MAR output for testing of SEMIC. However, since SEMIC calculates surface-atmosphere heat fluxes such latent heat,

sensible heat, and upward longwave radiation, in the future it is planned to couple SEMIC bi-directionally with an appropriate atmosphere model. Then atmosphere-snowpack interaction will be properly accounted for.

- However, we will add a brief explanation that the current setup only serves the purpose of mimicking the response of SEMIC to an atmosphere forcing but that the surface response cannot be not taken into account by the atmosphere.
- *Thirdly, it is true that MAR is very slow in respect to SEMIC [...] due to the physical atmospheric downscaling. [...] This should be mentioned in the manuscript.*
  - We do not want to blame MAR in terms of runtime. But explaining why a regional climate model needs more computational time is not within the scope of our paper. However, we can make clear that SEMIC and MAR are two different classes of models and we will add sentence about the distinction in the part above (Sect. 2.5).
- *Finally, the SISVAT snow model as well as the raw CROCUS snow model can be run in stand alone mode like SEMIC. Therefore, this shows well that this paper is well SEMIC vs CROCUS and not SEMIC vs MAR.*
  - We use the term MAR for simplicity but will stick to it, also because SISVAT is a component of the MAR model (see our first bullet point).

## 0.0.2 2. Calibration with MAR outputs only

- *I am a bit surprised that the calibration was only made over three years [...]. But 3 yrs is very short and a validation [...] over both 10 yrs periods (2090-2100 and 1990-2000) will be more robust.*

- We agree that a longer calibration period over both, present-day and future-warming conditions is more robust and would lead to more robust optimal parameter estimate. We changed the forcing data for the proposed periods, 1990-2000 and 2090-2100, but because of the computational overhead we used just a subset of the MAR data, i.e., a random sub-sample accounting for 20% of land and ice points.
- The calibration procedure will be thoroughly revised and extended in Sect. 3, Model parameter calibration (page 8).
- *[...] the sensitivity of the bare ice albedo value is not tested. In MAR, this one is the more sensible parameters (as explained in Fettweis et al., 2016). As SEMIC underestimates melt in respect to MAR, lower values of bare ice albedo can reduce this bias.*
  - Yes, the bare ice albedo has not been tested. We will add the sensitivity of bare ice albedo  $\alpha_i$ , as well as of bare land albedo  $\alpha_l$ , and the missed  $f_R$  to Sect. 3.4, Parameter Sensitivity (p. 10-11). Figure 6 will be also updated accordingly (page 22).
  - Note, that we will no longer use the Slater et al. (1998) albedo parameterisation (for reasons, see our response to referee #1). Therefore,  $\alpha_{s,\min}$  will no longer be part of the sensitivity in Figure 6 (page 22) and the text (p. 10-11).
- *MARv2 [...] overestimates the melt in respect to MARv3.5.2. A calibration/validation over current climate using the SMB PROMICE data set will be more robust. [...] I don't ask to recalibrate SEMIC over current climate using the SMB PROMICE data set but this issue should be at least mentioned in the manuscript.*
  - We know that with each model update several aspects of that model are being improved. However, with this paper we show that SEMIC can be a

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surrogate of a sophisticated snow-pack model and we prove it. The parameters will likely change if forced with different data and calibrated for different data.

- We will add a brief discussion of this issue in Sect. 5, Discussion (p. 13-14).

### 0.0.3 3. Cumulated SMB change

- *SEMIC seems to diverge from MAR after 2050. What are the total cumulated differences in 2100? For me, the calibration should be made to have the same cumulated SMB changes over 2000-2100 than MAR and not to have good results over 2098-2100 only. Due to error compensations, having a too high/too low SMB several years in respect to MAR is not a problem for an ice sheet model which will give the same results at the end than if it will be forced by MAR. The best will be to calibrate SEMIC over current climate when we have other estimations of cumulated SMB changes than MAR (van den broeke et al., TC, 2016).*
  - Yes, SEMIC diverges from MAR in the RCP8.5 scenario. We aim to be as close to MAR results as possible. But we cannot use the whole period of MAR data (i.e, 1970-2100) to calibrate our model. First, we need to strictly differentiate between training data and test data. We do so by defining the periods 1990-2000 and 2090-2100 as our training data. Second, it is computationally not feasible to use all MAR model years for the parameter calibration, which needs to be run several tens of thousands of times.
  - There is a valid point in this comment. That is to quantify the differences between SEMIC and MAR over time, i.e., the cumulative difference. For that reason we can add a figure, similar to Fig. 4, but showing the cumulative differences of mass balance terms over time, e.g., for the whole period 1970-2100 or for the historical and RCP8.5 period separately.

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- *Fig 2: the SMB zones shown in Fig 2 were only valid over the 1990's [...]. These boundaries are already no more relevant for current climate of the 2000's. This issue should be mentioned in the manuscript.*
  - We use the zones only to differentiate the major climatic regimes across the Greenland Ice Sheet. For example, on page 9, ll.3 we point out that the *regions crudely represent the main ablation zones at the ice-sheet margins (region 1), the main accumulation zone at ice-sheet interior*. However, we will remark here that the regions only represent different SMB zones for today's climate and may not be valid for any future warming scenario such as RCP8.5. (Sect 3.1, p. 9)
  - The only distinction *SEMIC* makes is between ice-covered and ice-free zones, i.e., land/ice mask. We will also add a remark to Fig. 2 to explain that the differentiation is only valid for present day. (page 18)
- *Fig 3: MAR/ERA-40 must be SISVAT/CanESM2. It should be interesting to show the differences over current climate (in supplementary material) when MAR is forced by reanalysis. This error in the legends means that such a comparison has already been done.*
  - Indeed, *MAR/ERA-40* output has been used at an earlier stage of our research. However, to minimize the number of different datasets used for that study, we decided to solely focus on *MAR/CanESM2* output for our calibration and validation process. The error in the legend has been changed accordingly.
- *Fig. 5: not useful => supplementary material.*

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- We disagree, while the maps in Fig. 3 provides a visual for the spatial (but time-averaged) differences between MAR and SEMIC, Fig. 5 provides a visual for the temporal differences between the two models. Having both figures in the main text will provide a more complete picture of SEMIC and MAR, both in space and time.
- *Fig. 8: showing an equivalent of Fig 4 with cumulated values will be more useful.*
  - This will be shown in a new figure that depicts the cumulative differences between SEMIC and MAR (see our last bullet point in the comment section 3, cumulated SMB changes).

Mario Krapp (on behalf of the authors)

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