

I would like to thank the authors for the effort they put in the revision of the manuscript. Please find below some minor additional remarks (line numbers refer to the revised manuscript with marked changes):

We appreciate that the reviewer has read through the manuscript again and helped us improve the clarity of the writing. We thank the reviewer for their comments and suggestions, and we have made changes to the manuscript accordingly.

### Point-comments

**L105:** I would specify the precipitation types that were used from MERRA-2 – e.g. “precipitation rate (convective/large-scale rainfall and snowfall)”

Thank you for this suggestion. We’ve changed it to **rainfall and snowfall**.

**Fig. 1:** You added degree symbols to this figure in the author’s response – but they are not present in the final manuscript (maybe you forgot to update this figure).

Thank you very much for pointing this out. You are correct that we forgot to update the figure in the manuscript after adding the updated one to the reviewer response. We have double-checked that the figures in the manuscript have been updated as reported in the response.

**Table 3:** You could refer to Sect. 3.2 here: “Undetectable signals (see Sect. 3.2) are...”

We appreciate this idea and have made the suggested change in the Table 3 caption.

**L291:** You could move the liquid-to-solid ratio (LTSR) computation to Sect. 2 (Methods and data)

Thank you for this suggestion. We have moved these lines to Section 2 and created a new subsection (Section 2.6) after the description of the firn air content calculation. The text and equation are the same.

**L317:** Now, I’m a bit confused. Do you set all grid cells that do not receive enough accumulation to build up a firn layer to NaN? It seems so from Fig. 6. That means that spatial averages (e.g. for FAC) are actually rather computed over the accumulation zone than over the entire GrIS – right? I think it would be useful to state this somewhere explicitly (in case you apply this method...).

We appreciate the reviewer pointing this out and we now understand how those added sentences create confusion. Many of the ablation zone grid cells do successfully build up a firn/ice layer over time. In Fig. 6, most grid cells within (and even some outside of) the black boundaries were successful. However, there were a few locations that are mostly along the southwest margin where accumulation was too low (or melt was too high) for a layer to build up over time. The 50% ice coverage threshold (Sec. 2.1) means that some grid cells are only half glaciated. This creates the chance for a snow/ice layer to not build up since the conditions for snow to accumulate and remain through the year may not be met. To clarify this, we have changed these sentences to now read as: **For example, if a grid cell does not receive enough accumulation to build up a firn/ice layer over time, we treat that grid point as missing data.**

Additionally, as to the comment on the spatial averages, we acknowledge that these values will be affected by the spatial coverage. However, the averages do not simply represent the accumulation zone (see Fig. 6 and the grid cells outside of the black boundaries). The spatial averages are for the modeled region, defined by the 50% threshold. There are grid cells both along the margin (where we expect low FAC) and in the interior (where we expect higher FAC) that returned NaN’s in the model simulations. It’s possible that these could even out the effect of missing data on the average, but it’s difficult to say with any certainty. Moreover, the grid cells in the east and northeast outside of the Rignot and Mouginot (2012) ice sheet boundaries have generally low FAC (Fig. 6), which may bring the spatial average down. All of this is to say that the spatial average is not representative of any region in particular. To convey this to the reader, we have modified this sentence in Section 3.2: “*These values represent all modeled grid cells, meaning they include some areas outside of the six basins defined by Rignot and Mouginot (2012).*” to now say **These values represent all modeled grid cells, meaning they include some areas outside of the six basins defined by Rignot and Mouginot (2012) and may not be directly comparable to other studies.**

We hope that these modifications and explanations help clarify this point of confusion.

**L401:** Value “52” inconsistent with table 3.

Thank you for pointing this out. This is a typo in the text, so we have changed “52” to **53**.

**L423:** Sorry, I did not notice this during the first review iteration. There seems to be a systematic deviation between the modelled and observed ice slabs – i.e. the observed ice slabs are typically located a bit more towards the interior of the ice sheet (and thus probably buried by firn). Is this an indication that both models underestimate the formation of (such buried) ice slabs?

This is an interesting point and we thank the reviewer for noticing. There are likely at least three possibilities for the different locations: (1) as stated in this comment, the models both underestimate ice slab formation in the near surface; (2) the coarse resolution of the MERRA-2 grid cells is insufficient for the spatial heterogeneity of ice slabs; and/or (3) the IceBridge flight lines do not sample the entire ice sheet. We have added to this line: ***though the observed ice slabs are located slightly up-glacier from the modeled ones on average***. We do not speculate as to why this is, since there are several potential options that are difficult to test.

### **Typos, phrasing and stylistic comments**

**L314:** “A few areas of missing data exist (see Fig. 6), which is caused by modelling issues in one or both firn models.”

Done.

**L354:** “sine wave” → “sine function”

Done.

**L435:** “than in any other subset”

Done.

**L436:** “models at greater (>10 m) depths.”

Done.

**L477:** “have higher model uncertainties” or “have a higher model uncertainty” (?)

Done.

**L552:** “atmospheric forcing and the variable densification schemes.”

Done.

**L581:** “at greater (>? m) depth.” (?)

We appreciate this suggestion, however, we have chosen to leave this as ***at depth*** because the depth in question could vary substantially based on annual accumulate rates (which also vary greatly across the ice sheet).

**L613:** “reveal significant differences but also perform well within a reasonable range.” (or similar...)

Done.

**L656:** “required conditions” (?)

Done.

**Fig. A1:** “which falls near many...” → “which agrees well with mean observed surface density.” (it’s probably better to mention this fact in the context of panel (b)).

Thank you for this suggestion. We have updated the sentence as suggested and reorganized the caption. It now reads:

**(a) Observed surface density ( $\rho_0$ ) from SUMup versus SNOWPACK. Since some observations begin farther below the surface, in this figure, observed  $\rho_0$  is defined as the uppermost density measurement that is within 0.1 m from the surface. The SNOWPACK  $\rho_0$  is calculated over the same vertical segment as the SUMup observation. (b) Histogram of observed surface density with the mean represented by the black line. The CFM-GSFC uses a prescribed surface density of 350 kg m<sup>-3</sup> (green vertical line in both panels), which agrees well with the mean observed surface density.**

Review of Thompson-Munson et al.: An evaluation of a physics-based and a semi-empirical firm model across the Greenland Ice Sheet (1980–2020)  
by Vincent Verjans.

This study applies two state-of-the-art firm models at the scale of the Greenland Ice Sheet (GrIS). The Community Firm Model is used with the semi-empirical NASA GSFC-FDMv1.2 .1 densification scheme (CFMGSFC). SNOWPACK is a more physically-detailed snow compaction model. The goal of this study is to compare results from these two different approaches to firm modeling over the GrIS. The authors also perform a comparison of model output against in-situ firm core observations. The authors have thoroughly reworked the manuscript since its first version. This includes an improved evaluation of model output with respect to firm core data, and a better interpretation of the results. This review only includes specific comments, which are still important to be addressed. I recognize the thorough work of the authors to address all my comments from the first round of reviews, and I sincerely appreciate their extensive answers in the author responses. Provided some very minor issues in the updated manuscript are addressed by the authors, I encourage the publication of this study in The Cryosphere.

[We thank the reviewer for again reading and reviewing the manuscript. We appreciate the suggestions and comments and have updated the manuscript accordingly.](#)

Specific comments

I 45-46

Change “in both observations (e.g., Vandecrux et al., 2019; Benson, 1996; Braithwaite et al., 1994; Sørensen et al., 2011; Kuipers Munneke et al., 2015) and models (e.g., Medley et al., 2022)” to “in both observations (e.g., Vandecrux et al., 2019; Benson, 1996; Braithwaite et al., 1994) and models (e.g., Sørensen et al., 2011; Kuipers Munneke et al., 2015; Medley et al., 2022)”.

[Done.](#)

I 69

Change “densification based constitutive” to “densification based on constitutive”.

[Done.](#)

I 82

Change “e.g. “ to “e.g., “.

[Done.](#)

I 124

Change “from the MERRA-2 grids” to “from the MERRA-2 fields”.

[Done.](#)

I 131

Change “in adjacent layers” to “between adjacent layers”.

[Done.](#)

I 149-150

Change “it is important to specific” to “it is important to specify”.

[Done.](#)

I 156-159

I suggest removing the sentences “The CFM-GSFC uses a layer-merging scheme at 5- and 10-m depth to reduce computational demands. The CFM-GSFC is coded so that each model time step adds a new layer. As such, daily time stepping generates many thin layers.” And changing the next sentence to “To reduce computational demands associated with many daily accumulation events, we use the CFM-GSFC’s layer merging scheme.” This makes the text less repetitive.

[Done.](#)

I 227

Add a comma: "In these shallow cores, where densification".

Done.

I 248-249

Change "values comparable to" to "values comparable or improved with respect to".

Done.

I 284-285

Remove ", which represents the averaged difference in FAC between the two models," because this is an incorrect definition of the RMSD.

Done.

I 355

Specify "remains relatively constant (Fig. 9a, 9b)" to make clear that this statement refers to the northwest and central west basins.

Done.

I 413

Change "Verjans et al., 2021" to "Verjans et al., 2019".

Done. Thank you for noting this citation error (both here and below).

I 511

Change "is likely" to "are likely".

Done.

I 539

Change "not often well-represented" to "often not well-represented".

Done.

I 542

Change "Verjans et al., 2021" to "Verjans et al., 2019".

Done.

I 549

Change "Model error is higher in comparisons with deeper cores than in shallower ones" to "Model error is higher with respect to deeper cores than to shallower ones".

Done.

I 569

Change "from a model" to "from a regional climate model".

Done.

I 581

Change "drawback" to "drawbacks".

Done.

I 582

Change "biased toward available observational data" to "constrained toward available observational data".

Thank you for this suggestion. We have changed this to **constrained by available observation data**.

I 582-583

Change "This may result in more realistic simulations of firm properties under future climate conditions," to "This avoids simulations beyond the calibration range of the firm model under future climate conditions,".

Done. Thank you for this suggested rewording that improves the meaning of the sentence.