Review of (revised version of)
Improved representation of the contemporary Greenland ice sheet firn layer by IMAU-FDM v1.2G
by Brils et al.

Reviewer: C. Max Stevens

General comments:

I appreciate the work the authors have done to address the comments from the other reviewers and me on the previous version of the manuscript, and I think the current version is a significant improvement. I recommend that the paper be published after minor edits. I have provided line-by-line comments only. The gist of most of my comments has to do with writing clarity: in numerous places I found explanations to be unclear, and in some cases I was looking for more details about methods or assumptions.

21: the word 'by' occurs 3 times in this sentence

27: I think you mean changing the mass, not changing the mass balance – mass balance in my mind refers to the mass sum of accumulation and ablation processes.

34: Not sure if it is worth mentioning here or following paragraph, but recent work by Rennermalm et al. (2022) suggests that pore-space loss (in SW Greenland, at least) is not entirely irreversible.

50: be specific of what kind of observations – density? Temperature? Depth-age?

52: can you give an example or two of a coupled RCM/firn model?

59, Section 2.1, and Section 3: You define v.1.2G on line 59, but you do not in the paper explicitly define what v1.1G is – is that model version described in Kuipers Munneke et al. (2015)? Given that section 3 is mostly comparing the outputs from the two versions, I think that more detail is needed at the start of section 3 describing the comparison. For example, at the end of the paper I was still not sure if the v1.1G and v1.2G results were both produced using the same version of RACMO (i.e. the same forcing) with different FDM physics, or if the v1.1G is uses a different, older version of the RACMO forcing. A short paragraph describing the two model runs that are being compared will help.

71-72: this neglects to mention Section 5. If you are outlining the paper with this amount of detail I think it is worth mentioning that section as well.

159: This is written as if you have already introduced the new set of observations; I suggest "In order to calibrate Eq. 3 to a new, expanded set of observations (Section X.X), we …". Also, consider rewording here to indicate that MO is changed from the previous model version but retains the same general form.

169: I think there is an issue of confusing wording – I would think that the previous calibration used 22 cores and the new calibration used 29 – but this implies that previous calibration used an expanded data set? Reading forward to section 2.4, it is a bit unclear also – there are 123 observations. Those are used just for evaluation? I think it would be helpful if you added 1-2 sentences in section 2.1.2 describing the new observations used in the present work, or add a bit more detail in section 2.4 (in which case make a reference to 2.4 in section 2.1.2) about the data that were used for the new calibration. (I am not suggesting you list all the calibration cores; rather, just add a bit of text differentiating the calibration data and the evaluation data. E.g., are the calibration cores a subset of the evaluation data, or do you keep them separate?)

176: I think this is what you get at in the following paragraph, but you could be more explicit here: the very low r^2 value for MO_{550} indicates that the linear model is not any better than just using the mean of the data (0.67). So: does the new model use the α_{new} and β_{new} for MO_{550}, or do you just use a value of 0.67? If the former, can you further justify your choice given the low r^2?

239: I agree with you that this is probably a fine assumption to make on the spatial scales you are looking at – but I would appreciate a bit of discussion on the implications of that vis-à-vis the discussion of ice lens formation in your introduction: can thick ice lenses/slabs form while using this assumption, or is it necessary to be able to include ponded water?

298: Ok, now I see that you are using 92 cores and the fitting cores are included. I think it would clarify your paper if you add a bit more detail in Section 2.4 about the observations and how you are using them. For example, I was expecting that you used 123 cores based on reading the start of section 2.4. Now I see that the number 123 refers to observations in general – it would be much clearer if you specified e.g., 'we used 92 depth-density profiles, X depth-temperature profiles, and one observation of meltwater intrusion', or something along those lines.

306: "up to a depth" is colloquial and somewhat self-contradictory (up is the opposite of depth perhaps?).

310: comma after FAC, and remove word 'obviously'.

Figure 10: is it possible for you to label the study sites on the figure?

331: please add units on 2.0x10^3. (And note: I think these should be formatted with a latex \times rather than a dot.)

345: It seems that you are initially talking about Das 2 (336), and then it seems here you are talking about Summit? Which is it? Looking at the figure, I am guessing that you may have mislabeled Summit as Das 2? If it is indeed Das 2, please consider changing the figure to be for Summit rather than Das 2 to be consistent with your section 4 (i.e., you provide specific information about Summit, but not Das 2.) Likewise, consider changing Figure 1 to be density at one of your 3 case study sites.

351: The new model does fit the upper density better, but it is still a rather large misfit in the upper firn. I would like to see a bit more discussion of what is causing that misfit, or at least acknowledgement that there is a deficiency in the model at this sort of site – and I don't mean to pick on this model in particular, because it is a deficiency in firn models in general probably.

360: I know this was picked out in the previous reviews, and it is still not entirely clear: first you say that RACMO2 has a cold bias, but then you say it has a warm bias. Are you saying that the RACMO biases vary spatially? I think changing the text here a little bit will clarify this significantly. Perhaps the issue is the word 'model' – RACMO2 is a model (RCM), and the FDM is also a model – so when you say "a persistent warm model bias remains", it is not clear if you mean a persistent bias in RACMO or resulting from FDM physics.

371/Figure 8: It is not clear to me that the temperature maximum is the refreezing depth – can you justify further why this maximum is assumed to be the refreezing depth? Further, the width of the blue summer DYE-2 temperature curve at ~1m depth (the maximum) would indicate to me that diffusion has happened rapidly, not slower as you posit; i.e., a melt event would cause the firn to be at the freezing temperature, causing a large temperature gradient, which will diffuse much faster than a smaller temperature gradient. I am willing to believe your explanation, but in their current form the explanations seem incomplete.

392: How are you calculating RMSE of penetration depth and volume fraction? E.g. is one time step in the model compared with one observation over that time period? What is the temporal resolution of the upGPR data? Are you including all of the zero-water periods in your RMSE calculation?

438: change 'like': "… in exceptional years; for example, 1983 was …" (and change to past tense "was")

459: I appreciate the work done for these uncertainty analyses. Can you provide a bit more information that summarizes these sensitivity runs? It is not clear to me from the text for example how many runs were done, and I am curious if the accumulation, melt, and temperature variations were applied in simultaneously in single run? You say one-by-one, but the ensuing sentences do not make it clear if each sentence describes one of those runs or several runs. Perhaps a table in the supplement might work? E.g.

Run #	Variation
1	Increased Density by X
2	Decreased accumulation by Y%

Rennermalm, Å, Hock, R., Covi, F., Xiao, J., Corti, G., Kingslake, J., . . . McConnell, J. (2022). Shallow firn cores 1989–2019 in southwest Greenland's percolation zone reveal decreasing density and ice layer thickness after 2012. *Journal of Glaciology*, *68*(269), 431-442. doi:10.1017/jog.2021.102