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The Cryosphere Discussions
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Interactive comment on "The diurnal Energy Balance Model (dEBM): A convenient surface mass balance solution for ice sheets in Earth System modeling" *by* Uta Krebs-Kanzow et al.

Anonymous Referee #2

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The authors propose a new SMB model to quickly simulate SMB of the Greenland Ice Sheet for a long time (hundreds to millennium). The manuscript is well written, many tables and figures are of good quality. I appreciate the careful preparation of the manuscript. The model performance of dEBM compares favorably with that of the regional climate model. This study will bring new knowledge on the past reconstruction and future projection of SMB of the Greenland Ice Sheet and therefore fall within the scope of The Cryosphere. However, I would like to suggest authors do some modifications before acceptance for publication. Major and specific comments are as below. I hope that my comment is very useful for the improvement of the manuscript.

Printer-friendly version

Discussion paper

Major comment:

JJA albedo simulated with dEBM was significant greater in south-western Greenland than that simulated with MAR (Figure 10). This is the reason that dEBM does not consider the effect of dark region (Wientjes et al., 2011) on SMB, which frequently appears on south-western Greenland during summer I guess. Previous studies suggest that the dark region significantly affects the SMB of the GrIS (e.g. Cook et al., 2020). The effect cannot be ignored to evaluate the SMB of the GrIS. dEBM uses the same albedo values (0.55) for ice and wet snow, but it's not realistic to assume an ice albedo of 0.55 in the coastal region. Fig. 13 showed negative SMB simulated with dEBM appeared in the late 21st century, whereas it showed SMB simulated with MAR appeared in the early 21st century. I guess this is due to the overestimation of SMB in the ablation area of the GrIS in the case of dEBM. Because the generation of the dark region is related to microbial activity, the incorporation of the albedo reduction caused by the dark region into dEBM may be still difficult. However, at least, authors should more discuss a factor affecting JJA albedo in Greenland. In addition to that, I suggest authors to more describe future challenges to improve dEBM.

Reference:

Cook, J.M., Tedstone, A. J., Williamson, C., McCutcheon, J., Hodson, A. J., Dayal, A., Skiles, M., Hofer, S., Bryant, R., McAree, O., McGonigle, A., Ryan, J., Anesio, A.M., Irvine-Fynn, T. D. L., Hubbard, A., Hanna, E., Flanner, M., Mayanna, S., Benning, L. G., van As, D., Yallop, M., McQuaid, J. B., Gribbin, T. and Tranter, M. (2020): Glacier algae accelerate melt rates on the southwestern Greenland ice sheet. Cryosphere, 14, 309-330, doi:10.5194/tc-14-309-2020.

Wientjes, I. G. M., Van de Wal, R. S.W., Reichart, G. J., Sluijs, A. and Oerlemans, J. (2011): Dust from the dark region in the western ablation zone of the Greenland ice sheet. Cryosphere, 5, 589-601, doi:10.5194/tc-5-589-2011. 2011.

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Specific comments:

- 1 Introduction

P. 2 Line 4: Replace “cemtury” with “century”.

P. 3 Line 4-5: I suggest adding NHM-SMAP (Niwano et al., 2018), which is a 5km resolution regional climate model, to the list of regional climate models to evaluate SMB of the GrIS.

Reference: Niwano, M., Aoki, T., Hashimoto, A., Matoba, S., Yamaguchi, S., Tanikawa, T., Fujita, K., Tsushima, A., Iizuka, Y., Shimada, R. and Hori, M. (2018): NHM-SMAP: spatially and temporally high-resolution nonhydrostatic atmospheric model coupled with detailed snow process model for Greenland Ice Sheet. The Cryosphere, 12, 635-655.

- 2 Model Description

P. 6 Line 14-15: Please more explain why does this study neglect the effect of sublimation, evaporation, and hoar on SMB of the GrIS. Also, to calculate these properties by dEBM, what atmospheric forcing does dEBM require?

P. 7 Line 5: Why is the albedo differentiated between fair and cloudy sky conditions? In my understanding, albedo is used as a constant value for each surface type in dEBM. Please explain clearly more.

P. 8 Line 5: Could you show me a map of Hice and Hint? Also, how did you get such elevation information? Because spatial interpolation is an important part of this study, the authors should describe the elevation data clearly.

P. 8 Line 13-16: Does dEBM require rainfall and snowfall rate as atmospheric forcings (input data), respectively? In section 2.1, the authors describe that total precipitation rate is used as an atmospheric forcing for dEBM simulation.

P. 8 Line 16: Please replace “. respectively.” with “, respectively.”

P. 8 Line 20: Is CC in eq. (10) interpolated? If not, please describe the reason not to interpolate CC. If interpolated, please describe the method. LW seems highly dependent on CC according to eq. (10).

P. 9 Line 1-2: How did you classify sky conditions (cloudy and fair) in the other season such as MAM (March, April and May)?

P. 9 Line 7: Isn't "CC > 0.9"?

P. 11 Sub-section 2.7: Can dEBM output the volume of the transformed ice? I think that such spatio-temporal information would be useful to evaluate SMB from the past to the future.

P. 11 Sub-section 2.7: Replace "m" with "mth" because "mth" is used in eq. (4).

P. 11 Sub-section 2.7: Add "(15)" to the later equation.

- 3 Parameter selection and evaluation based on observations

P. 12 Line 6: Replace "(Fettweis et al., 2020)" with "Fettweis et al. (2020)".

P. 12 Line 6-8: It's better to add information on original spatial resolution (before interpolation). P. 12 Line 9-10: Modify italics

P. 13-14 Figures 4 and 5: Could you show me the relationship between the simulated mWE (Gt/yr) and observed mWE (Gt/yr)? I did not understand the messages of Figures 4 and 5 due to much information. Authors should show a model bias for local and GRACE observation, respectively, first.

- 4 Evaluation based on the regional climate model MAR

P. 15 Experimental design: Authors mentioned that dEBM showed good performance in the simulated SMB using atmospheric forcing derived from MAR simulation. In my understanding, dEBM has an advantage of computational time for the SMB simulation compared with MAR. However, Isn't the calculation time of dEBMMAR, ERA more than

that of MARERA? If so, is there any advantage to using dEBMMAR, ERA? MARERA has already shown reasonable performance in SMB in my sense. Please describe this section more carefully and emphasize the advantage of dEBM compared with MAR.

- 5 Sensitivity of the SMB to climate

P. 21 Line 16: Please describe the original spatial resolution of AWI-ESM forcing. Also, how did you get the forcing dataset? Please describe the information on the dataset clearly.

P. 23 Figure. 12: Ice sheet area gradually would change from past (Mid Holocene) to future (2099) I think. Could dEBM simulate the ice sheet area in Greenland? The ice sheet is being retreated under climate warming, so the ice sheet dynamics would significantly affect the SMB of the GrIS. I suggest adding a brief discussion about inter-annual changes in the ice sheet area.

- 6 Conclusion

P. 26 Line 5-7: I'm curious about the computational time of dEBM. Authors should describe the specific time in the manuscript. For example, how long did H6K and Industrial simulation take, respectively?

P. 26 Line 8-9: As I mentioned in the major comment, further study is necessary to accurately evaluate SMB in GrIS, especially the south-western region. Please describe future challenges briefly.

- Appendix A

Table A1: Please add CC as forcing into the table.

- References

P. 33 Line 9-15: The paper has been published on TC. Please replace.

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