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Interactive comment on "Analysis of the Surface Mass Balance for Deglacial Climate Simulations" *by* Marie-Luise Kapsch et al.

Anonymous Referee #2

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Kapsch et al., Analysis of the Surface Mass Balance for Deglacial Climate Simulations

In review in The Cryosphere Discussions

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This paper is of a potential interest for the geosciences and (paleo-)climate modeling communities.

This study explores the simulated surface mass balance over the Northern Hemisphere ice sheets in the last deglaciation, the last millennium, and the recent past. A special focus is placed on the Greenland mass balance, but the authors also discuss the evolution of surface conditions over the Laurentide and Eurasia ice sheets over the deglaciation.

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Discussion paper

The manuscript starts with a detailed analysis of how the simulated Greenland climate conditions compare to state-of-the-art regional climate model simulations. Despite the comparatively coarse horizontal resolution, the climate model shows an impressive skill and captures accumulation and ablation patters in the right areas, and with roughly the right magnitude. This comparison gives credibility to the model – at least for simulation of the recent past. The authors then spend some time describing transient paleo-climate simulations from the last glacial maximum to present, and show figures of how the mass balance components of the Laurentide and Eurasian ice sheets evolve in time. The authors also attribute changes in mass balance patterns to changes in the ocean state.

The paper is well written and it presents an interesting and compelling storyline that is of potential interest for the broader (paleo-)climate modeling and cryosphere research communities. I recommend resubmit, subject to some moderate revisions.

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Major comments:

My only slightly larger comment has to do with a lack of discussion and references of literature on atmospheric circulation changes at the LGM and through the deglaciation. You mention several times that the atmospheric circulation changes over this time period, but no previous studies are cited. Atmospheric circulation changes is arguably not a main focus of your study, but it is a nice gesture to acknowledge work that has been done on this topic in the last several years, not least since it is relevant for your overall modeling approach and for the interpretation of your results.

It is generally accepted that the North Atlantic jet stream and storm track was quite different at the LGM than it is today. Specifically, modeling simulations suggest that the large scale circulation was more zonally oriented than today. Several explanations for this has been proposed, but the most recent explanation (that links all previous interpretations into one the-

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Discussion paper

ory) of the zonal North Atlantic jet stream and stormtrack is described in: https://www.sciencedirect.com/science/article/abs/pii/S0012821X20300248

A recent overview paper on the PMIP4 LGM simulations: https://cp.copernicus.org/preprints/cp-2019-169/

Circulation changes in the North Atlantic and over Greenland over the last deglaciation: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL074274 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL066042 https://cp.copernicus.org/articles/15/1621/2019/

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Line comments:

Page 1, line 3: comprehensive -> high complexity?

Page 1, line 5: “downscale atmospheric processes” I assume that you mean radiation?

Page 1, line 6: Here and elsewhere. Maybe more appropriate to say “satellite era” or “recent past” instead of historical period. The latter is used to describe 1850 – present in CMIP6.

Page 1, line 7: “from regional modeling” — add that this is constrained by reanalysis data at the lateral boundaries

Page 1, line 10: Specify that you refer to Northern Hemisphere summer insolation

Page 1, line 19: Here is a relatively recent, comprehensive review that may be worth mentioning in this context: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018RG000600

Page 2, line 35-36: Good place to mention some work on atmospheric circulation changes in the last deglacial period

Page 2, line 36: “Atlantic Meridional Overturning Circulation”

Page 2, line 42: “Mainly” is repeated. Maybe change the latter to “employed”?

Page 3, line 53: Two kind -> Two kinds

Page 3, line 54: Again, not sure if “historical” is the best word here

Page 3, line 56: SMBs to SMBs — awkward wording

Page 3, line 60: Meaning here is not clear. How do you use an EBM to downscale SMB? Do you mean that the radiation from the EBM is downscaled, or something else?

Page 3, line 60: What influence of clouds? SW radiation? LW radiation?

Page 3, line 70: Meaning of “movement of the snow/ice properties and compaction” is not clear

Page 3, line 71: Explain what elevation classes are

Page 3, line 72: It was technically Lipscomb et al, 2013 that introduced elevation classes in the model https://journals.ametsoc.org/jcli/article/26/19/7352/34179/Implementation-and-Initial-Evaluation-of-the

Page 3, line 80: How is the lapse rate for these factors determined? Also, do you use the same lapse rate in summer and in winter? If yes, is this a valid assumption? What is the sensitivity to this choice?

Page 4, line 85: Not sure if I understand this description. How do you conserve water if this is the case?

Page 4, line 87: This lapse rate is quite a bit lower than the ICAO value of -6.5 K/km. Explain this choice, and did you test the sensitivity to this value?

Page 4, line 97: Technical detail but what happens to (latent and sensible) energy fluxes if the atmosphere model simulates liquid precipitation, but the height corrected

temperature is below freezing (and vice versa)?

Page 5, line 136: It is a bit clunky to define WE at the end of the sentence. Can this definition be moved earlier in the sentence?

Page 5, line 141: brighten -> increase (?)

Page 6, line 165: “Once. . .” — Meaning here is not clear. Do you mean that it is removed?

Page 6, line 180: Technical detail, but please specify that this is the horizontal resolution

Page 7, line 189: Acronym “ka BP” is not defined

Page 7, line 195: Not sure if I fully understand this modeling strategy. Do you run 10 years with a constant forcing before updating the boundary conditions, or do you advance the orbital clock, topography, etc. by 10 years every model year?

Page 7, line 196: What happens to vegetation in areas that are deglaciated?

Page 7, line 203: “it is a good proxy” –> "hence, it is a proxy for..."

Page 8, line 214: “ for a long enough adjustment” is a bit colloquial

Page 8, line 232: Why did you use ERA-Interim instead of the newer ERA5? Do you expect different results with a newer reanalysis product?

Page 9, line 250: . . .historical climate conditions -> recent past

Page 9, line 254: remind the reader that this is the "coarse" and "low resolution" simulations

Page 9, line 264: Say something about how these numbers change over Greenland (latitudes of interest). Should be a factor of 2-3 difference from the equator

Page 10, line 286: Good reference https://tc.copernicus.org/articles/13/1547/2019/

Page 10, line 287: Sentence starting “The overestimation” is a bit clunky and can be simplified

Page 11, line 316: What figure(s) are you discussion here?

Page 12, line 344: Good place to cite some work on atmospheric dynamics /circulation in the deglaciation. See major comment

Page 12, line 354: shrinks -> recedes

Page 12, line 357: Further, it points towards the fact -> Further, it suggests

Page 13, line 380: typo: his -> its (?)

Page 14, line 416: Even though the AMOC probably plays an important role for this response, it is the atmosphere that primarily interacts with the ice sheets. I would suggest extending this discussion with changes in the atmospheric circulation in mind, and perhaps cite a few papers that have looked at these interactions before

Page 15, line 467: What about regional and large scale atmospheric circulation?

Page 15, line 468: You could cite this paper when talking about other feedback processes: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018RG000600

Page 16, line 491: Can you end with a slightly more comprehensive future outlook? Where do you want to take this in the future, and how will this new modeling capability be used in e.g. simulations of the future climate evolution, and/or other paleo-climate states?

Table 2: This simulation contributed to CMIP6

Figure 1: Here and elsewhere. Spectral colorbars are bad for people with color blindness. Please us a non-spectral color scale if possible

Figure 4: Here and elsewhere. The SMB colorscale is a but crowded. If possible, use fewer intervals.

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