Review of "Coupling the regional climate MAR model with the ice sheet model PISM mitigates the melt-elevation positive feedback" by Alison Delhasse et al.

The authors present an original simulation framework which involves a 2-way coupling on yearly basis between a regional climate model (MAR) forced by a global climate model (CESM2), and an ice sheet model (PISM), to simulate the evolution of the Greenland ice sheet between 1990 until 2100. The simulations are extended to 2200 by randomly sampling the last 10 years of CESM2. The modelled surface mass balance by MAR, and the modelled surface lowering by PISM using the 2-way coupling are then investigated. Finally, the melt evaluation feedback is quantified by comparing the 2-way coupling experiment to two simplified coupling experiments that can be applied on existing MAR simulations on a fixed topography.

This study contains an innovative simulation that for the first time combines different models widely used in the research community (MAR, PISM, CESM), thereby pushing the boundary and providing new insights on ice sheet/atmosphere interactions on decennial time scales. The methods are robust and suitable to model fast (within 100 years) deglaciation in a more realistic manner than previously used. Some parts of the methods could be explained in a simpler manner (the initialisation), while adding details in some other parts would improve readability and reproducibility (the offline correction). The significance of this work is high, in the way that it is one of the few studies to explicitly resolve the 2-way interaction between ice sheet and climate without the use of heavily parameterized equations for the surface mass balance used in ice sheet models. The figures including the supplementary material are clear, and the paper is well written for the most part.

Therefore I recommend publication in The Cryosphere, and I would like to congratulate the authors on implementing such a coupling. The following part contains some suggestions that could be implemented to further improve/clarify the manuscript.

Major comments

- The algorithm used to correct for elevation differences (the offline correction) is a key part of the methodology, and it is extensively mentioned in the results and discussion. I would recommend to provide a more detailed description of this correction in the methods section, and possibly mention how this algorithm was optimised for the Greenland ice sheet. This would help the reader to better understand the main conclusion of this manuscript. For instance, it is not clear now if the surface temperature was corrected with a lapse rate, and if so, using which value ?
- 25km horizontal resolution seems rather coarse to represent the narrow ablation zone in the most part of the Greenland ice sheet. The observed SMB can vary by a factor 2 within such a distance (e.g. on the K-transect, Van de Wal et al 2012), or even contain the entire ablation zone (e.g. on the Q-transect, Hermann et al 2018). While I acknowledge that the aim of this study is not to accurately model the SMB, it is likely that such a relatively coarse resolution strongly deteriorates the modelled wind and temperature patterns near the edges, therefore significantly changing the turbulent heat fluxes, and therefore surface melt. I would recommend to mention this in the discussion, and possibly refer to some studies which have shown that RCMs are still not yet accurately modelling turbulent heat fluxes near the edges of the ice sheet (e.g Fausto et al. 2016), or are sensitive the horizontal resolution (e.g. Franco

2012, van de Berg et al. 2020)

- One of the main results of the research is found in p12 L12 "ME depends on the sensible heat flux (SHF) related to air temperature and wind speed which are also overestimated on the margins by MAPI-1w (Fig. 7d and e)". I would recommend mentioning this very interesting result in both the abstract and the conclusion, since this is a key mechanism explaining the lower lapse rates in the coupled experiment.
- In the discussion, a very interesting link is suggested between the lower melt rates in the 2W coupled experiment and the mitigation of barrier winds due to drastic surface lowering. While this is a plausible explanation for the changes, this would require further analysis to properly quantify. For instance the increase in surface slope is also expected to affect the katabatic forcing in the momentum budget. Therefore I would recommend to either perform a more detailed analysis of modelled wind patterns, e.g. by investigating the entire momentum budget (van Angelen et al 2016) between the 1W and 2W experiments, or to mention in the text that changes in barrier winds are just one (of the possibly many) possible effects of surface lowering. In the conclusion (p18 L5) the reduction in barrier winds is now stated as a fact yet it has not been demonstrated in this study.

Minor comments

- p2 L25 The statement that the offline correction works well as long as SMB is mainly dominated by elevation could be reformulated. In principle there is no reason to believe that the SMB is a linear function of elevation, yet this is what is observed in the field.
- p2 L34 "What becomes GrIS" should be reformulated
- p3 L16 "good performance". Providing some numbers would be useful to better describe the uncertainties in modelled SMB by regional climate models. It would also help to mention that the evaluation of MAR by the authors (Delhasse et al, 2020) was using a higher horizontal resolution in MAR (15 km). See also Major comment #2.
- p6 It would be useful to extend Figure 1 with the initialisation steps to better understand section 2.3.1.
- It is not clear why the surface mass balance is sometimes referred to as "(surface) mass balance" (e.g. p7 L29) or "surface mass balance". Using the same would improve readability.
- p8 I believe there is something wrong with the notation of mass loss in L2 :"-50 Gt.10−3". Should it be 50 10.3 Gt ? Also in L4.
- p1 L5 What is meant exactly by "as well" ? Do the authors refer to the performance of degree-day models in ice sheet models ? Please be more specific.
- p8 The unit of the y-ax in fig 8b is missing. Adding the variables of each ax would also increase readability.
- p14 L3. Why is only the north-south wind component investigated, and not the wind vector or even the entire vertical profile of modelled wind speeds ? The latter would give a clear indication of changing boundary layer structure and therefore surface fluxes.

Technical comments

- o1 L10 "to" $->$ "for"
- p1 L12 "avoid"
- p5 L8: (Franco et al, 2012)
- p5 "2.3.1 Inisialisation"
- p17 L16 "Do"

References

Van De Wal RSW, Boot W, Smeets CJPP, et al (2012) Twenty-one years of mass balance observations along the K-transect, West Greenland. Earth Syst Sci Data 4:31–35. https://doi.org/10.5194/essd-4-31-2012

Van de Berg WJ, van Meijgaard E, van Ulft L (2020) The added value of high resolution in estimating the surface mass balance in southern Greenland. Cryosph 1–28. https://doi.org/10.5194/tc-2019-256

Franco B, Fettweis X, Lang C, Erpicum M (2012) Impact of spatial resolution on the modelling of the Greenland ice sheet surface mass balance between 1990-2010, using the regional climate model MAR. Cryosphere 6:695–711. https://doi.org/10.5194/tc-6-695-2012

Van Angelen JH, van den Broeke MR, van de Berg WJ (2011) Momentum budget of the atmospheric boundary layer over the Greenland ice sheet and its surrounding seas. J Geophys Res 116:. https://doi.org/10.1029/2010jd015485

Delhasse A, Kittel C, Amory C, et al (2020) Brief communication: Evaluation of the near-surface climate in ERA5 over the Greenland Ice Sheet. Cryosphere 14:957–965. https://doi.org/10.5194/tc-14-957-2020

Fausto RS, van As D, Box JE, et al (2016) The implication of nonradiative energy fluxes dominating Greenland ice sheet exceptional ablation area surface melt in 2012. Geophys Res Lett 43:2649–2658. https://doi.org/10.1002/2016GL067720

Hermann M, Box JE, Fausto RS, et al (2018) Application of PROMICE Q-Transect in situ accumulation and ablation measurements (2000-2017) to constrain mass balance at the southern tip of the Greenland ice sheet. J Geophys Res Earth Surf 123:1235–1256. https://doi.org/10.1029/2017JF004408