Reply to Reviewer#1

We sincerely appreciate the reviewer for taking the time to provide valuable comments and suggestions. Below we describe our responses (in blue text) point-by-point to each comment (in black text). In addition, we indicate revisions in the updated manuscript together with new line numbers. Please also refer to the revised marked-up manuscript uploaded in the discussion board.

General synopsis

This is a useful and original study of Greenland climate and surface mass balance conducted using a non-hydrostatic regional climate model. I would like to see some comparison of NHM-SMAP model output, for example as presented in Figures 9 and 10, with other RCM model output (e.g. MAR, RACMO, HIRHAM). The paper is generally well structured, written and illustrated, and should be publishable with relatively minor modifications. Citation of related work can be improved in places.

We highly appreciate for this positive evaluation. In the revised manuscript, we have included simulation results from MAR v3.5.2 forced by JRA-55. At present, there are many different points in model formulations and configurations of existing RCMs, namely, resolution, ice sheet mask, dynamic core of atmospheric model, albedo model, water percolation scheme for snow/firn, etc. Therefore, detailed model inter-comparison is beyond the scope of this paper; however, we do hope to perform such a comparison in the near future. Regarding the insufficiency of references, we have included all the references suggested by the reviewer in the revised manuscript.

Specific comments

p.2, l.35 Consider adding more recent relevant references, e.g. van den Broeke 2016 The Cryosphere, Hanna et al. 2013 Nature:

van den Broeke, M. R., Enderlin, E. M., Howat, I. M., Kuipers Munneke, P., Noël, B. P. Y., van de Berg, W. J., van Meijgaard, E., and Wouters, B.: On the recent contribution of the Greenland ice sheet to sea level change, The Cryosphere, 10, 1933-1946, doi:10.5194/tc-10-1933-2016, 2016.

Hanna, Edward and Navarro, Francisco J. and Pattyn, Frank and Domingues, Catia M. and Fettweis, Xavier and Ivins, Erik R. and Nicholls, Robert J. and Ritz, Catherine and Smith, Ben and Tulaczyk, Slawek and Whitehouse, Pippa L. and Jay Zwally, H. (2013) Ice-sheet mass balance and climate change. Nature, 498 (7452). pp. 51-59. ISSN: 0028-0836.

Thank you for the suggestion. We have added these important references in the updated manuscript. (P. 2, L. 35 - 36)

p.2, l.66: Not just RCMs but also statistically-downscaled meteorological reanalysis data have been successfully used here (Hanna et al. 2005 & 2011, Wilton et al. 2017)
– please add these relevant references:

Hanna, E. and Huybrechts, P. and Janssens, I. and Cappelen, J. and Steffen, K. and Stenhens, A. (2005) Runoff and mass balance of the Greenland ice sheet: 1958-2003. Journal of Geophysical Research Atmospheres, 110 (13). ISSN: 2169-897X.

Hanna, E. and Huybrechts, P. and Cappelen, J. and Steffen, K. and Bales, R. C. and Burgess, E. and McConnell, J. R. and Steffensen, J. P. and Van Den Broeke, M. and Wake, L. and Bigg, G. and Griffiths, M. and Savas, D. (2011) Greenland Ice Sheet surface mass balance 1870 to 2010 based on Twentieth Century Reanalysis, and links with global climate forcing. Journal of Geophysical Research: Atmospheres, 116 (24). ISSN: 2169-897x.

Wilton, D. J. and Jowett, A. and Hanna, E. and Bigg, G. R. and Van Den Broeke, M. R. and Fettweis, X. and Huybrechts, P. (2017) High resolution (1 km) positive degree-day modelling of Greenland ice sheet surface mass balance, 1870-2012 using reanalysis data. Journal of Glaciology, 63 (237). pp. 176-193. ISSN:0022-1430.

We agree with this point. All the suggested papers have been listed up in the reference, and we have revised the sentence as follows:
"Several physically based regional climate models (RCMs) have been applied in the GrIS (e.g., MAR: Fettweis, 2007; RACMO2: Noël et al., 2015; Polar MM5: Box, 2013; and HIRHAM5: Langen et al., 2015) that have been found reliable in terms of reproducing current climate conditions (e.g., Fettweis, 2007; Box, 2013; Fausto et al., 2016; van den Broeke et al., 2016) and simulating realistic future climate change (e.g., Franco et al., 2013)."
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"Several physically based regional climate models (RCMs) (e.g., MAR: Fettweis, 2007; RACMO2: Noël et al., 2015; Polar MM5: Box, 2013; and HIRHAM5: Langen et al., 2015) and statistically-downscaled meteorological reanalysis data (Hanna et al., 2005, 2011; Wilton et al., 2017) that have been found reliable in terms of reproducing current climate conditions (e.g., Fettweis, 2007; Hanna et al., 2011; Box, 2013; Fausto et al., 2016; van den Broeke et al., 2016) have been applied in the GrIS and simulating realistic future climate change (e.g., Franco et al., 2013)." (P. 2, L. 64-69)

p.3, ll.83-85: Consider emphasising more that a key advantage of using a nonhydostatic model is its ability to be run at much higher spatial resolutions («5 km) than hydrostatic models. Bearing the above in mind, was it considered to run the JMA-NHM at higher spatial resolutions than 5km (p.6, l.204)?

Thank you for the encouraging comment. To emphasize a key advantage of a non-hydrostati model more, we have revised the sentence as follows:
"In general, a high-resolution non-hydrostatic atmospheric model has the advantage of simulating detailed meso-scale cloud structures, unlike a traditional hydrostatic atmospheric model."
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"In general, a non-hydrostatic atmospheric model can be run at much higher horizontal resolution (less than 10km, the limit of validity of the hydrostatic approximation) than a hydrostatic atmospheric model. Accordingly, a high-resolution non-hydrostatic atmospheric model has the advantage of simulating detailed meso-scale cloud structures, unlike a traditional hydrostatic atmospheric model. In light of recent evolution of supercomputers, it is inevitable to perform dynamical downscaling with a very high horizontal resolution, which allows us to consider effects of complex terrain like the GrIS margin on the atmospheric field explicitly." (P. 3, L. 84-90)

Regarding the latter comment, the 5km horizontal resolution was selected considering computational costs in the supercomputer of Meteorological Research Institute (Fujitsu PRIMEHPC FX100 and PRIMERGY CX2550M1). Now, the described model configuration faces a performance limit of the supercomputer. At the end of Sect. 2.3.1, we have added the following comment:
"At present, the above-mentioned domain setting faces a limitation imposed by practical computational costs in the supercomputer of Meteorological Research Institute (Fujitsu PRIMEHPC FX100 and PRIMERGY CX2550M1)." (P. 7, L. 224-226)

p.6, l.218 "increased with altitude from 40 m NEAR the surface to: : :"

OK. Revised as suggested. (P. 7, L. 238)

p.7, l.234: "for PRODUCING daily weather forecasts: : :"

The sentence has been corrected as suggested. (P. 7, L. 254)

p.9, l.307: add that PROMICE data were also used for validating 1x1-km statistically downscaled SMB based on ERA-I reanalysis data (Wilton et al. 2017, reference as above).

Thank you for the comment. We have added the explanation as follows:
"Recently, SMB data from PROMICE were used for the validations of MAR (Fettweis et al., 2017), and the 1km horizontal resolution GrIS SMB product statistically downscaled from the daily output of RACMO2.3 (Noël et al., 2016) and ERA-Interim (Wilton et al., 2017)." (P. 9, L. 332-334)

p.9, l.322 “were superior on average” – quantify by how much and say whether statistically significant.

OK. We have indicated differences in ME and RMSE from on-line and off-line simulations. In addition, significance of these differences are explained by utilizing the p-value. Now the updated sentence is as follows:
“Average ME and RMSE at all sites were improved for the on-line simulation by 1.4 °C ($p < 0.01$) and 0.7°C ($p < 0.1$), respectively.” (P. 10, L. 348-349)

p.9, l.324: “ME was WITHIN 2.3ˆºC at all sites”.

Corrected as suggested. (P. 10, L. 350)

p.10, l.338: change comma to colon.

Corrected as suggested. (P. 10, L. 367)

p.10, l.354: “except for Summit” – why the difference there?

At present, we have no idea why the difference was made at Summit; however, it should be noted that ME and RMSE are still reasonable when they are compared against those obtained at other sites (Table S2). We have added the following explanation:
“Even at Summit, ME and RMSE were still reasonable when they were compared against those obtained at other sites (Table S2). The reason why R2 at Summit was relatively low should be investigated in the future.” (P. 11, L. 385-387)

p.10, l.359 add the relevant reference Orr et al. (2005):
Orr, Andrew and Hanna, Edward and Hunt, Julian C. R. and Cappelen, John and Steffen, Konrad and Stephens, Ag (2005) Characteristics of stable flows over Southern Greenland. Pure and Applied Geophysics, 162 (10). pp. 1747-1778. ISSN: 0033-4553

Thank you for introducing the paper. The suggested reference has been added. (P. 11, L. 392)

p.14, l.11 at end of sentence suggest to add “Moreover, Wilton et al. (2017) show generally favourable results from a 1x1-km statistical downscaling of reanalysis data, with results generally

comparing well with MAR and RACMO RCM output.“.

OK. We have added the following sentence as suggested:
“Moreover, Wilton et al. (2017) showed generally favourable results from a 1km statistical downscaling of reanalysis data, with results generally comparing well with MAR and RACMO RCM output.” (P. 16, L. 580-582)

p.16, l.605 after “statistical downscaling or further dynamical downscaling”, add “to a higher spatial resolution than used here, e.g. 1 km (Noel et al. 2016, Wilton et al. 2017): : :”.

OK. The suggested explanation has been added. (P. 18, L. 673-675)

p.27, Table 3: Suggest giving mean values in new row at bottom of table.

Thank you for the constructive suggestion. We have added a new row indicating mean values. In addition, tables in the supplementary file has been updated in the same manner.