

Review of "Climate of the Greenland Ice Sheet using a high-resolution climate model – Part 1: Evaluation" by J. Ettema, M. R. van den Broeke, E. van Meijgaard, W. J. van de Berg, J. E. Box and K. Steffen

General Comments

This paper presents a validation of high-resolution regional climate model (RCM) by comparison of model output with observations on and around the Greenland Ice Sheet. This paper is well written, clear and concise contribution and the topic relevant and appropriate for TC. Authors show that the RCM simulates realistic present-day near-surface characteristics of the Greenland atmosphere on daily and monthly timescales without post-calibration or re-initialisation during the 51 year simulation. I find missing, however, discussion and presentation of the temporal evolution of the variables discussed in the paper; temperature, humidity, wind speed and direction, as well as the surface energy balance components during the 51 years model simulation. Is the model evolution similar as the available data? Can the model simulate the observed variability? Is there a climate signal in the model similar to the observations? The paper would improve considerably if authors would include discussion of this. My recommendation is to publish the paper with the suggested addition and consideration of the comments listed below.

Specific Comments

The paper presents a validation of the model rather than evaluation and the title and the text could be changed accordingly.

Please be consistent in writing the name of the model, sometimes it is written as RACMO2, RACMO2v1 (abstract line 7), version 2.1 (page 564 line 4) and RACMO2/GR. Is RACMO2/GR a different model or a version of the original model? Please clarify in the text.

Throughout the paper, except in a few instances authors write solar radiation, should it not be short wave radiation (page 572, line 23) in all places? In text and figure labels and captions I suggest to write out, rather than write SW and LW for shortwave and longwave radiation, at least be consistent in figure labels and figure captions.

I am not sure about the use or not use of capital letters in Greenland Ice Sheet, GC-Net and van den Broeke (and other Dutch names), make sure to be consistent. Also spelling of rime ice, I have found both rime and rhime ice, I am not sure which one is correct or whether it is UK, US spelling difference.

The model initialisation is not clearly described (page 569-570), I recommend to rewrite this paragraph so that it becomes clearer. From the description it seems like two different model runs are used to create initial conditions for SIF on one hand (16 year earlier integration of RACMO2/GR – is that forced by ERA-Interim boundaries or ERA40 boundaries? - is there a reference to this?) and for initial firn density profiles on the other hand - values are taken from ERA40 forced off line simulation of same snow model (Bougamont, et al., 2005). Why is not same source for initial values used in both cases? In line 3 page 570 it is not clear what "first spin-up" is, is that conditions of the model before the first model year is run 3 times? Line 13 is unclear, rewrite "the melt rate is taken averaged over the period". Suggest to move the description of initial values together, for example move text in line 21, closer to the text in line 3. It is common to use h or S

for elevation of the surface and ϕ (lower case phi) for latitude, I recommend to use this convention rather than E and L.

Page 571 The GC-Net AWS have been operating after 2001, why do you not use more recent data? The data is available on the project's website. Using all the recent data, not only the short period 1998-2001, as well as the temporal evolution of the model output compared to data (see comment above) would make the validation of the RCM even more valuable.

Page 574. It appears from the text that both model and measurements are transformed to 2m T with some model or interpolation. Can you give an estimate of the errors involved in that transformation? Is the error likely to be of similar size for the model output and observations?

Technical Corrections

Abstract line 3 RACMO2/GR (?)

Abstract, line 4 ECMWF RE-Analysis (cf. line 12 page 564)

Page 562 line 17 Greenland Ice Sheet (? – and other places in text)
 line 19 equivalent TO

page 563 line 4 GC-Net (and other places in text)
 line 9 model output is not data, rewrite this sentence
 lines 25-30 Observations are described in Section 3, line 29 Section 4,

page 564 line 2, Section 5.
 Line 20, from what data or observation are the open sea surface temperature and sea ice fraction, ERA-40 as well?

Page 565 line 8 ice mask FROM the digital elevation model
 Lines 11-12 how can shelf ice and multi-year sea ice area impact the ice sheet area?

Page 566 lines 4-14 Write clearer how the present model differs from the other two discussed here. Line 4 “This model”- what model, explain better. Line 7 “slightly modified” How? What is changed? Is the cloud correction applied in the RACMO2/GR model, it is not clear from the text.
 Line 17, snow cover

Page 567 line 1, multi-layer – how many layers are in the model?
 Lines 19-22 Is it correctly understood from the text that a is kept constant throughout the simulation? Or is a changing with the simulated accumulation of the model?

Page 568 eq. 3 replace m with M , or change M in the text to m
 Line 7, those terms are not shown in equation 3 (only the SW_{net} and LW_{net}) – shortwave, rather than solar radiation?
 Line 10 LHF and SHF are in different order in equation 3
 Line 11-12 It is not clear from the text what direction is positive, upwards or downwards? Is it snow surface-atmosphere interface?

Page 569 line 1 replace remaining with excess energy, used for melting (snow or ice?)

- Page 571 line 1 suggest to use validation, rather than evaluation
 Line 2 “thereof” – what do you mean? Suggest to rewrite
 Line 10, (and elsewhere in text) isn’t it lower case v in the name? change order of references to a,b
 Line 19 “has consisted until” rewrite, suggest something like “has consisted of 15 AWSs until 2001” – why isn’t data after 2001 used? (see comment above)
 Line 21 are (not is)
 Line 27 – what levels? Explain better.
- Page 572 lines 20-26 the text is not clear, how are the observations corrected? Are the observations input to what model (“this model” is not clear in text) suggest to rewrite. At what two levels?
- Page 573 lines 1-8 I find missing some discussion that the DMI observation records are of different lengths. It would be valuable validation of the model to compare the variability of the model to the variability of the observations, daily values are available for all the stations.
 Line 9 and line 17 suggest Model validation
- Page 574 line 12 in abstract the bias is stated -0.9°C shouldn’t it be the same number both places?
 Line 21 A similar (not An)
 Line 25 suggest “Figure 4b shows” rather than groups
- Page 575 line 3 omit “also”
 Line 6 can you do better than speculate? Do you have surface albedo estimates to confirm this hypothesis?
 Line 14 suggest whereas – or rewrite the sentence.
 Line 15 “it is well known” – from what? Can you give an example?
 Line 25 what “local effects” can you give an example?
- Page 576 line 2 causes (not cases)
- Page 577 line 6, katabatic wind forcing
 Line 16 too strongly
 Line 17 suggest: due to underestimated surface roughness length
 Line 20 Are you describing general properties or the model output? Is the correspondence due to elevation differences or seasonal changes? – can you do better than speculate? Do you have data to support this hypothesis?
 Line 22 saturation point, or temperature
 Line 23 water vapour
- Page 578 line 1 water vapour. Is there more condensation as well at these sites?
 Line 2 what values?
 Line 18 rewrite without the abbreviation and double downslope in the sentence
 Line 20 do you mean skin temperature?
 Line 21 SEB is defined on page 567, line 24, and does not have to be defined again
 Line 25 take out “to”. Again it is not clear from the text what direction towards the surface is positive, upwards or downwards?
- Page 579 and page 580 suggest to write out shortwave and longwave rather than use abbreviations

lines 12-25. Rewrite. It is not clear when natural process or observations are described and when model feature/property

Line 7, what is the albedo of dry snow pack?

Line 18 suggest appearing or revelation, rather than surfacing

Line 22 either “there is some redistribution of falling snow by the wind” or “some redistribution of falling snow by wind occurs”

Page 580 Line 27 Similarly

Page 581 line 2 text is not clear, rewrite and omit “since”

Line 8 “shortwave and longwave” radiation?

Line 14 in summer? There is large disagreement also in June and July.

Line 24 excess compared to observations

Line 25 From figure 14 a) it seems more like $>20 \text{ Wm}^{-2}$ model bias for S6 and S9 and about 10 Wm^{-2} at S5 in winter and during summer the bias at S6 is also $>20 \text{ Wm}^{-2}$, suggest to rewrite this sentence

Page 582 line 7 biases

Line 9 “deposition” do you mean condensation?

Line 13 do you mean less than $\pm 5 \text{ W m}^{-2}$? Eyeballing the figure the difference is both positive and negative, the difference during summer is mostly negative, do you mean less than -10 Wm^{-2} ? Or are you discussing absolute values of the difference? Explain better in text.

Line 25 RMSE= 4.0°C where does this value come from? In abstract it is stated that 2m T bias is less than -0.9°C and in text (page 574) it is stated as -0.8°C . and further it is stated to reduce from 2.3 to 2.0°C when taking all location into account. Are you discussing mean annual or monthly values here? Please clarify.

Page 583 line 3 well captured

Line 6 RMSE= 1.9 ms^{-1} , in abstract it is stated to be 0.3 ms^{-1} - why is this difference?

Line 12 roughness lengths in the model?

Line 21 in comparison to the model grid cell size?

Line 23 explain better or omit this statement here.

Line 26 measurements AT the K-transect

Line 28 suggest that the ...

Line 26 – line 1 page 584, this is a long sentence, split in two for clarity

Page 584 line 2 write out SHF and LW (and in other places in the text)

Line 5 suggest to start a new paragraph for the concluding sentence.

Figure 1 caption last line: Thick black line represents the ice sheet outline or margin, rather than contour

Figure 4 y-labe in figure 4(b) should indicate that this is model bias or T difference, indicate in figure caption for which period the bias figure is made.

Figure 6 ylabel in figure 6(b) should indicate that it is model bias

Same for Figure 10b, 12a and b and 14 a and b, the y-label should indicate that this is difference

Figure 11 write out SW and LW in y-axis label

Figure 12 for consistency write out LW in the y-label and figure caption

Figure 13 and 14, similarly, write out SHF and LHF in y-axis labels and figure caption

Figure 13, explain better “observed”, why the “”?

Figure 14 a) and b) seem to have been swapped