

Reply to Editor comments on

“The importance of cloud properties when assessing surface melting in an offline coupled firn model over Ross Ice shelf, West Antarctica”

by

Nicolaj Hansen, Andrew Orr, Xun Zou, Fredrik Boberg, Thomas J. Bracegirdle, Ella Gilbert, Peter L. Langen, Matthew A. Lazzara, Ruth Mottram, Tony Phillips, Ruth Price, Sebastian B. Simonsen, and Stuart Webster

Dear Editor,

We are very glad that the reviewers have accepted our manuscript. Thank you for these final comments. We very much appreciate the expertise and time that has been spent on this task and sincerely believe that your efforts have resulted in a considerably improved manuscript. We have implemented the vast majority of your suggested changes/comments and very much hope that you now find the manuscript acceptable for publication. In the few occasions that we did not implement your suggested changes to the text it was because we thought that the original text was clear. In the following, we provide a point-by-point reply to each of these.

Yours sincerely,

Nicolaj Hansen

Technical corrections:

- All Figures are quite pixelated, please upload higher resolution images. For instance, in Fig. 2b the low HIRHAM5 of melt days values are hardly visible (see L169-170). In Fig. 4, AWS labels are not readable, the same holds for the legend in Fig. 5. **We have remade Figures 2, 3, 4, 5, 6, 7, and 8 in a higher resolution, and made the labels larger in Fig 4 and the legends larger in Fig 5. Regarding Fig 2b, the number of melt days is so low that a higher resolution does not make a difference.**

- You could improve the referencing of figures across the manuscript, i.e., by referring to specific sub-panels (e.g., Fig. 2a) where appropriate. You can find a few examples below: L170: “central sector (Fig. 2b).” L171: “with the observations (Fig. 2c).” L173: “entire RIS (Figs. 2d,e).” L183: “15th of January (Fig. 3X)” L184: “18th of January (Fig. 3X)” L187: “Fig. 3X” L190: “this period (Figs. 4a,b)” L191: “this threshold (Fig. 4c,d)” L195: “(Fig. 4c,d)” L254: “(>80%) (Fig. 9).” L258: “to the models (Fig. 9).” L265: “(Fig. 10a)” L267: “(Fig. 9c)” L268: “(Fig. 10b)” L280: “(Fig. 10b)” L284: “(Fig. 9f)”
We have added these examples and others to the text, which have improved the clarity of the results section.
- L215: What do you mean by “transition in SEB” please, clarify.
We mean from negative to positive, and we have added: “This suggests that the primary energy source responsible for the transition from negative to positive SEB is from radiative fluxes and not sensible or latent heat fluxes”
- L294: By “resolution” do you mean spatial/temporal resolution or both, please clarify.
We mean spatial resolution, which we have clarified in the text.
- L302: “(two order of magnitude)” larger than what? Please clarify.
We have now clarified this by adding the following: “are extremely large (MetUM estimates are two orders of magnitude lower than CERES), which suggests that the more likely reason for this is that the MetUM...”

Figures corrections:

- Caption Fig. 1 L2-4: Remove “and over left ... on the map.” and “and is over the right ... of the map”.
We have removed this.
- Figure 3: To clarify, you could add a label in front of each row e.g., “Passive microwave”, “HIRHAM5” and “MetUM”.
We have added OBS, HIRHAM5 and MetUM to the rows, which is consistent with the labeling used in Fig. 2.
- Caption of Fig. 8 L3: Remove “Downward fluxes are positive”.
We have kept this in the caption, as it was also included in Figures 6 and 7. .
- Figure 9: The colour scale could be counterintuitive, as one may expect grey shades for cloudy conditions. You could consider reversing the colour scale.
We have not implemented this suggestion as its standard practice to plot cloud cover from MODIS as white. See for example, Fig. 2 of Pincus et al. (2023); <https://essd.copernicus.org/articles/15/2483/2023/>). Also, please refer to the following NASA / MODIS website: https://earthobservatory.nasa.gov/global-maps/MODAL2_M_CLD_FR
- Figure 10 caption L2-3: “The light blue bars... include the parts of the satellite ground track that overlap with the RIS region highlighted in Fig. 1.”
We have changed the caption

Thanks for all the stylistic suggestions, we have implemented almost all of them.

Stylistic suggestions:

- L11: “a transition from clear-sky to cloudy conditions, with clouds containing both...”
Done
- L18: “This can lead to ice shelves thinning...”
Done
- L20-21: “and thus enhanced global sea-level rise...”
Done
- L22: “ice/snow at 0°C, ...”
Done
- L25: “ice shelf melting are usually driven/triggered by local...”
Done
- L31: “grid box of ~10 km resolution or less.”
Done
- L32: “enhance the representation of crucial...”
Done
- L33: “coastal margins, and better resolve small ice shelves at spatial scales of...”
Done
- L36: “changes of snow/firn properties in the upper...”
Done
- L38: “feedback, and meltwater retention and refreezing in the firn layer”
Done
- L40: “these effects vary considerably; the spin-up time selected to simulate the evolution of the snow/firn layer also affects model performance.”
We have taken your suggestion partly into account, and revised the sentence to be: ‘The ability and sophistication of land surface and subsurface snow schemes in regional atmospheric models to represent these effects varies considerably, with the choice of spin-up time selected to simulate the evolution of the snow/firn layer also affecting the model performance’
- L44-45: “atmospheric models. The representation of cloud properties,...”
We have altered the first line of this paragraph to be consistent with the previous paragraph, and also follow your suggestion. It now states ‘The representation of cloud properties, particularly cloud phase and microphysics, are also a major challenge for regional atmospheric models.’
- L60-61: “(2017), that represents ... feedback, ...”
Done
- L64: “2023). In particular, the January 2016 event is attributed to...”
Done
- L67: “models that require further improvements.”
Done
- L69: “Trusel et al. (2015) suggest...”
Done
- L70-71: “under a high-emission climate scenario (RCP or SSPX-X.X)” Please mention the scenario used.
Done

- L73-75: “Thus, improving the representation of surface melting (and hence surface mass balance) that is an indicator for ... 2019) is essential ... stability, and estimate/quantify its contribution...”
Done
- L85: “dry fresh snow at temperatures below -5°C ”
Done
- L127: “temperature exceeds 0°C ”
Done
- L132: “and nighttime, and clear and cloudy conditions”
Done
- L140: “see Fig. 1 for AWS locations”
Done
- L141: “occur, as suggested”
Done
- L151: Do you mean “depolarised” by “depolarising”?
This was unclear. The sentence has been modified to ‘These observations use differences in the polarization properties of light backscattered from non-spherical ice particles and spherical water droplets to determine important information on the cloud phase (Hu et al., 2009).’
- L165: “showed that this”
Done
- L189: “For example, Elaine and Sabrina AWS both ...”
Done
- L192-193: “of the RIS, where the satellite ... identify melt-free conditions during...”
Done
- L200: “compares timeseries of surface radiative fluxes for this period that are spatially...”
Done
- L201: “From the 13th to 14th, ... during nighttime ranging from -20 to -40 W m^{-2} ”.
Done
- L203: “freezing conditions, ...”
This suggestion was not implemented as the grammar was correct.
- L206: “of freezing, ”
Done
- L210: “being more extensive over the western”
Done
- L211: “as well as with HIRHAM5 ... over this region than MetUM”
Done
- L212-214: “cycle of modelled SEB broadly follows... minimum modelled SEB shows negative... values for [provide days] and zero/positive values for [provide days]”
Done
- L217: “radiative fluxes contribution to surface melt is balanced.”
This suggestion has not been implemented.
- L220: Remove “(as expected)”
Done
- L231: Remove “here”
Done

- L266: “January, the MODIS imagery”
Done
- L268: “over the same region where models show”
Done
- L271: Remove “here”
Done
- L279: “1 kg m⁻², i.e., two orders”
Done
- L292: “observations suggesting that both...”
Done
- L296: “which results in significant ... that are nearly non-depolarised”
Done
- L299: “for the 16th to the 18th of January”
Done
- L302-303: “which suggests that discrepancies result from MetUM severely underestimating ... water, and not from uncertainties in the observations.”
Done
- L306: “case, the associated additional surface melting would ... measurements, showing ...”
Done
- L309-310: “For example, issues in simulating cloud microphysics may affect other ...”
Done
- L312-313: “Unfortunately, neither AWS ... output fields are available...”
Done
- L314-315: “will require an increasing number of... able to comprehensively measure radiation and cloud properties”
Done
- L316-320: “surface observation network compiling full ... require maintenance to ensure sufficient measurements quality for use in future studies. A similar study focusing on melt events that include such measurements... worthwhile. By repeating the ... scheme, we could examine whether model upgrades could improve the representation of cloud microphysical properties (... 2023).”
Done
- L325: “particularly since the model simulates Antarctic ...”
This has not been implemented. The grammar was fine in the text we had originally used.
- L330: “higher resolution grids, ...”
Done
- L353: “This results from models simulating... ”
Done