

Review of “The influence of snow on sea ice as assessed from simulations of CESM2” by Marika M. Holland et al

General comments:

The impact of snow on sea ice is difficult to assess due to the relative lack of long-term observations in remote polar regions. Given the many, competing feedbacks between snow on sea ice and sea ice itself, it is important to quantify these feedbacks and their climate impacts. In my view, this paper significantly adds to our current understanding of snow on sea ice and its impacts. It presents a study of the influence of snow thickness on sea ice in both pre-industrial and 2xCO₂ experiments in coupled slab-ocean CESM2, varying the snow thickness by multiplying the snowfall on sea ice by different constant factors. The paper finds that overall, in both hemispheres, snow on sea ice tends to result in increased sea ice volume and cooler temperatures, although the ice mass budget response differs between the hemispheres. In a 2xCO₂ climate, the study finds that Arctic sea ice sensitivity to snow depth is reduced, whereas the Antarctic sensitivity is similar to the pre-industrial climate.

The paper is overall well-structured, clear, and well-written, and presents results that, in my view, are of high scientific interest. It is well-referenced, with an appropriate number of references. There is a good number of figures, and the figures are generally clear, although I have a few minor suggestions below. There are some parts of the paper where I think some additional detail would be helpful, (as explained in my comments,) but overall, I strongly recommend that this paper be accepted for publication, with minor revisions.

Specific comments:

My first suggestion pertains to the use of the slab-ocean model (SOM); I recommend that the authors discuss some of the associated caveats in more detail in the paper. (To be clear, I do not think the use of a SOM is inappropriate for this study; I simply would encourage the authors to expand some of the discussion of the SOM.) The paper mentions that the SOM used has a prescribed ocean heat flux convergence from the CESM2 preindustrial control (line 113-114). However, it has been found that ocean heat convergence weakens near the ice edge with increased CO₂ (as mentioned in Bitz et al 2005, which this paper cites) and thus, I wonder if the Qflux used in this configuration may still retain some bias related to this. Also, the lack of representation of ocean dynamics in the SOM is briefly mentioned, but I think it would be helpful to briefly discuss possible impacts the lack of ocean dynamics could have on the results of this study, where applicable (eg. possibly in terms of hemispheric differences being modified by ocean dynamics).

Secondly, although several snow processes are mentioned, it is not always clear which of these processes are represented in the model (eg. wind-driven blowing snow, rain-on-snow, snow density and thermal conductivity, etc.). I think it would be helpful to include a brief description of which snow processes and properties are described by the model, and possibly what biases could be present from the exclusion of certain processes. (It seems to me that this is briefly discussed in places, but I think more detail would be beneficial.)

Finally, I think there could be additional discussion included in the conclusion about what uncertainties remain, and possible next steps.

Specific comments line-by-line:

(N.b.: These comments may be taken as suggestions .)

105: Is this due to processes not being represented in the model?

116: Can you be more specific about what “mostly equilibrated” means in this context?

117: Perhaps describe how missing ocean dynamical feedbacks could impact the results here.

120: It would be helpful to include some description of the snow processes in the model in or before this paragraph (or somewhere else in the section, where appropriate).

145-146: There seems to be a missing citation here for “lack of significant anthropogenic ice loss that has been observed in recent decades”

Figure 1: If possible, I suggest that these map figures be made without the grid, since it is too faint to be visible and it seems to be producing artefacts. Also, for clarity, consider specifying the spacing of the black isolines somewhere (perhaps in the figure caption).

Also, although snow observations are limited, I think it could be beneficial to include a comparison with snow thickness observations if those are available; perhaps as a supplementary figure if it does not fit well within the main text.

164: Are there any ice processes not simulated by the model that could have an impact on the results?

172: Some points that may be helpful to discuss briefly: how might the constant density impact the results? In what regions would we expect results to be most impacted by this density assumption?

Figure 3,5: Consider aligning the months here to the seasons as in Fig. 2.

273: The term “basically equivalent” is vague; could you clarify what do you mean by this?

Figure 10: Some of the overlapping bars are difficult to see; is it possible to make them narrower so that they overlap less?

331 (and other places where ice motion is mentioned): It would be helpful to mention what drives the ice motion in this model.

426: This is the first time in this paper that these cases are specifically referred to as regimes so it seems to come somewhat out of nowhere; consider mentioning it earlier in the paper.

Technical corrections/notes:

111: I think “mixed-layer-averaged” should be hyphenated, or this could be rephrased to avoid hyphenation (the wording is somewhat ambiguous as-is)

117: Missing comma after “excluded”

173: The 3 should be a superscript in kg/m^3

212: I think “snow free” should be “snow-free”

224: It would be clearer if this said something like “a significant jump in ice volume and area from the $F_{\text{snow}}=0$ case to the $F_{\text{snow}}=0.25$ case”; clarifying that the jump is between the 0 and 0.25 cases.

240: Missing word, should be “the colors are the same”

258: Hyphen missing in “high-latitude”

259: Missing word, should be “consistent with a reduced”

300: As in 212, I think this should be “snow-free”

304: Hyphen missing in “snow-covered”

341: I think there should be a comma before “but”

349,363: Hyphen missing in “snow-ice” (assuming that the convention being used is to hyphenate)

379,415,422, etc.: Inconsistencies in hyphenation of “preindustrial” vs “pre-industrial”

References (general): Many entries here include italicization, but TC guidelines indicate to not italicize text in references.