

Dear Dr. Derksen,

We would like to thank the two reviewers for their constructive comments. Indeed while double and triple checking our calculations for precipitation in ERA5 we noticed that an error had slipped in our calculations. As both reviewers noted, the increase in precipitation and snowfall are consistent in ERA5 relative to ERA-I. This change is now reflected in the revised manuscript. And we have addressed the reviewers concerns and suggestions.

Given the comments from Alek Petty, we also added a new figure (new Fig. 8) to show the ratio of snowfall to total precipitation, which has changed substantially (i.e. increased) in the new ERA5. Given that the readership will also have use of absolute amounts of precipitation and snowfall (and not only differences or ratios between ERA5 and ERA-I shown in Fig. 2 and 7), we added new figures to the Supplementary Material (S1 and S2), as we consider that these are also valuable to show (and we refer to this in the revised text. The new results are reflected in a rewritten abstract, section 3.1-3.2, and Conclusions.

We also read through the manuscript again thoroughly to edit the text for clarity and fluency.

Overall, we find that with the insights of the two reviewers, this paper has now become much improved, and valuable contribution for the community. It will hopefully spur some more in-depth studies on the exact causes of the changes from ERA-I to ERA5, which are beyond the scope of the current study.

Detailed responses to the reviews are given below.

We hope you find this work publishable in The Cryosphere.

Yours truly,

Caixin Wang

on behalf all co-authors

## Reply to reviewer Alex Petty

Thanks for your insightful comments. Our reply to your comments are written with blue text. In brief, we identified an error in our ERA5 precipitation calculations, and corrected the corresponding figures and updated the text to reflect these changes. We also added the figure on the snowfall to precipitation ratio, thank you.

Comments from Alek Petty:

### **Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)**

Most importantly, I recently had a look at the ERA5 snowfall and my brief analysis suggested it's pretty consistently higher than ERA-I snowfall over the Arctic in all seasons, which isn't what you find in this paper. I think it's worth you (and me!) taking a closer look at your ERAI and ERA5 snowfall results. Perhaps the time period matters here, but there was some difference with the data from ERAI to ERA5 (summing hourly ERA5 values within a day instead of 6-hourly ERA-I data). This needs to be resolved and could have a significant impact on your results that would need correcting if I am right.

Thanks for pointing this out!! (as did the 2<sup>nd</sup> reviewer). You are correct. We double checked our analysis, and found errors in our calculation of the ERA5 total precipitation and snowfall accumulation. Now we corrected our results, and included them in the updated manuscript. In the revised manuscript, we show that the total precipitation and snowfall in ERA5 are larger than those in ERA-I in all seasons over Arctic sea ice and along the buoy drift trajectories. Following this, we replaced the old Fig. 2 (e-h) and (i-l), Fig. 7 and Fig. S4-5 with updated figures, and rewrote the corresponding text in section 3.1, section 3.2.2. Accordingly, the old Figs. 8-9 for model runs were replotted, and renamed as Fig. 9 and 10, respectively. The main results concerning our model runs have no big change.

We have also updated the abstract and conclusions to reflect these changes, in addition to the section discussion snowfall and precipitation.

Other comments:

I still think you need to make clearer the changing ratio of snowfall to precip as it seems a big part of the story and not beyond the scope of this work at all.

We now agree this aspect is indeed valuable to show. For this, we added ratio values in the new Fig. 7 and Figs. S6-7, and one new Fig. 8 for its ratio in four seasons, and also added some discussion on this matter in text (refer to P7) (including abstract and conclusions).

New Figure 2: Drop the colorbars in the first three columns as they are the same as the colorbar on the right. Add the variable (i.e. 2m air temperature (C)). Unclear what you've done with the ice extent as I can't make it out on the maps.

Figure 2 was re-made. The new Figure 2 only shows the colorbars on the right-hand side. In the figure, the ice extent is used as a mask to distinguish ocean and sea ice.

New Figures 3 and 4: thanks for making this change, I think it's an improvement but I still think it could be better! It's tough to jump between the figures and interpret the differences, and again I think the comparison to the buoys is more important so I would suggest merging these figures and just showing one or two buoy profiles instead in each figure. Can you place the Figure 4 buoy comparison panel between the raw and difference plots in Figure 3? It would also be nice to have RMSE values included here too for the buoy comparisons to ERAI and ERA5.

Thank you for this suggestion. Figures 3 and 4 were merged. The new Figure 3 and 4 only both show two buoys each, with all panels for one buoy in one of the figures. Additional buoys are shown in the Supplementary Material (Fig. S6-7). Each buoy consists of three panels, in the upper panel for the variation of ERA5, ERA-I and buoys, the mid-panel for the difference between ERA5 and ERA-I, and the lower panel for the ERA5/ERA-I and buoys. In addition, the RMSE values are included in the new Figure 3 and 4.

New Figure 6: nice!

Thanks!

New Figure 7: looks better! I would suggest dropping the second y-axis as this has the same units and just stating that in the left y labels (snow water equivalent (mm)) and make clear that you have cumulated reanalysis values and measured buoy snow depth values shown.

The second y-axis was dropped.

## Reply to Anonymous reviewer

Thanks for your insightful comments. Our detailed replies are written with blue text. In brief, we identified an error in our ERA5 precipitation calculations, and corrected the corresponding figures and updated the text to reflect these changes.

### Comments from Anonymous Referee #1

#### **Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)**

Review of Wang et al., Round 2

Thanks to the authors for addressing my concerns in the previous round of edits. I feel like the changes made improve the paper, and that it should be suitable for publication after these changes are made.

Section 3: I find it a little odd that the ERA5 total precipitation and snowfall values are lower than ERA-I. I thought and saw some preliminary results that the ERA5 snowfall was biased high from other reanalyses and CloudSat and was more similar to MERRA2? I thought their overall total precipitation magnitudes didn't increase but the partition between rain and snow changed from ERA-I to ERA5 so the snowfall year round was much larger in ERA5 compared to ERA-I. Not just in the summer months as is shown in Figure 2. Also it would be beneficial to try to explain or hypothesize why there are differences between ERA-I and ERA5 fields. Was cloud microphysics changed? Representation of the sea ice? Etc.

Thanks for pointing this out (as did the other reviewer). We double and triple checked our calculations for ERA5 and found a mistake in the integration of the ERA5 precipitation/snowfall in our calculations. You are right, the total precipitation and snowfall was larger in ERA5 than in ERA-I (see updated Figure 2). We corrected our results, and included them in the new manuscript. In the revised manuscript, we show that the total precipitation and snowfall in ERA5 are larger than those in ERA-I in all seasons over the Arctic and along all the buoy drift trajectories. Following this, we replaced the old Fig. 2 (e-h) and (i-l), Fig. 7 and Fig. S4-5 with new figures, and rewrote the corresponding text in section 3.1 and section 3.2.2. Accordingly, the old Figs. 8-9 for model runs were replotted, and renamed as Fig. 9 and 10, respectively. The main results concerning our model runs have no big change.

In response to the other reviewer, we also added a new figure (now figure 8), of the ratio of snowfall to total precipitation in ERA-I and ERA5 (refer to P7), to show the increase of snowfall at the expense of rain in ERA5 over Arctic sea ice, likely due to the improved cloud physics scheme.

In our manuscript, we had tried to explain or hypothesize why there are differences between ERA-I and ERA5 fields through talking about the different (improved) cloud physics scheme used in ERA5 (see section 3.2.2). The representation of sea ice in physics seems not have changed (see IFS Cy41r2 and Cy31r2). But there is more consistent sea ice concentration (SIC) product used in ERA5 due to using OSI-SAFr, the reprocessed version of the Ocean and Sea Ice Satellite Application Facilities (OSI-SAF) (Hersbach and Dee, 2016), which produces a large ice extent when the SIC is over 10% or 50% compared with previous version of OSI-SAF (ERA-I). Large sea ice concentration means less open water, possibly less water vapor. However, this is quite speculative, although could indeed also affect T2M.

After reading on I notice that you try to explain some of the differences in the cloud physics. But what about the sea ice representation? Has this changed?

There is more consistent sea ice concentration product used in ERA5 (Herbsh and Dee, 2016). However, how the sea-ice-atmosphere interface is treated in ERA5 compared to ERA-I has not changed to our knowledge, and is simply for the boundary condition in the model. The full effect on the model sensitivity to this change has not as far we know been examined to any detail, and is beyond the scope of our work. Please also see our reply to your comments above. We have now indicated this in the text (refer to P4).

Any thoughts on why the temperature bias is larger for ERA5 than ERA-i?

It is difficult for us to answer this question at the moment, as there has not been a thorough comparison of the ERA-I and ERA5 model systems over sea ice as far as we know. In the reanalysis output we see this result, and an in-depth study is required by the model development team to answer this question.

Page 6 line 2: Could the warmer t2m in ERA5 be due to the representation of the sea ice cover and thickness in the model? This will likely affect that as well.

We know the sea ice concentration used in the ERA5 is different than in ERA-I, however, there are no detailed studies to show that this only would change the t2m in the Arctic. Given that largest deviations are in winter when ice concentrations are nearly 100% it would be unlikely to assume sea ice concentration would affect this. In any case, including this would be highly speculative on our part.

Page 7 line 11: Remove 'is' before 'indicates'.  
"is" was removed

Page 8 Line 15: are the "some periods" where the ERA5/I snow depths different from the buoys seasonally or regionally dependent? Or is it just random? At the buoy locations where ERA5/I are always producing more snow regionally dependent?

From the analysis of the buoys in question we do not see any definite patterns in the differences by region. But we see a seasonality effect in the snowfall, as most of autumn snowfall in ERA5 was in fact rain in ERA-I, and as noted snowfall in ERA5 is especially higher in summer/autumn. We also note this in the text. As we note in the manuscript, we have mentioned that " snow drifting up against the buoy structure, snow erosion/sublimation around the buoy, or reflect anomalously high/low precipitation in the reanalyses may contribute to the difference between ERA5/I and buoy", among others, can cause dynamic changes of snow depth, not captured by reanalysis precipitation/snowfall fields

Page 11 Linen 18: "Sp-ERA-I runs" should be changed.  
Thanks for pointing out. Changed to "TPI\_T2MI".