The Cryosphere Discussions

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# Comment on tc-2021-195

Anonymous Referee #1

Referee comment on "Evaluation of Northern Hemisphere snow water equivalent in CMIP6 models during 1982–2014" by Kerttu Kouki et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-195-RC1, 2021

**Review of manuscript # tc-2021-195 entitled "Evaluation of Northern Hemisphere snow water equivalent in CMIP6 models with satellite-based SnowCCI data during 1982-2014".**

## Summary

Kouki et al. compare climatological Northern Hemisphere snow water equivalent from a subset of CMIP6 models with observations from SnowCCI. The authors focus on two snow metrics: the 1982-2014 mean SWE during the month of February and the mean spring snow melt (from February to May). To better understand the drivers of climatological snow bias they seek to extract the influence of temperature and precipitation biases. The paper rather unsurprisingly finds that precipitation is the main driver of winter SWE biases while temperature and a residual term (meant to represent various other factors) are the main drivers of biases in spring snow melt. The study is of interest to The Cryosphere's audience but requires revision before it can be considered for publication.

## Major comments

Model selection: The decision to limit analysis to a subset of high resolution GCMs seems somewhat arbitrary and limits the paper's value. This decision should be better justified in the text. For example, the authors could show a comparison of winter SWE in high vs low resolution models as supplemental material. Otherwise, the authors should consider adding a few of the HighResMIP historical simulations (https://gmd.copernicus.org/articles/9/4185/2016/gmd-9-4185-2016.pdf) to their analysis so as to increase the ensemble size.

Interpretation of results: The authors point out discrepancies between models and observations but offer little commentary on what could be driving biases in specific GCMs. For example, they discuss a cold bias in the EC-Earth models as unique to the ensemble but fail to connect this to the fact that EC-Earth is the largest outlier in terms of snow cover extent among CMIP6 models (Mudryk et al. 2020). More insight could also be added when discussing the CESM models, which feature anomalous winter SWE.

Readability: There are also several notations used throughout which can be improved to help the reader. For example, the "model-minus-observations difference" can simply be referred to as model bias. The results section can also be better tied together. Most paragraphs in Section 3 start with "Figure __ shows ...", which becomes very repetitive and causes the paper to lack flow.

**Minor comments**

L13-14 and throughout: change "SWE change rate in spring" to "spring SWE loss" or similar since the February to May SWE should decrease everywhere.

L16: I don't understand what point is being made hre: "Even too cold temperatures cannot cause too high SWE without precipitation".

L47: State that this is largely because of the increased atmospheric moisture holding capacity.

L48: "Trends in seasonal snow also vary seasonally" awkward wording.

L48-49: State why spring snow is especially sensitive to warming (e.g., surface albedo feedback is strongest during spring).

L50: Clarify what is meant by "early-winter"?

L70: Change "the difference" to "the model bias"

L72-73: They stated that analysis is needed to understand SWE trends, but this paper only looks at climatological values.

L88-89: Could be worth showing this for one GCM in the supplement. E.g. a version of Figure 2 where the grey lines represent internal variability rather than intermodel variability.

Table 1: Add model resolution as a column since that is one of the requirements for this study.

L109: Remove "year"

L109-110: Awkward wording, rephrase: "cover non-mountainous regions, and glaciers and ice sheets are excluded."

L119: Sun et al 2018 (doi: 10.1002/2017RG000574) is a good reference for this statement.

L120: Why not convert it to mm/month so they are directly comparable?

L125: Citation needed for this statement.

L133: Is there any downside to comparing the models at the observational resolution rather than regridding the observations to match the GCMs?

L138: Is this snow covered area calculated for each GCM or is a common snow covered area used across all models? We know from Mudryk et al. (2020) that snow cover extent is highly variable across CMIP6 models.

L144: Shouldn't February be included in this as well since you are assessing the February mean rather than Feb 1 SWE?

L159 and throughout: change "model-minus-observation difference" to "model bias".

L188: The precipitation and temperature biases seem fairly important to the overall story so it might be worth promoting this material to the main text.

Fig 3: “Mean difference in SWE” should be referred to as “SWE Bias” throughout

Fig 3-4: Slightly confusing how “SWE in winter” refers to February, but “Mean P in winter” refers to the Nov-Jan mean.

L221-222: Can you quantify this bias in terms of a percent of the climatology?

L225: “Overall, the GFDL models are the most consistent with the SnowCCI data” -- add “during February” after this statement.

L230: add “NH extratropical” between overestimate and precipitation.

L231: remove “dotted”

L237: reword “either too high SWE and too low T or too low SWE and too high T”

L251-252: “whereas in other models, deltaSWE is clearly smaller.” This is not the most meaningful insight, can you be more detailed.

L277: Is it realistic to treat T and P as independent variables?

L280-284: Hypothesize what is unique about these models that could be driving this.

Prior to Figure 8: it seems like there should be a figure showing spring SWE change from OBS and models before showing the biases.

L294: DeltaSWEchange is confusing notation. Consider alternatives such as DeltaSWEmelt?

L298-299 and elsewhere: change “melts more slowly” to “there is less snowmelt”. What is shown does not necessarily mean snow is melting faster because they all have different SWEmax values.

L316: change “mutually biases” to “mutual biases”

L327-348: Discussion of EC-Earth biases could mention that these models drastically overestimate NH snow cover extent.

L337: “biases in snow melt rate in spring are dominated by other factors than T or P” – further discuss some possible factors in the text (e.g. snow-covered surface albedo biases, which have been documented by numerous studies, albedo feedback strength).