

## ***Interactive comment on “Historical Northern Hemisphere snow cover trends and projected changes in the CMIP-6 multi-model ensemble” by Lawrence Mudryk et al.***

**Lawrence Mudryk et al.**

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Thanks to both reviewers for their constructive comments on the manuscript. Changes prompted by these comments have improved the clarity and impact of the paper. Please note that we found and corrected an error in the selection of model simulations analyzed for future projections which affected Figures 8, 9, and 10. Previous figures were being generated using only a single model (which had metrics close to the ensemble median); the updated figures are based on all available models. None of the conclusions were affected, however we performed some additional analysis related to the seasonality of snow sensitivity (Figures 9 and 10) which was incorporated

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as additional commentary as shown in the tracked-changes version of the manuscript. Our response to each comment is outlined below in **bold**. Revised text is in *red italics*.

General comment:

This is a relevant article, presenting significant results based on very recent data from the CMIP-6 project. The manuscript is well-written and pleasant to read. I have no major concerns, only a few suggestions for minor revisions, outlined below.

Specific comments:

- A few things appear throughout the manuscript, showing that it was written by different authors. One of those is the use of capital letters (or absence thereof) for "Northern Hemisphere". Another one is the use of "autumn" or "fall". Please be consistent throughout the manuscript.

**We have changed all instances of northern hemisphere to Northern Hemisphere and those of fall to autumn.**

- l. 35: "due in part to the insulating properties of snow". This last part of the sentence is a bit confusing and I can't see the causal link with the beginning of the sentence. Could you please elaborate on this?

**This paragraph was revised as follows:**

*Snow cover influences the carbon balance across biomes and seasons. Across tundra regions in winter, snow cover insulation of the underlying soil is a key factor in driving winter season carbon losses from northern permafrost (Natali et al., 2019). Across the boreal forest in spring, gross primary production and carbon uptake during the subsequent months is directly related to the timing of spring snow melt such that earlier snow melt drives greater carbon uptake (Pulliainen et al., 2017). The net effect of these processes on large scale carbon budgets remains uncertain.*

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- l. 88: the acronyms "SCE" and "SWE" are never defined.

**The acronyms were only used in the titles for Sections 2 and 3. We've replaced them with "snow extent" and "snow mass"**

- l. 199: There seems to be a sentence missing before the last sentence of the paragraph to explain why the authors refer to "The remaining Tier 1 CMIP-6 ScenarioMIP simulations".

**We have rephrased the end of the paragraph to read:**

*For analysis of model projections we do not examine simulated trends. Hence the multi-model ensembles analyzed are based on the first realization available for each model.*

- l. 202: I would maybe change the section title to something like "Observation-based historical trends". As is, the difference between sections 3.1 and 3.2 is not so clear  
**Section 3.1 title changed to: "Observation-based trends of snow extent and snow mass"**

**Corresponding title in Discussion (section 4.1) changed to: "Observation-based trends"**

- l. 247 and 252: the figure numbering seems wrong. For l. 247, I guess it should read "Figures 5d and 5e" and for l. 252, "Figures 5a and 5b"? Also at l. 254, it would be useful to include: "... in the Hindu-Kush area further west (Figure 5h).

**Changed to "Figures 5d-f" at Line 247, "Figures 5a-c" at line 252 and "(Figure 5h)" added at Line 254.**

- l. 269: Figure 6 doesn't really show closer agreement between CMIP-6 and observations than for CMIP-5 during the entire fall. The improvement is valid for November and December, but for October for instance, this is not the case. Please reformulate and/or clearly define at some point the seasons you're referring to.

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**This section was rewritten to emphasize the differences between CMIP5 and CMIP6 but now remains agnostic about whether either ensemble has better agreement.**

- l. 390: Figure 13d doesn't exist; please replace it by "Figure 12d".

**Done. Thanks!**

- Figure 2: why does the shading stop in 1967? It would be interesting to see both the grey and blue shadings superimposed during their common period.

**We've provided a new figure for the manuscript with extended shading (Attached Fig 1)**

- Figures 3 and 4: it is generally not recommended to use both green and red colours on the same figure, especially when they overlap. Please try to find a more colour-blind friendly alternative.

**New figures provided (red was changed to blue).**

- Figure 5: The resolution and/or quality of this figure seems rather poor. Please improve it.

**Once finalized, PDF and PS versions of the figures will be submitted.**

- Figure 10: I am not sure both panels in this figure are needed, as they show almost the same thing. I would recommend keeping panel b), and maybe include it in Figure 9.

**We have changed this figure to keep a modified version of panel a to show that the linearity demonstrated in Figure 9 applies more generally for most calendar months. As stated at the beginning of this document, the original version was erroneously presenting results from a single model. The new version shows results from the multi-model ensemble. The kink in the time series at 3.5K (relative to 1995-2014) is due to changes in the number of models available as this level of**

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warming corresponds roughly to the end of the 21st century, beyond which fewer modelling groups contributed realizations. We comment on this in the revised text and demonstrate this explicitly in attached Fig 2.

Technical corrections: - l. 98 and throughout the manuscript: please order your citations by either chronological order or alphabetical order.

**We have reordered them using chronological order.**

- l. 12 and 13: "An ensemble ... is used" and "a subset ... is used".

- l. 144: please delete the word "for".

- l. 239: "the upper part ... features".

- l. 365: duplicate use of the word "successive". I would replace one of those by the word "consecutive" for example.

**All changed. Thanks!**

- Figure 9: There is an unnecessary "b)" in the figure title. **Removed.**

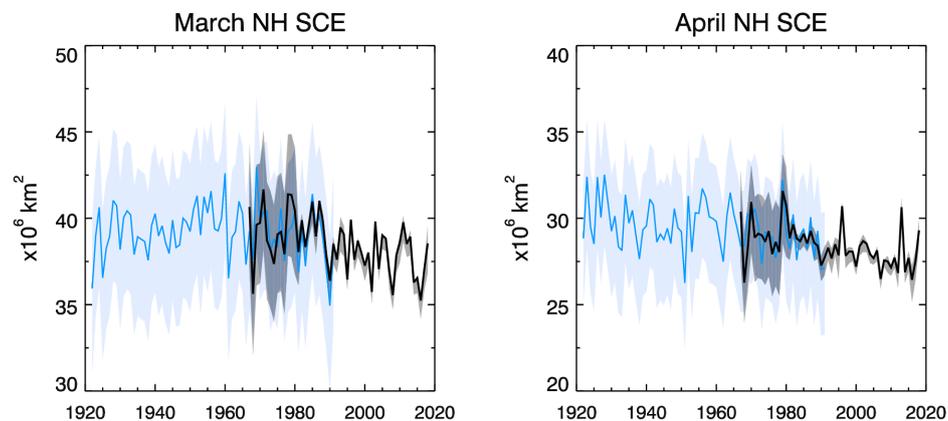
- Figure 11: the x-axis label is missing. Additionally, in the figure caption, maybe include "... hemispheric snow cover extent (SCE)".

**Changed.**

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Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2019-320>, 2020.

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**Fig. 1.** New Figure 2

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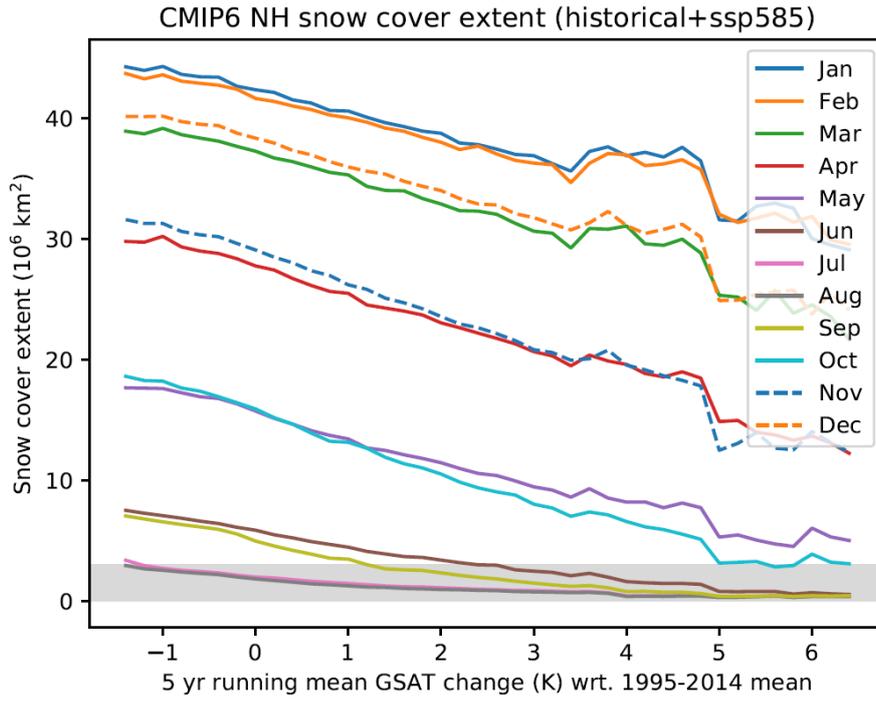


Fig. 2. New Figure 10

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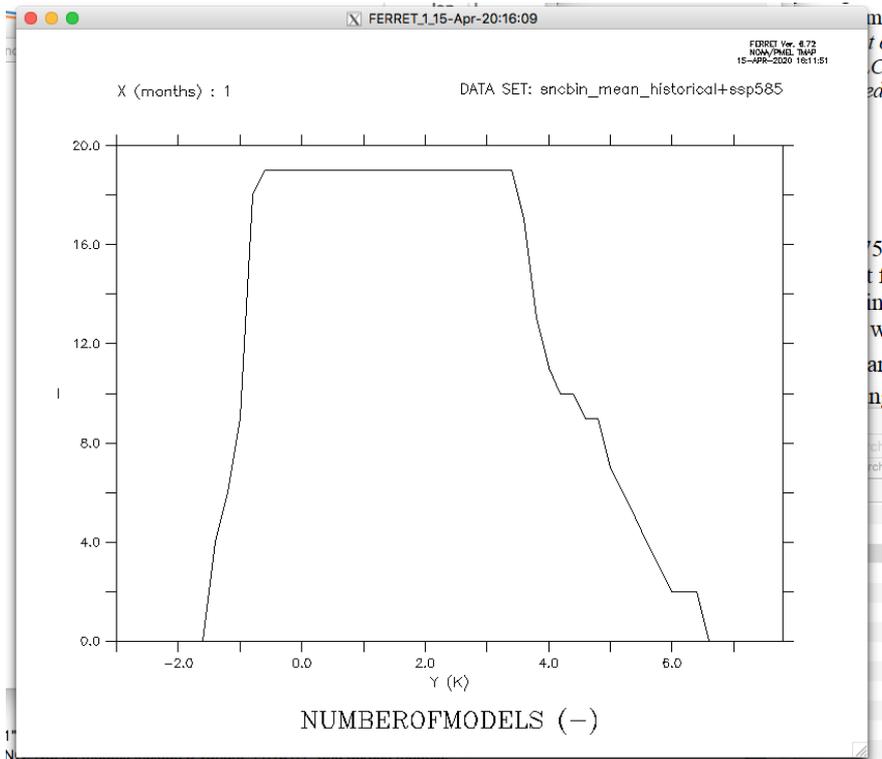


Fig. 3. Reduced number of models available after +3.5K warming

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