Response to Reviewer 1

I thank the reviewer for his / her valuable comments on the manuscript. My response to the comments and the changes to be made in the revised manuscript are detailed below. For clarity, the comments are in blue font, while my response is in black. In some cases, I have included the text planned to appear in the revised manuscript in red font.

General comments:

This interesting research documents the impact of different factors on changes in March SWE by analyzing two reanalyses products and 22 CMIP6 models. The study shows that SWE is decreasing over most of the Northern Hemisphere, as decreases in snowfall and snow-on-ground are more significant than the increase in total precipitation. However, there are large variations between the products analyzed. In general, the study is wellwritten and easy to follow, and I only have a few comments as outlined below.

As the author discusses, there are large differences between different models/reanalyses analyzed in this research and making definitive conclusions might be difficult but, as the paper discusses changes in SWE, I think it might be good to have a bit more clear statements about these changes in the conclusion.

The following characterization of the geographical distribution of the 1951-to-2022 SWE trends will appear in the Conclusions section of the revised manuscript. Repeating this for the more noisy 1981-to-2022 trends would become too complicated.

Trends from winter 1951 to 2022. … Both ERA5L and the CMIP6 models share an increase in SWE in most parts of Alaska, northern Canada, and Siberia, together with decreases in much of southern Canada, the contiguous United States and Europe, excluding northern Scandinavia in ERA5L (Figure 2).

Also, some comments on how the changes in March mean SWE differ from the findings of other papers mentioned in the introduction (e.g., Pulliainen et al. (2020) and Mudryk et al. (2020)) might be good. This research has some similarities to Kouki et al. (2022) which analyses SWE in CIMP6 models and the effects of different factors (temperature and precipitation), though this article covers a larger time span and includes also analyses of reanalysis products. This manuscript mentions that CMIP6 SWE exceeds the GlobSnow estimates similarly to Kouki et al. (2022) but maybe a few more words about any similarities/differences would be good...?

The last two paragraphs in Section 6 of the revised manuscript will include some comparison of the SWE trends to Mudryk et al. (2020) and Pulliainen et al. (2020). Following one of your later comments, the second of these paragraphs makes this comparison separately for Eurasia and North America. **The revised Table 5, the new Table B1, and the new Figure B2, which the text refers to, are included in the end of this file**.

The CMIP6 MMM Total Snow area mean SWE trend in March 1981-2022 (-5.8 mm) falls between the trends in ERAL (-6.9 mm) and MERRA2 (-3.1 mm), whereas the corresponding trend in March 1981-2018 in the GlobSnow area (-3.8 mm) is slightly less negative than those in ERA5L, MERRA2 and GlobSnow (-5.4 to -8 mm). The Mudryk et al. (2020) consensus estimate of Northern Hemisphere March mean SWE trend in the same period suggests an even larger decrease (~9 mm by unit conversion from their Fig. 1c).

The SWE trends in the various data sets have higher spatial correlations in Eurasia than in North America (last two columns of Table 5). However, there is a striking discrepancy in both the Eurasian and North American area mean 1981-to-2022 and 1981-to-2018 SWE trends between ERA5L and the other data sets (Table B1). ERA5L suggests an increase in average SWE in North America and a major decrease in Eurasia, while MERRA2, GlobSnow and CMIP6 MMM all indicate larger decreases in North America than Eurasia. In particular, GlobSnow shows a near-zero SWE trend in Eurasia but a 17 mm decrease from 1981 to 2018 in North America, in good agreement with Pulliainen et al. (2020). Mirroring these mean values, maps of the inter-data-set trend differences (Fig. B2) reveal a particularly pervasive difference between ERA5L and GlobSnow, with more negative trends in ERA5L in much of Eurasia but more positive trends in North America (Fig. B2c). Nonetheless, in the longer 1951-to-2022 period, the SWE decrease in ERA5L is also slightly larger in North America than in Eurasia (Table B1).

Regarding comparison to Kouki et al. (2022), the following text will be added to Section 4.

The CMIP6 22-model mean SWE in the Total Snow Area is close to MERRA2 but 15 % below ERA5L; in the GlobSnow Area it is also below MERRA2. The average precipitation in the CMIP6 models exceeds both ERA5L and MERRA2, but this is compensated by lower mean values of F* and G (third row in Fig. 1). On the other hand, the average CMIP6 SWE exceeds the GlobSnow estimate (bottom-right corner in Fig. 1) by nearly 10 %. Kouki et al. (2022) also used GlobSnow as their main observational data set, finding an average ~15 % overestimate of March mean SWE for a larger set of 38 CMIP6 models (their Fig. 2b). Both the different sets of models and the inclusion of mountainous areas (where GlobSnow was replaced by other observational estimates) by Kouki et al. (2022) may contribute to this slight difference. Using linear regression, Kouki et al. (2022) attributed the overestimate of simulated SWE in February to too large November-to-January precipitation in the CMIP6 models. Although they made this regression analysis for February rather than March mean SWE, this result is in line with the CMIP6 MMM overestimate of area mean P* suggested by Fig. 1.

Specific comments:

L11: 'This is repeated…' This sentence is a bit unclear, what is repeated?

This will be clarified as: This trend attribution is repeated

L130: A sentence or two describing MERRA 2 might be good (as there is a short description of ERA5-Land).

This sentence will be added to Section 2: MERRA2 is an atmosphere-land reanalysis produced by version 5.12.4 of the Goddard Earth Observing System atmospheric data assimilation system.

Table 1.: Possibly line numbers have jumped to the last column of the table? Or what are the numbers (145, 150) in the table?

Yes, they are line numbers. Unfortunately, as this jump was generated in the conversion from the MS Word document to a pdf file, I can do little to prevent its possible re-appearance in the revised manuscript.

Figure 3: It might be interesting to see the difference in SWE between different versions? Different spatial trends are visible in the figures but the same figures showing the differences might be beneficial.

These differences are shown in the new **Figure B2, included in the end of this file**.

L520: Are there some areas where the spatial correlation is better? The average SWE values are larger in North America and some products have problems with this and thus have better performance in Eurasia.

I made the comparison separately for Eurasia and North America. In line with your speculation, the spatial correlations between the different data sets are better in Eurasia. However, there is a major discrepancy between the continental mean SWE trends between ERA5-Land and the other data sets. This will be discussed in the last paragraph of Section 6 in the revised manuscript. The revised Table 5, the new Table B1 and the new Figure B2 are in the end of this file.

The SWE trends in the various data sets have higher spatial correlations in Eurasia than in North America (last two columns of Table 5). However, there is a striking discrepancy in both the Eurasian and North American area mean 1981-to-2022 and 1981-to-2018 SWE trends between ERA5L and the other data sets (Table B1). ERA5L suggests an increase in average SWE in North America and a major decrease in Eurasia, while MERRA2, GlobSnow and CMIP6 MMM all indicate larger decreases in North America than Eurasia. In particular, GlobSnow shows a near-zero SWE trend in Eurasia but a 17 mm decrease from 1981 to 2018 in North America, in good agreement with Pulliainen et al. (2020). Mirroring these mean values, maps of the inter-data-set trend differences (Fig. B2) reveal a particularly pervasive difference between ERA5L and GlobSnow, with more negative trends in ERA5L in much of Eurasia but more positive trends in North America (Fig. B2c). Nonetheless, in the longer 1951-to-2022 period, the SWE decrease in ERA5L is also slightly larger in North America than in Eurasia (Table B1).

L521-523: “However, compared with both ERA5L and MERRA2…” I find this sentence bit unclear, what does overestimating the SWE decrease mean?

To be reformulated as:

However, compared with both ERA5L and MERRA2, the CMIP6 models tend to simulate both larger SWE increases due to increasing precipitation and larger SWE decreases due to decreasing snowfall and snow-on-ground fractions.

Revised Table 5 (with two new columns on the right):

Table 5. Spatial correlation of the trend in March mean SWE and its contributing terms (Eq. 2) between different data sets. SWE-EUR and SWE-NAM refer to SWE trends in Eurasia and North America, respectively. The values without (within) parentheses represent the Total Snow Area (GlobSnow Area).

Years		$\Delta SWE(\Delta P)$	$\Delta SWE(\Delta F)$	$\Delta SWE(\Delta G)$	SWE	$SWE\text{-}EUR$	$SWE\text{-}NAM$
1951-2022	ERA5L vs. CMIP6	0.45	0.75	0.58	0.51	0.59	0.49
1981-2022	ERA5L vs. MERRA2	0.42	0.79	0.39	0.29 (0.48)	0.52 (0.70)	0.11 (0.15)
	ERA5L vs. CMIP6	0.35	0.61	0.27	0.09 (0.16)	0.45 (0.37)	-0.34 (-0.12)
	MERRA2 vs. CMIP6	0.17	0.57	0.30	0.16 (0.12)	0.23 (0.21)	0.02 (-0.05)
1981-2018	ERA5L vs. GlobSnow				(0.13)	(0.41)	(0.02)
	MERRA2 vs. GlobSnow				(0.24)	(0.31)	(0.16)
	CMIP6 vs. GlobSnow				(0.34)	(0.51)	(0.07)

New Table B1:

Table B1. Average March mean SWE trends (mm) separately in Eurasia and North America. The values without parentheses represent trends until 2022 in the Total Snow Area and those in parentheses trends until 2018 in the GlobSnow Area. CMIP6 = CMIP6 MMM.

	Trend from 1951 to 2022		Trend from 1981 to 2022 (2018)	
	Eurasia	North America	Eurasia	North America
ERA5L	-7.6	-10.0	-12.6 (-12.8)	4.7 (1.2)
MERRA2			-1.3 (-4.5)	-6.1 (-7.1)
CMIP6	-4.1	-10.8	-3.7 (-2.4)	-9.6 (-6.5)
GlobSnow			(0.5)	(-16.9)

New Figure B2:

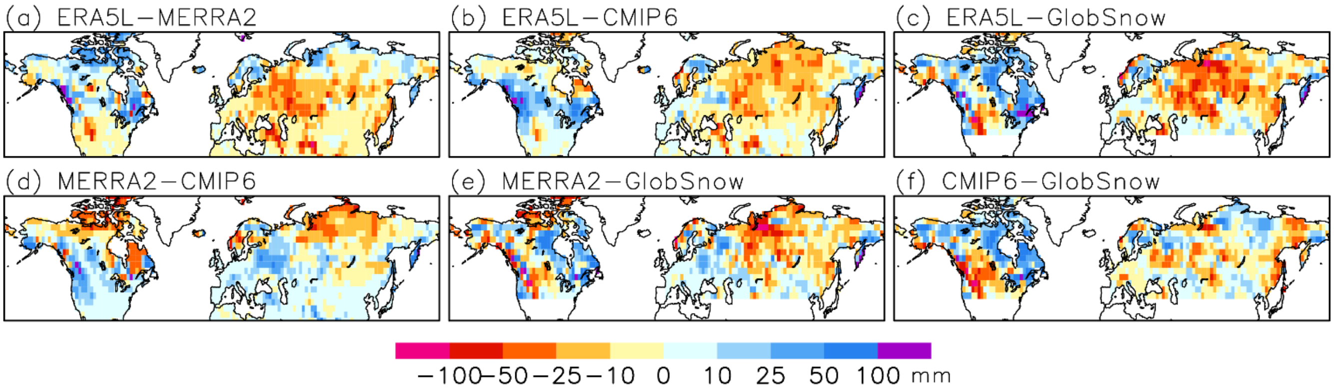

Figure B2. Differences in March mean SWE trends between the data sets identified in the map headers. Periods and units: (a, b, d) 1981 to 2022 (mm (41 yr)$^{-1}$); (c, e, f) 1981 to 2018 (mm (37 yr)$^{-1}$).