Reviewer 2

I thank the reviewer for their comments.

This study uses a long snow cover data to examine the Eurasian autumn snow cover change and its relation with AO. This is an important and interesting topic because of the critical effect of snow cover on the various components of the earth system especially under the warming climate. Overall, this paper has clear structure and the results are well supported by the figures and tables. However, I think the paper lacks impressive findings. The characters of snow cover change and the snow-AO relationship have been investigated by numerous previous studies. Although author uses the long data to explore these issues, there is no new thing in comparison with other studies. Therefore, I would recommend rejecting it for publication in TC.

Considering the comments of all three reviewers, the emphasis for the revised paper will be shifted to how the changes in the autumn SC indices and their relationship to the AO derived from the adjusted 20CRv3 data compares to previous studies. While not necessarily 'impressive', I would argue that the revised paper will achieve the following important results:

1. Ascertain the accuracy of 20CRv3 snow depth data and whether it is an improvement over previous versions. This will help prospective users of the data decide whether it is appropriate for their research needs. The pair of figures below, which are a direct comparison with snow depth from observations, suggest that the high bias in 20CRv2c is indeed carried through to 20CRv3.

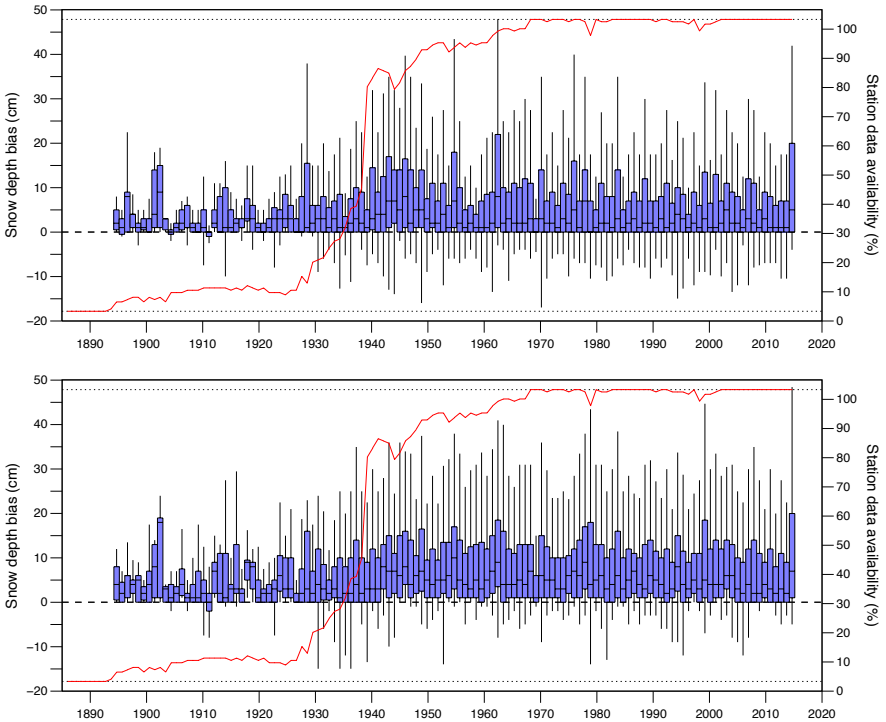

Figure SD. Bias of the median October-November snow depth in 20CRv2c (top) and 20CRv3 (bottom) from 125 stations

2. Examine the robustness of the relationship between the AO and the two Han & Sun (2018) SC indices — an October index and a November dipole index — in the 20CRv3 data. An initial analysis, based on the scrambled AO methodology proposed by Reviewer 1, suggests that this October SC-AO relationship is not robust at all, while SC in only one of the two regions that comprise the November dipole SC index appears significantly correlated to the AO more frequently than chance (see Table HS below).

Table HS. Proportion of decades that the Han & Sun (2018) SC indices derived from 20CRv3 have positive and negative correlations with the 20CRv3 AO, and the proportion that are statistically significant based on a one-tailed test ($p < 0.10$): *** is $p < 0.01$, ** is $p < 0.05$, * is $p < 0.10$. The period covered is 1831-40 to 2006-2015.

Snow Cover Index	Positive (%)	Negative (%)	Pos. (significant) (%)	Neg. (significant) (%)
Oct_SNOWI	62.36	37.64	12.94	11.76
Nov_SNOWI	31.18	68.82	5.88	32.94***
Nov_SNOWI (west)	75.29	24.71	32.94***	4.12*
Nov_SNOWI (east)	34.71	65.29	7.65	18.72

3. Examine how the temporal variability of the correlation between these indices and the AO compares to 20CRv2c, for example, as demonstrated by Wegmann et al. (2020) in their Fig. 7b: an equivalent plot using 20CRv3 is shown below. Comparing the two plots indicates a broad similarity, with statistically significant negative SC-AO relationships in the 1920s and the present. Differences include some short periods of positive correlations in the 20CRv3 plot that are not present in 20CRv2c. Moreover, being able to extend the time series back further using 20CRv3 reveals that periods of positive correlation were actually dominant during the mid 19th Century, thus indicating that the negative Han & Sun (2018) November dipole-AO relationship is less temporally invariant than previously thought.

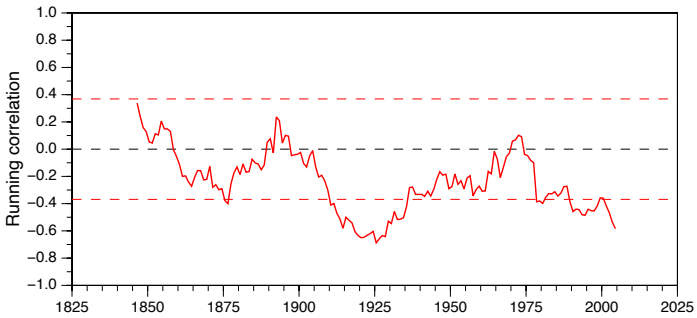

Figure W. Running 21-year correlations between the Han & Sun (2018) November dipole index and winter AO. The dashed horizontal lines of the same colour indicate significance levels at $p < 0.10$ for a one-tailed test.

4. Introduce an apparently robust SC-AO relationship with the September SC in the north-east of Eurasia (120-180°E, 60-70°N) that has not been described previously. For this region, SCI_09 has both a statistically significantly low frequency of decades with a positive AO correlation and vice versa for a negative AO (see revised Fig. 8 below).

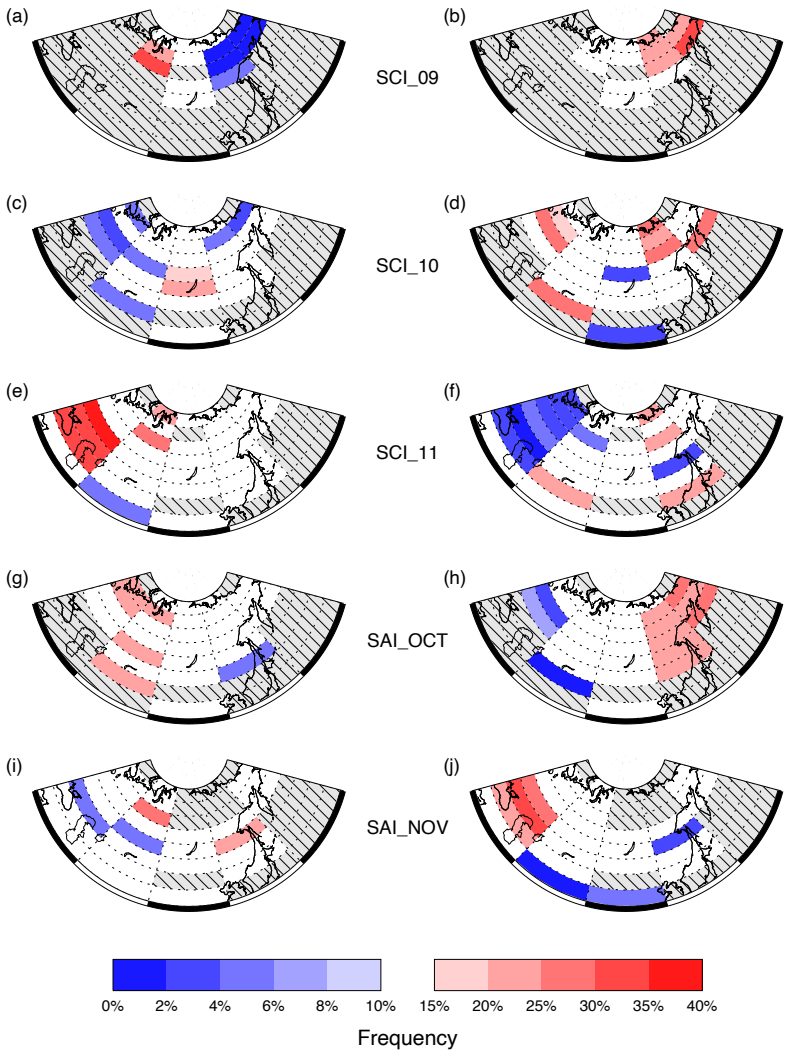

Figure 8. The frequency of decades with statistically significant correlations with the AO ($p < 0.10$) from the 20CRv3 data (1831-1840 to 2005-2014) for the five SC indices. Frequencies for positive correlations are shown on the left in red and negative correlations on the right in blue. Hatched subregions are where no value was calculated because data availability was less than 50%.

5. Demonstrate that in 20CRv3 using SC in south-west Eurasia (30-60°E, 40-55) provides a more robust SCI_11-AO relationship than the Han & Sun (2018) Nov_SNOWI index (compare Table_new below with Table HS above); i.e. it has a higher frequency of decades with a significant SC-AO relationship.

Table_new. Proportion of decades SC indices derived from 20CRv3 have positive and negative correlations with the 20CRv3 AO, and the proportion that are statistically significant based on a one-tailed test ($p < 0.10$): *** is $p < 0.01$, ** is $p < 0.05$, * is $p < 0.10$. The period covered is 1831-40 to 2006-2015.

Snow Cover Index	Positive (%)	Negative (%)	Pos. (significant) (%)	Neg. (significant) (%)
SCI_09_NE	26.47	73.53	1.76**	27.64***
SCI_11_SW	76.47	23.53	38.34***	4.12*

Han, S., and Sun, J.: Impacts of autumnal Eurasian snow cover on predominant modes of boreal winter surface air temperature over Eurasia, J. Geophys. Res. Atmos., 123, 10076–10091, https://doi.org/10.1029/2018JD028443, 2018.

Wegmann, M., Rohrer, M., Sanolaria-Otín, M., and Lohmann, G.: Eurasian autumn snow link to winter North Atlantic Oscillation is strongest for Arctic warming periods, Earth Syst. Dynam., 11, 509–524, https://doi.org/10.5194/esd-11-509-2020, 2020.

Major issues

This is a quite long paper. The author has put a lot of efforts into the Introduction, Data and Method parts, while the Results part seems a little hasty. Also, I cannot easily get the point from the lengthy introduction. I suggest the author to delete the text that unrelated to the main topic of your study and put some methods into the supplementary materials.

As neither of the other reviewers mention this issue, I would prefer to keep the Introduction as it is. However, if the revised paper shifts emphasis as proposed then there is the potential to remove the paragraph about previous modelling studies.

Form figure 7 and table 3, I find that there is hardly any significant correlation between snow and AO. Does it imply that the Eurasian snow cover has little influence on the AO, or the snow-AO relation is a stochastic event?

Based on the statistics from the new 'scrambled data' methodology and new Eurasia region suggested by Reviewer 1, the revised Table 3 is shown below. This demonstrates that the proportion of decades with a significant SC-AO relationship for Eurasia as a whole is statistically high and low for SCI_09 and SCI_10 for negative and positive relationships with the AO, respectively. In addition, the proportion of decades with a positive SAI_11-AO relationship is significantly small. Therefore, it appears likely that Eurasian snow cover does have some influence on the AO and the relationship is not purely stochastic. This is also the conclusion of Wegmann et al. (2020), who examined SC-AO relationships over the 20th Century and between November SC and the NAO rather than AO and stated that, "We find evidence for a negative NAO-like signal after November … which is valid throughout the last 150 years."

Wegmann, M., Rohrer, M., Sanolaria-Otín, M., and Lohmann, G.: Eurasian autumn snow link to winter North Atlantic Oscillation is strongest for Arctic warming periods, Earth Syst. Dynam., 11, 509–524, https://doi.org/10.5194/esd-11-509-2020, 2020.

Table 3. Proportion of decades that the 20CRv3 SC indices have positive and negative correlations with the 20CRv3 AO, and the proportion that are statistically significant based on a one-tailed test ($p < 0.10$). The significance of the proportion of decades with a significant SC-AO correlation is determined based on a probability distribution function derived from 10000 scrambled AO time-series using a one-tailed test for each sign of correlation: *** is $p < 0.01$, ** is $p < 0.05$, * is $p < 0.10$. The period covered is 1831-40 to 2006-2015.

Snow Cover Index	Positive (%)	Negative (%)	Pos. (significant) (%)	Neg. (significant) (%)
SCI_09	32.35	67.65	2.35**	27.65***
SCI_10	48.82	51.18	4.12*	22.35**
SCI_11	52.94	47.06	11.18	10.00
SAI_OCT	38.82	61.18	11.18	13.53
SAI_NOV	47.06	52.94	2.94**	9.41

How to calculate the running decadal mean and correlation in figure 5 and 7? How long is the sliding window? If you use different sliding window, will it change the existing results?

The sliding window is 10 years as we are interested in decadal means and correlations. This will now be explicitly stated in the appropriate figure captions. Figure W2 below provides an example of changing the length of the sliding window: it represents running correlations between the Han & Sun (2018) November dipole index and winter AO.

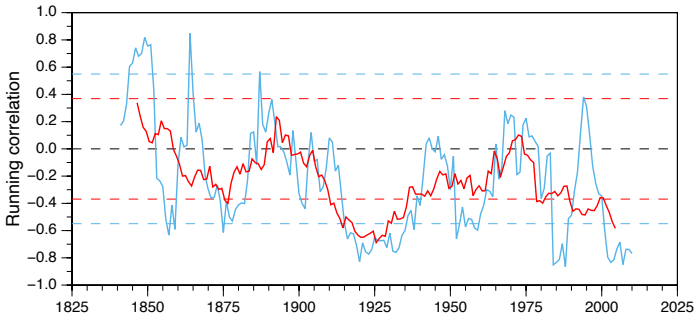

Figure W2. Running 10-year (blue) and 21-year (red) correlations between the Han & Sun (2018) November dipole index and winter AO. The dashed horizontal lines of the same colour indicate significance levels at $p < 0.10$ for a two-tailed test.

As expected, this figure indicates that the longer periods where the SC-AO relationship is statistically significant are similar for both sliding windows; e.g., the period of negative correlation centred around 1925. Of course, the shorter window has more temporal detail, such as the two short periods of statistically significant positive correlations towards the start of the time series, which are not seen in the longer window. However, overall, the principal outcomes are independent on the window length.

Line 160: Why reverse the sign of SAI index? It is contrary to common sense and makes readers difficult to follow.

This follows from the work of Cohen & Jones (2011) and Peings et al. (2013). It was originally done in Cohen & Jones (2011) so that an SAI time series could be easily compared to a winter AO time series: there was a strong negative correlation between the rate of snow advance and the subsequent winter AO in the period encompassed by the earlier work (cf. their Fig. 1). For consistency, I have kept the same definition as the previous literature but would be happy to change the sign of the SAI indices if the editor thinks it appropriate.