Comment on egusphere-2022-939
Anonymous Referee #1

The paper uses an ensemble of AMIP simulations, from 8 different atmospheric models, to explore drivers of Northern Hemisphere (NH) snow cover trend/interannual variability, and its feedback on the winter atmospheric circulation, over 1979-2014. Two types of experiments are analyzed. ALL includes prescription of observed external forcings, sea surface temperature (SST) and sea ice concentration (SIC), while no-SIC is similar but with climatological SIC, such that the difference between ALL and SIC highlights the influence of observed SIC variability. Daily SST and SIC are prescribed to the atmospheric models.

The paper is well-written and clear. One of the main result is that SIC has little impact on both the trend and interannual variability in NH snow. This is convincingly demonstrated and described in the paper/abstract. Although internal variability dominates, the authors find that SST/external forcings have a greater influence than SIC in driving NH snow variability. The influence of snow on the atmospheric circulation and NH climate is then explored. No robust influence of November and April snow is found, but the authors identify a significant polar vortex anomaly (and associated surface climate response) lagging the 1st mode of variability of January snow cover (snow cover EOF1_int) in the models. This connection is further explored singling out the LMDZOR6 model, for data availability consideration.

I think the paper is interesting and overall in good shape, but I have a few comments that may help improving the study. Please find them hereafter.

1) My first comment is about the observed trend in Eurasia/North America snow cover in November. The CanSISE observations you use stop in 2010, but it is notorious that snow cover in fall has had a tendency to increase since 2010, roughly. See the timeserie of snow cover from the Rutgers University Global Snow Lab for November, that shows the Eurasia and North America snow cover extent for the 1966-2022 period. There is a clear positive trend in both domains. This is for 1966-2022, but even over the 1979-2010 period that you use in your study, I do not see a decreasing trend as shown in your Fig. 5. Could you elaborate on this discrepancy? Is this due to uncertainties in observations, periods, both?

Link to the Rutgers Univ. snow extent timeseries: https://climate.rutgers.edu/snowcover/chart_anom.php?ui_set=1&ui_region=nmland&ui_
2) In link to my previous comment, section 3.4 shows there are large differences between the observed datasets in November. This is something that could be discussed further. Which dataset is more reliable in fall? NOAA-CDR, because it consists of direct satellite measurement of snow cover?

3) The most interesting result of the study, other than highlighting the limited impact of SIC on snow cover variability, is the potential feedback of January snow cover anomalies on polar vortex warming events (section 4.3). You find that snow cover EOF1_{int} is preceded then followed by a significant weakening of the polar vortex, and you hypothesize that snow may act as a feedback in increasing the persistence, possibly amplitude, of the anomaly in the stratosphere. This is interesting but only speculation since no analyses are shown to demonstrate it. I think this is where the paper can be improved, and I have a few suggestions. In the analyses of LMDZOR6, you could select winters that exhibit persistent polar vortex weakening (similar to Fig. 15), and differentiate these events between those that also exhibit high snow cover EOF1_{int} anomalies, and those that do not (composite analyses). This would be a way to verify whether snow cover EOF1_{int} anomalies are indeed necessary to enhance the persistence and amplitude of the polar vortex warming. If possible, it would also be nice to see how snow cover EOF1_{int} affects the stationary wave structure over Eurasia, and wave activity, that could potentially cause a higher persistence of polar warming anomalies. This section needs improvement to be more convincing.