Response to Referee #2:

GENERAL COMMENTS

This paper uses sensitivity experiments to increase our knowledge and understanding of the dynamics and teleconnections whereby Arctic sea ice decline could influence pollution and air quality in China. This is a timely study with some interesting diagnostics and analysis. The approach toward the sensitivity experiments, the diagnostics defined, and the quality and quantity of figures and tables is all good.

However, I have a couple of concerns as outlined below.

Response: Thank you very much for your comments and suggestions. We have revised the manuscript accordingly to address your concerns. Please see below our responses in blue to your specific comments.

SPECIFIC COMMENTS

I think lines 22 and 32 are not quite correct as they stand. I'd suggest changing "positive correlations with the regional Arctic sea ice decline" to "positive correlations with the regional Arctic sea ice concentrations", and "positive correlation with the declining sea ice" to "positive correlation with sea ice concentrations". My reading of Figure 1 is that the positive correlation between the EU index and sea ice concentrations in R2 (Figure 1b) suggests that the EU index will decrease as sea ice decreases in R2. Then, the positive PPI index in East Asia in the negative phase of the EU (Figure 1d) suggests that this decreasing EU index will lead to increased pollution in East Asia. Therefore, pollution gets worse in East Asia as sea ice declines in R2. Perhaps section 3.1 would be clearer if re-written slightly to emphasize this?

Response: Thank you for the suggestion. We revised the sentence here to "The winter EUI shows positive correlations with regional Arctic sea ice concentrations with the strongest correlation over the East Siberian Sea and Chukchi Sea (Fig. 1b), suggesting a decrease of EUI in winter following the sea ice decline over these regions in preceding months.". We also explicitly state in the next paragraph that "Since the EUI shows a positive correlation with declining sea ice in the Pacific sector of the Arctic, we would expect more severe air stagnation over East Asia coinciding with the decrease of EUI and regional Arctic sea ice."
Please see Section 3.1 in the revised manuscript for details.

My major concern with this paper is with regards to how relevant this key conclusion is to the real world (which will experience SENSall). Figure 1b shows negative correlations in R1 and R3, so declining sea ice in these regions will improve pollution in East Asia, cancelling the impacts of sea ice decline in R2. Indeed, Tables S3 and S4 indicate no significant difference in PPI between the CTRL and SENSall experiments. This concern, that the substantial conclusions in this paper are all based on SENSr2 which may not be a realistic scenario, will need to be addressed.

Response: Thank you for the helpful discussion. We agree with you that the climate system in the real world has much more complex interactive processes among different components than in climate models, and it's still difficult to find a consensus on the potential influence of Arctic warming and sea ice decline on midlatitude extreme weather due to relatively low signal-to-noise ratios (Cohen et al., 2020). Resonating with a common aphorism that "all models are wrong, but some are useful", we interpret our modeling results from the following perspectives:

(1) The key conclusion suggests distinct climate impacts of sea ice loss in different Arctic regions, which is consistent with previous studies (Screen, 2017; Sun et al. 2015, McKenna et al., 2018). Such region-dependent sensitivity along with the associated dynamic process analysis helps to improve understanding of how Arctic warming can affect midlatitude weather and climate extremes. Previously, Barnes and Screen (2015) discussed a similar topic by framing their inquiries around three different questions: "*Can Arctic warming influence the midlatitude jet-stream? (Can it?) Has Arctic warming significantly influenced the midlatitude jet-stream? (Has it?) Will Arctic warming significantly influence the midlatitude jet-stream? (Will it?)*". They concluded that a growing consensus in the model-based studies that Arctic warming *can* significantly influence the midlatitude circulation does not necessarily imply that it *has* in the past, nor that it *will* in the future (Barnes and Screen, 2015). Their thoughts about these three questions provide insight into the discussion here—that is, our modeling results can be more suitably used to answer the "*Can it?*" question rather than the "*Has it?*" one posed in your comment. The answer to the second question is closely related with dynamic processes that actually happened in the real atmosphere, while the answer to the first one is not. Therefore, we can rely on idealized modeling experiments to isolate specific climate effects of interest to answer the "*Can it?*" question, which is the major motive of this study. It's noted that the real world does not experience the SENSall experiment since the sea surface temperatures and sea ice concentrations in the WACCM model experiments are prescribed without the two-way air-sea interactions. These processes are considered by the fully coupled CMIP6 model simulations as shown in Section 3.4 and Fig.7, which also help to answer the "*Can it?*" and "*Will it?*" questions rather than "*Has it?*".
(2) The sensitivity results identify key regions of interest to improve air quality seasonal forecasts. Satellite observations show varying sea ice variability in different years and Arctic regions (Fig. R1/R2). The teleconnection between high latitudes and midlatitudes may be dominated by different dynamic processes associated with changes in subregions of the Arctic from interseasonal to interannual time scales. Previous studies have suggested changing importance of regional sea ice forcing in different months/seasons (Screens, 2017), which is also evident in our SENSall monthly results (Fig. R3/R4). The proposed teleconnection relationship among regional Arctic sea ice, EUI, and ECP_PPI is most prominent in December, with negatively shifted EUI (Fig. R4a) and more positive extremes of ECP_PPI (Fig. R4d) in this month than others. Figure S10 in the Supplement shows similar intra-seasonal variations in SENSr2 atmosphere responses, with more negative EU patterns emerging in early winter than in late winter. However, the studied R2 regional forcing-response relationship can be overwhelmed by other Arctic regional forcings or other climate factors such as tropical forcings in the real atmosphere. That's why a consensus on the climate impact of Arctic warming is difficult to achieve. Our idealized modeling experiments and dynamic diagnosis provide a plausible pathway of how regional Arctic change can affect midlatitude air stagnation weather extremes, while extended and fully coupled experiments are suggested in the discussion part to further investigate the relative importance of different pathways and their roles in the real atmosphere.

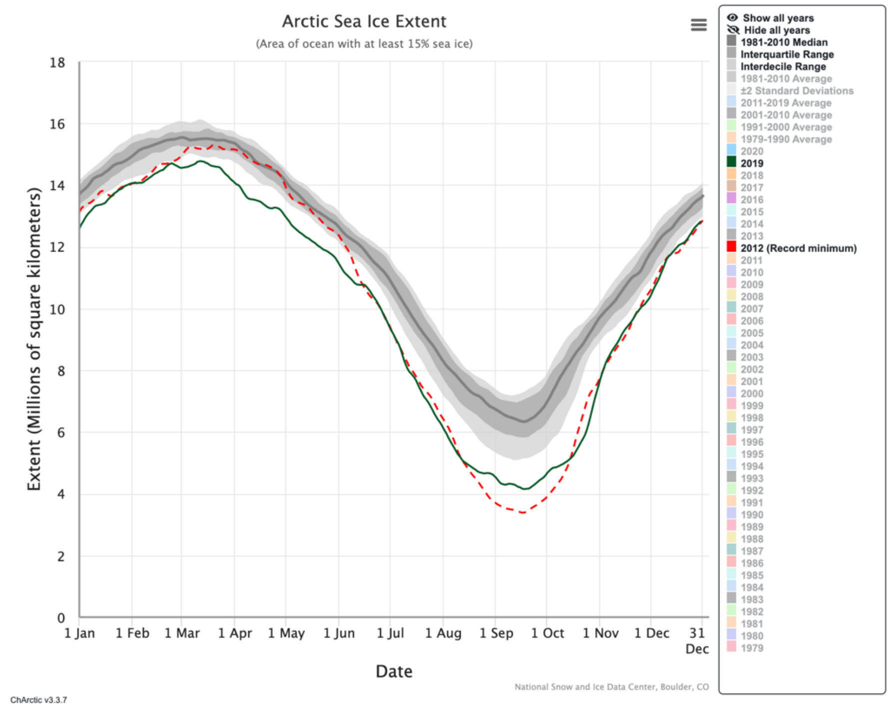

Figure R1: Comparison of Arctic sea ice extent time series between 2012 and 2019 (adapted from the NSIDC website at https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/; last access: 14 February, 2020).

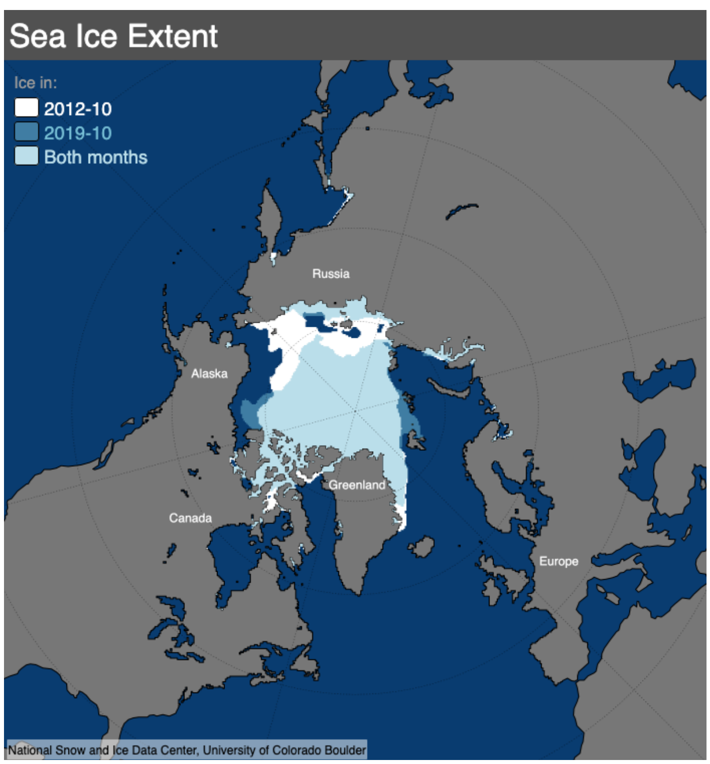

Figure R2: Comparison of Arctic sea ice extent spatial distributions between 2012/10 and 2019/10 (adapted from the NSIDC website at http://nsidc.org/arcticseaicenews/sea-ice-comparison-tool/; last access: 14 February, 2020)

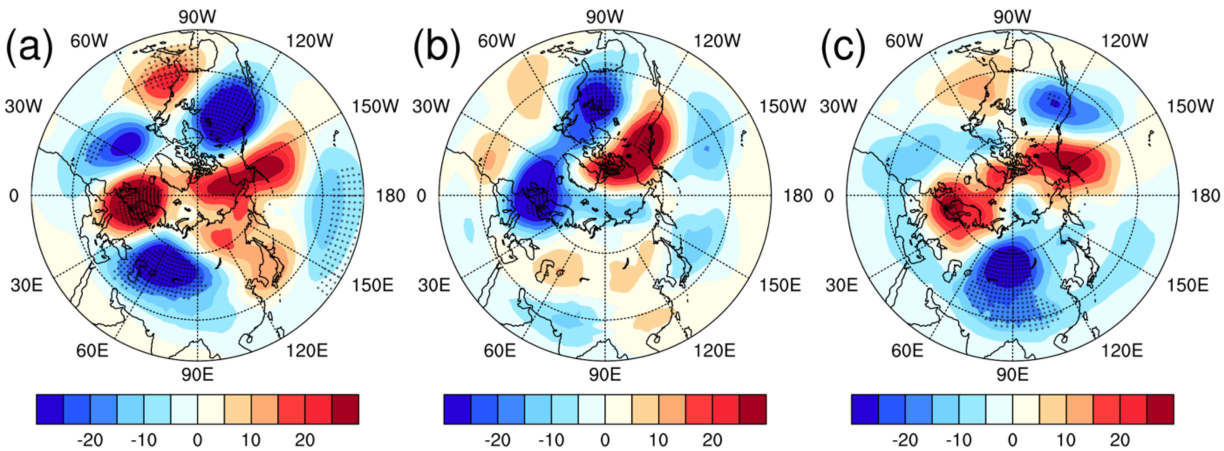

Figure R3: SENSall geopotential height anomalies at 500 hPa in (a) December; (b) January; (c) February. The stipples denote the 0.05 significance level.

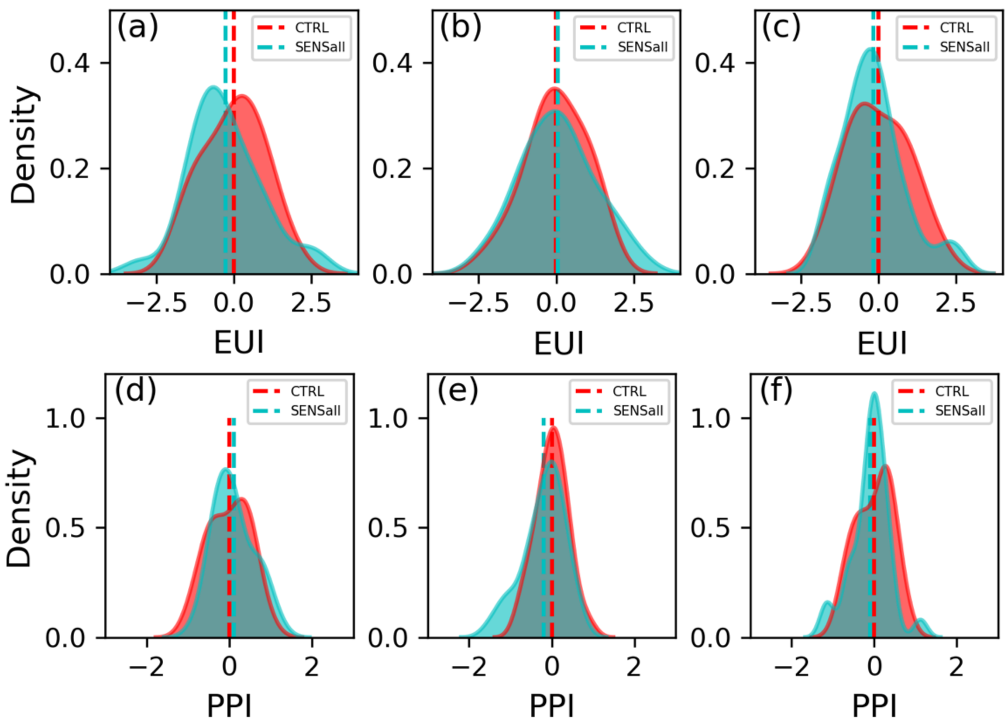

Figure R4: Comparison of KDE-based distribution density estimates in CTRL and SENSall for (a) EUI in December; (b) EUI in January; (c) EUI in February; (d) ECP_PPI in December; (e) ECP_PPI in January; (f) ECP_PPI in February; The dash lines denote ensemble averages.

Checking of the English grammar and language throughout the manuscript is required. To give a couple of examples: on page 2 line 4 "environmental stressors" should be "environmental stresses", and on page 7 line 21 "are the same with these" should be "are the same as those".

Response: We have now checked the English language throughout the manuscript and made a few more corrections.

The description of some of the calculations and diagnostics used in the paper could be slightly clearer. For example, in section 2.3, which "statistical functions in Python" were used, and what is meant by "proper distributions"? Also, please expand on the definitions of WSI and ATGI to make clearer exactly how these are calculated.

Response: Thank you for the suggestion. We have added more detailed descriptions for the calculations and definitions. For example, the Python statistical functions include “normaltest” and “shapiro” for normality tests in Table S2 and Fig. S2/S3, “skew” and “kurtosis” to compute skewness and kurtosis of data sets in Table S2, “norm.fit” to fit normal distributions if the data samples pass normality tests (Fig. S2/S3), or “gumbel_r.fit”/“gumbel_l.fit” to fit right-skewed/left-skewed Gumbel distributions if not (Fig.S2/S3), etc. These explanations are added in Section 2.3 of the revised manuscript.
We also added the descriptions of WSI and ATGI in lines 34-37 of page 3:
“WSI was standardized by subtracting time-averaged climatological mean of near-surface wind speed over the 1981-2010 period from the monthly values at each grid cell and then dividing by its standard deviations in the same period. ATGI was the standardized potential temperature gradient field between 925 and 1000 hPa using the same method. These two indices are used to reflect horizontal and vertical dispersions of near-surface air pollutants, respectively.”
We revised the manuscript extensively to address these problems. Please see our revised manuscript with tracked changes for details.

MINOR COMMENTS AND TYPOGRAPHICAL ERRORS
Page 3, line 32: Person should be Pearson.

Response: Thank you. We corrected the typo here.

Page 5: Perhaps change "Fig. 1" to "Fig. 1a" on line 28, and then add reference to "Fig. 1b" on line 31.

Response: Thank you. We added the specific references in the revised manuscript.

Page 10, line 6: "(et al." should be "(et al."

Response: Thank you. It’s corrected.

References

Barnes, E. A., and Screen, J. A.: The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?, WIREs Climate Change, 6, 277-286, 10.1002/wcc.337, 2015.

Cohen, J., Zhang, X., Francis, J. et al.: Divergent consensuses on Arctic amplification influence on midlatitude severe winter weather, Nat. Clim. Chang., https://doi.org/10.1038/s41558-019-0662-y, 10, 20–29, 2020.

Screen, J. A.: Simulated atmospheric response to regional and pan-Arctic sea ice loss, J. Climate, 30, 3945-3962, 2017.

Sun, L., Deser, C., and Tomas, R.A.: Mechanisms of stratospheric and tropospheric circulation response to projected Arctic sea ice loss, J. Climate, 28, 7824-7845, DOI: 10.1175/JCLI-D-15-0169.1, 2015.

McKenna, C. M., Bracegirdle, T. J., Shuckburgh, E. F., Haynes, P. H., Joshi, M. M.: Arctic sea-ice loss in different regions leads to contrasting Northern Hemisphere impacts, Geophys. Res. Lett., https://doi.org/10.1002/2017GL076433, 2018.