Reply to Reviewer#2 (comments in *italics*)

Review of acp-2021-249

Haze pollution is a very serious environmental issue in China, especially in winter and spring. This manuscript discusses the possible connections of haze pollution in winter and spring. The authors show that conditions of the North Atlantic SST anomalies play a key role in determining seasonal evolutions of haze pollution over North China Plain. I find this study very interesting. The obtained results have important implications for the prediction of haze pollution. I suggest this manuscript to be accepted if satisfactorily addressing the following concerns.

General comments:

The authors define a DECC index by averaging the DECC anomalies over the 26 stations to describe variation of haze pollution over the NCPR. The authors need to prove that the DECC over NCPR varied similarly, i.e., the DEC of the 26 stations can be treated as a whole.

Reply: Thanks for the Reviewer's suggestion. Following previous studies (Chen et al. 2019, 2020), the region for the NCPR we choose for analysis extends from 34°N to 43°N and from 114°E to 120°E. Chen et al. (2019) has demonstrated that interannual variations of the DECC at the 28 stations over the NCPR are largely similar, and can be treated as a whole. Figure R2A shows the first EOF mode (EOF1) of interannual anomalies of DECC in winter and spring over the NCPR (i.e. 34°-43°N and 114°-120°E) for the period of 1979-2010. Spatial structures of the EOF1 in winter and spring are generally featured by same-sign DECC anomalies over the NCPR, except for small patch of regions (Figs. R2Aa and R2Ab). In particular, the correlation coefficient between the PC time series corresponding to the EOF1 of winter DECC anomalies (Fig. R2C, red curve) and the winter NDI shown in Fig. 1b (in the revised manuscript) reaches 0.86, which is significant at the 99.9% confidence level. Similarly, the correlation coefficient between the PC time series corresponding to the EOF1 of spring DECC anomalies (Fig. R2Ac, blue curve) and the spring NDI shown in Fig. 1b (in the revised manuscript) is as high as 0.93. Above evidences suggest that the 28 stations in the NCPR can be generally considered as a whole. Figure R2A (below) and related discussions have been added in the revised manuscript. **Please see Figure 2 and Lines 241-254 in the revised manuscript.**

References

Chen, S., Guo, J., Song, L., Li, J., Liu, L., and Cohen, J.: Interannual variation of the spring haze pollution over the North China Plain: Roles of atmospheric circulation and sea surface temperature, Int. J. Climatol., 39, 783-798, 2019.

Chen, S., Guo, J., Song, L., Cohen, J., and Wang, Y.: Temporal disparity of the atmospheric systems contributing to interannual variation of wintertime haze pollution in the North China Plain, Int. J. Climatol., 40,128-144, 2020.

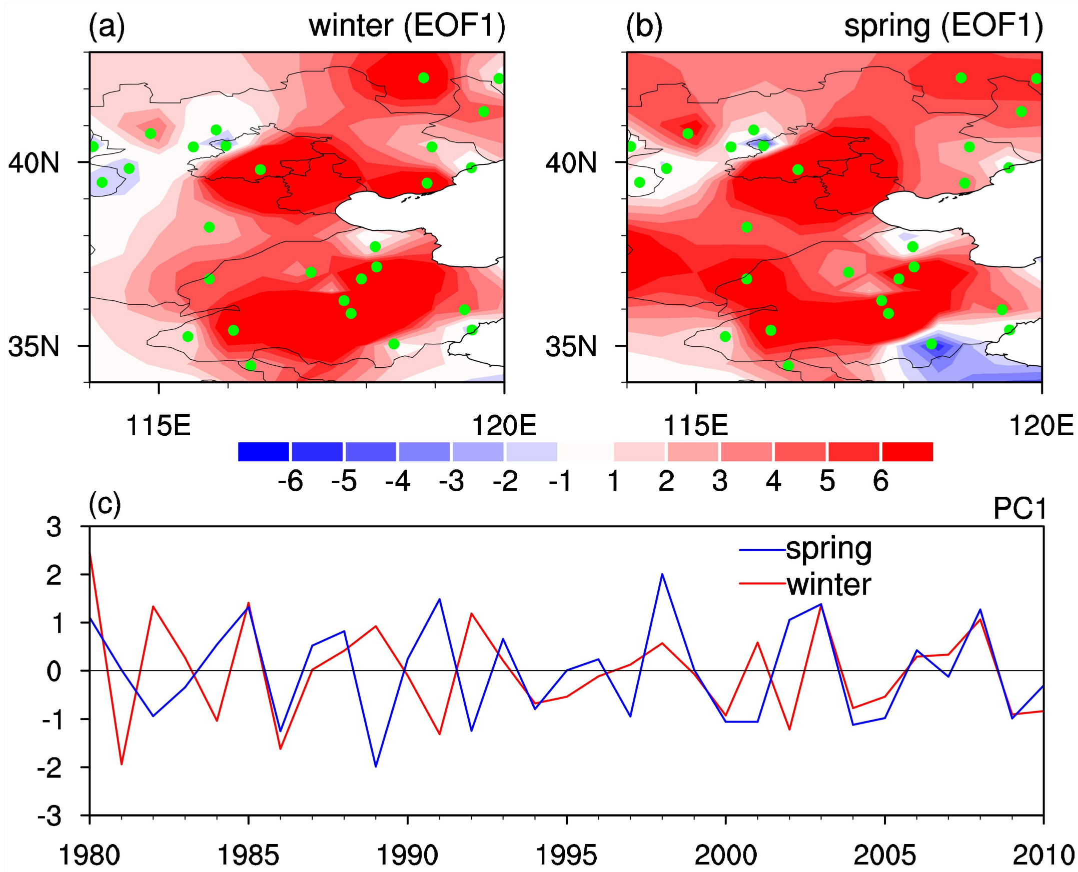

Figure R2A. The first EOF mode (EOF1) of interannual anomalies of DECC in (a) winter and (b) spring over the NCPR (i.e. 34°-43°N and 114°-120°E) for the period of 1979-2010. (c) The corresponding PC time series of EOF1 of interannual anomalies of DECC in winter (red curve) and spring (blue curve). The green dots in (a-b) indicate the stations in the NCPR.

Lines 340-341 and Figure 5: I agree with the view that atmospheric circulation anomalies could exert impacts on haze pollution via modulating surface wind speed and humidity. Whether change in the boundary layer height (BLH) also plays a role? Studies have demonstrated BLH is also a very important factor in modulating Haze pollution via change in the vertical diffusion of pollutant. For example, the anticyclonic anomaly and associated increase in sea level pressure over the North China plain may lead to decrease in the BLH, which would result in more serious haze pollution. The role of the BLH should be examined.

Reply: Thanks for the Reviewer's good suggestion. Following your suggestion, we have examined anomalies of the boundary layer height (BLH). Figure R2B (below) shows composite anomalies of BLH in winter and spring for the persistent and reverse years. Consistent with the Reviewer's view, it shows that decrease in the BLH, which is associated with an anticyclonic anomaly, is seen over the NCPR in winter and spring for the persistent year (Figs. R2Ba and R2Bc). Decrease in the BLH is unfavorable for vertical diffusion of pollutant and thus contributes to maintenance of the above normal DECC from winter to spring for the persistent year (Figs. 3a and 3c in the revised manuscript). By contrast, in the reverse year, the winter decreased BLH (Fig. R2Bb) is replaced by increased BLH in the subsequent spring over the NCPR (Fig. R2Bd). Increase in the BLH in spring over the NCPR contributes to less serious haze pollution via increase in the vertical diffusion of pollutant. Following the Reviewer's suggestion, we have discussed the role of the BLH anomalies in the different evolutions of haze pollution from winter to spring. **Figure R2B (below) have also been added to the revised manuscript. Please see Figure 7 in the revised manuscript.**

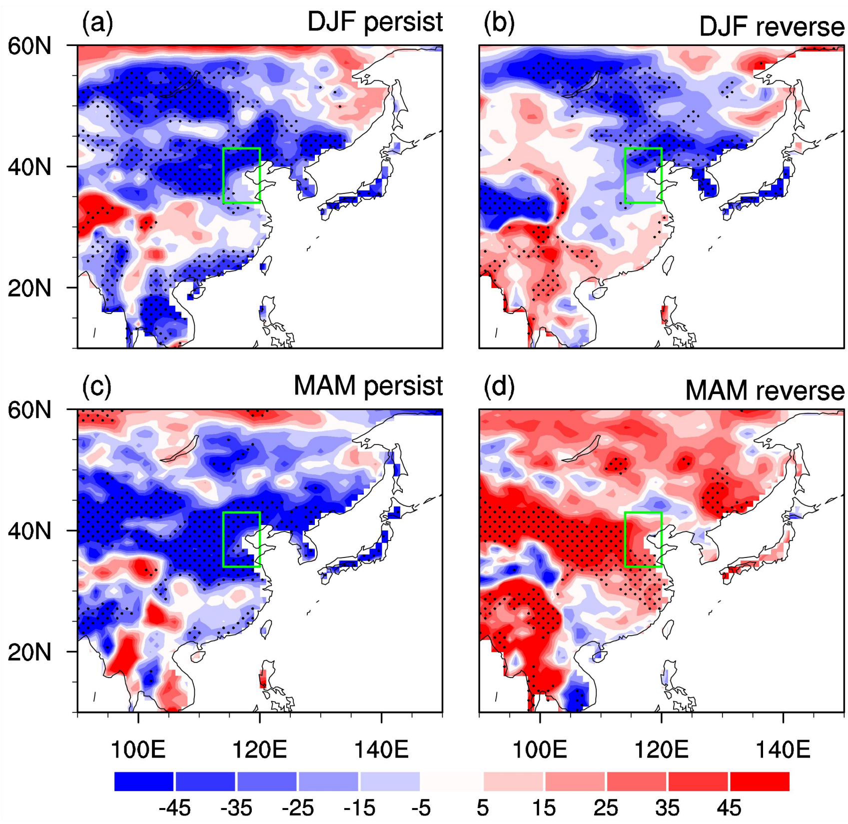

Figure R2B. Composite anomalies of boundary layer height (BLH, unit: m) in (a, b) winter and (c, d) spring in the (left column) persistent years and the (right column) reverse years. Stippling regions indicate anomalies that are statistically significant at the 5% level.

This study reported that North Atlantic SST anomalies play a key role in the formation of the atmospheric circulation anomalies via atmospheric teleconnection, which further determine evolutions of haze pollution over North China. From Fig. 6, it seems that geopotential height anomalies in the Arctic region also show large differences. Previous studies have shown that Arctic sea ice anomalies can significantly impact atmospheric circulation anomalies over East Asia and haze pollution over China. Hence, I suggest authors examine Arctic sea ice anomalies and discuss whether Arctic sea ice conditions also play a role in the different evolution of atmospheric circulation anomalies and haze pollution.

Reply: Thanks for the Reviewer's suggestion. Following your suggestion, we have examined evolutions of Arctic sea ice anomalies for the persistent and reverse years

(Fig. R2C below). From Fig. R2C, sea ice anomalies in winter and spring for the persistent and reverse years are weak over most portions of the Arctic. This suggests that the distinct evolutions of atmospheric circulation and haze pollution over the NCPR for the persistent and reverse years are not likely due to the Arctic sea ice anomalies. We have added discussions in the revised manuscript. **Please see Lines 773-778 in the revised manuscript.**

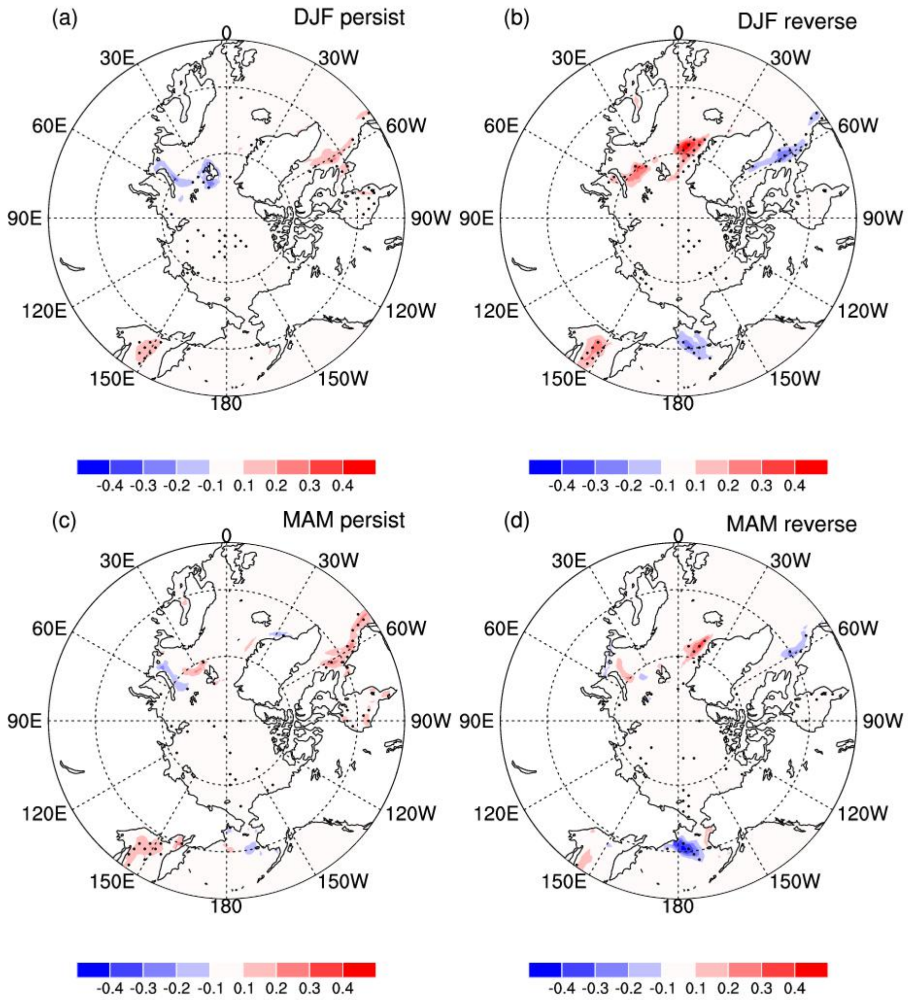

Figure R2C. Composite anomalies of Arctic sea ice concentration (unit: %) in (a, b) winter and (c, d) spring in the (left column) persistent years and the (right column) reverse years. Stippling regions indicate anomalies that are statistically significant at the 5% level.

I suggest add associated wave activity flux into Figure 11 to more clearly illustrate propagation of the atmospheric wave train induced by the forcing over the North

Atlantic.

Reply: Following the Reviewer's suggestion, we have added the associated wave activity fluxes to Figure 13 (in the revised manuscript, or please see Figure R2D below) in order to more clearly illustrate propagation of the atmospheric wave train.

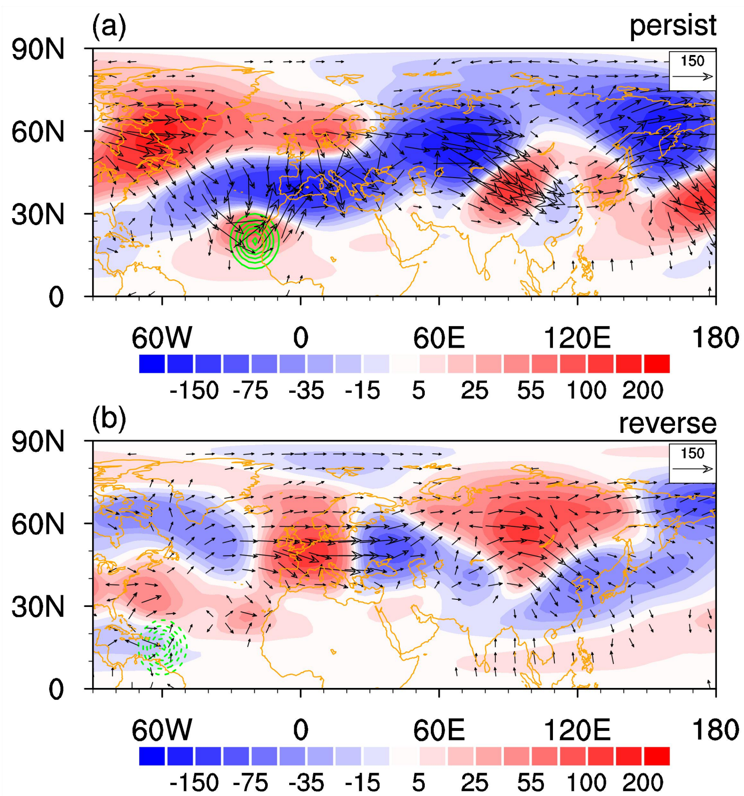

Figure R2D. Barotropic model height perturbation (unit: m) averaged from days 31 to 40 as a response to the given divergence anomaly (green contours with an interval of 10^{-6} s^{-1}) over the subtropical eastern North Atlantic with the center at 20°N, 20°W. (b) Barotropic model height perturbation (unit: m) averaged from days 31 to 40 as a response to the given convergence anomaly (green contours with an interval of 10^{-6} s^{-1}) over the subtropical western North Atlantic with the center at 15°N, 60°W. Vectors in (a)-(b) indicate the corresponding wave activity fluxes.

The barotropic experiment simulations can well confirm the observed results. It is interesting. My question is: why the barotropic experiment simulation is only integrated for 40 days? In addition, why selected 31-40 days to analyze? Why not *selected 25-35 days or other days to analyze?*

Reply: Thanks for the Reviewer's suggestion. As indicated by previous studies (Sardeshmukh and Hoskins, 1988; Watanabe, 2004; Wu et al. 2010; Chen et al. 2016, 2019), experiments of the barotropic model only need several days to reach balance. Therefore, following many previous studies (e.g., Wu et al., 2010; Chen et al., 2016, 2019, etc), the average of 31-40 days were selected in the present study, as it is almost certain that the barotropic model must have reached balance for model day 31-40.

In addition, following the Reviewer's question, Figure R2E is further displayed to explore the results for the average of 25-35 days. Result shows that the atmospheric anomalies for the average of 25-35 days (Figure R2E below) are generally similar to the average of 31-40 days (Figure 13 in the revised manuscript), which indicate that the barotropic model may have reached balance before day 25 in our experiment.. We have added discussions in the revised manuscript. **Please see Lines 656-660 in the revised manuscript.**

References

Chen, S., Wu, R., and Liu, Y.: Dominant modes of interannual variability in Eurasian surface air temperature during boreal spring, J. Clim., 29, 1109–1125, 2016.

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Watanabe, M.: Asian jet waveguide and a downstream extension of the North Atlantic Oscillation, J. Clim., 17, 4674–4691, 2004.

Wu, R., Yang, S., Liu, S., Sun, L., Lian, Y., and Gao, Z.: Northeast China summer temperature and North Atlantic SST, J. Geophys. Res., 116, D16116, 2011.

Sardeshmukh, P. D., and Hoskins, B. J.: The generation of global rotational flow by steady idealized tropical divergence, J. Atmos. Sci., 45, 1228–1251, 1988.

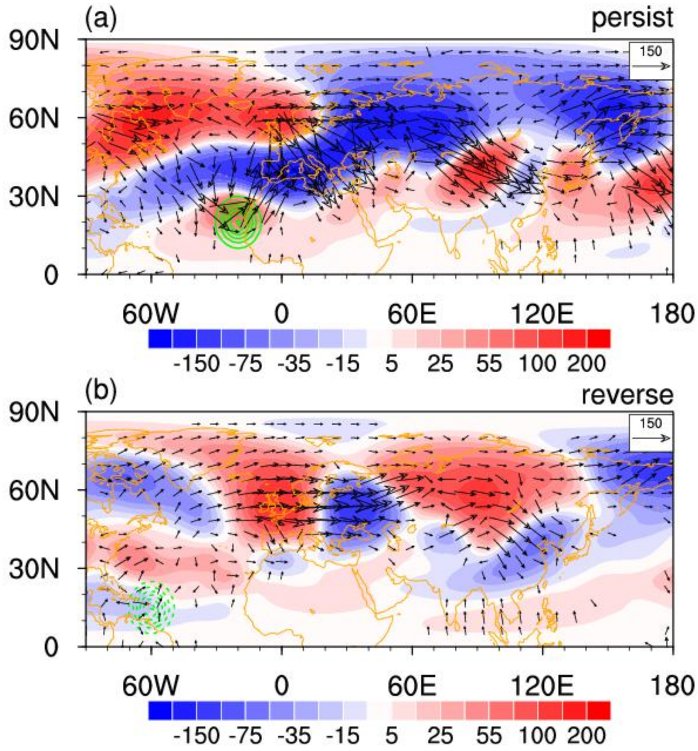

Figure R2E. As in Fig. R2D, but for the average from days 25 to 35.

Specific comments:

Line 53-54: the occurrences of haze pollution event -> the occurrence of haze pollution events

Reply: Modified as suggested.

Please re-plot Fig 2(c), as there is a text spelling mistake (presist->persist).

Reply: Thanks for pointing this out. We have modified the related Figure.

Line 308: winds anomalies -> wind anomalies

Reply: Modified.

Line 358: leads to -> and leads to

Reply: Modified as suggested.

Line 410: also resembles -> and also resembles

Reply: We have modified it.

Line 413: similar region-> same region?

Reply: Modified as suggested.

Line 421: have -> has

Reply: Modified.

Line 466: leads -> lead

Reply: Modified.

Line 473: plays -> play

Reply: Modified.

Line 488: closest -> the closest

Reply: Modified as suggested. Thanks for the Reviewer for pointing those mistakes in English grammar.

Please check the references carefully, such as Wang et al. 2014 in line 64 is not found in the references. In addition, it is better to arrange the references in alphabetical order.

Reply: Thanks for pointing this out. We have checked the references carefully. In addition, we have arranged the references in the alphabetical order following the Reviewer's suggestion.