Response to the Comments

Dear reviewer,

We thank you so much for taking time to enhance the quality of our paper. We have revised the manuscript, and changes are shown with red color in the revised manuscript. Below are our responses to the reviewers' comments. All reviewers' comments are in black, while the authors' responses are in blue. And all revisions in the revised manuscript are highlighted in red color.

The influence of blocking and wave-train cold surges (CSs) on haze dispersion over eastern China is investigated in this study. The blocking CSs have relative weaker ability to remove the haze compared with the wave-train CSs. The topic aligns well with the scope of ACP. The manuscript is well-written with minor corrections of some comments.

1. The observed atmospheric visibility and relative humidity dataset are used to defined the occurrence of haze days in this study, with the threshold of 10 km visibility. However, the visibility observation in China was switched from manual observation to high temporal resolution automated observation since the year of 2013-2014. There are some systematic biases between manual and automated observation. And 7.5 Km automated observed visibility is suggested as the occurrence of haze. I would suggest re-defined the case of haze using different thresholds before and after the automated observation.

Response: Thanks for your suggestion. We use this definition to reproduce the evolution of haze during the occurrence of two types of cold surges, and its distribution is consistent with the results of our previous studies. It should be added that the cold surges and haze events involved from 2013 to 2016 have hardly changed after revising the definition of haze. Therefore, we modified the relevant contents and figures of haze definition. See lines 99-105: After filtering the other weather parameters affecting visibility (i.e., dust, precipitation, sandstorm), we defined a haze day as a day with visibility lower than 10 km and the Rhum less than 90 % occurring at any of the four times (02:00, 08:00, 14:00, and 20:00LT) (Yin et al., 2019a) from 1980-2013. However, the visibility observation in China was switched from manual observation to high temporal resolution automated observation after 2013 (Yin et al., 2017). Therefore, because of systematic biases between manual and automated observation, the 7.5 km automated observed visibility (Zhang et al., 2021) and Rhum less than 90 % are suggested as the occurrence of haze.

References:

Yin, Z.C., Li, Y. Y., Wang, H. J.: Response of early winter haze in the North China Plain to autumn Beaufort sea ice, Atmos. Chem. Phys., 19, 1439–1453, https://doi.org/10.5194/acp-19-1439-2019, 2019a.

Yin, Z. C., Wang, H. J.: Role of atmospheric circulations in haze pollution in December 2016., 17, 11673-11681, https://doi.org/10.5194/acp-17-11673-2017, 2017.

Zhang X. Y., Yin, Z. C., Wang, H. J., and Duan M. K.: Monthly Variations of Atmospheric Circulations Associated with Haze Pollution in the Yangtze River Delta and North China, Adv. Atmos. Sci., 38(4), 569−580, https://doi.org/10.1007/s00376-020-0227-z, 2021.

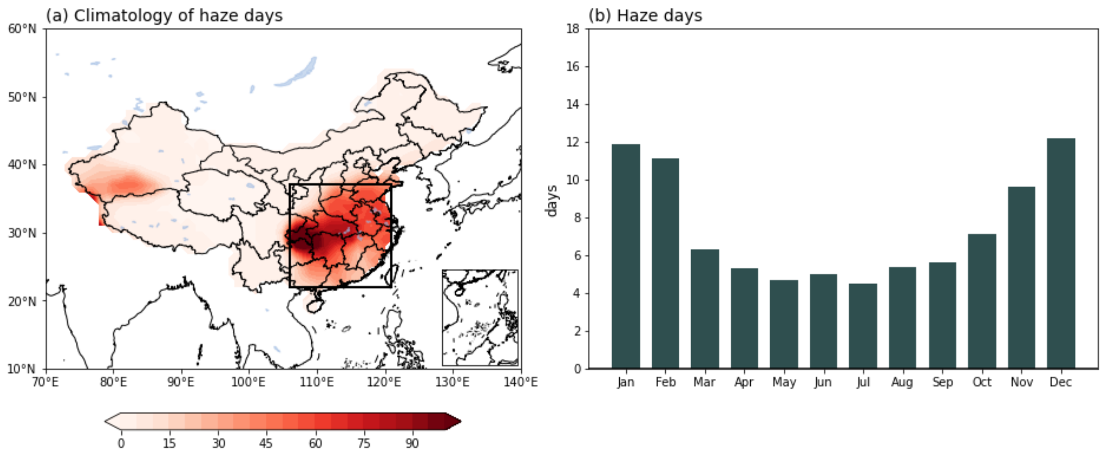

Figure S1. (a) Spatial distribution of the annual haze days (day) in China averaged from 1980 to 2017. (b) Monthly variation of the regional-averaged haze days in the area of 22°N-37°N, 106°E-121°E.

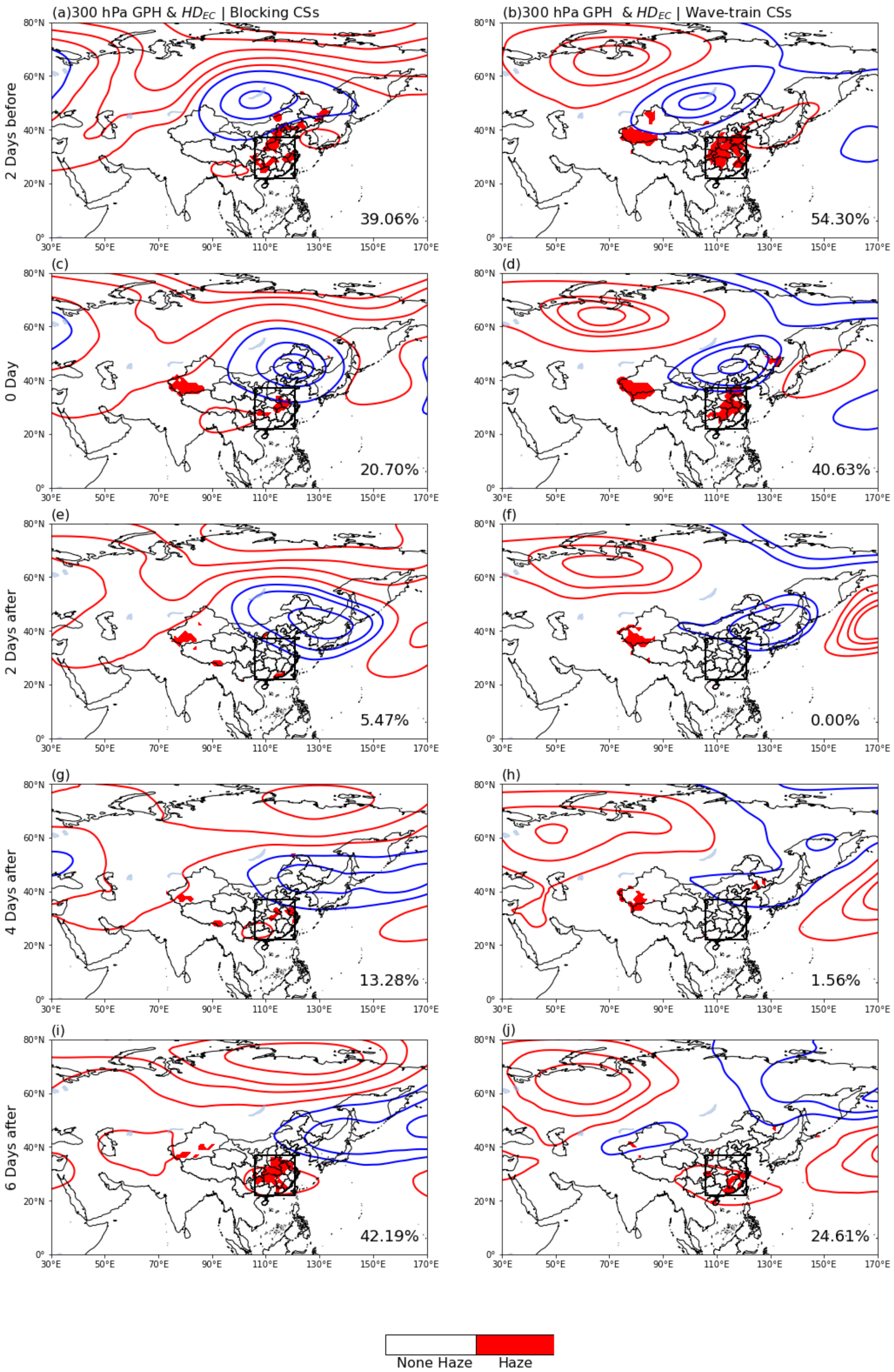

Figure 4. Composite of GPH anomalies at 300 hPa (contour; in intervals of 20 gpm) from day -2 to day 6 relative to the outbreak of CSs and the corresponding spatial distribution of HD_{EC} (shading, only shows the areas which are statistically significant at the 95% confidence level by t-test.) for blocking CSs (a, c, e, g, i) and wave-train CSs (b, d, f, h, j). The number in the lower right corner of each figure represents the ratio of the grids of HD_{EC} to that of EC.

2. Three criteria are involved to select the CSs in lines 102-106. The quantitative thresholds of SLP and temperature drop need detailed reference.

Response: We use the same criteria as Park et al (2008, 2011b, 2015), which investigated the classification and variation of cold surge in East Asia in detail. Setting the threshold to 1.5 times the standard deviation can not only obtain the cold surge time with sufficient intensity relative to the local climate, but also ensure enough cold surge samples. Therefore, we have added the setting of threshold (see lines 118-121): (2) the daily temperature drops ($SAT_t - SAT_{t-1}$) and the SAT anomalies should exceed −1.5 standard deviation (i.e., the standard deviation of the SAT from 1980 to 2017) at least one box (setting the threshold to 1.5 times the standard deviation can not only obtain the cold surge time with sufficient intensity relative to the local climate, but also ensure enough cold surge samples).

References:

Park, T. W., Ho, C. H., Yang, S.: Relationship between the Arctic Oscillation and Cold Surges over East Asia, J Clim, 24(1), 68–83, https://doi.org/10.1175/2010jcli3529.1, 2011b.

Park, T. W., Jeong, J.H., Ho, C.H., et al.: Characteristics of atmospheric circulation associated with cold surge occurrences in East Asia: A case study during 2005/06 winter, Adv. Atmos. Sci, 25, 791–804, https://doi.org/10.1007/s00376-008-0791-0, 2008.

Park, T. W, Ho, C. H, Jeong, J. H, et al.: A new dynamical index for classification of cold surge types over East Asia, Climate dynamics, 45(9): 2469-2484, https://doi.org/10.1007/s00382-015-2483-7, 2015.

3. Some detailed data processing is suggested to add for Fig 5-6. What does those lines mean? Are they regional average over the EC (dotted box in Fig 1) or just the grids average where haze occurred?

Response: The lines are the regional average over the EC. Since the response of haze to cold surges is a dynamic process and will not stay in the same box, the response of haze to two types of cold surges in East Asia can be more objectively obtained by using the average results of the whole EC region. We modified the caption of Figure 5 and Figure 6 (see lines 214-216 and lines 239-241):

Figure 5. Regional averaged (a) visibility anomalies (km), and (b) Rhum anomalies (%) over EC during 9 days before and after the outbreak of the blocking CSs (blue lines) and wave-train CSs (red lines), respectively. Shading represents plus/minus one standard deviation among the CSs.

Figure 6. Regional averaged (a) TIP anomalies (K), (b) UV_sfc anomalies (m s^{-1}), (c) SAT anomalies (K), and (d) SLP anomalies (hPa) over EC during 9 days before and after the outbreak of the blocking CSs (blue lines) and wave-train CSs (red lines), respectively. Shading represents plus/minus one standard deviation among the CSs.

4. According to the definition of haze coving the information of visibility and relative humidity (RH) in this study, the time series of visibility and RH are discussed in Fig.5. However, except the haze definition, RH also has significant effects on the hygroscopic growth of particles, which will change the mass concentration of aerosols and in turn the visibility (doi:1029/2018JD029269). Therefore, RH usually shows negative correlation with the observed visibility as shown in Fig. 5. RH is an important factor dominating the variation of air quality in some situations. Thus, the spatial variations of RH before and after CSs are suggested to involved to explain the variation of haze over EC.

Response: Thanks for your good suggestion. Adding the evolution of relative humidity is very helpful to understand the dissipation of haze by cold surge. We cited relevant literature and supplemented the corresponding figure and descriptions (see lines 271-276): In addition, Rhum also has significant effects on the hygroscopic growth of particles, which will change the mass concentration of aerosols and in turn the visibility (Wang et al., 2019). After the occurrence of the two types of CSs, most regions of EC present negative Rhum anomalies. The negative Rhum anomalies caused by wave-train CSs have a longer duration, stronger intensity, and wider influence range (Figure S4).

This shows that the wave-train CS has a stronger ability to dissipate haze.

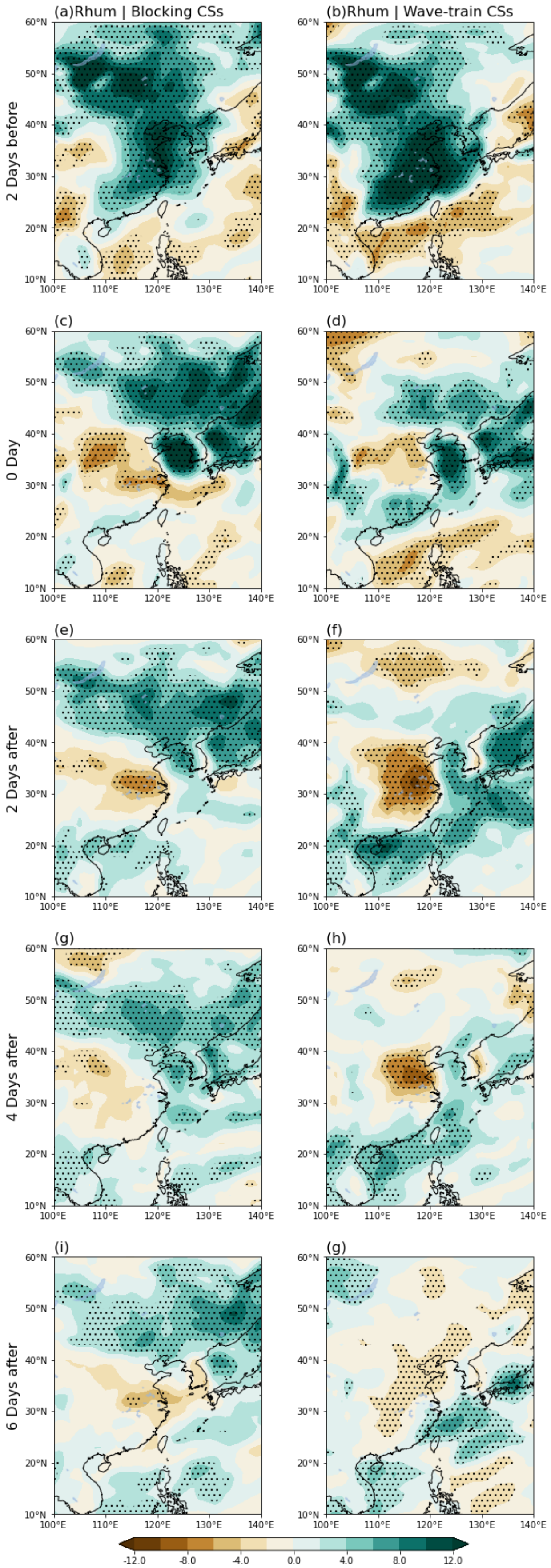

Figure S4. Composite anomalies of Rhum (shading; Dotted areas are statistically significant at the 95% confidence level) from day -2 to day 6 relative to the outbreak of blocking CSs (a, c, e, g, i) and the wave-train CSs (b, d, f, h, j).