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 physical mechanism of severe winter haze in eastern China has been revealed in this work. Three dominant atmospheric circulation patterns effecting the haze occurrence have been clustered. The paper is generally well written and recommended for publication after addressing the following specific comments.

1. Air pollution mainly occurred in the atmospheric boundary layer, which is usually under 2km above the surface. While, the 500hPa geopotential height anomalies are used for circulation clustering. Could you please give more details about the reason for selecting the 500hPa data?

Response: Previous studies have shown that the upper-level circulation represented by 500-hPa geopotential height anomalies play an important role in the generation and accumulation of haze (Wang et al., 2015; Yin and Wang, 2017; Zhong et al., 2019). On the one hand, the upper-level circulation can affect the haze through meteorological factors such as thermal inversion potential and vertical movement; on the other hand, the upper-level circulation can also affect the haze by regulating the near surface circulation. Secondly, we focus on a large spatial scale circulation anomaly. The near surface circulation is difficult to display obvious characteristics due to the complex terrain, so we choose to cluster the 500-hPa geopotential height anomalies.

The revised sentence is as follows (see lines 135-141): Secondly, the circulation samples selected are not in a fixed region, but the rectangular regions of the same size centered on each station with severe haze. Since the upper-level circulation represented by 500-hPa geopotential height anomalies play an important role in the generation and accumulation of haze (Wang et al., 2015; Yin and Wang, 2017; Zhong et al., 2019), the GPH anomalies at 500-hPa in a rectangular region of 30 degrees from east, west, north, and south with each station as the center on the day of severe HD_{EC} were taken as the samples to perform HCA.

References:

Wang, H. J., Chen, H. P., Liu, J. P.: Arctic Sea Ice Decline Intensified Haze Pollution in

Eastern China. Atmos. Oceanic Sci., 8:1, 1-9, https://doi.org/10.3878/AOSL20140081, 2015.

Yin, Z. C., Wang, H. J.: Role of atmospheric circulations in haze pollution in December 2016, Atmospheric Chemistry and Physics, 17(18): 11673-11681, https://doi.org/10.5194/acp-17-11673-2017, 2017.

Zhong, W. G., Yin, Z. C., Wang, H. J.: The relationship between anticyclonic anomalies in northeastern Asia and severe haze in the Beijing–Tianjin–Hebei region, Atmos. Chem. Phys., 19, 5941-5957, https://doi.org/10.5194/acp-19-5941-2019, 2019.

2. The samples used in the clustering are not in a fixed region, which is a rectangular box moving with the specific observation station. This clustering method is different from the usual treatment. What is the advantage of this method?

Response: Due to the geographical nature of east china which is large, there may be differences in the circulation anomalies during haze pollution between the southern stations and northern stations. The circulation patterns obtained by clustering the circulation over the local area of each station are relative to the local climate statement, which is conducive to understanding the mechanism of haze formation in different regions. When we cluster the circulation anomalies in a fixed region, influence of the same circulation pattern on other stations is different due to variations in stations' location.

The sentence was revised as follows (see lines 141-143): It means that our classification results focus on the local circulation anomalies accompanied by haze, which can help us more accurately understand the impact of different local circulation patterns on different stations.

3. I would like to suggest to change a colormap for Fig. 3(a), in which the Type1 and Type 2 is hard to distinguish based on the current color

Response: Thanks for your suggestion. The revised figure3 is as follows:

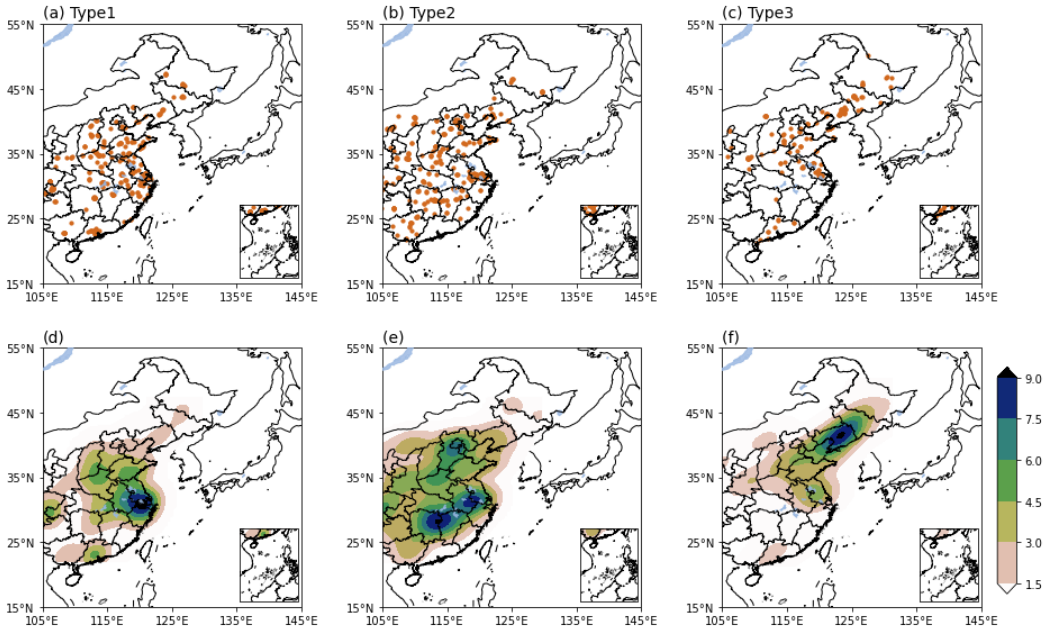

Figure 3. Distribution of stations dominated by (a) Type1, (b) Type2, and (c) Type3 synoptic circulation pattern. Weighted probability density distribution of stations dominated by (d) Type1, (e) Type2, and (f) Type3 synoptic circulation pattern.