Response to Reviewer 2 Comments

Dear reviewer:

Thanks very much for taking your time to review this manuscript. We really appreciate all your valuable comments and suggestions! We have carefully addressed each comment in blue with the original comments in black. Changes are highlighted in yellow in the revised manuscript.

General comments:

Multiple dust aerosol related datasets of MERRA-2, OMI and CALIPSO were used in this manuscript to study the spatiotemporal distribution of dust in China. Also, the dust transport and sources were analyzed using air mass trajectory statistic methods. Although the manuscript includes many valuable data and statistic results, it lacks one or more focused scientific points which leading the data analysis and most results are basic statistics from the data directly. The spatiotemporal characteristics of China dust have been investigated in many previous studies, what are the new scientific discoveries in this study? In my opinion, the manuscript needs to be rearranged focused one or two scientific points with deeper data analysis and scientific discussion.

Response:

First of all, we agree with you on that the spatiotemporal characteristics of dust aerosols in China have been investigated in many previous studies. These studies offer excellent support for the advancement of our work. Our study utilizes MERRA-2 and CALIPSO data to analyse the four-dimensional (latitude, longitude, altitude, and time) features of dust aerosols. Additionally, the distinctiveness of this study lies in its emphasis on the sources and transport pathways of dust for 16 selected cities (13 provincial capitals and 3 dust source cities) in the "Three-North" region. To make it clearer, we have revised the final paragraph of the introduction to underscore the paper's aim, which is to conduct a more comprehensive analysis of the spatial and temporal dynamics and trajectories of dust in this region. The new scientific discoveries in this study are as follows:

(1) Regarding the four-dimensional analysis of dust storm changes, we have noticed an increasing trend in dust storms during autumn in the northwest region in recent years, as shown in Fig. R1 (Fig. 3b in the revised version). This is in contrast to the downward trend in other three seasons which is more consistent to previous studies. Exploration of the autumn trend anomaly is a challenging task due to the lack of ground-based DAOD observation data for MERRA-2 DAOD validation in the northwest region. We here instead analyzed the seasonal horizontal visibility in this area to confirm the observed trend. The results indicate that from 2007 to 2021, there is a general downward trend in the autumnal average visibility in the northwest region, as depicted in Fig. R2a. This decrease is very likely to be attributed to the increased presence of dust aerosols, which is reflected in the increased DAOD. Additionally, a significant correlation is observed between DAOD and visibility (Fig. R2b). The distribution of stations used to calculate the seasonal average visibility in the northwest is illustrated in Fig. R3. Nonetheless, the underlying causes of this phenomenon remain to be elucidated, and future research will necessitate a comprehensive analysis that incorporates additional datasets to discern the driving factors behind it. Our findings should stimulate further research in this area.

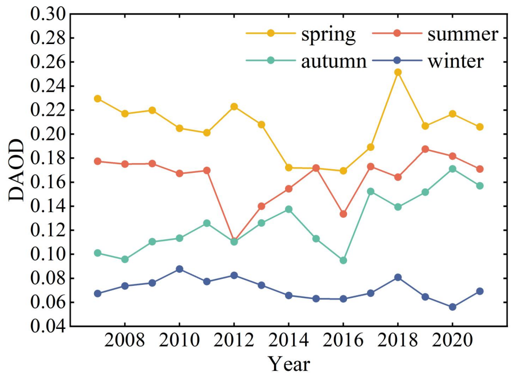


Fig. R1: Interannual variation of seasonal mean DAOD in northwest China.

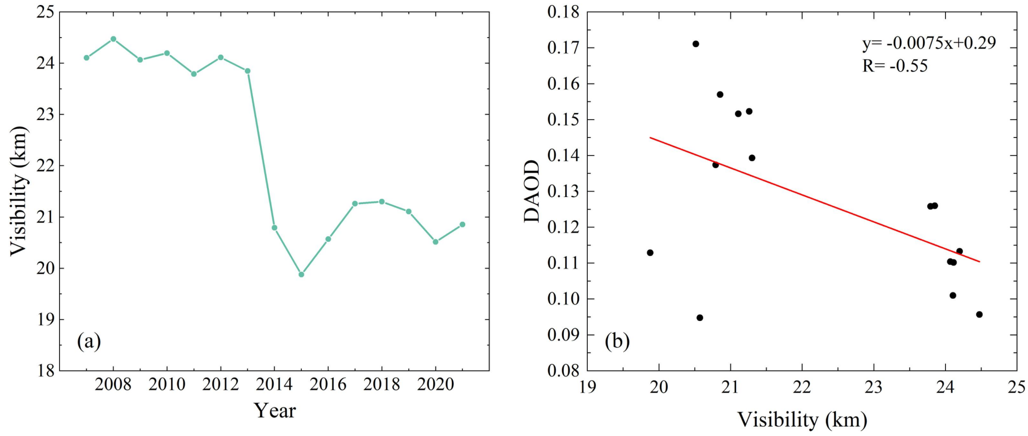


Fig. R2: Interannual variation of Autumn mean visibility in northwest China (a) and the scatterplot of Autumn DAOD means vs. visibility means (b).

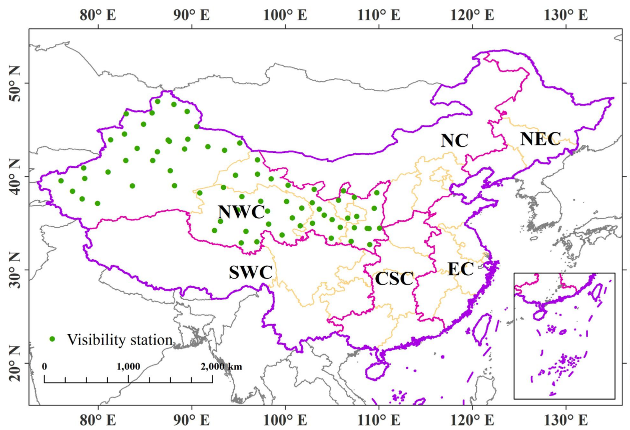


Fig. R3: Distribution of visibility sites.

(2) Regarding the trajectory analysis of dust storms, most studies typically examined a limited number of events or focus on a few selected sites. Instead, we have undertaken a more comprehensive analysis that spans a seven-year timeframe, encompassing the origins and trajectories of all dust storms across 16 representative cities in the entirety of Northwest China (NWC), North China (NC), and Northeast China (NEC), aka "Three-North" region. Our findings reveal substantial variability in the sources and trajectories of dust storms within the same region, with distinct patterns emerging across different seasons. For instance:

(a) The air mass trajectories with the highest proportion reaching Lanzhou originate from different dust sources depending on seasons: the Tengger Desert during spring (48.86%,), the Badain Jaran Desert during summer and winter (52.67% and 49.69%, respectively), and Hexi Corridor during autumn (42.46%) . Western Inner Mongolia and the Hexi Corridor are the major dust sources with extremely high WPSCF values in winter and spring, while in winter dust source was more concentrated around the Tengger Desert. In the other two seasons, dust sources remain consistent in these two regions but with lower WPSCF values.

(b) During spring in Hohhot, high WPSCF values are widely distributed around the Gobi Desert in Inner Mongolia and Mongolia. From autumn to winter, the dust sources become more concentrated around the Chinese part of the Gobi Desert.

(c) In the provincial capital cities of Northeast, potential dust sources during spring are widespread but are particularly concentrated around the Horqin Sandy Land in all seasons except summer, indicated by high WPSCF values.

(3) Furthermore, several dust source analysis studies used long-term CALIPSO satellite aerosol products, which has much lower observation frequencies compared to those from ground stations and may lead to the omission of some dust events. In contrast, our study leverages PM measurements from ground stations, which provide an hourly temporal resolution. The seven-year time span minimizes the impact of statistical randomness on our findings, thereby facilitating a comprehensive and detailed source-trajectory analysis of dust storms.

Specific comments:

1. Figure 1, Inner Mongolia should not be included in Northwest area.

Response :

Thank you for your reminder. In the revised manuscript, we have reorganized the study area into six sub-regions based on China's administrative divisions (Song et al., 2021; Liu, et al., 2022; Wang et al., 2023): Northwest China (NWC), North China (NC), Northeast China (NEC), Southwest China (SWC), Central South China (CSC), and East China (EC). In accordance with this new classification, Inner Mongolia is included in North China, as shown in Fig. R4 (Fig.1 in the revised version). Additionally, we have made corresponding revisions to Section 2.1, which introduces the study area, along with the analytical sections, 4.1 and 4.2, to ensure they are in harmony with these refined regional divisions.

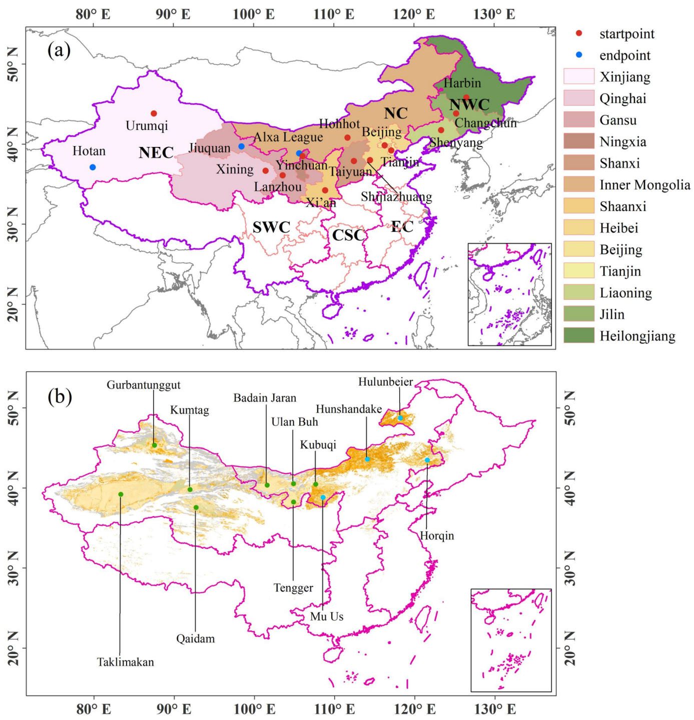


Fig. R4: The study area (a) and the main deserts in the study area (colored in b), with the distribution of Ambient air quality monitoring stations (dots in a)


Li, Y. R., Niu, Y., Wei, T. X., Liang, Y. S., Chen, P., Ji, X. D., and Zhang, C. J.: Mapping rainfall interception for assessing ecological restoration sustainability in China. Environ. Res. Lett., 7(10): 104007, https://doi.org/10.1088/1748-9326/ac8605, 2022.

Song, Z. H., Xia, J., She, D. X., Li, L. C., Hu, C., Hong, S.: Assessment of meteorological drought change in the 21st century based on CMIP6 multi-model ensemble projections over mainland China, J. Hydrol., 601: 126643, https://doi.org/10.1016/j.jhydrol.2021.126643, 2021.

Wang, Y., Xu, T. T., Shi, G. M., Yang, F. M., Tang, X. L., Zhao, X. L., Wan, C. Y., Liu, S. L.:Climatology of the planetary boundary layer height over China and its characteristics during periods of extremely temperature, Atmos. Res., 294, 106960, https://doi.org/10.1016/j.atmosres.2023.106960, 2023.

2. For PSCF dust source analysis, how to distinguish the contribution of local emitted air pollution and long-range transported dust aerosol?

Response:

The PSCF does not directly differentiate between local sources and long-range transported dust aerosols; it merely calculates the probability of each grid cell being a dust source based on backward trajectories produced by the HYSPLIT model. To calculate the PSCF, the study area was divided into 0.5° × 0.5° grid cells. $PSCF_{ij}$ is defined as: $PSCF_{ij} = m_{ij}/n_{ij}$, where $n_{ij}$ is the total number of backward trajectory endpoints that fall in the ij-th cell, and $m_{ij}$ is the number of backward trajectory endpoints in the same cell with PM10 exceeding the criterion value. Considering that our initial explanation of the PSCF may have been misleading, we have rewritten section 3.2.3 in the introduction to provide a more accurate and detailed explanation of the PSCF methodology.