$PM_{2.5}$ concentrations based on near-surface visibility in the Northern Hemisphere from 1959 to 2022

We thank the referees for the constructive and helpful comments. We have carefully thought about the comments, made corresponding revisions to the manuscript and the datasets, and checked the manuscript carefully, which have substantially improved the manuscript and the datasets.

Main modifications:

- Collected more $PM_{2.5}$ concentrations data (371 sites with more than 3-year observations) from openAQ in the Northern Hemisphere in Section 2.2.6, increasing the coverage in the NH.
- Used visibility data from ISD instead of the original visibility data in Section 2.3, which resulting in more than 1000 stations added than previous version. Based on ISD visibility, the distances decrease significantly. And the upper limit is set to 100 km.
- Added the comparisons on the daily/monthly scale and before/after 2010 in Section 4.1, to evaluate the predictive ability of the model and the consistency of estimated $PM_{2.5}$ concentration.
- Used GAMM to analyze the interannual trends and spatial patterns on the regional scale due to irregular site distribution in Section 5.
- Adjusted the structure and content of the manuscript. And all figures and tables have been modified or replaced.

Response to Anonymous Referee #3

It is a very interesting paper that estimates the long-term $PM_{2.5}$ concentration in the northern hemisphere using machine learning, and I believe this dataset is meaningful. Still, there are several questions I want to ask.

***Comment 3.1**. Consider presenting the methodology in a tabular format, summarizing key details such as the number of sites, time span, time resolution, and other pertinent information across different regions. It may be clearer.*

- **Response 3.1:**

Thank you for your suggestion. We have added a table to describe the data information in Table 1.

***Comment 3.2**. Is there variation in regional rankings for variable importance?*

- **Response 3.2:**

We have added the most important variables of different regions in Figure 2 in Section 3.1.

***Comment 3.3.** The trends in the Indian seems to be very different. Is this attributed to the overestimation of $PM_{2.5}$ in dusty areas, as mentioned in Line 793? Furthermore, Figure 12 indicates ACAG has superior agreement with your dataset compared to MERRA-2 and CAMS. Could this disparity be attributed to differences in resolution or time span? In addition, given the high time resolution characteristic of your dataset, a daily comparison would be interesting.*

- **Response 3.3:**

(1) We have checked the estimated $PM_{2.5}$ concentration and investigated some studies about the trend in India. For example, Singh et al. (2021) have found that $PM_{2.5}$ concentration of five major cities in India show a downward trend from 2014 to 2019, and the largest declining trend (-4.2 μg/m^3 per year) is in New Delhi. Ravindra et al. (2024) also finds that the trend in New Delhi is about -5 μg/m^3 per year from 2014 to 2020.

(2) We have added the comparisons on the daily scale in Section 4.1.

Comment 3.4. *The authors should clarify how $PM_{2.5}$ and visibility data were matched spatially and temporally. It would be good to clarify whether the machine learning is based on hourly data or corresponding daily mean data.*

- **Response 3.4:**

We have added the spatiotemporal matching method and clarified that the machine learning is based on daily mean data in Section 2.4.

Comment 3.5. *If $PM_{2.5}$ concentration and visibility data have differing daily hour intervals, how were they aligned? Furthermore, is it really reasonable to include stations located several hundred kilometers apart in the training dataset?*

- **Response 3.5:**

We have added the temporal matching method in section 2.4. We have used the visibility data from ISD instead of original visibility data and the upper limit of distance is set to 100 km.

Additionally, the authors may attention to details, such as:

Comment 3.6. *In Line 940, it would be preferable to maintain consistency by unifying "20%" and "80%".*

- **Response 3.6:**

Thank you for your correction. We have made modifications.

Comment 3.7. *Line 947 requires a ".".*

- **Response 3.7:**

Thank you for your correction. We have made modifications.

Comment 3.8. *Line 950 should specify "$PM_{2.5}$ concentration" rather than "$PM_{2.5}$" (this problem exists in the whole paper). And maybe discussions on past decade trends should be moved to the annual section for better organization.*

- **Response 3.8:**

Thank you for your suggestion. We have made modifications and adjusted the structure.