$PM_{2.5}$ 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 #1

Hao et al. used the visibility to estimate the historical $PM_{2.5}$ concentration in the northern hemisphere in the past 60 years. Overall, the topic is very interesting and the manuscript is well-organized. However, the manuscript still suffers from some major flaws and thus I recommend the manuscript for publication on ESSD after the following comments have been well addressed.

***Comment 1.1**. Visibility is a useful tool to estimate the long-term $PM_{2.5}$ concentration during a long period. However, the accuracy based on visibility was generally less than that based on AOD. Why do not you use the combination scheme of AOD and visibility? For instance, you could use AOD during 2000-2022, and use visibility before 2000. I think you should evaluate the performances of two schemes and compared the difference in your study.*

- **Response 1.1:**

Near-surface visibility quantifies surface optical concentration of aerosols, which is directly related to the surface mass concentration, i.e., $PM_{2.5}$. AOD describes the column total optical concentration of atmospheric aerosols, which indirectly correlates with $PM_{2.5}$ bridging by the atmospheric aerosol scale height. These differences are discussed in Section 4.3. Independent evaluation in this study shows $PM_{2.5}$ concentration based on visibility is reliable with high correlation coefficients and low root mean square errors. More important, the visibility derived $PM_{2.5}$ concentration is long-term and consistent and can provide time series from 1959 to 2022. However,

satellite AOD based methods can provide time series of $PM_{2.5}$ since 2000. To avoid inconsistency, we would like to keep same input data.

Comment 1.2. *Visibility station is scattered around the world. Why do you only focus on China, Europe, US, and India? I think the estimates of long-term $PM_{2.5}$ concentrations across the northern hemisphere might be more valuable. You could even construct the full-coverage grid-based $PM_{2.5}$ dataset across the northern hemisphere.*

- **Response 1.2:**

Thank you for your suggestion.

(1) We have further collected more $PM_{2.5}$ observations and used visibility data from ISD to increase the coverage. $PM_{2.5}$ concentrations of 1012 sites are added, as shown in Figure 1.

(2) We are aiming at establishing a long-term site-scale dataset in this study. We are trying our best to build a grid-scale $PM_{2.5}$ product based on visibility by another method. Therefore, this study does not involve grid products.

Comment 1.3. *Section 3.2.2: The validation of constructed $PM_{2.5}$ dataset in recent years might be not enough because the major novelty of this study is a long-term estimate. Thus, the authors should add more examinations of $PM_{2.5}$ estimates before 2010 especially in China and India. I think the authors could search many previous references to obtain these ground-level observations.*

- **Response 1.3:**

We have added the examinations of $PM_{2.5}$ concentration before/after 2010 in Section 4.

Comment 1.4. *I think the comparison of your dataset with other reanalysis data might be not very necessary because the dataset in this study is site-based instead of grid-based. I think you must confirm your dataset is much superior to all of the previous reanalysis dataset if you want to compare them*

- **Response 1.4:**

We have removed the comparisons with the reanalysis data.

Comment 1.5. *Figure 14: Why do the $PM_{2.5}$ in India experience dramatic decreases from 2010 to 2022? I think India proposed clean air policy since 2019. The authors should test the observations to examine whether the estimate is right.*

- **Response 1.5:**

We have checked the estimated $PM_{2.5}$ concentrations and investigated some studies about the trends in India. Our results are similar to previous studies.

For example, Singh et al. (2021) has 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 $\mu g/m^3$ per year) is in New Delhi. Ravindra et al. (2024) also finds that the trend in New Delhi is about -5 $\mu g/m^3$ per year from 2014 to 2020.