

Reply to Reviewer #1 for Manuscript of “Estimating hourly ground-level aerosols using GEMS aerosol optical depth: A machine learning approach” by O et al.

The manuscript is based on the estimation of PM_{2.5} and PM₁₀ from GEMS AOD. The main objective is to evaluate the effectiveness of GEMS AOD in estimating ground level PM concentrations. This study attempts to study how GEMS AOD can provide air quality estimates in a global scale, which is of great importance

- ⇒ *We thank the reviewer for recognizing the value of our study and for their thoughtful comments and efforts in reviewing our manuscript. Below, we provide point-by-point responses to the comments.*
- ⇒ *Here, we summarize the main revisions planned for the manuscript:*
 - **Data Update:** *The dataset will be updated to include data through December 2023, resulting in two years of data being analyzed.*
 - **Additional Machine Learning Algorithm:** *To enhance the robustness of our machine learning-based modeling, we will employ an additional algorithm, XGBoost (XGB).*
 - **Expanded Input Features:** *We will include additional chemical gas features, such as SO₂, NO₂, and O₃, in the modeling process.*
 - **Revised Manuscript Structure:** *The manuscript structure will be reorganized. Specifically:*
 - *The Data and Methodology sections will be separated.*
 - *The comparison results between GEMS AOD and AERONET AOD will be presented first, followed by the PM estimation results.*

However, there are few concerns regarding the formulation of the study and the structure of the manuscript. Given below are my suggestions.

- The overall paper lacks adequate explanations and citations to corroborate the objective of the study and how it differs from existing studies/novelty. (Ex: are there any ML based studies for estimation of PM concentrations? What are the advantages of this method over the existing?)
- ⇒ *To address the concern, we will enhance the introduction section to clearly state the objective of the study and highlight its novelty. We will also include a discussion on existing machine learning-based studies for PM concentration estimation and emphasize the advantages of our approach compared to previous methods.*

- The introduction of the manuscript should include a brief description on the sections of the manuscript. Results and discussion should be a separate section from data and methodology. I suggest separating data and methodology as separate sections, as this manuscript lacks proper description on the methodology (there is too little information on the machine learning method (RF), selection criteria for input variables, ranges of the input variables).
 - ⇒ *Thank you for the suggestion. We will reorganize the sections as recommended and provide additional explanations to clarify the methodology.*
- What is the sample size of the data used in RF?
 - ⇒ *Since RF models are applied to individual station points, the size of the training data varies for each model (station). To illustrate this, we will add a figure showing the distribution of training data sizes across all stations.*
- RF was selected to estimate PM concentrations out of some other ML methods. How do you evaluate the model effectiveness in this work? Model performance can also affect the conclusions you draw regarding the ability of GEMS AOD to accurately provide PM concentrations.
 - ⇒ *We will provide a more detailed explanation of why RF was selected over other machine learning methods and elaborate on its effectiveness in this study. Additionally, we will employ another machine learning method, XGBoost, to compare the performance of different models and further validate our approach.*
- The first part of the results should be to validate the GEMS AOD retrievals
 - ⇒ *We will reorganize the section to present the comparison between GEMS AOD and AERONET AOD first.*
- The labeling of PM measurements used in RF, and the PM estimations, is vague. Make it more distinct.
 - ⇒ *Okay, we will revise the labeling to make the PM measurements and the PM estimations more distinct.*
- The use of mean vs error plots would be a better way of understanding the model performance rather than comparing the correlation coefficients. (Refer, Bland-Altman analysis)
 - ⇒ *We will consider additional metrics to evaluate the model's performance from a broader perspective.*
- Add more details description on SHAP analysis.
 - ⇒ *We will add more description on SHAP.*
- L 59-61 Include more details about GEMS instrument (uncertainties, wavelength channels). Do you perform any pixel averaging?

- ⇒ *We will add more information in the data section. We do not perform any pixel averaging to GEMS. This point will be further explained.*
- You need to add a description on GEMS AOD retrieval algorithm and explain possible uncertainties in AOD retrievals. The citation is not enough.
 - ⇒ *Thank you for pointing this out. We will add a detailed description of the GEMS AOD retrieval algorithm and discuss the possible uncertainties in GEMS AOD retrievals.*
- L 74 – Do you perform any geolocation of data? How do you collocate reanalysis data? What is the maximum possible difference in the collocation of ground-based PM concentrations, AOD and reanalysis data?
 - ⇒ *We will add more explanation on the geolocation of data (Inverse Distance Weighting).*
- L 115 – Is this something evident across all AOD values? Are there any differences seen for PM estimations under lower AOD and higher AOD values. Is there any detection limit?
 - ⇒ *To address the reviewer's concern, we will conduct additional analyses to illustrate how the model's performance varies under different conditions.*
- L 154 – AERONET data should be introduced under the data section. How do you collocate AERONET data? What do you mean by closest? You should specify the distance limit. How do you average temporal data. Does the difference between AERONET AOD and GEMS AOD lies with AEROENT AOD uncertainty?
 - ⇒ *We will include a detailed description of the AOD data and the preprocessing steps involved.*
- L 63 – What is ARA?
 - ⇒ *Aerosol Retrieval Algorithm, we will explain this.*
- L 69 – What is ERA5?
 - ⇒ *ECMWF Reanalysis v5 (ERA5) data, we will explain this.*
- L 75 – How did you perform the AOD-PM simulations? Or do you mean estimations?
 - ⇒ *We meant the PM estimation through the model simulations, we will make it clear.*
- L 83 – 89 This paragraph should go under the data section
 - ⇒ *Thank you for the suggestion. We will modify it.*

- L 157 – Has it been observed for low AOD or high AOD?
⇒ *We will add more details.*
- L 164 -165 Does the GEMS AOD algorithm consider any non-sphericity dust? You should add a description about the AOD algorithm
⇒ *We will add more description on the AOD algorithm*
- L 176 – Fig 6. What does $n=1,2,\dots$ stand for?
⇒ *It refers to the number of stations providing the training dataset. We will clarify this explanation in the manuscript.*