

Response to the Reviewers

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Classification-Constrained Retrieval of $\text{PM}_{2.5}$ Vertical Profiles from Fluorescence–Raman–Mie Polarization Lidar

Dear Editor and Reviewers,

We sincerely thank the reviewers for their careful reassessment of our manuscript and for recognizing the substantial improvements made during the previous revision. We have carefully considered the remaining comments and further clarified the scope of the near-surface validation, the interpretation of the classification-end-member sensitivity analysis, and the data and code availability statement. The corresponding changes are marked in the track-changes manuscript. Our point-by-point responses are provided below.

Response to Reviewer 1

We sincerely thank the reviewer for the positive assessment of the revised manuscript and for recognizing the improvements in model validation, sensitivity and uncertainty analyses, methodological clarification, and discussion of model applicability.

Comment:

The new near-surface comparison provides important quantitative validation of the empirical retrieval model, but it should be clearly distinguished from independent validation of the complete vertical $\text{PM}_{2.5}$ profiles. As the authors appropriately acknowledge in the Conclusions, direct vertically resolved $\text{PM}_{2.5}$ observations from UAVs, tethered balloons, or aircraft are not available. Please ensure that the terminology used throughout the Abstract, Results, and Conclusions does not imply that the full vertical profiles have been independently validated.

Response:

We agree with the reviewer. We rechecked the relevant terminology throughout the Abstract, Results, and Conclusions. The Abstract does not claim independent validation of the complete vertical profiles, and the Conclusions already state the limitation arising from the absence of direct vertically resolved $\text{PM}_{2.5}$ observations. To make the scope of the comparison fully explicit, we added a sentence in Sect. 3.1 clarifying that the date-separated comparison evaluates the near-surface performance of the empirical retrieval model and should not be interpreted as independent validation of the complete vertical $\text{PM}_{2.5}$ profiles.

Revised manuscript text:

“These statistics quantify the near-surface performance of the empirical retrieval model and should not be interpreted as independent validation of the complete vertical $\text{PM}_{2.5}$ profiles.”

Comment:

The uncertainty analysis based on perturbations of the PDR and Gf end-member parameters represents sensitivity to the assumed classification parameters rather than instrument-level measurement uncertainties in PDR and Gf. The manuscript recognizes this distinction in Methods. I suggest maintaining this distinction explicitly when discussing “classification uncertainty” elsewhere in the manuscript.

Response:

We agree and have revised the relevant terminology accordingly. The analysis is now explicitly described as sensitivity to the assumed classification end-member parameters. In Sect. 2.3.1, the manuscript already distinguishes this analysis from instrument-level measurement uncertainty in PDR or Gf. The wording in Sect. 3.3 has now also been revised so that the discussion consistently refers to classification-end-member parameter sensitivity or uncertainty rather than using the broader term “classification uncertainty.”

Revised manuscript text:

“Sensitivity to the assumed classification end-member parameters was quantified using 100 Monte Carlo perturbations of the pure-component PDR and Gf end-member parameters.”

Revised manuscript text:

“When the classification-end-member, LR, extinction-coefficient measurement, and model-parameter uncertainties were jointly propagated, the median widths of the 95 % intervals for the mean PM_{2.5} estimates were 12.02 and 12.79 $\mu\text{g m}^{-3}$ for the two cases.”

Comment:

I still encourage the authors to improve the data and code availability statement. At present, the lidar data, processed datasets, and analysis scripts are available upon reasonable request. If possible, the processed datasets underlying the principal figures and validation analysis, together with the relevant analysis code, should be deposited in a public repository with a persistent DOI. This would substantially improve reproducibility.

Response:

We appreciate this valuable recommendation and agree that public archiving would further improve reproducibility. However, the multi-year lidar datasets and associated processing workflows require instrument-specific calibration information and additional documentation before they can be released as a self-contained public dataset. We are therefore unable to establish a DOI-based public repository at the present stage. We have carefully checked the Data and code availability statement to clarify that the lidar data, the processed datasets underlying the principal figures and validation analyses, and the relevant analysis scripts are available from the corresponding author upon reasonable request.

Revised manuscript text:

“The lidar data, processed datasets, and analysis scripts supporting the findings of this study are available from the corresponding author upon reasonable request. Ground-level air-quality data were provided by the Beijing Environmental Protection Monitoring Center, and radiosonde data were obtained from the Beijing 54511 Meteorological Observation Station.”

We again thank the reviewer for the constructive comments. These clarifications have improved the precision of the terminology and the description of the scope and limitations of the validation.

Response to Reviewer 2**Comment:**

Overall, I find that the authors have satisfactorily addressed the concerns raised in my previous review. The revised manuscript is substantially improved in terms of methodology, validation, uncertainty assessment, discussion of limitations, and presentation. I have no further scientific comments and the manuscript can be accepted in its present form.

Response:

We sincerely thank the reviewer for the positive assessment of the revised manuscript and for confirming that the previous scientific and presentation-related concerns have been satisfactorily addressed. We greatly appreciate the reviewer’s recognition of the strengthened validation, uncertainty and sensitivity analyses, methodological clarification, and discussion of the applicability and limitations of the retrieval approach. Following the reviewer’s remarks, we performed an additional careful check of the manuscript to ensure that the near-surface comparison is not presented as direct validation of the complete vertical PM_{2.5} profiles and that sensitivity to the assumed classification end-member parameters is clearly distinguished from instrument-level measurement uncertainty. We thank the reviewer again for the constructive comments provided throughout the review process.

Sincerely,
The authors