

Reviewers Response

Reviewer 1

This manuscript presents a multi-platform characterization of a polluted dust episode using in situ optical measurements, particle size distributions, single-particle composition, and an inverse Mie-based retrieval of aerosol complex refractive index (ACRI). The dataset is valuable and scientifically relevant. The combination of optical properties, size distributions, and compositional information is particularly useful for understanding aerosol processes in a dust-influenced environment. The manuscript is clearly within the scope of ACP and represents a meaningful contribution. The inversion framework used to retrieve refractive index is also appropriate and follows a class of optical-closure approaches that has precedent in the literature. The main concern raised in this review is therefore not related to the existence of the inversion itself, but to the strength of the interpretation attached to the retrieved refractive index.

We sincerely thank the reviewer for the thorough and constructive assessment of our manuscript. A point-by-point response to the comments is provided below.

Comment: The reviewer unpacks the mathematics of the optical-closure inversion and demonstrates that good agreement in σ_{sca} and σ_{abs} does not imply uniqueness or intrinsic correctness of the retrieved (n, k) . Missing physics (shape, size distribution, mixing state) can be absorbed into the retrieved refractive index. The inversion is mathematically valid, but it is not strictly unique, even if the fit appears excellent.

Response: Thank you for the comment. We have revised Section 2.5 to explicitly state that our inversion follows an optical-closure framework with established precedent, and that it solves for an effective refractive-index pair that minimizes the error between modeled and observed optical coefficients.

We now write:

Line 187: The retrieval follows an optical-closure framework in line with previous studies (Müller et al., 2011; Liu et al., 2024; Womack et al., 2021), in which the modeled and measured optical coefficients are compared to infer the effective refractive index.

We have also added a new section regarding the limitations of the inversion Mie model in Appendix A7.

Comment: A good fit does not imply a uniquely determined or directly physical refractive index. If the retrieved refractive index is interpreted as an intrinsic material property of the aerosol, then the interpretation becomes too strong relative to what the inversion actually demonstrates. A more accurate formulation is: The retrieved refractive index represents an effective parameter that reproduces the observed optical properties under the assumptions of the model.

Response: We agree with this point. We have carefully revised the Abstract, Section 3.4, and Conclusions to remove all language suggesting that the retrieved ACRI represents a uniquely determined intrinsic property of the dust.

Comment: The introduction should include Adebisi et al. (2023, Aeolian Research), which provides a comprehensive synthesis of mineral dust in the Earth system.

Response: We have added the reference to Adebisi et al. (2023) in the Introduction.

We now write:

Line 14: Atmospheric aerosols, particularly mineral dust, play a critical role in the Earth's climate system by influencing radiative forcing, air quality, and atmospheric dynamics (Manavi et al., 2025; Uddin et al., 2025; Choobari et al., 2014; Schepanski, 2018; Adebisi et al., 2023).

Comment: The manuscript should clarify that the inversion follows an optical-closure framework with precedent in earlier studies. This is important because the central concern is not the use of the framework itself, but the interpretation attached to its output.

Response: We have added the following sentence at the beginning of Section 2.5

We now write:

Line 187: The retrieval follows an optical-closure framework in line with previous studies (Müller et al., 2011; Liu et al., 2024; Womack et al., 2021), in which the modeled and measured optical coefficients are compared to infer the effective refractive index.

Comment: The retrieved refractive index should be described as model dependent. In particular, it should not be presented as a uniquely determined intrinsic material property unless that stronger claim is justified.

Response: We have added the following sentence at the end of Section 2.5. Also, we have modified the explanation in Section 3.4.

Comment: The manuscript should explicitly note that Mie theory assumes spherical particles, whereas mineral dust particles are nonspherical and often inhomogeneous. This is not a minor limitation. It is central to the inversion.

Response: We agree completely. We have added a separate section regarding the limitation of the inversion Mie model in the Appendix A7.

Comment: Higher values than literature should be interpreted cautiously. Such differences may arise from inversion degeneracy, particle size-distribution uncertainty, particle nonsphericity, mixing-state assumptions, or measurement uncertainty, rather than from a true physical enhancement alone.

Response: We have revised Section 3.4 and added the following sentence.

We now write:

Line 401: Therefore, a direct comparison with values in the literature for pure dust should be made with caution, as the retrieved refractive index also incorporates the influence of the bulk aerosol composition.

Comment: The dependence of the retrieval on particle size should be stated more explicitly. A perturbation in $N(D_p)$ propagates directly into the retrieved m . This is especially important for coarse-mode dust particles and in the context of SMPS–OPC merging.

Response: We have added a subsection in Appendix A7.

We now write:

Line 592: The retrieved complex refractive index is sensitive to the measured particle size distribution, $N(D_p)$, because uncertainties in $N(D_p)$ propagate directly into the inversion. This sensitivity may be particularly important for coarse-mode dust particles and for uncertainties associated with merging the SMPS and OPC size distributions.

Comment: Please clarify whether a regular daily maintenance or instrument-check period was applied between 11:45 and 12:15 (UTC +05:30), including filter changes at 12:00. If so, it would be helpful to explicitly state how these periods were treated in the dataset (e.g., excluded from analysis or flagged) and whether they influence the reported averages.

Response: We have clarified this in Section 2.2.1

We now write:

Line 86: The sampler was operated for 23.5 hours per day, from 12:15 to 11:45 the following day, with filter papers changed daily at 12:00 (UTC + 05:30). The 30-minute interval between 11:45 and 12:15 was reserved for routine maintenance and filter replacement, during which no sampling data were collected; therefore, this period was excluded from the analysis, and the reported averages were calculated.

Comment: Line 3 of Section A4 needs a citation for the statement that the sampling lines were kept below 1 m for all instruments.

Response: We have added a citation to standard aerosol sampling practice guidelines (Wiedensohler et al., 2012) and noted that the inlet lengths were verified during the field setup.

We now write:

Line 525: The total length of these sampling lines was kept below 1 m for all instruments, consistent with standard practice to minimize diffusional and inertial particle losses (Wiedensohler et al., 2012), and was verified during field installation.

Comment: Reword caption for clarity.

Response: We have revised the Figure 1 caption as suggested.

We now write:

The figure presents the study location and the flow chart used to calculate the bulk aerosol complex refractive index. Panel (a) shows the digital elevation map (DEM) of India, with the Dhundi Research Site indicated by a black pentagon. Topographic data were obtained from the ASTER Digital Elevation Model V003 (last accessed: July 1, 2023). Panel (b) illustrates the retrieval workflow for the bulk aerosol complex refractive index. Input variables are shown in blue boxes, the model is represented by the grey box, and the error calculations are shown in the white box with a black border. The retrieved real (RRI) and imaginary (IRI) refractive indices are shown as the final outputs in the green boxes.

References

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