Response to Reviewer 1 Comments

Manuscript ID: egusphere-2025-5580

Title: Retrieving Stratospheric Ozone Profiles from OMPS Limb Profiler Measurements

Author(s): Fang Zhu et al.

We sincerely thank you for the insightful and critical evaluation of our manuscript. We acknowledge the concerns regarding the novelty and practical significance of our work. Below, we provide a detailed point-by-point response addressing these concerns. All modifications in the revised manuscript have been marked.

General comments:

The authors present a retrieval algorithm that combines wavelength pairing with the multiplicative algebraic reconstruction technique (MART) and apply it to OMPS-LP L1G data to obtain ozone profiles. The results derived from this algorithm are validated using multiple ozone profile observations. However, wavelength pairing and MART are well-established and commonly used techniques in limb sounding. This study essentially applied these mature methods to a different dataset, thus offering limited novelty. Furthermore, the authors do not clearly articulate the advantages of their algorithm over the official OMPS-LP algorithm. In terms of retrieval accuracy, the presented algorithm does not demonstrate sufficient improvement over the official OMPS-LP retrievals, which diminishes the practical significance of this work.

Response: We thank you for the insightful and critical evaluation. We acknowledge the concerns regarding the novelty and practical significance of our work. Below we provide detailed responses addressing these concerns.

Point 1: The authors present a retrieval algorithm that combines wavelength pairing with the multiplicative algebraic reconstruction technique (MART) and apply it to OMPS-LP L1G data to obtain ozone profiles. The results derived from this algorithm are validated using multiple ozone profile observations. However, wavelength pairing and MART are well-established and commonly used techniques in limb sounding. This study essentially applied these mature methods to a different dataset, thus offering limited novelty.

Response 1: We thank you for raising this important point. We agree that the core components of our algorithm—wavelength pairing and MART—are established techniques in atmospheric remote sensing. However, we respectfully argue that the novelty and scientific contribution of this study lie not in the invention of a new fundamental method, but in its tailored adaptation, comprehensive validation, and strategic application to OMPS/LP, which presents unique challenges and opportunities. We clarify this contribution in three key aspects:

1. Instrument-Specific Adaptation and Optimization

Porting an algorithm from OSIRIS to OMPS/LP is non-trivial. The two instruments differ significantly in spectral resolution, wavelength coverage, sampling geometry, signal-to-noise characteristics, and radiometric calibration. Our work involved substantial re-engineering, including developing a new forward model configuration within SCIATRAN specifically optimized for OMPS/LP's spectral response and limb-viewing geometry, and re-deriving the optimal wavelength triplet (512 nm, 606.3 nm, 675.5 nm) based on OMPS/LP's specific sensitivity and noise properties, which differs from those used for OSIRIS. Moreover, we integrated NASA's v2.6 L1G data with its enhanced stray light and pointing corrections, which required adjustments in the normalization and cloud filtering steps to ensure consistency. Our retrieval workflow had to be adapted to handle these pre-processed inputs correctly. This rigorous adaptation, detailed in Sections 2.2 and 3, represents a significant technical contribution for the OMPS user community and ensures the method is correctly tuned for this specific sensor. To clarify this point more explicitly, we have added the following content in the revised manuscript.

Modification in Manuscript:

Introduction, Lines 67–74:

"While the core retrieval methodology of wavelength pairing and MART is well-established in limb sounding, the novelty of this work lies in its tailored adaptation to the OMPS/LP instrument. Given the significant differences between OMPS/LP and OSIRIS in measurement technologies—including spectral resolution, spectral channels, wavelength range, atmospheric sampling, and radiance acquisition—this study has performed targeted optimizations and innovations on the algorithm, with significant adaptations in radiative transfer model construction, selection of retrieval spectra, and application of atmospheric parameter databases."

Section 3.1, Lines 153–160:

"In this study, the peak wavelength λ_p= 606.3 nm adheres to the visible channel configuration employed in the NASA OMPS/LP v2.6 operational algorithm (Kramarova, et al., 2024), thereby consistency with established OMPS retrieval products. The weakly absorbing reference wavelengths λ_{ref1}=512 nm and λ_{ref2}=675.5 nm were optimized according to the selection criteria proposed by Zhu et al. (2021) for limb scattering ozone retrievals within the Chappuis-Wulf band, which take into account the specific spectral response and noise characteristics of OMPS/LP. Unlike the NASA algorithm, which uses spectral averages over multiple wavelengths for its visible triplet (510 nm, 606 nm, 675 nm; Kramarova and DeLand, 2023), the proposed method adopts individual discrete wavelength channels."

2. Providing an Independent Retrieval Pathway for Validation and Uncertainty Analysis

The existence of an official operational algorithm (NASA OMPS/LP v2.6) does not diminish the value of an independently developed algorithm. In remote sensing, multi-algorithm intercomparison is a fundamental tool for assessing data quality and characterizing structural uncertainties. Our algorithm serves as a completely independent reference for validating the official product. The strong agreement we find with the official product in the 20-36 km altitude range (deviations generally≤5%) provides robust, independent validation of OMPS/LP data quality in this region. Conversely, the systematic differences we identify (e.g., high biases above 35 km and in the tropical UTLS) are diagnostically valuable. We trace these differences to specific algorithmic choices, such as using visible-only spectra versus a UV-Vis synergy, and different prior constraints and aerosol handling. This analysis, presented in Sections 4.2–4.5, offers crucial insights into the inherent uncertainties of limb-scattering ozone retrievals.

Modification in Manuscript:

Abstract, Line 13-14:

“Developed as a complementary dataset for validating operational products, the algorithm is tailored to OMPS/LP’s specific characteristics.**”**

Introduction, Lines 73–74:

“Furthermore, this study provides an independently developed retrieval pathway for OMPS/LP, offering a complementary source for cross-validation with official products.”

3. Foundational Step Towards Long-Term, Multi-Mission Data Harmonization

A primary motivation stated in our manuscript is to facilitate the creation of long-term, consistent ozone profile records. OSIRIS (launched 2001) and OMPS/LP (launched 2011) are two pivotal limb-sounding missions for stratospheric monitoring. By successfully applying a consistent retrieval core (MART with wavelength pairing) to both instruments, we take a concrete step towards minimizing algorithm-induced discontinuities in combined datasets. This work is therefore a necessary contribution towards building seamless multi-decadal climate data records, which is a high-priority goal for the atmospheric composition community. The novelty here lies in the strategic cross-platform methodological harmonization. This aligns with the reviewer's perspective that the current work serves as a foundation for future improvements, including the incorporation of UV information and operational aerosol products.

Modification in Manuscript:

Introduction, Lines 77–80:

“The research aims to demonstrate the effectiveness of the wavelength pairing and MART algorithm in retrieving OMPS/LP ozone profiles, thereby laying a theoretical and technical foundation for integrating OMPS/LP and OSIRIS data to construct long-term continuous datasets.”

Conclusions, Lines 557–559:

"Finally, the consistent retrieval core shared with OSIRIS lays a solid technical foundation for constructing long-term, coherent stratospheric ozone records, thereby minimizing discrepancies in multi-satellite data merging and supporting climate studies that require stable, multi-decadal observational records."

Point 2: Furthermore, the authors do not clearly articulate the advantages of their algorithm over the official OMPS-LP algorithm. In terms of retrieval accuracy, the presented algorithm does not demonstrate sufficient improvement over the official OMPS-LP retrievals, which diminishes the practical significance of this work.

Response 2: We thank you for this comment, which allows us to clarify the practical significance of our work. We respectfully submit that the value of an independent algorithm is not solely—or even primarily—defined by its ability to outperform the official product in terms of accuracy. Its significance is multifaceted.

Firstly, our study provides a transparent and comprehensive error analysis (Section 4.1) that is valuable for all users of OMPS/LP data. We explicitly quantify the contributions from the prior profile (~5% error in the tropical lower stratosphere based on a +5% perturbation experiment), aerosol extinction uncertainty (~5% error at 15–25 km), cross-section temperature dependence (localized biases of −3% to −5% in the tropics and Southern Hemisphere), and measurement noise (random uncertainty ranging from <10% in the mid-stratosphere to >20% at high altitudes and in the tropical UTLS, as quantified by Monte Carlo simulations). This detailed error budget helps data users understand the limitations and optimal altitude ranges (e.g., 20–35 km in the tropics) for ozone profiles derived from OMPS/LP's visible channels. This is a practical contribution to the community's understanding of the data. Secondly, the systematic high bias we find above 35 km is a key result with practical implications. We demonstrate that this bias is linked to the inherently reduced sensitivity of visible wavelengths to ozone in the upper stratosphere. This finding objectively validates the design choice of the official algorithm to merge ultraviolet and visible spectral information at high altitudes. Our work, therefore, helps define the reliable altitude boundaries for visible-only retrievals from OMPS/LP, which is valuable for studies focusing on the middle stratosphere or for instrument cross-checks. Last but not least, different retrieval philosophies have different strengths. The official optimal estimation (OE) algorithm is robust and effectively incorporates prior knowledge and constraints. Our MART-based approach, in contrast, has a simpler, more computationally straightforward framework with fewer explicit prior constraints. This makes its response to the measured radiance more direct and its error characteristics highly transparent. It can thus serve as a useful complementary product for specific research applications, such as in regions where prior information is highly uncertain, or for studies focused on understanding the pure information content of the limb radiances.

To ensure these points are communicated clearly, we have revised the manuscript to better highlight our contributions. We believe these revisions will significantly clarify the novelty and practical importance of our work. We are grateful for your constructive feedback, which has helped us improve the presentation of our study's contributions.

Modification in Manuscript:

Abstract, Lines 18–22:

"A comprehensive error analysis reveals that prior uncertainty contributes ~5% error in the tropical lower stratosphere (based on a +5% perturbation experiment), while a 30% uncertainty in the aerosol extinction coefficient causes ~5% error at 15–25 km. Absorption cross-section uncertainties introduce localized biases of −3% to −5%, and random measurement noise exhibits strong altitude dependence, with values below 10% in the mid-stratosphere and exceeding 20% at high altitudes and in the tropical upper troposphere."

Section 4.2, Lines 368–370:

"The large positive deviation at the upper boundary of retrieval may be caused by the decreased ability of the visible spectrum to retrieve ozone at high altitudes, while the NASA product uses combined ultraviolet and visible spectrum information for retrieval at this altitude."

Section 4.1, Lines 263–265:

"However, unlike OE approaches, the MART algorithm used in this study does not produce formal averaging kernels. Therefore, we assess the sensitivity of the retrieval to the prior profile through a perturbation-based approach."

Specific comments:

Point 3: Line 122: Tangent height normalization can reduce absolute calibration errors to some extent. However, the impact of wavelength shifts on retrieval results is unlikely to be eliminated through normalization. This is because wavelength shift affects the calculation of ozone absorption cross-sections.

Response 3: We thank you for this important clarification. We agree that tangent height normalization primarily addresses radiometric calibration errors and surface albedo effects by referencing radiance to a high-altitude measurement where ozone absorption is minimal, but it does not correct for wavelength-dependent errors that affect the spectral shape of the measurement, such as those introduced by wavelength shifts. In response, we have revised the relevant text in the manuscript to more accurately reflect the limitations of normalization and to explicitly acknowledge the potential impact of wavelength shifts on cross-section calculations.

Modification in Manuscript: Section 3.1, Lines 142–144

"Although radiance normalization cannot completely eliminate the influence of surface reflection or correct spectral errors such as wavelength shifts (which affect the calculation of ozone absorption cross-sections), it significantly reduces the requirements for both absolute radiometric calibration accuracy and modeling accuracy (Flittner et al., 2000)."

We have also added a brief discussion in Section 2.2 regarding the instrument's wavelength stability and its effect on retrieval.

Modification in Manuscript: Section 2.2, Lines 122–124

"While thermally induced wavelength shifts have negligible impact on height-normalized radiances in ozone retrieval, we note that residual wavelength-dependent errors could affect cross-section matching in regions of strong ozone absorption."

Point 4: Line 221: SCIATRAN v2.2 is a relatively old version. Has the new version made improvements in computational accuracy?

Response 4: We thank you for raising this point. Indeed, newer versions of SCIATRAN (e.g., v4.6) offer enhancements in computational efficiency, support for additional physical processes (such as rotational Raman scattering), and updated absorption cross-section databases. However, for limb-scattering radiative transfer simulations in the visible Chappuis–Wulf band—the spectral range used in this study—the core physics of multiple scattering and ozone absorption are already well-established and sufficiently represented in SCIATRAN v2.2 for the purpose of this study.

Our sensitivity analysis (Section 4.1) indicates that the primary sources of uncertainty in the retrieved ozone profiles stem from the prior profile, aerosol extinction, and measurement noise—not from radiative transfer modeling errors. Any potential differences in simulated radiances between v2.2 and newer versions are expected to be minor in the context of ozone retrieval in this spectral region, and well within the estimated error budget of the retrieval.

We appreciate your attention to this technical detail and agree that future work could benefit from adopting the latest model version, particularly for studies focusing on ultraviolet wavelengths or requiring advanced treatment of inelastic scattering. However, for the present study, the use of v2.2 does not compromise the validity or accuracy of our results, as demonstrated by the good agreement with multiple independent datasets presented in Section 4.

Point 5: Line 512: How significant is the impact of a priori profiles on retrieval accuracy in the official OMPS-LP algorithm? The current algorithm appears to be highly dependent on the a priori profile, which raises concerns regarding the credibility of the retrieval results.

Response 5: We appreciate your attention to the role of a priori information in both the official OMPS-LP retrieval and our proposed algorithm. Below, we clarify the influence of a priori constraints in each case.

The official OMPS/LP retrieval employs an optimal estimation (OE) framework, which indeed incorporates a priori ozone profiles as part of its regularization strategy. However, the algorithm's dependence on the a priori is highly altitude- and latitude-dependent. As noted by Kramarova et al. (2024), “The LP ozone retrieval algorithm is very insensitive to a priori between 17 and 52 km in mid-latitudes and about 22–52 km in the tropics (Arosio et al., 2022). Sensitivity to a priori increases at the upper (above 52 km) and lower portion (below 17 km in mid-latitudes and 22 km in the tropics) of the profile where sensitivity of the LP measurements to ozone sharply declines.” This indicates that within the core stratospheric altitude range (≈20–35 km) where limb-scattering measurements exhibit strong sensitivity, the retrieval is largely observation-driven, and a priori influence is minimal. Therefore, the credibility of the official product remains high in this scientifically critical region.

In contrast to the OE approach, the multiplicative algebraic reconstruction technique (MART) used in our study does not rely on an explicit a priori constraint term in its objective function. Instead, the retrieval is initiated from a first-guess profile, but the iterative update is driven directly by the normalized radiance gradients. As shown in our sensitivity analysis (Section 4.1, Fig. 4), the impact of the initial profile on the final retrieval is largely confined to altitudes below 20 km in the tropics, where measurement sensitivity declines. Above this altitude, the retrieval is dominated by the measurement signal. Unlike the official algorithm based on optimal estimation, which relies on explicit a priori constraints particularly at extreme altitudes, our MART retrieval is less affected by the a priori. This design makes our algorithm particularly useful for diagnosing prior-induced biases in regions where independent validation is needed.

Nevertheless, both retrievals show strong consistency in the 20–35 km range, where satellite limb measurements are most sensitive and prior dependence is low. The cited studies confirm that the official OMPS-LP retrieval is not “highly dependent” on the a priori in the altitude range where most scientific analyses are conducted, which supports the credibility of the product within its well-validated vertical domain. Our independent retrieval further corroborates this by showing close agreement in that same region.

Thank you again for raising this important methodological issue. The cited studies confirm that the official OMPS-LP retrieval is not “highly dependent” on the a priori in the altitude range where most scientific analyses are conducted, which supports the credibility of the product within its well-validated vertical domain. Our independent retrieval further corroborates this by showing close agreement in that same region.

We thank you again for the thorough and constructive feedback, which has significantly improved the quality of our manuscript.

Sincerely,
Fang Zhu
On behalf of all authors

Response to Reviewer 2 Comments

Manuscript ID: egusphere-2025-5580

Title: Retrieving Stratospheric Ozone Profiles from OMPS Limb Profiler Measurements

Author(s): Fang Zhu et al.

This manuscript presents the retrieval of ozone profiles from OMPS limb observations, using wavelength pairing and the MART technique. Results are compared with the NASA official product and with correlative observations such as ozonesondes and satellite data, in an extensive way. The paper provides a quite detailed overview of the work, with well structured flow. However several explanations and descriptions need clarifications; in addition, English usage and references need an overall review. The most problematic section of the paper, in my opinion, is the error analysis, which I think needs a complete re-work. A major weakness of the presented product is that there is no dedicated retrieval of aerosol extinction, instead a climatology is used. I would suggest the authors to test the usage of already existing OMPS aerosol retrievals such as the NASA or the Bremen ones, as a feasibility test. The presented work does not offer by itself significant elements of novelty, as other 3 OMPS retrievals are currently existing and the results shown in the manuscript do not display significant improvements with respect to the NASA product, when compared with correlative observations. It is rather a feasibility study of the application of MART to OMPS data, with a perspective to improve the retrieval, include the UV information and proper aerosol extinction profiles.

Response: We sincerely thank you for your careful reading of our manuscript and for providing detailed and constructive comments. The suggestions have helped us significantly improve the clarity, rigor, and presentation of our work. Below we provide a point-by-point response to all comments. All modifications in the revised manuscript have been marked.

Major comments

Point 1: I have several questions and issues related to the error analysis section. I find the usage of the “prior averaging kernel (AK)” matrix quite confusing. In my understanding you are assessing the sensitivity of your retrieved profile to the a-priori profile, by perturbing the a priori values and assess the related changes in the retrieved ozone. I would introduce this concept without using the AK terminology, as it is rather a perturbation technique you are applying. Do you have proper AK for your retrievals (the product of G, gain matrix, and K, weighting functions, providing a measure of the sensitivity of the retrieval to a perturbation in the true state)? SCIATRAN should provide AK as output. In Fig. 5 panel (a), are you actually plotting prior AK or SCIATRAN AK? According to your reasoning at lines 263-265, higher peaks in panel (a) indicate that the retrieval is most sensitive to the a priori profile at 26 km. This is exactly what we don't want: the retrieval should be as far as possible independent from the a priori. In panel (b) however you show that the error due to a priori is small above 20 km, which is in contradiction with the previous reasoning. Ideally, the AK should look like a spike centered at the corresponding altitude, to indicate that the perturbation at that altitude is affecting only this altitude, i.e. the vertical resolution is equal to the sampling. If you compute the area of your AK, this gives you the measurement response, i.e. an estimation of the a priori contribution to the retrieved profile (see e.g. Rodgers2000; von Clarmann et al., 2020; Arosio et al., 2022).Another question on Fig. 5, panel (b), are you perturbing the a-priori profiles by +5 % and then plotting the difference between the perturbed retrievals and the standard one? I cannot explain otherwise the negative values between 15 and 19 km. Regarding Fig. 6, are you perturbing the aerosol extinction by +30% and then plotting the results? It is also not clear what you have done regarding the cross section (CS) error. Did you use everywhere the CS at 223 K instead of the one at 243K? I suggest to assess this term by perturbing the CS at all temperatures by 2% (typical error value) and then see the effects of using these CS in the retrieval. The plot and reasoning about the retrieval noise is very confusing. How did you get a negative measurement noise error? If you perturb randomly your radiance several times and then perform the retrievals, the standard deviation of your perturbed retrievals should give you an estimate of the random noise.

Response 1: We sincerely thank you for this thorough and highly constructive critique of our error analysis section. We recognize that the original presentation was confusing, contained inappropriate terminology, and included methodological flaws. In response, we have completely rewritten Section 4.1, following your recommendations and the established framework of retrieval error analysis (Rodgers, 2000; von Clarmann et al., 2020). Below we provide a point-by-point response and describe the corresponding revisions.

1.1 Terminology and the Use of "Prior Averaging Kernel"

Our use of the term "prior averaging kernel" was technically inappropriate and misleading. We were not computing a formal averaging kernel matrix $A = GK$, which requires a gain matrix G and weighting functions K. Our MART-based retrieval algorithm does not naturally produce these quantities. What we actually did was a perturbation sensitivity analysis by modifying the prior profile and observing the resulting changes in the retrieved profile.

Modification in Manuscript: Section 4.1, Lines 263–266:

We have removed all references to “prior averaging kernel” throughout Section 4.1. We now refer to this analysis as “prior sensitivity analysis”.

We explicitly state: “Unlike OE approaches, the MART algorithm used in this study does not produce formal averaging kernels. Therefore, we assess the sensitivity of the retrieval to the prior profile through a perturbation-based approach. In this study, the prior sensitivity analysis matrix $\mathbf{A}_0$…”.

1.2. Interpretation of the original Figure 5a (Now Fig. 4a)

We thank you for correctly identifying a conceptual contradiction in our original reasoning. We claimed that higher peaks in the original Fig. 5a indicate the retrieval is “most sensitive to the prior” at that altitude, yet the original Fig. 5b shows that prior-induced errors are small above 20 km. This contradiction arose because we failed to distinguish between sensitivity to perturbations and actual error magnitude.

Modification in Manuscript: Section 4.1, Lines 272–279:

“Fig. 4a illustrates the distribution of the prior sensitivity analysis matrix ($\mathbf{A}_0$) column vectors across the 12–40 km altitude range, with each curve plotted at a vertical resolution of 2 km. A peak centered near the perturbation altitude indicates that the retrieval at that altitude retains sensitivity to the prior value at the same level. The width of the peak reflects the degree of vertical smoothing inherent in the retrieval. At the lower boundary (below 15 km), the response amplitudes are weak, indicating that perturbations in the prior at these altitudes have limited influence on the retrieved profile. This is consistent with the reduced information content of limb measurements in the upper troposphere and lower stratosphere, where the retrieval is primarily constrained by the measurement geometry and cloud filtering rather than the prior.”

1.3. Prior Perturbation Experiment in the original Figure 5b (Now Fig. 4b)

We thank you for this important question and the opportunity to clarify our methodology. Below we provide a detailed explanation of what the original Figure 5b showed, what we have now added in response to your suggestion.

In the original submission, Figure 5b did not show the effect of perturbing a single prior profile by +5%. Instead, it compared the relative retrieval errors obtained when using two different climatological prior profiles: a low-latitude prior (5.5 °S) and a mid-latitude prior (45 °N).

These two prior profiles were each used as the initial guess for the MART retrieval under the same atmospheric conditions (same orbit, same geolocation). The relative error shown in the original Figure 5b was computed as:

$$\text{Relative Error} = \frac{\hat{\boldsymbol{x}}_{\text{prior\_A}} - \hat{\boldsymbol{x}}_{\text{prior\_B}}}{\hat{\boldsymbol{x}}_{\text{prior\_B}}} \times 100\%$$

where $\hat{x}_{\text{prior\_A}}$ is the retrieval initialized with the low-latitude prior, and $\hat{x}_{\text{prior\_B}}$ is the retrieval initialized with the mid-latitude prior. This was intended to illustrate the sensitivity of the retrieval to the choice of prior climatology, not the response to a controlled uniform perturbation.

Following your suggestion, we have performed a new sensitivity experiment in which the entire prior profile was uniformly scaled by +5% at all altitudes, and the retrieval was repeated. The relative difference between the perturbed retrieval and the standard (unperturbed) retrieval was computed as:

$$\text{Relative Error} = \frac{\hat{\boldsymbol{x}}_{\text{pert}} - \hat{\boldsymbol{x}}_{\text{std}}}{\hat{\boldsymbol{x}}_{\text{std}}} \times 100\%$$

The results of this new experiment are now presented in the revised Figure 4b.

Modification in Manuscript: Section 4.1, Lines 280–294:

“While Fig. 4a illustrates the pattern of prior influence, it does not quantify the actual retrieval error that would result from an inaccurate prior. To assess this, the entire prior profile was uniformly scaled by +5% at all altitudes, and the relative difference between the perturbed retrieval and the standard retrieval was computed. Figure 4b shows the relative error induced by a +5% perturbation of the prior profile. Below 20 km, the retrieval shows sensitivity to the a priori, with relative errors −5% in tropical regions. This indicates that a small increase in the prior profile leads to a noticeable underestimation of retrieved ozone concentrations in the tropical lower stratosphere, reflecting the high sensitivity of the retrieval to prior information in this region where measurement information content is low. With increasing altitude, the magnitude of the error progressively decreases. Above 25 km, the error approaches 0% across all latitudes, At high latitudes, the error magnitude remains relatively small at all altitudes, indicating weaker prior dependence compared to tropical and mid-latitude regions.”

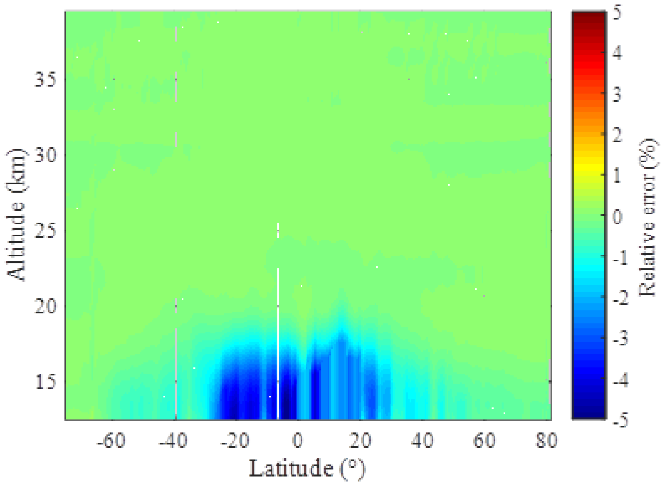

Figure 4. (b) Relative retrieval error resulting from a uniform +5% perturbation of the entire prior profile (orbit 51220 on September 15, 2021).

1.4. Aerosol Extinction Perturbation (original Figure 6a, now Figure 5a)

Your understanding is correct. We perturbed the climatological aerosol extinction profile by +30% at all altitudes and computed the resulting relative change in the retrieved ozone profile.

Modification in Manuscript: Section 4.1, Lines 297–300:

"…To assess the impact of this uncertainty on our ozone retrieval, we perturbed the climatological aerosol extinction profile by uniformly scaling it by +30% at all altitudes and repeated the retrieval. The relative difference between the perturbed retrieval and the standard retrieval was then computed. Fig. 5a depicts the resulting ozone retrieval errors as a function of latitude and altitude.…"

1.5. Absorption Cross-Section Error (original Figure 6b, now Figure 5b)

Thank you for this important clarification and for the helpful suggestion. You are correct that our original approach—comparing retrievals using cross-sections at two fixed temperatures (223 K and 243 K)—does not represent a realistic estimate of absorption cross-section uncertainty.

Following your recommendation, we have completely revised this part of the error analysis. Instead of comparing two discrete temperatures, we now apply a uniform +2% perturbation to the ozone absorption cross-sections at all temperatures relevant to the stratospheric conditions in our forward model. The retrieval is then repeated using the perturbed cross-sections, and the relative difference relative to the standard retrieval is computed. This approach follows the suggestion in the literature (e.g., Arosio et al., 2022) that a ±2% uncertainty is a typical conservative estimate for ozone absorption cross-sections in the Chappuis band.

Modification in Manuscript: Section 4.1, Lines 305–323:

"The temperature dependence of ozone absorption cross-sections has the potential to introduce errors in the retrieved profiles. To assess this effect quantitatively, we followed the approach which applied a uniform +2% perturbations to the ozone absorption cross-sections at all temperatures used in the forward model. This perturbation magnitude represents a typical conservative estimate of cross-section uncertainty in the Chappuis band (Arosio et al., 2022). The retrieval was then repeated using the perturbed cross-sections, and the relative difference relative to the standard retrieval was computed.

As shown in Fig. 5b, the resulting retrieval error exhibits a distinct vertical and latitudinal structure. In the tropics, the largest negative deviations (−3% to −5%) appear below 20 km, indicating that retrievals in the tropical lower stratosphere are most sensitive to uncertainties in ozone absorption cross-sections. In the Southern Hemisphere (SH) mid-to-high latitudes, prominent negative deviations (−3% to −4%) are found below 26 km. In the Arctic region, the negative bias below 20 km is relatively smaller, at approximately −2%. Across all latitudinal bands, the error stabilizes near −2% above 25 km. These results confirm that uncertainties in ozone absorption cross-sections introduce systematic biases in lower stratospheric ozone retrievals, especially in the tropics and SH mid-to-high latitudes. Specifically, a positive perturbation in the cross-sections leads to an underestimation of ozone concentrations, as observed in the negative biases in Fig. 5b."

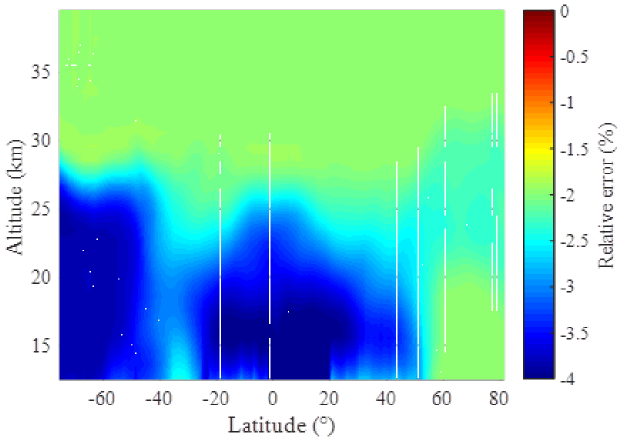

Figure 5. Distribution of relative errors in ozone retrieval with latitude and altitude, resulting from: (b) a +2% uniform perturbation of ozone absorption cross-sections at all temperatures.

1.6. Measurement Noise Error (original Figure 6c, now Figure 6)

Thank you for identifying the confusion in our original measurement noise analysis. We acknowledge that our original methodology was flawed. In the original manuscript, we added a 1% perturbation to the retrieval vector y_j (defined in Eq. 2) at each tangent height and then computed the relative difference between this perturbed retrieval and the standard retrieval. This approach does not provide a statistically meaningful estimate of random uncertainty.

Following your suggestion, we have completely redesigned this analysis using a proper Monte Carlo simulation. The revised methodology and results are described below.

Revised Approach (Monte Carlo Simulation):

Gaussian random noise with a standard deviation of 1% was added to the retrieval vector y_j (Eq. 2) at each tangent height. This perturbation level represents a conservative estimate of the radiometric noise in OMPS/LP limb radiances. The noise addition process was repeated 100 times, generating an ensemble of 100 independent noisy retrieval vectors. A full MART retrieval was performed for each of the 100 noisy realizations, producing an ensemble of 100 retrieved ozone profiles. For each altitude, the standard deviation of the 100 retrieved profiles was computed and expressed as a percentage of the mean retrieved value. This standard deviation represents the random uncertainty (precision) of the retrieval due to measurement noise.

$$\boldsymbol{\sigma}_{\mathrm{rand}} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\widehat{\boldsymbol{x}}_i - \overline{\boldsymbol{x}})^2} \times \frac{100\%}{\overline{\boldsymbol{x}}}$$

where N=100, $\widehat{\boldsymbol{x}}_i$is the retrieved ozone concentration from the i^{th} noisy realization, and $\overline{\boldsymbol{x}}$ is the average of the unperturbed profiles.

Modification in Manuscript: Section 4.1, Lines 324–340:

"To quantify the impact of random measurement noise on retrieval precision, a Monte Carlo simulation was performed using data from OMPS/LP orbit 51220. Sixteen representative latitudes spanning from 80 °S to 80 °N were selected. For each latitude, Gaussian random noise with a standard deviation of 1% was added independently at each tangent height to the retrieval vector y_j (Eq. 2). This process was repeated 100 times, generating 100 independent noisy realizations per latitude. A full MART retrieval was conducted for each realization, producing an ensemble of 100 retrieved ozone profiles for each latitude. The random uncertainty due to measurement noise was quantified as the standard deviation of the 100 retrieved profiles at each altitude, expressed as a percentage of the average of the unperturbed profiles.

Fig. 6 shows the latitudinal and altitudinal distribution of the resulting random uncertainty. It can be observed that uncertainty remains low (<10%) at most latitudes within the 20–33 km mid-stratosphere, reflecting robust and stable retrieval performance. Above 30 km, especially at high latitudes, uncertainty increases sharply to above 20 %, which is mainly attributed to weaker signals in the visible spectral range. In the tropics below 20 km, a region of elevated uncertainty (>15%) is identified, likely associated with low ozone abundances, strong atmospheric variability, or reduced information content from the measurements."

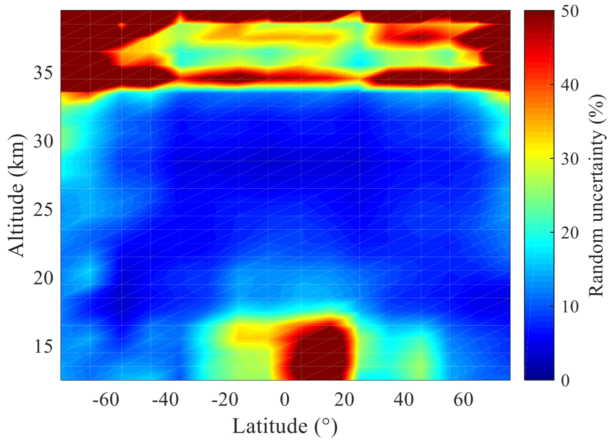

Figure 6. Random uncertainty in retrieved ozone profiles due to measurement noise, quantified as the standard deviation of 100 Monte Carlo realizations with 1% Gaussian noise added to the retrieval vector.

In addition, we have revised the content related to error analysis in the abstract.

Modification in Manuscript: Abstract, Lines 17–22:

“A comprehensive error analysis reveals that prior uncertainty contributes ~5% error in the tropical lower stratosphere (based on a +5% perturbation experiment), while a 30% uncertainty in the aerosol extinction coefficient causes ~5% error at 15–25 km. Absorption cross-section uncertainties introduce localized biases of −3% to −5%, and random measurement noise exhibits strong altitude dependence, with values below 10% in the mid-stratosphere and exceeding 20% at high altitudes and in the tropical upper troposphere.”

Point 2: L152-162 and Fig.2. I find this figure and the preceding explanation not really informative. I suggest to reformulate this paragraph or omit this figure. The author could simply state that the CTV and the vertical distribution of ozone are highly correlated.

Response 2: Thank you for the suggestion. Following the advice, we have removed original Figure 2 and condensed the paragraph to focus only on the essential information regarding the CTV’s altitude limitations, which is directly relevant to our retrieval setup.

Modification in Manuscript: Section 3.1, Lines 161–165:

“The Chappuis triplet vector (CTV) is designed to be positively correlated with ozone concentration (Degenstein et al., 2009). As expected, the CTV values and the retrieved ozone profiles show consistent vertical and latitudinal variations, with peak altitudes decreasing from the tropics to high latitudes. In this study, CTV values near zero above 35 km exhibit insufficient sensitivity to ozone, and values above 40 km become negative; therefore, the retrieval is restricted to altitudes below 40 km.”

Point 3: At lines 233-235, there seem to be some confusion between vertical resolution and vertical sampling (gridding) of the profiles. The vertical grid can be 1 km. However, the effective vertical resolution of the retrieved profile is defined by the averaging kernel matrix: inverse of the diagonal elements of the AK matrix times the layer width.

Response 3: Thank you for this important clarification regarding the distinction between vertical sampling and effective vertical resolution. You are absolutely correct that the two terms are not interchangeable. In the original manuscript, we inadvertently used “vertical resolution” to refer to the 1 km grid spacing of the input L1G data. This was imprecise and has been corrected.

Modification in Manuscript: Section 3.4, Lines 238–240:

“The retrieved ozone profiles are reported on the same vertical grid as the OMPS/LP L1G input data, which has a fixed spacing of 1 km in tangent height. However, this sampling interval does not imply an equivalent effective vertical resolution. The true vertical resolution is generally coarser than 1 km, particularly in regions of lower measurement sensitivity.”

We acknowledge that, unlike optimal estimation approaches, our MART-based retrieval does not produce formal averaging kernels. Therefore, we do not provide quantitative estimates of the effective vertical resolution in this study.

Point 4: In the validation part, I don't think that the panels (a) of Figs. 7, 9, 12 and 15 are really informative: this is an average of very different ozone profiles, as the standard deviation points out. It makes more sense to show only the relative differences, however depending on how they are computed. Is panel (b) simply the relative difference between the two curves in panel (a) or is this the mean absolute difference calculated for each collocation divided by the mean profile? The plots divided by latitude bands are more informative and valuable, I would suggest to make them larger.

Response 4: Thank you for the thoughtful comments regarding the validation figures. After careful consideration, we have implemented the following revisions to address the concerns while improving the clarity and focus of our validation presentation:

4.1. Retention of Panels (a) in Figs. 7, 9, 12, and 15:

We respectfully retain the annual mean ozone profile comparisons in panels (a) of these figures. While the standard deviations are indeed large—reflecting the natural geophysical variability of ozone across latitudes, seasons, and atmospheric conditions—the mean profiles themselves provide essential context for interpreting the relative differences shown in panels (b). These mean profiles represent the central tendency of the ozone distribution and serve as a reference baseline for understanding the absolute scale and altitude structure of ozone. We have, however, revised the figure captions to explicitly clarify that panel (b) is not the simple difference between the two mean curves in panel (a), but rather the mean of pairwise relative differences calculated for each collocated measurement using Eq. (7).

Modification in Manuscript: Section 4, Lines 377、414、468、517:

Figure 7. (b) The corresponding annual mean relative differences calculated pairwise for each collocated measurement using Eq. (7), with the standard deviation shown as a dashed line.

Figures 9, 12, 15 Captions: Similarly updated.

4.2. Revision of Figs. 8, 10, 13, and 16 (Latitude Band Comparisons):

We agree with you that the latitude-band relative difference plots are more informative and valuable than the mean profile comparisons within the same figures. To better highlight these key results and accommodate your suggestion to enlarge them, we have removed the mean ozone profile sub-panels from Figs. 8, 10, 13, and 16. Each of these figures now exclusively presents the zonal mean relative difference profiles for the five latitude bands. This modification allows us to significantly enlarge the remaining panels, improving readability and focusing the reader's attention on the most scientifically meaningful validation metrics—the latitudinal and altitudinal structure of the biases. The figure captions have been updated accordingly.

Modification in Manuscript: Section 4, Lines 380、417、471、520:

Figures 8, 10, 13, 16: Sub-panels removed; only latitude-band relative difference plots remain; figures enlarged.

Point 5: References need an overall check, I pointed out some inconsistencies in the minor commentsection below.

Response 5: Thank you for the thorough review of the references. All specific inconsistencies mentioned in the minor comments have been addressed and corrected in the revised manuscript. In addition, we have conducted a full check of the reference list to ensure consistency in formatting, completeness, and appropriateness of all citations. Key references suggested by you (Rodgers, 2000; von Clarmann et al., 2020; Zawada et al., 2018) have been added and cited appropriately.

Minor comments and typos

Point 6: L14: “at the upper tangent height” → “at an upper tangent height”

Response 6: Corrected as suggested.

Modification in Manuscript: Abstract, Line 15.

Point 7:L16: instrument’s → instrument

Response 7: Corrected as suggested.

Modification in Manuscript: Abstract, Line 17.

Point 8:L29: I suggest to remove this reference here, or find a more general one about stratospheric ozone

Response 8: Thank you for your suggestion. We have removed the specific citation here.

Modification in Manuscript: Introduction, Line 17.

Point 9:L41: detect → observe

Response 9: Corrected as suggested.

Modification in Manuscript: Introduction, Line 45.

Point 10: L47: “strong signal strength” → “good signal-to-noise ratio”

Response 10: Corrected as suggested.

Modification in Manuscript: Introduction, Line 51-52.

Point 11: L53: reference not appropriate: I think, Flynn et al. 2014 is more appropriate.

Response 11: Thank you for the suggestion. We have updated the reference as recommended.

Modification in Manuscript: Introduction, Line 57.

Point 12: L60: reference not appropriate, Flynn et al. describes the OMPS performance. Use for example, Zawada etal., 2018, https://doi.org/10.5194/amt-11-2375-2018 to reference USask product.

Response 12: Thank you for the suggestion. We have updated the reference as recommended.

Modification in Manuscript: Introduction, Line 64.

Point 13: L74: “combined with” → “against”

Response 13: Corrected as suggested.

Modification in Manuscript: Introduction, Line 81.

Point 14: L82: Reference not appropriate, rather Flynn et al., 2014.

Response 14: Thank you for the correction. We have updated the reference as suggested.

Modification in Manuscript: Section 2.1, Line 89.

Point 15: L84: I would say "imaging" rather than "scanning".

Response 15: Corrected as suggested.

Modification in Manuscript: Section 2.1, Line 91.

Point 16: L85: I find this sentence quite misleading, as the line of sight does not necessarily intersect the Earth's surface. The tangent point is the point along the line-of-sight having the lowest altitude.

Response 16: Thank you for this important clarification. We have revised the sentence to accurately define the tangent point.

Modification in Manuscript: Section 2.1, Line 92-93.

"During a limb observation, the sensor's line-of-sight passes tangentially through the atmosphere, and the point along this path with the lowest altitude is termed the tangent point (TP)."

Point 17: L88: "by wavelength – reaching 1.5 nm at the short-wavelength end and 40 nm…" → "with wavelength:from 1.5 nm at short wavelengths to 40 nm…"

Response 17: Corrected as suggested.

Modification in Manuscript: Section 2.1, Line 97.

Point 18: L92: remove "resolution"

Response 18: Removed as suggested.

Modification in Manuscript: Section 2.1, Line 100.

Point 19: L97: "operates in 14 orbits daily," → "completes 14 orbits daily,"; "completing approximately…" →"performing approximately…"

Response 19: Corrected as suggested.

Modification in Manuscript: Section 2.1, Line 105.

Point 20: L115: Can you better specify which +0.1 km correction is here meant?

Response 20: Thank you for your attention to this detail. In response to your suggestion regarding the level of detail in Section 2.2 (Point 21), we have streamlined that section and removed the specific mention of the +0.1 km time-dependent correction to avoid overly technical descriptions.

Point 21: Sect. 2.2: I found this section too detailed for the aim of this paper: readers can find these details in the provided references, such as Kramarova et al. 2024. As the authors do no use this information for the described retrieval algorithm, this information could be summarized in the previous section.

Response 21: Thank you for the constructive suggestion to improve the conciseness of the manuscript. In response, we have streamlined Section 2.2 by focusing only on the key corrections applied to the L1G v2.6 dataset that directly impact the radiance quality used in our retrieval, while referring readers to the cited literature for further implementation details.

Modification in Manuscript: Section 2.2, Line 112-126.

"2.2 Key corrections in OMPS/LP L1G v2.6 data

Radiometric errors and sensor pointing errors are the two main error sources affecting limb-scattering ozone retrieval accuracy (Kramarova et al., 2024). The OMPS/LP L1G v2.6 dataset incorporates essential corrections to address these issues.

Pointing (altitude registration) corrections are applied to mitigate tangent height offsets caused by instrument alignment and thermal effects. Multi-point corrections include static, intra-orbit, and time-dependent adjustments following Moy et al. (2017).

Stray light correction is performed using an updated point spread function (PSF) based on pre-launch measurements (Jaross et al., 2014). In version 2.6, the PSF tail intensity in UV and VIS/NIR bands is increased by ~12% to improve high-altitude stray light estimation (Kramarova et al., 2024). An additional factor of 1.5 is applied in VIS/NIR wavelengths to correct for in-band scattering. While thermally induced wavelength shifts have negligible impact on height-normalized radiances in ozone retrieval, we note that residual wavelength-dependent errors could affect cross-section matching in regions of strong ozone absorption.

These calibration steps are critical for ensuring the radiometric and geometric accuracy of the radiances used in our retrieval. Further details can be found in the cited references."

Point 22: L142: and Flittner et al. 2000.

Response 22: The reference has been added as suggested.

Modification in Manuscript: Section 3.1, Line 146.

Point 23: L145: What does "thereby enhancing the specificity of the retrieved signal" mean? Can you better state what is the difference between your choice and the triplet vector selected by NASA?

Response 23: Thank you for these helpful questions. Below we provide clarification and the corresponding revisions made in the manuscript.

The original phrase "enhancing the specificity of the retrieved signal" was intended to convey that the Chappuis triplet vector (CTV) construction helps isolate the ozone absorption signal by reducing the influence of common interfering factors. We have rephrased this for clarity.

Modification in Manuscript: Section 3.1, Line 148-149.

The revised text now reads:

"…thereby isolating the ozone absorption signal from common background scattering effects (e.g., aerosol scattering).”

This revision makes explicit what the CTV accomplishes: it enhances the signal-to-background ratio for ozone by canceling out contributions that affect the two reference wavelengths similarly.

To further clarify the differences between our wavelength selection and the NASA OMPS/LP v2.6 algorithm, we have added the following explanation in Section 3.1.

Modification in Manuscript: Section 3.1, Line 153-160.

“In this study, the peak wavelength λ_p=606.3 nm follows the visible channel configuration used in the NASA OMPS/LP v2.6 operational algorithm (Kramarova, et al., 2024), ensuring consistency with established OMPS retrievals. The weakly absorbing reference wavelengths λ_{ref1}=512 nm and λ_{ref2}=675.5 nm were optimized based on the selection criteria developed by Zhu et al. (2021) for limb scattering ozone retrievals in the Chappuis-Wulf band, which account for the specific spectral response and noise characteristics of OMPS/LP. In contrast to the NASA algorithm, which uses spectral averages over multiple wavelengths for its visible triplet (510 nm, 606 nm, 675 nm; Kramarova and DeLand, 2023), our method employs individual discrete wavelength channels.”

The NASA OMPS LP v2.6 algorithm uses a similar triplet method but may differ in the exact wavelengths and their application within an Optimal Estimation framework that also incorporates UV channels. Our selection was optimized for OMPS/LP's spectral response and noise characteristics in the visible range, and is applied within a MART retrieval scheme.

Point 24: L164: There are two reference Li et al., 2023.

Response 24: Thank you for your careful review of the references. You are correct that both citations refer to different Li et al. publications, and each is correctly associated with its respective topic in the manuscript. To avoid ambiguity, we have clarified the citations by including the first author's full initial in the text where appropriate.

Modification in Manuscript: Section 3.1, Line 168; Introduction, Line 34.

Point 25: L165: “with a relative increment of red waves in the spectrum being higher than that of blue waves”. This is a very confusing sentence. Do you mean that the scattering by aerosol is wavelength dependent?

Response 25: Thank you for pointing out the confusing wording. Yes, we intended to convey that aerosol scattering is wavelength-dependent, with stronger scattering at longer (red) wavelengths compared to shorter (blue) wavelengths, a characteristic described by Angstrom exponent.

Modification in Manuscript: Section 3.1, Line 168-170.

“The presence of aerosols enhances the intensity of atmospheric scattered light, with the effect being stronger at longer (red) wavelengths than at shorter (blue) wavelengths due to wavelength-dependent scattering.”

Point 26: L168: Please remove “with different multiples” or replace with “scaling”.

Response 26: Corrected as suggested.

Modification in Manuscript: Section 3.1, Line 173.

Point 27: L171: Below 30 km you mean?

Response 27: Corrected as suggested.

Modification in Manuscript: Section 3.1, Line 176.

Point 28: L191: Regarding Wji maybe better say: “indicating the importance of the jth TH or line of sight to the ozone retrieved at altitude i“.

Response 28: Revised as suggested.

Modification in Manuscript: Section 3.2, Line 196.

Point 29: L213: Please clarify this sentence

Response 29: Thank you for the clarification. To avoid confusion and improve readability, we have revised the sentence.

Modification in Manuscript: Section 3.2, Line 218.

“During the ozone retrieval process, retrieval below the cloud top height is not performed, and the profile in this region remains unchanged.”

Point 30: L225-226: Are you really performing forward simulation in a fully spherical atmosphere or in the pseudospherical approximation?

Response 30: Thank you for the insightful question. The "RTM TYPE" was set to "spher_scat" in this study. This mode employs accurate spherical ray-tracing for single-scattered radiation and uses a pseudo-spherical approximation for the multiple scattering contributions. To clarify this in the manuscript, we have revised the relevant sentence.

Modification in Manuscript: Section 3.3, Line 230-231.

"The radiative transfer solution in the forward model is based on the discrete ordinate method applied to a spherical atmosphere with a pseudo-spherical approximation for multiple scattering."

Point 31: L244: “Error research” → “Error analysis”

Response 31: Revised as suggested.

Modification in Manuscript: Section 4.1, Line 251.

Point 32: L245: Please remove “technology“

Response 32: Revised as suggested.

Modification in Manuscript: Section 4.1, Line 252.

Point 33: L248: Remove DOAS and spell out Optimal Estimation.

Response 33: Revised as suggested.

Modification in Manuscript: Section 4.1, Line 255.

Point 34: L253: The TH corrections are already included in v2.6 of OMPS data, isn't it?

Response 34: Thank you for your review. You are absolutely correct. The tangent height (TH) corrections are already applied in the OMPS/LP L1G v2.6 dataset, and we did not apply any additional corrections in our retrieval.

Modification in Manuscript: Section 4.1, Line 260.

Point 35: L256: I think the proper term is "averaging kernel".

Response 35: We thank you for this helpful terminological clarification. Following your earlier suggestion in Point 1, we have already replaced the misleading term "prior averaging kernel matrix" with the more appropriate "prior sensitivity analysis matrix" throughout Section 4.1. This revised terminology reflects that we are performing a perturbation-based sensitivity analysis rather than computing formal averaging kernels, which our MART algorithm does not produce. We have also updated the corresponding figure captions and text to maintain consistency with this corrected terminology.

Modification in Manuscript: Section 4.1, Line 265.

Point 36: L302-303: It is hard to follow these two sentences: what does it mean that "corrected TH are integrated"? The verb is missing in the aerosol extinction sentence.

Response 36: Thank you for highlighting the unclear phrasing and missing verb. The sentences have been revised for clarity and grammatical correctness.

Modification in Manuscript: Section 4.2, Line 346-347.

"During algorithm implementation, the retrieved surface albedo, cloud top height, and corrected tangent height are incorporated. In the forward model, aerosol extinction coefficients retrieved from OMPS/LP measured data are used."

Point 37: L316 and at several other points, e.g. lines 364, 382, 416 etc.: remove "controlled" or replace it with "confined", for example.

Response 37: Thank you for this suggestion to improve phrasing. We have replaced the word "controlled" with "confined" or similar context-appropriate terms (e.g., "within", "limited to") at the noted locations and throughout the manuscript for consistency.

Modification in Manuscript:

The changes are as follows: L316 (now revised line): "…the deviation between 17 and 36 km is confined within 5 %."

Lines 360, 400, 404, 421, 456, and similar instances have been updated accordingly.

Point 38: L318: "region" → "regions"

Response 38: Corrected as suggested.

Modification in Manuscript: Section 4.2, Line 362.

Point 39: L319: “In the northern mid-latitude region” → “At northern mid-high latitudes”

Response 39: Corrected as suggested.

Modification in Manuscript: Section 4.2, Line 363.

Point 40: L322: I would say “this positive deviation reaches approximately 10% around 18 km”.

Response 40: Revised as suggested.

Modification in Manuscript: Section 4.2, Line 366.

Point 41: L324: Please remove “in low latitudes”.

Response 41: Removed as suggested.

Modification in Manuscript: Section 4.2, Line 368.

Point 42: L342: “operates along” → “completes about”

Response 42: Corrected as suggested.

Modification in Manuscript: Section 4.3, Line 384.

Point 43: L348: I would remove “substantial”.

Response 43: Removed as suggested.

Modification in Manuscript: Section 4.3, Line 390.

Point 44: L353: geopotential height and temperature?

Response 44: Thank you for this correction. It has been added.

Modification in Manuscript: Section 4.3, Line 395.

Point 45: L358: Please remove “the increase”

Response 45: Revised as suggested.

Modification in Manuscript: Section 4.3, Line 400.

Point 46: L366: “further expands” → “increases”

Response 46: Corrected as suggested.

Modification in Manuscript: Section 4.3, Line 406.

Point 47: L367**:** “The tropical shows obvious stratifications characteristics” → “In the tropical regions the differences change sign with altitude”.

Response 47: Revised as suggested.

Modification in Manuscript: Section 4.3, Line 407.

Point 48: Please review the paragraph at lines 385-390 to make it more clear.

Response 48: Thank you for pointing out the lack of clarity in this paragraph. We have substantially rewritten these lines to improve readability, logical flow, and precision. The revised paragraph now clearly separates the discussion of tropical UTLS discrepancies, mid-latitude performance, and high-altitude biases.

Modification in Manuscript: Section 4.3, Line 421-430.

The revised text now reads:

"The altitude-dependent behavior of the retrieval biases can be summarized as follows. In the tropical UTLS region, oscillating differences exceeding 30 % are observed, which may be attributed to several factors: the highly dynamic variability of ozone concentrations, the limited detection sensitivity at the lowest retrieval altitudes, and the influence of cloud filtering. Furthermore, the inherently low ozone abundance in this region exacerbates retrieval uncertainties. A distinct negative bias in retrieved ozone values is evident at 20–23 km in the tropics, particularly pronounced during winter (Fig. 11c). Conversely, a positive bias is observed over Antarctica, possibly linked to biases in surface albedo retrieval at high southern latitudes during polar winter. Above 35 km, the retrievals exhibit a positive bias in the tropics. This altitude range coincides with the transition zone between ultraviolet and visible spectral windows, where inconsistencies in the merging of data from these two spectral regions may contribute to the observed discrepancies."

Point 49: L395-396: "effectiveness" → "accuracy"

Response 49: Corrected as suggested.

Modification in Manuscript: Section 4.3, Line 436.

Point 50: L432: MLS → OSIRIS

Response 50: Corrected as suggested.

Modification in Manuscript: Section 4.4, Line 471.

Point 51: Which AK are you taking for the smoothing of the sondes, as in Fig. 14? Do you have your own AK?

Response 51: Thank you for your review. In Fig. 14, the ozonesonde profiles were smoothed using the averaging kernels (AK) from the official NASA OMPS/LP v2.6 product, not from our own retrieval. For the collocated OMPS/LP observation, we extracted the corresponding averaging kernel matrix and a priori profile from the NASA v2.6 data product and applied them to the ozonesonde profile.

Modification in Manuscript: Section 4.5, Line 491-492.

"In addition, another processing approach involves convolving ozonesonde measurements with the averaging kernels (AKs) retrieved from OMPS/LP v2.6 (see Arosio et al., 2018 for details)."

We do not have formal averaging kernels (AK) for our MART-based retrieval.

Point 52: L464: "denotes" → "indicates"

Response 52: Corrected as suggested.

Modification in Manuscript: Section 4.3, Line 502.

Point 53: L511: What do you mean with "the adjustment factor above clouds"?

Response 53: Thank you for this question. The original phrase "the adjustment factor above clouds" was unclear and poorly defined. We apologize for the confusion. In the MART algorithm, the ozone profile is updated iteratively using a multiplicative correction factor applied at each tangent height. This factor is the weighted average of the ratios between observed and simulated retrieval vectors (Eq.3). However, below the detected cloud top height, the retrieval update is suspended, and the ozone profile from the previous iteration (or the initial guess) is retained without modification. The original wording incorrectly suggested that a specific "adjustment factor" is applied above clouds and propagated downward. The intended meaning was simply that the retrieval is not updated below cloud top.

Modification in Manuscript: Conclusions, Line 546-547.

"... retrievals of lower-altitude ozone profiles are still constrained by the initial, as no iterative update is applied below the detected cloud top height. Consequently, ozone abundances above cloud tops are overestimated by more than 25%."

Point 54: L512: Why do you expect the a priori profile to be inaccurate in the low altitudes? In my opinion, the missing aerosol retrievals and the missing UV information are the main responsible of the described biases.

Response 54: Thank you for this important observation. Upon re-evaluation, we agree that the original statement "Inaccurate prior profiles in the mid- to low latitude regions introduce retrieval biases exceeding 20%" is misleading and not supported by our updated prior sensitivity analysis.

Following your suggestion to use a uniform +5% prior perturbation (rather than comparing two different climatological priors), our revised analysis (Fig. 4b) shows that prior-induced errors are approximately −5% in the tropical lower stratosphere, not exceeding 20%. The original statement was based on a different experimental setup (comparing low-latitude vs. mid-latitude priors) and does not accurately represent the sensitivity of the retrieval to prior uncertainties. Therefore, we have removed this sentence.

We agree with you that the absence of dedicated aerosol extinction retrievals is a physical limitation of our current algorithm, and that aerosol scattering effects are particularly important in the UTLS region.

We agree with you that the lack of UV spectral information is the primary cause of the positive bias observed above 35 km. This is already clearly stated in Section 4.2 and the Conclusions: "The large positive deviation at the upper boundary of retrieval may be caused by the decreased ability of the visible spectrum to retrieve ozone at high altitudes, while the NASA product uses combined ultraviolet and visible spectrum information for retrieval at this altitude." We have retained and reinforced this statement in the revised manuscript.

Modification in Manuscript: Conclusions, Line 547-559.

“These discrepancies are further exacerbated by low ozone abundance, strong dynamical variability in the tropics, and the reduced sensitivity of limb retrievals at lower altitudes, while inconsistencies between the background aerosols used in retrievals and real atmospheric conditions also contribute. The overestimation of ozone abundances above 35 km across all latitudes results from the limited sensitivity of the visible spectrum for high-altitude ozone retrievals, in contrast to the operational product that employs combined ultraviolet and visible spectral information.

Based on these findings, several priorities for follow-up research are identified. First, integrating operational aerosol extinction products from NASA will be essential to replace the current climatological approach and reduce systematic biases in the UTLS region. Second, including ultraviolet channels will improve retrieval accuracy above 35 km, where visible-only measurements have low sensitivity. Third, refining cloud filtering will better constrain lower altitude retrievals. Finally, the consistent retrieval core shared with OSIRIS lays a solid technical foundation for constructing long-term, coherent stratospheric ozone records, thereby minimizing discrepancies in multi-satellite data merging and supporting climate studies that require stable, multi-decadal observational records.”

Point 55: L544: “thanks” → “thankful”

Response 55: Corrected as suggested.

Modification in Manuscript: Acknowledgements, Line 579.

Point 56: References

Rodgers, Clive D. Inverse methods for atmospheric sounding: theory and practice. Vol. 2. World scientific, 2000.

von Clarmann, Thomas, et al. "Overview: Estimating and reporting uncertainties in remotely sensed atmospheric composition and temperature." Atmospheric Measurement Techniques 13.8 (2020): 4393-4436.

Zawada, Daniel J., et al. "Tomographic retrievals of ozone with the OMPS Limb Profiler: algorithm description and preliminary results." Atmospheric Measurement Techniques 11.4 (2018): 2375-2393.

Response 56: We thank you for providing these essential references. All three have been added to the reference list and cited appropriately in the revised manuscript.

Modification in Manuscript: Line 677、696、710.

We thank you again for the thorough and constructive feedback, which has significantly improved the quality of our manuscript.

Sincerely,
Fang Zhu

On behalf of all authors