Response to RC2: 'Comment on egusphere-2025-91', Anonymous Referee #2, 30 Jun 2025

Review of Manuscript egusphere-2025-91 entitled '**Global validation of the Particulate Observing Scanning Polarimeter (POSP) Aerosol Optical Depth products over land**' by Zhe Ji, Zhengqiang Li, Gerrit de Leeuw, Zihan Zhang, Yan Ma, Zheng Shi, Cheng Fan, and Qian Yao

On behalf of all co-authors, we thank Referee #2 for the insightful and extensive comments which certainly contribute to the substantial improvement of the manuscript (MS). Below we respond to each of the general, major and specific comments which are copied below (in black). In addition to the numbered major and specific comments, we have numbered the general comments as GC1-GC7. After each comment we provide our response, in red, together with changes in the revised MS. Line numbers (indicated by L) mentioned by Referee #2 refer to the original MS as published in the AMT discussion Section and revisions are quoted with line numbers (indicated by LR) referring to the revised MS.

GC1: Given that POSP is a new instrument with a novel retrieval algorithm, more detailed information should be provided on the AOD retrieval methodology, particularly regarding the estimation of surface reflectance over land. Since surface reflectance is a critical factor in satellite AOD retrieval, a lack of clarity on how it is treated limits the reader's ability to understand regional differences in retrieval performance. Clear articulation of the algorithm's treatment of land surface properties would help explain spatial variations in validation results.

Responds to GC1: Thanks for your suggestion. We have added a description of surface reflectance estimation in Section 2.1, as follows:

"The POSP was launched on board the GF-5(02) satellite in July 2021. It has a field of view of ±50° with a swath width of ~1850 km, and provides global observations in nine spectral bands spanning wavelengths from 380 to 2250 nm (Lei et al., 2023). The local time of the descending node for GF-5(02) is 10:30 a.m. The POSP is equipped with a comprehensive onboard calibration system (the radiometric calibration accuracy is within 5%, and the polarimetric calibration accuracy is within 0.005). Ji et al. (2025) developed an enhanced AOD retrieval algorithm using POSP data. Due to the limited number of observations, POSP faces an ill-posed inversion problem when the directional characteristics of the surface are taken into account. To reduce the discrepancy between the number of observations and the number of retrieval parameters, the following changes have been made to the algorithm presented in Ji et al. (2025). For aerosol parameters, the global aerosol distribution from the MODIS Dark Target algorithm has been used, but aerosol models over northern India and central Africa have been updated to achieve more accurate retrievals. For surface parameters, the bidirectional reflectance distribution function (BRDF) from MODIS (MCD43) was used to account for the directional reflectance characteristics of the surface during the inversion (Schaaf et al., 2002). The MODIS BRDF comprises an isotropic kernel (reflectance from Lambertian surface), a volumetric kernel (reflectance from multiple scattering within vegetation canopies), and a geometric-optical kernel (reflectance from object shadowing). To eliminate the differences in spectral response between POSP and MODIS, spectral reconstruction was performed using the Singular Value Decomposition (SVD) technique. The algorithm only retrieves the isotropic kernel to reduce the number of parameters to be inverted. Therefore, after spectral reconstruction, monthly averaged Ross-Thick and Li-Sparse kernel parameters were applied to account for the surface directional characteristics. Finally, the new aerosol models and surface directional characteristics were incorporated into the algorithm developed by Ji et al. (2025), and AOD was successfully retrieved. Ji et al. (2025) also presented the preliminary validation (from November 2021 to April 2022), the results show that the AOD retrievals have high accuracy." (LR 81-100)

GC2: The manuscript could benefit from being more concise. Since the primary objective is to validate the POSP AOD product, the content should remain focused on presenting the validation methods, metrics, regional analysis, and interpretation of results, minimizing peripheral discussions.

Responds to GC2: We fully agree with your suggestion and have streamlined most of the peripheral discussions. However, following the recommendation of the first reviewer, we have added a discussion on the impact of neglecting surface directional reflectance characteristics on the retrieval over urban areas. In addition, we have also included a comparison of the spatial distribution between POSP AOD and MODIS AOD.

Responds to GC3:: The current validation extends a previous preliminary comparison (Nov 2021 – Apr 2022) by covering a longer period (Dec 2021 – Nov 2022). However, the manuscript should clearly articulate the novel contributions of this extended study. For instance, does the longer time series reveal seasonal biases? Are regional patterns more robustly confirmed or refined? Clarifying what new insights are gained will better justify the value of this work.

Thanks for your suggestion. We have revised the manuscript and reorganized the highlights of this study, leading to the following conclusions:

This study is dedicated to the following two objectives: 1) To ensure the reliability of POSP AOD products and explore the potential factors influencing their performance; 2) To provide a valuable reference for the enhancement of these products in future iterations.

Firstly, the validation of the POSP AOD against AERONET site data is performed. Then, we obtained the retrieval accuracy of POSP AOD for one year (2022) and the accuracy metrics across different global regions.

"The validation of POSP AOD shows good consistency with AERONET AOD, with an R of 0.914, and the fraction within the EE of 78.45%. Global site-scale validation results show that POSP AOD is more consistent with AERONET AOD in high AOD regions than in low AOD regions. The bias is positive in Europe and negative in Asia. The fraction within the GCOS requirements is smaller in high aerosol loading regions than in low aerosol loading regions." (LR 458-461)

Secondly, we explored the potential factors influencing their performance and specifically discussed the impact of ignoring surface directional reflectance characteristics on the retrieval in urban areas.

"The accuracy of the POSP AOD varies significantly across different seasons, with the highest accuracy in the DJF (R^2 of 0.854, RMSE of 0.080) and the lowest in the JJA (R^2 of 0.667, RMSE of 0.083). The accuracy of the POSP AOD is higher over densely vegetated areas than over low-vegetated areas, with croplands achieving the highest accuracy (R^2 of 0.859, RMSE of 0.093). Moreover, the error analysis shows that the accuracy of POSP AOD is mainly influenced by surface vegetation cover and observation geometry. As NDVI or scattering angle increases, the uncertainty of POSP AOD decreases. POSP AOD consistently provides results with low bias irrespective of the values of NDVI or scattering angles. For aerosol retrieval over urban areas, the effect of surface anisotropy on retrieval accuracy is non-negligible in regions with high surface reflectance." (LR 462-469)

Finally, we analyzed the spatial reliability of POSP AOD by comparing the differences between the POSP AOD and MODIS AOD products.

"The comparison of MODIS and POSP AOD products shows that POSP AOD is in good agreement with MAIAC AOD over North Africa and the Arabian Peninsula, while it compares better with DB AOD over other regions. Cross-validation shows that the accuracy of the POSP AOD is higher than that of the MODIS AOD. The comparison metrics for DB versus POSP are as follows: R^2 of 0.853/0.791, RMSE of 0.075/0.090, fraction within EE of 82.51%/77.25% (POSP/DB); and for DT: R^2 of 0.862/0.770, RMSE of 0.080/0.103, fraction within EE of 80.72%/73.90% (POSP/DT). Comparison over different surface types shows that POSP AOD is more accurate than DB over City, Cropland, and Grassland areas, and better than DT under all surface types." (LR 470-476)

GC4: Cloud screening is especially crucial for POSP given its spatial resolution of 6.4 km. However, the current manuscript lacks sufficient details on the cloud masking procedures employed. Please describe how cloud contamination is identified and removed from the observations, and discuss the potential impact of residual cloud effects on the validation results.

Responds to GC4: Thank you very much for your suggestion. We indeed overlooked the description related to cloud masking. In response, we have added a description of **Data Preprocessing** in Section 3.3 as follows:

"As an optical sensor, POSP observations are inherently susceptible to cloud interference. To mitigate cloud contamination, it is essential to filter out cloud-affected pixels before retrieval. Given the single-angle observation method of POSP, this study adopts cloud detection strategies from MODIS, which have been extensively validated (Frey et al., 2008). Specifically, two methods are employed: the apparent reflectance threshold method and the apparent reflectance spatial variation detection method (Martins et al., 2002). The former effectively identifies optically thick clouds with high reflectance or substantial water vapor content, while the latter is particularly useful for detecting cloud edges, shadows, thin clouds, and dispersed cloud formations.

The land surface exhibits low reflectance in the blue band, whereas clouds have high reflectance. Therefore, a pixel is identified as a cloud when its reflectance at the 443 nm band exceeds a certain threshold. The 1380 nm band lies within a strong water vapor absorption region, where the reflectances from land surfaces and low clouds are generally low. As a result, only high clouds, mostly above the heights where atmospheric water vapor is located, are visible in this band. Pixels with high reflectance at 1380 nm are therefore typically classified as high clouds. Furthermore, cloud edges typically exhibit high spatial variability due to mixed pixels and partial cloud coverage. The spatial variation characteristics of the 443 nm and 1380 nm bands can effectively identify cloud-edge pixels. The combination of their spatial differences helps reduce misclassification at cloud boundaries and improves the accuracy of cloud detection.

Surface conditions such as snow and water also affect the inversion. Since the retrieval algorithm is explicitly designed for clear-sky over non-ice land surfaces, pixels over water, ice, and snow must be excluded. The detection of water and snow pixels is achieved using the Normalized Difference Water Index (NDWI) and the Normalized Difference Snow/Ice Index (NDSI), respectively, with specific identification thresholds presented in Table 1.

$$NDWI = \frac{\rho_{670} - \rho_{865}}{\rho_{670} + \rho_{865}} \quad (9)$$

$$NDSI = \frac{\rho_{670} - \rho_{2250}}{\rho_{670} + \rho_{2250}} \quad (10)$$

While the aforementioned cloud detection strategy provides a foundation for minimizing cloud contamination, potential for further improvement remains. Given the relatively coarse spatial resolution of POSP (6.4 km) and its limited spectral coverage, certain pixels that contain residual clouds may remain undetected. The simulation analysis by Kassianov and Ovtchinnikov (2008) pointed out that multiple scattering of clouds can lead to overestimated AOD retrievals when the residual clouds are not fully screened. Sogacheva et al. (2017) further removed the cloud-contaminated pixels using a cloud post-processing scheme. To enhance cloud-mask accuracy, a dedicated cloud detection algorithm for POSP is still needed. We aim to further enhance the cloud detection algorithm in future work.

Table 1 Summary of screening thresholds.

Items	**Purpose**
$\rho_{443} < 0.02\ or\ \rho_{443} > 0.4$	Cloud
$\sigma_{443} > 0.038$	Cloud
$\rho_{1380} > 0.02\ and\ Height < 1500$	Cloud
$\sigma_{1380} > 0.005$	Cloud
$NDWI > 0$	Water
$NDSI > 0.4$	Snow/Ice

” (LR 185-213)

Meanwhile, we have also added a discussion on the potential impact of residual cloud effects on the validation results, as follows:

“Given the relatively coarse spatial resolution of POSP (6.4 km) and its limited spectral coverage, certain pixels that contain residual clouds may remain undetected. The simulation analysis by Kassianov and Ovtchinnikov (2008) pointed out that multiple scattering of clouds can lead to overestimated AOD retrievals when the residual clouds are not fully screened. Sogacheva et al. (2017) further removed the cloud-contaminated pixels using a cloud post-processing scheme. To enhance cloud-mask accuracy, a dedicated cloud detection algorithm for POSP is still needed. We aim to further enhance the cloud detection algorithm in future work.” (LR 206-211)

GC5: The reference to Che (2015) is cited in the manuscript but not listed in the References section. Please ensure this citation is properly included and formatted.

Responds to GC5: Thank you for pointing this out, and we apologize for the confusion caused by our oversight. We have corrected all the reference formats.

GC6: The citation “Liangfu et al. (2021)” appears to be incorrect. It should be corrected to “Chen et al. (2021)” as per standard citation format.

Responds to GC6: Thank you very much for pointing this out. We have corrected it accordingly.

GC7: L85-90, Relying on the high-..., it should be polished.

Responds to GC7: We have revised it and removed the inappropriate parts, as follows:

"Ji et al. (2025) also presented the preliminary validation (from November 2021 to April 2022), the results show that the AOD retrievals have high accuracy." (LR 99-100)

Citation: https://doi.org/10.5194/egusphere-2025-91-RC2

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