Dear Editors and Reviewers,

Thanks very much for taking your time to review this manuscript. We really appreciate all your detailed valuable comments on our manuscript of "egusphere-2025-435". These suggestions have been so helpful that we have incorporated them into the newly revised manuscript. And we hope that the reviewers and the editors will be satisfied with our responses to the 'comments' and the revisions for this manuscript. Please find our itemized responses in below and my revisions in the re-submitted files.

Yours Sincerely,

Yong Xue

Response for Reviewer #2:

The authors developed a novel algorithm to retrieve BC surface concentration using satellite data through several steps, including determined the background aerosol model, the Maxwell–Garnett effective medium approximation model, lookup tables, and a conversion coefficient. The retrieved BC surface concentrations were validated by using ground measurements, and the statistical parameters outperform those obtained from MERRA-2 BC data. In general, this manuscript is well organized and written. Some explanations are needed for a clear understanding. Generally, this manuscript can be accepted for publication after minor revisions.

As for the proposed algorithms and models, it is suggested to introduce the physical and chemical mechanisms, and how to consider and apply them in model designs and improvements. What are the advantages and disadvantages of the algorithms and models in this study? They should be discussed somewhere in the text.

Response: Thank you very much for your positive comments. We have further described the advantages and disadvantages of this algorithm in the conclusion section: "The BC surface concentrations obtained by this algorithm show relatively high reliability and accuracy (R = 0.727, RMSE = 0.353, MAE = 0.211), though there is a slight overall underestimation ($y = 0.718x + 0.015$) compared to high-precision ground-based in-situ measurements. This might be due to a small number of BC particles being exposed on the outside of the shell, which led to the failure to estimate the relevant aspect. Additionally, uncertainty analysis of the inversion results indicates that the algorithm is more suitable for high AOD conditions. However, since there is no AE33 site data in the bright surface area, the performance of the inversion results on the bright surface still needs further verification. Therefore, future work will focus on improving the algorithm's performance low aerosol loading conditions and evaluating inversion results accuracy in bright surface." The specific responses to the comments are as follows:

1. L11-16, "In this study, we developed a novel algorithm for retrieving BC surface concentration using MODIS and AERONET data. The algorithm first determined the seasonal background aerosol model using the K-means clustering method, based on AERONET V3 daily products. It then employed the Maxwell–Garnett effective medium approximation model to calculate the complex refractive index of the internally mixed aerosols and used the 6SV2.1 radiative transfer code to establish lookup tables for optimal BC fraction and column concentration estimation", this paragraph should be rewritten.

Response: Thank you for your suggestion. We have rewritten this paragraph. "In this study, we developed a novel algorithm for retrieving BC surface concentration jointly using MODIS and AERONET data. Firstly, the algorithm employed the K-means clustering method to determine seasonal background aerosols model based on AERONET V3 daily products. Then, the Maxwell–Garnett effective medium approximation model was utilized to calculate the complex refractive index of the internally mixed aerosols. Subsequently, the lookup tables were established using the

6SV2.1 radiative transfer code to estimate optimal BC fraction and column concentration. Next, the column concentration data were converted to surface concentration using a conversion coefficient derived from MERRA-2. Finally, the retrieved MODIS BC surface concentration was validated with in-situ Aethalometer measurements.”

2. L77, These datasets can be obtained from this website (https://ladsweb.modaps.eosdis.nasa.gov/), the accessed date should be added. It is same for all websites used in the text.

Response: Thank you very much for your suggestion. We have supplemented the data access dates in the manuscript.

3. L137-138, which is associated with the frequent occurrence of dust aerosols from North Africa during this period (Meloni et al., 2008), please explain the time period (e.g., year) and the sites, as well as in Tables 2 and 3.

Response: Thank you for your suggestion. We have made the following revisions to the manuscript: “It can be observed that during spring and summer, the volume concentration of coarse-mode particles is higher in BAs, which is associated with the frequent occurrence of dust aerosols from North Africa during from March to June every year (Meloni et al., 2008). Moreover, the changes in SSA across different seasons are quite pronounced, with the absorption of fine aerosol particles being higher in winter. Using data from all seasons for clustering could introduce significant errors in the estimation of BAs. Therefore, this study clustered the AERONET data by season to obtain accurate seasonal variations in the physical properties of BAs. Table 2 and Table 3 show RI clustering results and particle volume size distribution parameters clustering results of BAs in different seasons.”

4. L167-168, since the proportion of BC in mixture aerosol particles generally does not exceed 6%, please explain where it is come from for 6%.

Response: Thank you for your suggestion. We have already added the data sources to the manuscript. “Since the fraction of BC in mixture aerosol particles generally does not exceed 6% (Bao et al., 2020).”

Bao, F., Li, Y., Cheng, T., Gao, J., and Yuan, S.: Estimating the Columnar Concentrations of Black Carbon Aerosols in China Using MODIS Products, Environ. Sci. Technol., 54, 11025-11036, https://doi.org/10.1021/acs.est.0c00816, 2020.

5. L200-201, Furthermore, at high aerosol loading (AOD ≥ 1.0), the model estimates a higher TOA standard deviation at lower surface reflectance, indicating better performance in BC estimation under these conditions. It is confused for that the model estimates a higher TOA standard deviation and better performance, more explanations are suggested.

Response: Under all the same conditions, if the estimated TOA differences under different FBCS are very small, that is, the standard deviation of TOA is very small, then the cost function will have difficulty distinguishing such differences, thereby resulting in a large error in the estimation of f_{BC}. In Fig. 5, in the case of high AOD, the differences in TOA estimated by different f_{BC} are obvious. At this time, the cost function will have a significant difference, thereby improving the estimation accuracy of f_{BC}.

6. L203-204, Fig. 5. Sensitivity analysis of BC inversion based on 6SV2.1. (a)-(b) represent ρ_S at 0.66μm change steps are 0.02 and 0.10, respectively, should be rewritten.
Response: We have rewritten it as follows: "**Fig. 5.** Sensitivity analysis of BC inversion based on 6SV2.1 model. The (a)-(d) represents the ρ_S at 0.66μm variation step sizes, which are 0.02, 0.10, 0.20, and 0.30, respectively. The (e) represents SSA and Standard deviation of TOA changes in different f_{BC}."

7. Fig. 9. BC surface concentration bias (MODIS - AE33) dependence analysis on the (a) AOD and (b) surface reflectance, please indicate the meanings of the bars.
Response: Thank you for your suggestion. We have already modified the title of Fig. 9: **Fig.9.** The box plot of BC surface concentration Bias (MODIS - AE33) independence analysis on the (a) AOD and (b) surface reflectance. The red box represents the interquartile range (IQR, 25th–75th percentiles), and the black whiskers extend to the most extreme data points within 1.5×IQR from the quartiles.

8. L224-236, it is recommended to make more comparisons with other studies, including the main statistical parameters shown in the text.
Response: Since there is no inversion results of other algorithms based on MODIS data at the same time and place, we don't verify the inversion products with other algorithms. However, in the manuscript, we compare the accuracy of the inversion results with that of MERRA-2 BC. The comparison results indicated that the inversion accuracy of this algorithm is better.

9. L219, transit time. (Remer et al., 2005), please remove the dot after time.
Response: Thank you for pointing out this issue. We have removed the redundant dot from the manuscript.