We would like to thank the Reviewer for his/her thorough and detailed review as well as for the suggested papers. Our responses (in blue) for each comment (in black) are provided below.

[updates in the algorithm]

Lowered the retrieval cutoff AHI AOD from 0.6 to 0.3.

Removed 10 km ATH cutoff.

Image-matching is no more conducted when 20 % of the pixels in moving (or, reference) window is cloud-contaminated.

[changes in figures]

Figures use updated version of ATH.

CALIOP L2 aerosol extinction profile is replaced to CALIOP L1 total attenuated backscatter in Fig.6 (e) and Fig. 7 (e).

Fig. 8 is replaced with 2-dimensional histogram.

Added x=0 line in Fig. 9.

Changed colormaps in Fig. 10 to the same colormap of Fig.6 and Fig.7.

Wrong figure in Fig. 10 (d) is replaced.; discussion in the manuscript is also changed. P14 L399-401.

General comments:

This study assessed the application of different viewing geometries for a pair of geostationary imagers, AHI-AGRI and AHI-AMI to retrieve aerosol top height (ATH) information. The stereoscopic algorithm is presented, which converts the lofted aerosol layer parallax, calculated using image-matching of two visible images, to ATH. What is strongly missing in the manuscript is a discussion on the required ATH quality for different applications. I am not an expert in utilizing the ATH data but knowing the PBL processes I assume that 1-2km offset between calculated and measured on the ground or retrieved from CALIOP ATH is too high and further improvements of the retrieval approach are needed to produce a product of the required quality. The insufficient quality of a product is a cause for my decision to reconsider the manuscript after major revision, when a better (required for certain applications) quality of the product has been achieved.

We appreciate the reviewer's comments. It has been very difficult and thus rare to have ATH information from satellite imaging instruments which would provide valuable dataset over wider area. As suggested by the reviewer, detailed PBL process studies require higher accuracy ATH information. However, ATH with lower accuracy would still provide valuable information in understanding the ATH of long-range transport, the conversion of columnar aerosol optical depth (AOD) to surface PM concentrations, and tracking of wildfire and dust outbreak aerosols etc.

Nanda et al. (2020)-AMT used hyperspectral observation from TROPOMI to retrieve aerosol layer height. The results are compared to CALIOP extinction weighted mean height from 1 May 2018 to 28 February 2019. The mean bias was -2.41 km for land, and -1.03 km for the ocean. The standard deviation was 3.56 km for land, and 1.97 km for the ocean. Lee et al. (2021)-IEEE used VIIRS, OMPS (passive), and CALIOP (active) data for simultaneous retrieval of aerosol scattering property and aerosol layer height. The retrievals were conducted only over wildfire smoke layers over 42 cases from 2012 to 2018. Using only passive sensors (VIIRS, OMPS), the result showed a mean bias of -0.1 km and RMSE of 1.1 km compared to CALIOP extinction weighted mean height. Chen et al. (2021)-RSE also used TROPOMI but a different wavelength from Nanda et al. to retrieve absorbing aerosol (smoke, dust) height. This study compared retrieved aerosol height with CALIOP extinction weighted mean height at over 5 smoke cases and 2 dust cases. The results showed a mean bias of -0.01 km and RMSE of 0.64 km.

To give insights into the retrieval quality from our algorithm, we conducted error analyses of AHI-AGRI ATH. Please note that the retrieval algorithm is changed. We generated two heights from the CALIOP profile. One is called “90 % extinction height”, which was used in our manuscript. The other is “extinction weighted mean height” which was used over other studies using spectroscopic methods such as Nanda et al. and Chen et al.

$$\text{ext. weighted mean height} = \frac{\sum_{i=1}^{n} \beta_{ext,i} Z_i}{\sum_{i=1}^{n} \beta_{ext,i}}$$

where $\beta_{ext,i}$ is extinction coefficient at 532 nm at height index i and Z_i is the altitude at i.

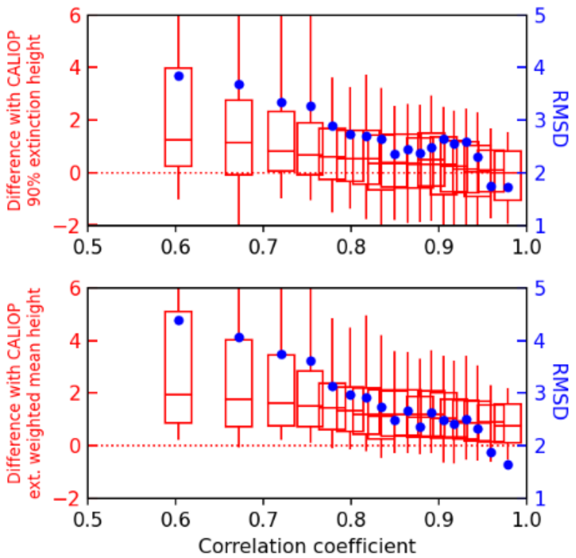

Figure AR1 Comparison with CALIOP 90 % extinction height (upper) and CALIOP extinction weighted mean height (lower) according to correlation coefficient of best correlated moving window during image-matching process. Red boxplots show 5th, 25th, 50th, 75th, 95th percentiles of (retrieved ATH – CALIOP height). Blue circles show RMSD of retrieved height and CALIOP height.

Here, the “correlation coefficient” means the value of the best correlated moving window (from the matching image) for a fixed window (from the reference image). As shown in figure AR1, it can be seen that as a the correlation coefficient becomes higher (which means that the algorithm successfully found the same aerosol layer on the image), the retrieval bias gets close to 0, and RMSD decreases. We then compared error analysis from all correlation coefficient data and that from quality-controlled (correlation coefficient > 0.95) data.

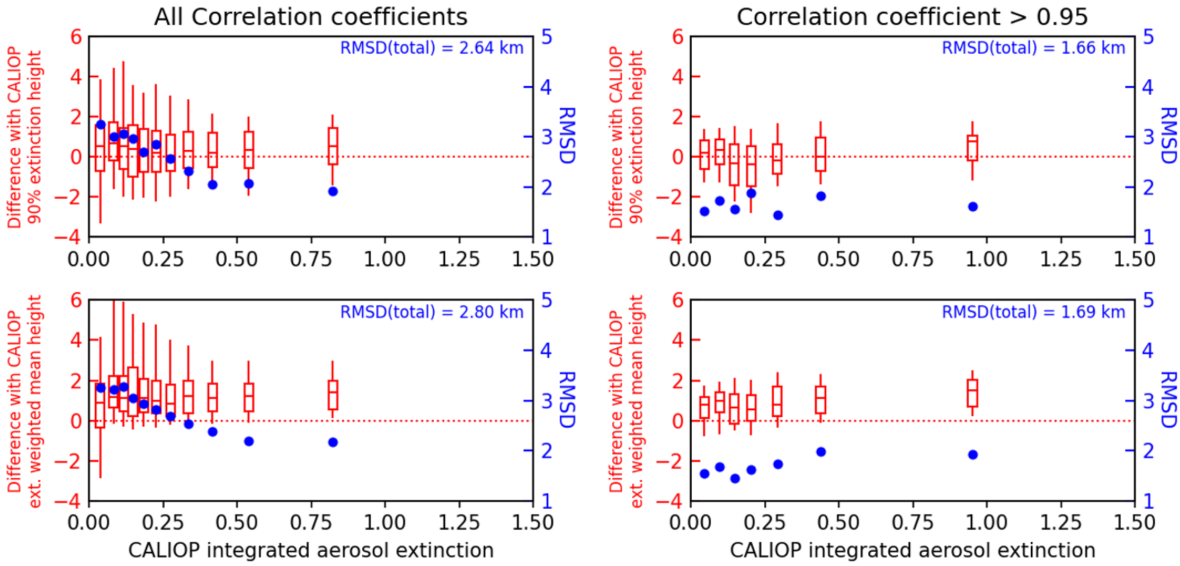

Figure AR2 Same as Fig. AR1. But according to CALIOP integrated aerosol extinction. Left panels are for all correlation coefficient values while right panels are only for correlation coefficient > 0.95.

Error analyses according to aerosol loading (column integrated CALIOP L2 aerosol extinction coefficient). Using all data regardless of the correlation coefficient, retrieval quality increases as aerosol loading increases. In this case, RMSD with CALIOP 90% extinction height (extinction weighted mean height) decreased from 3.21 (3.08) km to 2.07 (2.35) km. Meanwhile, using quality-controlled (correlation coefficient > 0.95) data, the total RMSD was 1.66 km. Therefore, we could say that our results are compatible with the other studies.

Additionally, comparing both 90 % extinction height and extinction weighted mean height to the stereoscopic ATH. We could also inductively say that the stereoscopic algorithm gives an altitude that is near the top of the aerosol profile.

Specific comments:

How is ATH defined in the study? How it differs from aerosol layer height? This question came to my mind on P8 L 232

We tried to explain what our algorithm would give in the last paragraph on Chap. 3.1, which however seems confusing because it is mixed up with the definition in terms of height-parallax conversion. We moved the definition of ATH that is formed by the height-parallax conversion process to the paragraph above (P 6 L164-168). Then we described how the products are going to work in different situations (e.g., dense aerosol plume, thinner aerosol layer, multiple layers of aerosol) in P6 L169-184)

P2, L 31. How narrow? Please, provide numbers or refer here to Sect. 2.2.1

According to Winker et al. (2010, BAMS), CALIOP has 70 m footprint diameter.; P2 L34-35

P2, L 31. Please, specify more exactly bypasses time

With the word “bypass”, we meant the active sensors missing the aerosol transport events. Sorry for the misleading. We changed the sentence to “active sensors such as CALIOP have very narrow swath (e.g., CALIOP footprint diameter is 70 m; Winker et al., 2010), which means that they may miss aerosol transport events most of the time.”.; P2 L34-35

P2, L 35. I suggest using the word “distribution” instead of “structure”

Done. Thanks.

P2, L 59. Remove "data"

Done. Thanks.

P2, L 62-64. Is it lack if channels or lack of the stereoscopic view, which is insufficient?

We meant lack of channels that are sensitive to the height of the aerosol layer. For the sake of clarity, we changed the sentence to "the visible to infrared (VIS–IR) wavelength channels that are usually employed by meteorological satellite instruments usually lack sensitivity to aerosol height information, thus insufficient for the retrieval of aerosol height from observed radiances."; P3 L64-66

P4, Sect 2.1.2. Please, add bands characteristics, as in 2.1.1

Thank you for the suggestion, detailed band characteristics like 2.1.1 seem better to understand. We added similar sentences about observation bands to 2.1.2 "AMI also has 16 spectral bands, including 3 VIS, 1 NIR, 2 shortwave IR, and 10 IR channels. Blue and green bands (0.47, 0.51 µm) have spatial resolutions of 1 km at the sub-satellite point, and a red band has 0.5 km resolution (0.64 µm)."; P4 L104-106

P4, L 96. The Advanced Meteorological Imager (AMI) ….

Done. Thanks.

P4, L 97. Please specify new channels if they are used in the study. If not, it is not necessarily to mentioned added channels here.

We appreciate the suggestion; we guess mentioning the new channels is not necessary for this paper. We simplified the sentence to "The Advanced Meteorological Imager (AMI) is a GEO meteorological instrument onboard Geo-KOMPSAT 2A (GK-2A), which was launched on 4 December 2018 by the National Meteorological Satellite Center (NMSC) of Korea succeeding the mission of its MI predecessor.".; P4 L 102-104

P4, L 99. Please, clarify: The AMI spectral bands are similar to those of AHI, except for a VIS and IR band; the center wavelengths and spatial resolutions of the VIS bands of AMI and AHI are similar.

Added band characteristics and deleted the unclear sentences.; P4 L104-106

P4, L 117-118. Please, rephrase

Done; P4 L123-124

P4, L 120. CALIOP product is less accurate compared to the ground-based measurements. I suggest naming of the inter-comparison with CALIOP as evaluation, instead of validation. I also suggest discussing first an opportunity for validation with ground instruments and second mention the evaluation with satellites (which in general have an advantage in coverage, though CALIOP coverage is quite small, but may allow evaluation in the conditions where ground instruments are missing)

We should've been careful in using "validation" when it comes to the aerosol height retrieval, thank you. We changed the word to "evaluation". P4 L124

We agree that long-term validation with ground-based lidar data would help demonstrate the feasibility of the stereoscopic aerosol height retrieval algorithm. Unfortunately, for the period from 1 January 2020 to 30 April 2020, only 49 days are collocated within 5 km from the lidar site. According to a conversation with Dr. Yeo, who provided us with the lidar data of SNU and GSN sites, the lidar signal would be totally dissipated when a thick aerosol layer is present. This indicates that a favorable condition for stereoscopic aerosol height retrieval algorithm is not the case for ground-based lidars. Also, even though the ground-based observation system works automatically, it needs manual maintenance from time to time, which leads to fewer data availability.

The objective of the comparison with ground-based lidar data is to show the possibility to monitor diurnal variation of aerosol height using geostationary passive sensors. Since many studies that used LEO satellites cannot monitor the hourly variation of aerosol vertical features, it is one of the strengths of the stereoscopic aerosol height retrieval algorithm using GEO satellites. We notice the need to clarify the purpose of comparison with ground-based lidar. Therefore, we put additional discussion as follows in P13 L 381-383.

P6, Sect. 3.1 Have you considered to develop two approaches, one for land and one for ocean, to resolve the ocean/land contribution at different wave lengths?

We did use different wavelengths to test our algorithm. On May 12, 2020, a thick dust plume was transported toward the Korean peninsula, which is a very favorable condition for a stereoscopic algorithm to work. Fig. AR3 shows image-matching correlation coefficients using 0.4, 0.6, and 0.8-micron channels to retrieve aerosol height. First, using a 0.4-micron channel, matching correlation values that find the same aerosol feature is low. A low correlation coefficient is expected over the ocean because the ocean is brighter at shorter wavelengths, but it was the same for the land. As shown in a single channel image in Fig. AR4, the surface seems darker at 0.4-micron but spatial patterns over the surface are more obvious at the channel too. This can be the reason why the correlation coefficient is lower than the 0.6-micron channel. For the 0.8-micron channel, correlation coefficient results seem okay. But as shown in a single channel image in Fig. AR4-c, the aerosol layer is brighter at 0.6-um channel. For this kind of thick aerosol plume, the 0.8-micron retrieval may work, but when it comes to lower aerosol loading, the 0.8-micron may lack sensitivity. Therefore, we fixed the algorithm to use a single 0.6-micron channel.

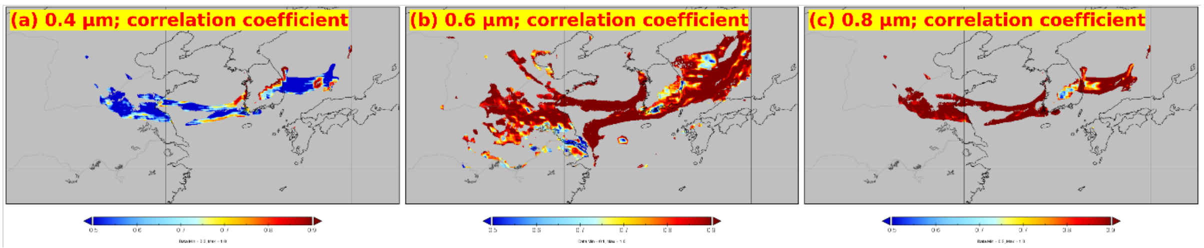

Figure AR3 Correlation coefficient of the best correlated moving window of 0.4 (a), 0.6 (b), and 0.8 (c) μm channels. *more spatial coverage of (b) is due to algorithm change of AOD cutoff from 0.6 to 0.3.

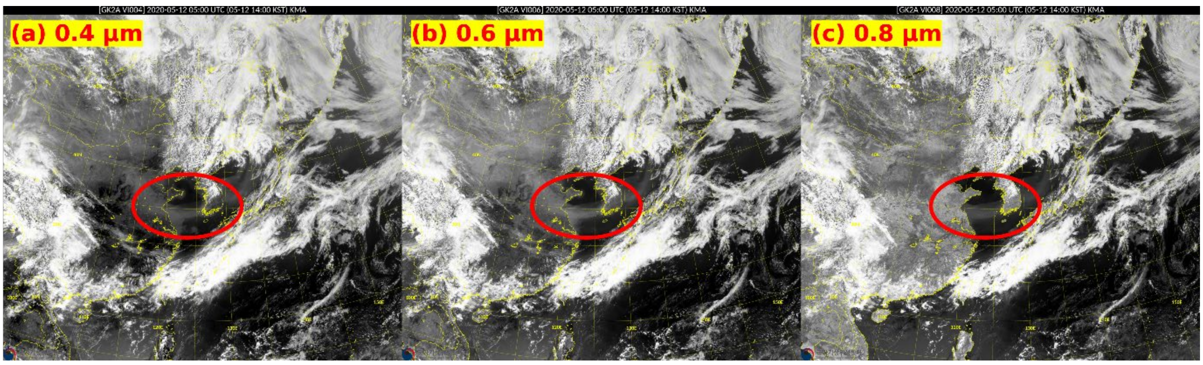

Figure AR4 Single channel images of 0.4 (a), 0.6 (b), and 0.8 (c) μm channels.

P6, L 160. Please, start with the definition of the parallax, then continue with the description of how is was calculated.

Thank you for your suggestion, we moved the definition of parallax to the front of the paragraph.; P6 L164-167.

P6, L 167. Please, provide short definitions here

The sentence is removed during revision and examples about other aerosol height retrieval algorithms can be found in Sect. 1.

P7, L 191. Based on what the AOD lower limit of 0.6 was chosen?

Since it was a feasibility study for stereoscopic aerosol height retrieval, we set the lower limit of AOD as 0.6 to get more robust results. We tested stereoscopic retrievals over pixels with AOD > 0.3. Through error analysis shown in Fig. AR1 and AR2, we showed that using data with the best matching correlation coefficient > 0.95, robust results were found regardless of aerosol loading. So, we changed the AOD lower limit from 0.6 to 0.3.

P8, L 228. Based on what the limit of 10km for the ALH was chosen? Can all pixels in the moving window be checked on the presence of AOD data? This will allow avoiding the influence of clouds.

The study area is a region where an aloft aerosol layer is observed with dust transport, which does not exceed 10 km usually. But the cutoff altitude of 10 km is still not physically reasonable because the aerosol layer can float over 10 km altitude during heavy smoke plume events and/or volcanic eruption.

For the sake of algorithm robustness, we removed the procedure. Also, thanks to your suggestion, we changed some parts of our algorithm as you mentioned. Moving windows that have more than 20% of total pixels identified as a cloud by AHI AOD were removed from the image-matching process. Fig. AR5 shows the result of simply discarding ATH over 10 km on the left and the result of the new algorithm on the right. We now see a more reasonable result with less cloud contamination. P7 L202-205 describes corresponding changes in the algorithm.

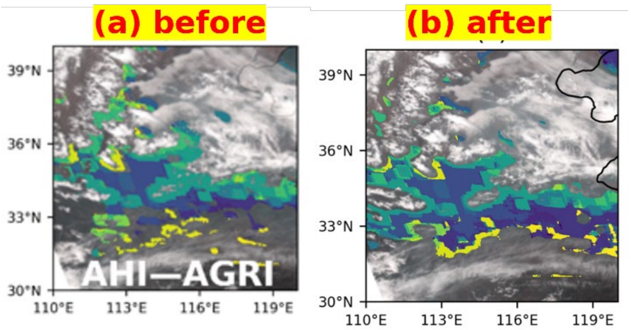

Figure AR5 ATH map of over-10 km-cutoff (a) and moving window cloud detection (b) on 4th April 2020.

P9, L 242. What is INR error? Is it calculated based in instrument specifications?

To evaluate the uncertainty caused by wrong grid registration, we moved all pixels of the AHI image by 1 km. This simulates INR error from a satellite. Although it is not calculated based on the instrument specification (pointing accuracy and stability), the evaluation of the uncertainty regards instrument specifications, wrote as "considering the actual INR errors of the satellites (approximately 0.5, 1, and 4 km at channels with 1 km resolution for AHI, AMI, and AGRI, respectively), the INR error would not be of concern for the retrieval of aerosol heights of a few kilometers.". To clarify, we changed the expression "INR error" to "INR shift" and rephrased P9 L247.

P9, L 273. Agree. Why "a simple cause of retrieval uncertainty was involved here?" (L 242)

The retrieval performance of the stereoscopic retrieval algorithm can be estimated by evaluating how accurately the algorithm calculates the parallax. Since a false location of the image is the biggest possible error source, only the INR error is considered. Still, minor errors can be introduced due to surface signal intrusion. However, quantitative computation of how much these sources affect the parallax calculation is impossible. So, we wrote as "a simple cause of retrieval uncertainty (which means the INR error) was involved here". It seems to be a confusing phrase, so we changed it to "Since false registration of satellite grid introduces error on parallax calculation, uncertainty from satellite INR error needs to be calculated."; P9 L248-250

P10, L 302. Please add the definition for EC

Done; P11 L315-316

P11, L 308. Please, replace "valid" with "retrieved" or "provided".

Done; P11 L321

P11, L 309. Please, replace "valid" with "retrieved" or "calculated".

Done; P11 L322

P11, L 306-309. Please add to the text the reference to Fig. 6a and 6b .

Thank you for pointing out, we added references of Fig. 6a, b and Fig. 7a, b to the relevant sentences.

P11, L 310. The difference of 2 km in the ATH estimation is significant, when one think about the location of aerosol layer regarding the planetary boundary layer (PBL). The knowledge on that (within or above PBL) is important for predicting the further aerosol transport directions and intensity. This is more critical for high AOD loading episodes, which you consider. Why 1 and 2km difference was chosen as criteria for evaluation? This is very big offset, if we think about possible applications of the calculated ATH. What are typical criteria for CALIOP ATH evaluation? Other ATH products?

There are a few studies that assessed the retrieval uncertainty of aerosol height from satellite remote sensing. For example, Lee et al. (2015) discussed uncertainties from individual error sources such as AOD, SSA, surface elevation, …, and concluded that the uncertainty in the retrieved aerosol height is estimated from -1.20 to 1.80 km over land and from -1.15 to 1.58 km over the ocean when favorable conditions are met. Therefore, 1 and 2 km difference was chosen based on the uncertainty assessment from previous work of Lee et al.

P11, L 315-331. Can you discuss the conditions in which the disagreement between two products is most pronounced? And provide plot for AHI-AGRI vs AHI-AMI ATH.

Fig. AR6 shows a 2-dimensional histogram plot of AHI-AGRI vs AHI-AMI ATH. Due to the lack of sensitivity for AHI-AMI pair, the result is very scattered. Comparing with CALIOP (Fig. 6 and 7 in the manuscript), we discussed that since the distance between AHI and AMI is too close for stereographic aerosol feature retrieval, result of the pair is erroneous in any conditions. Therefore, we concluded that AHI-AMI ATH is of no use.

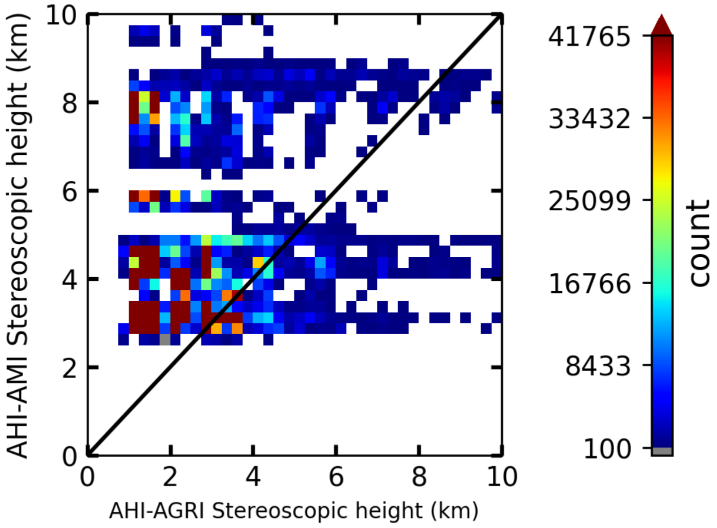

Figure AR6 2-dimensional histogram of AHI-AGRI ATH vs. AHI-AMI ATH.

P12, L 342 overestimated…. or aerosols were distributed evenly along the height

For the word "overestimated", we wanted to say that AHI AOD was overestimated. However, what we meant was that the retrieval error is due to small CALIOP EC53 values. It seems misleading, so we changed the sentence to "Unlike the first case, the CALIOP EC profile of the latter case has few values of > 0.3 cm^{-1}, indicating retrieval error caused by low aerosol loading."; P12 L351-352

P13, Sect.5. To my understanding, collocation of geostationary satellite with ground measurements provides an opportunity for considerably higher number of collocations than with CALIPSO. However, only two cases are considered. To make a conclusion on the validation results, statistics (bias!) should be calculated using all possible collocations. Scatter plot as Fig.8 as well as frequency distribution plot are needed to be presented and discussed.

Please find the limitation of using ground-based lidar data for validation in response to P4 L120.

P13, L 397. Why AOD limit of 0.6 was applied, if "…. not affected by variations in aerosol….

It seems misleading. We changed the sentence to "Furthermore, the method is not affected by variations in aerosol optical properties when the image-matching method is successfully worked.". Please refer to the supplement figures and related error analysis at P14 L 410.

Figure 4. Please, check the location of AMI

Done. Thanks.

Figure 6 c,d. Please change the color scale to see better the difference between two pairs.

Done. Thanks.

<References>

Chen, X., Wang, J., Xu, X. G., Zhou, M., Zhang, H. X., Garcia, L. C., Colarco, P. R., Janz, S. J., Yorks, J., McGill, M., Reid, J. S., de Graaf, M., and Kondragunta, S.: First retrieval of absorbing aerosol height over dark target using TROPOMI oxygen B band: Algorithm development and application for surface particulate matter estimates, Rem. Sens. Environ., 265, ARTN 112674, doi:10.1016/j.rse.2021.112674, 2021.

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