Referee: #1

We appreciate the reviewer's insights and helpful comments/suggestions, which helped improve the scientific quality of our manuscript. Basically, we reflected all the comments and suggestions. And, new references were added in revised manuscript.

1. General comments

This manuscript updates the Yonsei aerosol retrieval (YAER) version 1 to version 2 to overcome the errors related to uncertainties in surface reflectance and simple could masking and the current version is capable of near-real-time processing. The updated version has been compared to previous version and validated using multiple observations, including MODIS, VIIRS, AERONET and SONET data. This upgration is meaningful and will also be useful to improve model predicitons through data assimilation because it has lower error and is capable of NRT processing. This manuscript is well organized and wrriten. I would strongly recomend publication after some minor corrections.

2. Detailed comments

- Line 9: a role of to "the role of "

Ans.) A following sentence were revised in p.2/l.8–9 of revised manuscript:

"Thus, accurate AOP retrievals are important for quantifying the role of aerosols in climate change."

Line 12: sulfates nitrates to "sulfate nitrate"

Ans.) Following other reviewer's comment, a part of discussion about PM was shortened and that word was removed.

- Line 11: delete "The"

Ans.) The word was removed and a following sentence was revised in p.2/l.9−11 of revised manuscript:

"With respect to air pollution, ambient fine particulate matter (PM) affects respiratory and pulmonary systems, resulting in an increased incidence of heart disease, stroke, and lung cancer (Lim et al., 2012)."

- Line 25: add "This manuscript is organized as follows" before "in section2 "

Ans.) Following sentences were revised in p.3/l.22−26 of revised manuscript:

"The remainder of this paper is organized as follows. In section 2, improvements in the GOCI YAER V2 algorithm are summarized and a quantitative comparison with other satellite AODs is presented. In Section 3, the GOCI YAER V2 AOD is validated using ground-based sun-photometer observations along with other satellite AOD measurements. In Section 4, GOCI YAER V2 AOD errors are analyzed in relation to various parameters and expected errors are estimated. Finally, a summary and conclusions are presented in Section 5."

- Line 29: Delete "qualitative" since many quantative values are used in this section 6

Ans.) The word was removed in revised manuscript.

- Line 31: Please add description of the differences between All QA and QA of 3.

Ans.) Following sentences were revised/added in p.6/l.4−14 and p.8/l.20−22 of revised manuscript:

"The quality assurance (QA) value of the V1 algorithm was determined based on the range of retrieved AOD and the remaining number of pixels in a 12-pixel × 12-pixel block after all masking procedures were performed. A QA value of 0, 1, 2, or 3 for the V1 AOD was assigned for 6, 15, 22, or 36 remaining pixels, respectively. In addition, retrieved AOD values between −0.05 and 3.6 were assigned a QA value of 1, 2, or 3, and retrieved AOD values between −0.1 and −0.05 or between 3.6 and 5.0 were assigned a QA value of 0. The lower of these two QA values for each pixel was used as the final QA value."

"To evaluate the new masking techniques and climatological data used in the V2 algorithm, a retrieved dataset of GOCI YAER V2 AOD for 5 May 2015 is compared with that of the V1 algorithm under two scenarios: using all the quality assured (all QA; QA = 0, 1, 2, or 3) pixels and using only the highest quality assured (QA = 3) pixels."

Referee: #3

We appreciate the reviewer's detail comments/suggestions based on insights, which helped improve the scientific quality of our manuscript. Basically, we reflected all the comments and suggestions. And, new references were added in revised manuscript.

3. General comments

The paper describes an improved algorithm version for the multi-spectral AOD retrieval from geostationary GOCI observations over East Asia. With its capability of monitoring hourly AOD comparable to MODIS (two-time daily) observations the new version algorithm provides important temporal resolution and good coverage in particular for air quality applications and thus covers a highly relevant topic for AMT. The quality of the new dataset is thoroughly analysed with a 5-year dataset and significant improvements (accuracy, coverage) are documented. A specific strength of the paper is its discussion and definition of a parameterized uncertainty function, which is of particular importance for data assimilation of the datasets. The algorithm improvements benefit from experiences with algorithms for similar multi-spectral radiometers onboard polar platforms (MODIS and VIIRS), which are correctly cited and suitably adapted to the GOCI sensor. Several images and some aspects of discussions should be improved (see further comments). I therefore recommend a minor revision.

4. Further comments

- The paper needs a thorough native speaker English correction, since there are quite a lot of cases where the article ("the") is miss-used or other in-correct sentence structures occur.

Ans.) In the revised manuscript, English was corrected again by native speaker.

- The paper introduces aerosol properties AE, FMF, SSA as side variables, but does not discuss the information content of the measured "spectra" and the value of those properties as output – this discussion should be added (while not overstating the weak information content for those, in particular SSA) – without proper discussion the output of those properties must be named as simple diagnostics (output not validated) or removed.

Ans.1) Following sentences were added/revised in p.4/l.17−27 of revised manuscript:

All eight channels are used over ocean surfaces, and different combinations of channels are used over land, depending on surface conditions. Measured spectral TOA reflectance can be converted to spectral AOD for all aerosol models using the pre-calculated LUT, and spectral AOD can be converted to the corresponding value at 550 nm using the assumed AE of each aerosol model. Then, the mean value and standard deviation ("*Stddev*") of AOD at 550 nm from different channels are calculated for each aerosol model, and the three aerosol models with the lowest Stddev are selected. The Stddev-weighted average of mean AOD at 550 nm from the three selected aerosol models is used as the AOD at 550 nm. An identical Stddev-weighted average is applied to the assumed AE, FMF, and SSA of the selected aerosol models to determine the final AE, FMF, and SSA values. This inversion method is focused primarily on the retrieval of AOD at 550 nm from multi-channel spectral information, and the AE, FMF, and SSA are determined from aerosol models selected for the best AOD fit. Thus, AOD at 550 nm is the main retrieval product, and the AE, FMF, and SSA are considered as diagnostic parameters, or ancillary products.

In addition, following FMF, and SSA validation results and analyses were added in p.12/l.28−p.13/l.26 with Figure 5 of revised manuscript:

The FMF inter-comparisons between AERONET inversion data and GOCI YAER V2 are similar to those of AE, as shown in Figure 5c and d. This comparison also includes only AERONET AOD > 0.3 data. AERONET inversion products are retrieved from almucantar measurements, which are possible when the solar zenith angle is greater than 50° (Dubovik and King, 2000); thus, the number of points used in the comparison are fewer than the AOD and AE from direct measurements. The correlation coefficients of FMF over ocean and land surfaces are similar to those of AE, as both parameters are determined primarily by aerosol size.

The SSA inter-comparisons between AERONET and GOCI YAER V2 have the lowest R (0.206 for land and 0.251 for ocean) among the products. The visible–NIR wavelength range is more sensitive to aerosol size than absorptivity. Thus, aerosol models are constructed more coarsely for SSA than for FMF, and the inversion methods focus on spectral matching of AOD at 550 nm, rather than on SSA-optimized retrieval, such as the OMI aerosol retrieval algorithm using ultraviolet radiation (Torres et al., 2013; Jeong et al., 2016). Nevertheless, the ratio of GOCI V2 SSA to AERONET SSA in a ±0.03 and ±0.05 range is 47.7% and 68.0% for land and 69.7% and 88.3% for ocean, respectively, which is comparable to the OMI SSA presented by Jethva et al. (2014).

In conclusion, GOCI YAER V2 AE, FMF, and SSA compared with AERONET products are more biased and have lower correlation coefficients than seen for AOD. This indicates that the aerosol type selection is biased to coarse and non-absorbing aerosols. To improve the accuracy of these parameters, more accurate surface reflectance estimations and improved inversion methods are required.

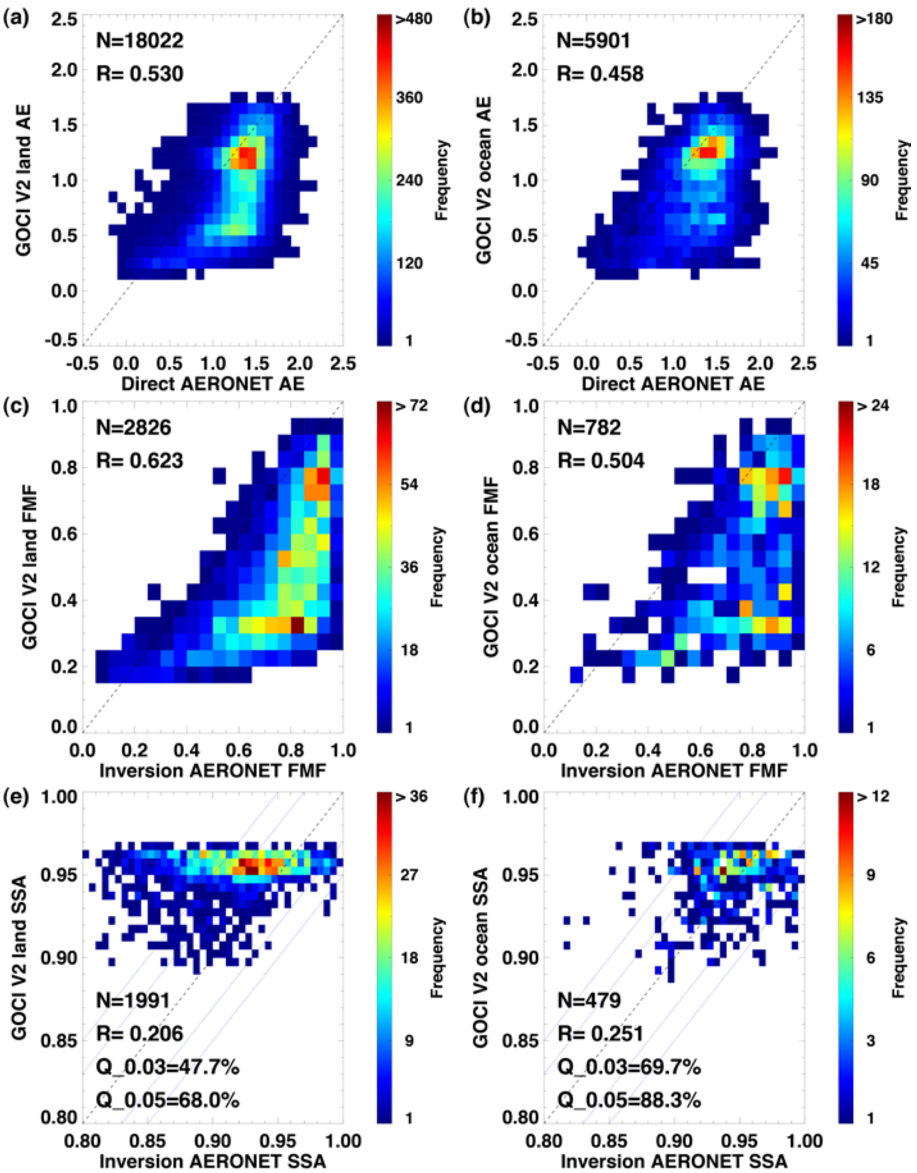

Figure 4 Comparison between AERONET and GOCI YAER V2 (a) land AE, (b) ocean AE, (c) land FMF, (d) ocean FMF, (e) land SSA, and (f) ocean SSA. Note that collocated data are only for AERONET AOD > 0.3 for the AE and FMF comparisons, and AERONET AOD > 0.4 for the SSA comparison. Each colored pixel represents a bin size of 0.10 for AE, 0.05 for FMF, and 0.005 for SSA. Black dashed lines denote the one-to-one line, and blue dotted lines in the SSA comparison denote the ±0.03 and ±0.05 ranges.

- In the conclusion the paper refers back to air quality applications, but misses to strongly state the importance of this retrieval with all its relevant positive aspects (hourly resolution, NRT capability, predicted uncertainties, thus well suited for data assimilation and regional air quality monitoring applications) – I recommend to strengthen this discussion in the conclusion before the outlook.

Ans.) Following sentences were added in the conclusion before outlook of revised manuscript (p.19/l.17-21):

Aerosol retrieval using GOCI is unique because of hourly monitoring of aerosols with multi-channel measurements in the visible to near-infrared range with high spatial resolution, over East Asia where aerosol emissions are very high, despite its limitation in observation area coverage. Hourly GOCI AOD retrievals with high accuracy, NRT availability, and quantitatively analyzed uncertainties are highly suitable for use with air-quality monitoring and data assimilation in air-quality forecasting models, particularly when rapid diurnal variations and transboundary transport are significant.

- Table 2 values of mean bias (MB) have too many significant digits, which should be reduced to a realistic level of detail within AERONET accuracy (e.g. 2 or 3 digits maximum); e.g. a value 3.22E−05 is exactly zero. I suggest that several figures can be improved to help better reading and avoid miss-interpretation.

Ans.) Table 2 values of mean bias were revised as 3 digits in revised manuscript. Figures are also revised for better reading.

- In fig. 2 I recommend to remove the linear fit (solid lines), which is not appropriate for AOD distributions.

Ans.) Linear fit lines were removed in Figure 2 of revised manuscript.

- I suggest to reduce the y-axis range of figures 7, 8, and 9 to [-0.2, 0.2], so that the main information (average lines) becomes clearer (I think we can compromise on a small part of the 16th / 84th percentile).

Ans.) Figures were revised as following reviewer's comments.

- The same applies for fig. 10, where the y-axis range would suffice up to 1.0 and the legend could be outside the plot.

Ans.) Figures were revised as following reviewer's comments.

- In section 4.1.5 I get confused how the fraction of pixels analysed after cloud masking is interpreted as cloud fraction.

Ans.) Revised sentences were in p.15/l.21−28 of revised manuscript:

First, the cloud fraction (CF) for one 6 km × 6 km aerosol-product pixel can be calculated using the number of 0.5 km × 0.5 km L1B pixels that remain after all masking steps. In the aggregation step from the original L1B resolution of 0.5 km × 0.5 km to Level 2 aerosol-product resolution of 6 km × 6 km, the maximum number of remaining pixels is 58 after performing all the individual masking processes and discarding the darkest 20% and brightest

40% of pixels in a block of 12 pixels × 12 pixels (i.e., 144 pixels). The minimum number is set as 29, which corresponds to 50% of the maximum value. If the number of remaining pixels is less than 29, then AOPs of that pixel are not retrieved. Note that pixels that are bright because of surface reflectance, not clouds, may be counted as high CF, but it is difficult to completely distinguish these two cases at 500-m spatial resolution.

- What does it mean that 3 plots with 3 different proxies for cloud cover in fig. 8 show different dependencies of the AOD error?

Ans.) The high cloud contamination in both each product-pixel (6 km × 6 km) and neighboring pixel (within 25 km) domains results in high positive biases of up to 0.1. However, an independent analysis of the cloud-contamination-only effect is complicated by various factors including surface reflectance errors resulting in high bias under low cloud-contamination conditions. Detail revised analyses were in p.15/l.17−p.16/l.22 of revised manuscript.

- In section 3 it would be of high interest to split off the analysis of coastal sites from the one over land and present a separate analysis for coastal areas.

Ans.) Following sentences were added in p.11/l.18−23 of revised manuscript:

The GOCI V2 land AOD results can be re-categorized as coastal or inland according to whether each site is collocated with both GOCI ocean and land AOD or with GOCI land AOD only. Mean AERONET AODs from coastal sites are lower (0.28) than those from inland sites (0.42). The inter-comparison between coastal-site AERONET AOD and GOCI

V2 land AOD has an R of 0.83, RMSE of 0.144, MB of – 0.004, and f within EE_MDT of 0.60. Results from inland sites have higher R (0.93), RMSE (0.171), MB (0.023), and the same f within EE_MDT (0.60). High AOD is detected more frequently at inland sites than at coastal sites.

5. Detailed comments

- p.2 / l. 7: this sentence needs rewording, since surface does not belong to aerosol properties

Ans.) A following sentence was revised in p.2/l.6−8 of revised manuscript:

Two aerosol optical properties (AOPs), the aerosol optical depth and single scattering albedo, determine the sign and magnitude of the shortwave aerosol radiative forcing of the atmosphere for different surface conditions (Takemura et al., 2002)

- p. 2 / l. 11: define PM when it is first used introduction: I recommend to shorten the discussion of air quality, since it is too detailed for this paper where it is only relevant as application domain, but not further discussed

Ans.) The PM is defined as "ambient fine particulate matter", and added in p.2/l.9−10 of revised manuscript. Discussions of air quality were also shortened.

- p. 2/ l. 32: I suggest to reword accuracy to agreement – an established satellite dataset is used as reference, which is valuable inter-comparison, but not validation (this would require a ground-based reference measurement)

Ans.) The word of ‘accuracy’ was revised as ‘agreement’, and in p.2/l.29 of revised manuscript.

- p.4 / l. 4-7 would benefit from a bit more detail on the unified aerosol model as in fig. 1 (e.g. how many types) `

Ans.) Following sentences were added/revised in p.4/l.3−9 of revised manuscript:

Unified aerosol models over land and ocean surfaces classify aerosols using AOD at 550 nm, FMF at 550 nm, and SSA at 440 nm derived from the global Aerosol Robotic Network (AERONET) Inversion database (Dubovik and King, 2000; Holben et al., 1998). This aerosol type classification (Lee et al., 2012) covers a range of AOPs: FMF from 0.1 to 1.0 at an interval of 0.1, and SSA from 0.85 to 1.00 at an interval of 0.05. A total of 26 aerosol models are assumed in the algorithm: 9 highly absorbing, 9 moderately absorbing, and 8 non-absorbing models. Note that AOPs to calculate AOD are constructed to account for hygroscopic growth and aggregation (Eck et al., 2003; Reid et al., 1998). Non-spherical properties are considered using the phase function derived from AERONET data.

- p. 4 / l. 16 / 17 would benefit from more explanation as in fig. 1 (how average least difference models to obtain AE, FMF, SSA

Ans.) It was answered together with previous comments of “the paper introduces aerosol properties AE, FMF, SSA as side variables, but does not discuss the information content of the measured “spectra” and the value of those properties as output – this discussion should be added (while not overstating the weak information content for those, in particular SSA) –

without proper discussion the output of those properties must be named as simple diagnostics (output not validated) or removed." The revised sentences to this comment were in p.4/l.17–27 of revised manuscript.

- p. 4 / l. 27 for more detail better refer to "next sub sections" rather than "thereafter"

Ans.) A following sentence were added/revised in p.5/l.2–3 of revised manuscript:

Details of the refined parts of the algorithm are introduced in the following subsections.

- p. 5 / l. 15 provide definition / formula of the GEMI

Ans.) A formula of the GEMI was added and following sentences were revised/added in p.5/l.22–29 of revised manuscript:

To identify aerosols and clouds using a different technique, a pseudo Global Environment Monitoring Index (GEMI), developed by Pinty and Verstraete (1992) and Kopp et al. (2014) and applied in the operational VIIRS cloud-mask algorithm (Godin, 2014), is adopted (Step 6 in Table 1). The GEMI is based on the reflectance ratio between 865 and 660 nm, and is defined as follows:

$$GEMI = G * (1.0 - 0.25 * G) - \frac{100*Ref_{660} - 0.125}{1.0 - 100*Ref_{660}},$$

where

$$G = \frac{200*(Ref_{865} - Ref_{660}) + 150*Ref_{865} + 50*Ref_{660}}{100*Ref_{865} + 100*Ref_{660} + 0.50}.$$

Note that Ref_{660} and Ref_{865} are the TOA reflectance at 660 and 865 nm, respectively.

- p. 5 / l. 20-30 motivate why you use AODmax=3.6; briefly discuss the use of negative AOD

Ans.) Following sentences were added/revised in p.6/l.10−14 of revised manuscript:

In addition, only pixels with retrieved AOD between −0.05 and 3.6 are included in the calculations. Small negative AOD values can be caused by surface reflectance errors in this algorithm. These are assumed to fall within the range of expected retrieval errors and are statistically significant under low-AOD conditions when compared with results from the MODIS DT algorithm (Levy et al., 2007, 2013). The threshold of maximum AOD of 3.6 is based on Lee et al. (2012), which considered the probability distribution of AOD in the region.

- p. 5 / l. 20-25 why do you use 1%-3%; also discuss the possible impact on algorithm outcome with a 5-year climatology in case of a major land use change during that period

Ans.) Following sentences were added/revised in p7/l.4−12 of revised manuscript:

The darkest samples (the lowest 0−1% of the aggregate sample) are assumed to be cloud shadow and the brightest samples (3%−100% of the aggregate sample) are assumed to be affected by aerosols and/or clouds. Thus, the darkest 1%−3% of the RCR samples are averaged and used to determine surface reflectance, as in the V1 algorithm. According to Hsu et al. (2004), surface reflectance can be obtained by finding the minimum RCR for each month, which corresponds to ~3% of the aggregate sample. The darkest 0−1% of pixels are assumed, based on empirical grounds, to be cloud shadow and are thus excluded. This composite procedure is implemented for each month, hour, and channel. Monthly surface reflectance climatological data correspond to the middle of each month (day 15) and are linearly-interpolated to the retrieval date. Major year-to-year land use changes over the 5-year period would result in an artificial AOD bias, and should be addressed in future work.

- p. 10 / l. 1 reword "whole" to "all"

Ans.) The word was corrected in p.10/l.26 of revised manuscript.

- p. 10 / l. 3 reference to numbered section

Ans.) It was corrected in p.10/l.27 of revised manuscript.

- p. 10 / l. 5: remove "of"

Ans.) A following sentence was revised in p.10/l.29−30 of revised manuscript:

Results of a comparison between AERONET/SONET AOD and GOCI-retrieved AOD over land and ocean surfaces are presented in Figure 3.

- p. 11 / l. 4 an increase of the correlation from 0.88 to 0.89 is absolutely insignificant and thus meaningless! One should avoid such over-interpretation

Ans.) A following sentence was revised in p.12/l.3−5 of revised manuscript:

The refinement of the ocean algorithm from V1 to V2 results in improvement in most statistical parameters: decreased *MB* from 0.043 to 0.008, increased *f* within EE_{MDT} from 0.62

to 0.71, and decreased *RMSE* from 0.13 to 0.11.

- p. 10 / l. 16f and p. 11 / l. 7ff "counterpart" should be reworded

Ans.) Following sentences were revised in p.11/l.10−12 and p.12/l.6−9 of revised manuscript:

The *R* of 0.91 is similar to that of τ_{G_V1QA3} (0.92). The *N* between τ_A and τ_{G_V2} is about 14 times greater than the corresponding τ_{MDT} and τ_{MDB}, mostly because of the hourly data available from GOCI compared with the twice-daily overpass data from MODIS.

The *N* between AERONET and GOCI V2 AOD over ocean surfaces is about 27 times greater than that for MODIS DT AOD, which is greater than that seen in the land comparison despite the same difference in observation frequency.

- p. 11 / sec. 3.6 – what does "mode near 0.11 (0.10-0.12)" mean section 3.6 the ocean mode looks not identical in the plot, but in the text you give identical numbers – please provide calculated values of modes

Ans.) A following sentence was revised in p.12/l.14−15 of revised manuscript:

In Figure 4, mean relative frequency histograms for land τ_A, collocated with GOCI and MODIS land AOD, have a mode of 0.11 (i.e. highest frequency in the range 0.105–0.115) and right-skewed distribution.

- p. 12 / l. 1 correct wrong wording "per each"

Ans.) The section 3.7 ('fitting residuals change in inversion procedure') including that wrong word of original manuscript was removed as the reviewer's comment.

- p. 12 / l. 1 the terms are somewhat mixed up. I think that systematic and random or one pair of terms, while bias and noise are the other pair

Ans.) A following sentence was revised in p.13/l.28−29 of revised manuscript:

Retrieved AOD likely has both a systematic and random error associated with various factors, including sun–earth–satellite geometry, cloud contamination, surface type, and assumed aerosol model, among others.

- fig. 7 colours red and rose are hard to distinguish – please use two more distinc colours

Ans.) The colors in that figure are changed for better distinction in revised manuscript.

- sec. 3.7 discussion of fig. 5 I see practically only very little change – one could therefore consider removing sec. 3.7 and fig. 5

Ans.) The section 3.7 ('fitting residuals change in inversion procedure') including that wrong word of original manuscript was removed as the reviewer's comment.

- p. 13 / l. 18 word more cautiously: you use one specific set of non-spherical parameters (which is better than assuming spherical particles), but there are many types of non-spherical particles, which you are not taking into account – the sentence on POLDER and MISR is somewhat out of context –you seem to try to say that those are better suited for non- spherical particles, but this is self-evident by information theory

Ans.) Following sentences were revised/added in p.14/l.17−24 of revised manuscript:

This could be due to errors in the assumed aerosol optical properties of extremely large particles. Assumed aerosol models based on the global AERONET climatological database are categorized according to FMF and SSA, and the phase functions of non-spherical properties are averaged to one value for each model. In reality, various non-spherical shapes with the same FMF value may be present, and may result in higher error at low values of AERONET AE. The differences may also be due to errors in aerosol type selection during the inversion process, as suggested by the decreased accuracy of low GOCI AE. Wavelength-dependent errors in calibration or surface reflectance assumptions may also contribute to the observed differences. Further investigation is required to quantify the relative contributions of these errors.

- p. 15 / l. 13 explain / define LEO

Ans.) It was defined as low earth orbit (LEO) in p.16/l.25−26 in revised manuscript.