Referee: 1

The manuscript presents significant improvements in GOCI Yonsei Aerosol Retrieval (YAER) over ocean and land and validation results with AERONET inversion data during the DRAGON-NE Asia 2012 campaign. The methods appear appropriate and the paper is well written. Therefore, this study is of interest to the reader community of Atmospheric Measurement Techniques (AMT), but only accepted after considering the following comments.

Ans) 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.

General comments

Some sections in the manuscript just show the threshold and retrieval methods, but not explain why and how they are designed. Therefore, the authors need to explain more details with relevant references for who want to apply these methods to the aerosol retrieval.

Specific comments

Pages 9565 in Affiliations: Please check the Affiliation 6, "… (NIER), Inchon, …". It might be changed into "Incheon".

Ans.) The word "Inchon" was revised as "Incheon" at lines 8 of the revised manuscript.

Pages 9566 in Abstract: The authors might want to highlight with few sentences why it is important to study about aerosol optical properties over East Asia, especially in spring time.

Ans) A sentence was inserted as "The evaluation during the spring season over East Asia is important because of high aerosol concentrations and diverse types with Asian dust and haze" at lines 30 – lines 32 of the revised manuscript.

Pages 9566, lines 7-8 in Abstract: Please provide the exact period of DRAGON-NE Asia 2012 campaign at the beginning part, instead of the mention, "… from March to May 2012." At lines 23 in Abstract. What does "DRAGON-NE" stand for?

Ans.) The sentence "the DRAGON-NE Asia 2012 campaign" was revised as "the Distributed Regional Aerosol Gridded Observation Networks – North East Asia 2012 campaign (DRAGON-NE Asia 2012 campaign)" at lines 29 – lines 30 of the revised manuscript.

Pages 9567, lines 16 in 1 Introduction: Please check the uncertainty of AERONET AOD observation, "… 0.01 …". It is known as "±0.01".

Ans.) The AERONET AOD uncertainty of "0.01" was revised as "±0.01" at lines 63 of the revised manuscript.

Pages 9568, line 1 in 1 Introduction: Please check the uncertainties of MODIS AOD retrievals,"… as 0.03+5% over ocean and 0.05+15% over land …". Are they ±0.03±5% over ocean and ±0.05±15% over land?

Ans.) The MODIS AOD uncertainties of "0.03+5%" and "0.05+15%" over ocean and land, respectively, was revised as "±(0.03 + 5%)" and "±(0.05 + 15%)" at lines 74 of the revised manuscript.

Pages 9568, lines 11 in 1 Introduction: Please also check the uncertainty of GOES retrieval, "… as 0.13 …".

Ans.) The GOES AOD uncertainty of "0.13" was revised as "±0.13" at lines 82 of the revised manuscript.

Pages 9568, lines 16-20 in 1 Introduction: Please discuss more in detail about other sensors' and GOCI calibration method/accuracy, spatial/temporal/spectral resolutions, platform orbit, swath, number of bands, local equatorial crossing time, launch date, AOD retrieval accuracy, and so on. It would be great to list them in an additional table.

Ans.) Table 1 was added in the revised manuscript.

Pages 9570, lines 7-10 in 2.1 Cloud masking and quality assurance: Please explain how to determine the threshold values for the cloud masking tests. Are they based on frequency test or from some relevant publications?

Ans.) References were attached at lines 130 –lines 135 of the revised manuscript:

Cloud masking and quality assurance methods are based on the MODIS DT and DB aerosol retrieval algorithm. The 865 nm band for the test of standard deviation over land is changed to that of 550 nm according to the reference. The sentences were as:

"1. ρ_{TOA}(490 nm) > 0.40 → cloud over land or ocean

2. Standard deviation of 3 × 3 pixels ρ_{TOA}(412 nm) > 0.0025 → cloud over land

Standard deviation of 3 × 3 pixels ρ_{TOA}(550 nm) > 0.0025 → cloud over ocean

3. ρ_{TOA}(412 nm) / ρ_{TOA}(660 nm) > 0.75 → Dust over ocean (not masked)

The standard deviation test over land is based on the MODIS DB algorithm (Hsu et al., 2004), and other tests are based on the MODIS DT (Remer et al., 2005)."

Thresholds of QA determination are based on the MODIS DT algorithm (Levy et al., 2013). The numbers of 500 m × 500 m pixels to make final retrieval pixels of MODIS DT (10 km × 10 km) and GOCI (6 km × 6 km) are 400 (20 × 20) and 144 (12 × 12), respectively. Therefore, the ratio of used pixels to total pixels in MODIS DT algorithm is applied to our GOCI YAER algorithm. The range of AOD to determine QA is also from MODIS DT algorithm. Following sentence was inserted at lines 142 – lines 143 of the revised manuscript:

"Thresholds of QA determination are based on the MODIS DT algorithm (Levy et al., 2013)."

Pages 9570, lines 20-21 in 2.1 Cloud masking and quality assurance: Please explain the physical meaning of negative AOD value.

Ans.) Following sentences were inserted at lines 145 –lines 147 of the revised manuscript:

"The algorithm allows randomly retrieved, small negative AOD caused by uncertainty in surface reflectance because it is within expected retrieval error as MODIS DT algorithm, and also has statistical meaning in low AOD range (Levy et al., 2007; 2013)."

Pages 9571, lines 16-18 in 2.2 Surface reflectance over land and ocean: Please explain how to determine the threshold values, the darkest 1% for cloud shadow and 3% for surface reflectance. Are they derived empirically from the frequency test of RCR at 412 nm, or cited from other publication?

Ans.) Corresponding sentences at lines 167 –lines 178 of the revised manuscript were revised as below.

"According to Hsu et al. (2004), surface reflectance database can be obtained by finding the minimum value of the 412 nm RCR for a given month, which corresponds to about 3% for the window. In this process, cloud shadows which could lead to false reflectance should not be selected to evaluate surface reflectance. For example, Lee et al. (2010) selected the second minimum value, and Fukuda et al. (2013) used the modified minimum reflectance method using first and second minimum values to avoid cloud shadow effects for determining surface reflectance. In GOCI YAER algorithm, the maximum number of L1B pixel samples for one surface reflectance pixel at a given time is 144 pixels × 30 days, a total of 4,320 samples. Therefore, only first or second minimum threshold is not appropriate for GOCI YAER algorithm. Instead, darkest 0-1% pixels are assumed to be cloud shadow thus excluded, empirically. Therefore, threshold for the lower and upper bound are set as 1% and 3%, respectively."

Pages 9571, lines 26-27 in 2.2 Surface reflectance over land and ocean: Please explain how to set the threshold value, 0.3 for applying land algorithm, and provide some relevant publications.

Ans.) Through the survey of reference studies about surface reflectance threshold for aerosol retrieval, we recognized that the threshold of "0.3" for dark surface is too high so that the threshold and retrieval channels were changed at lines 187 – lines 193 of the revised manuscript.

"According to von Hoyningen-Huene et al. (2003) which described the aerosol retrieval algorithm using ocean color sensors, pixels of which surface reflectance less than 0.15 correspond to the fully or partly covered with vegetation area. Also, Zhang et al. (2011) described that the operational GOES AOD retrieval algorithm use simple threshold of 0.15 surface reflectance to remove bright surface reflectance pixels. Final selected channels for retrieving aerosol over land are those of which surface reflectances are less than 0.15."

Pages 9571, lines 29 in 2.2 Surface reflectance over land and ocean: The authors might want to show the full name with the shortened form, i.e. "… metres above sea level (m.a.s.l.) …".

Ans.) The words of "the wind speed at 10 m a.s.l." were revised as "the wind speed at 10 meters above sea level" at lines 195 of the revised manuscript.

Pages 9572, lines 1-2 in 2.2 Surface reflectance over land and ocean: Please explain why the nodal points are irregularly divided like "1, 3, 5, 7, 9, and 20 m s- 1". Does the ocean surface reflectance vary drastically in low wind speed range and slightly with high wind speed range? This could be clear with a simple figure or a publication showing the relationship between surface reflectance and wind speed.

Ans.) In libRadtran package, several coefficients for calculating ocean surface bidirectional reflectance are set at those wind speed node points as defaults. Surface reflectance for other wind speeds is calculated using the interpolation. Corresponding sentence was revised as below at lines 196 – lines 198 of the revised manuscript.

"The nodal points of wind speed in the LUT calculation are 1, 3, 5, 7, 9, and 20 m s^{-1}, which are the default nodal points of libRadtran package."

Pages 9573, lines 20-21 in 2.3 Turbid water detection: Could you explain why the cloud-covered pixels are different between Fig. 4 (a) and (b), and between Fig. 4 (c) and (d)?

Ans.) Following sentences were inserted at lines 240 – lines 243 of the revised manuscript.

"Note that DAI and $\Delta\rho_{660}$ are plotted over cloud-free pixels, and only positive DAI pixels are presented to check the existence of absorbing aerosol such as dust in Fig. 4(e) and (f), because absorbing aerosol such as dust or smoke shows a DAI greater than 4 over ocean (Ciren and Kondragunta, 2014)."

Pages 9573, lines 22 in 2.3 Turbid water detection: I cannot find "true color image" in Fig. 4.

Ans.) Sorry for missing true color images. Those of 26 and 27 April 2012 were attached in Fig. 4 of the revised manuscript.

Pages 9574, lines 17-19 in 2.4 Aerosol models: Please explain why the authors used all available AERONET data to build up the LUTs of the aerosol models during the period up to February 2011 in all seasons even though the GOCI YAER algorithm was applied to retrieve the aerosol optical properties only for springtime. If the LUTs are based on the AERONET data in the spring, the retrieval accuracy can be improved?

Ans.) Specific aerosol models composition using AERONET data in this algorithm is a modified version of Lee et al. (2012). The number of data of only East Asia sites or spring season was insufficient to build segmented aerosol model according to FMF, SSA, and AOD. The GOCI YAER algorithm aims to retrieve all season aerosol properties, not limited to the spring season. This study focuses retrieval results during the specific DRAGON-NE Asia 2012 campaign in particular. Long-term validation including all seasons will be discussed in further studies.

Pages 9574, lines 19-20 in 2.4 Aerosol models: Please briefly explain why the AERONET sites having individual data more than "10 times" were selected.

Ans.) Following sentences were inserted at lines 274 – lines 277 of the revised manuscript.

"Observation periods of individual AERONET site are quite different from few individual observations to several years. Level 2.0 data are quality assured so that each individual observation is meaningful even if whole observation period is short. Therefore, we tried to use available AERONET individual data, and small threshold of "10 times" is applied."

Pages 9574, lines 22-24 in 2.4 Aerosol models: It should be mentioned that the temporal and spatial variations of the direct emissions, secondary production, and meteorological transport could also influence the AOPs’ change [Yoon et al. (2011, 2012, 2014) and references therein]. Additionally, the authors might want to change “… as AOD increases …” into “… as AOD varies …”.

Ans.) The sentences of your comments were inserted at lines 260 – lines 262 of the revised manuscript. The word of “increases” was also changed as “varies” at lines 280 of the revised manuscript.

Pages 9575, lines 12-25 in 2.5 LUT calculation and inversion procedure:

a. Please explain more in detail about “libRadtran” with few more sentences, e.g. how to get the model, what are the characteristics, and so on.

Ans.) “libRadtran” is a library of radiative transfer routines and programs, and a discrete ordinate radiative transfer (DISORT) code is used in this package to calculate TOA reflectances under various conditions of molecules, aerosols, and cloud conditions. It is freely available under the official homepage (http://libradtran.org). A corresponding sentence at lines 290 – lines 292 of the revised manuscript was revised as below.

“Table 4 shows the node points for calculating TOA reflectances using a discrete ordinate radiative transfer (DISORT) code of the libRadtran software package (http://libradtran.org) (Mayer and Kylling, 2005).”

b. Since the surface reflectance is lower and aerosol reflectance is higher at shorter wavelength in visible spectrum than at longer, generally the AOD retrieval accuracy is higher at the shorter wavelengths (e.g. 412, 443, 490, and 555 nm) than the longer wavelengths (660, 680, 745, and 865 nm for GOCI channel). The authors also mentioned this point at lines 13-15 on 9571 pages. Therefore, it is difficult to understand why the authors chose only four channels (443, 555, 660, and 680 nm) used to retrieve AOD over land except the GOCI shorter wavelengths (i.e. 412 and 490 nm).

Ans.) Revised channel selection for land aerosol retrieval was described in the answer for surface reflectance threshold question.

c. As the authors mentioned before in the manuscript, I agree that "at 412 nm, the variability of surface reflectance is lower and atmospheric signals such as Rayleigh scattering or aerosol reflectance are higher than at longer wavelengths". Then the retrieval accuracy of AOD at 412 nm should be the best among the other spectral GOCI AODs. However, the authors use the retrieved AOD at 550 nm as the reference value for the comparison between observed and calculated AODs, instead of the AOD at 412 nm. Please explain why.

Ans.)

Corresponding sentences at lines 297 – lines 320 of the revised manuscript were revised as below.

"The inversion method is adopted from that of Lee et al. (2012). That algorithm retrieves AOD at 550 nm using every MODIS wavelength (470, 555, 650, 860, 1240, 1630, and 2010 nm) and aerosol model, and then select the aerosol model that minimized the standard deviation of the seven different AODs retrieved from each wavelength. The final AOD is chosen from each wavelength. By doing so, each wavelength can contribute equally in selecting the aerosol model. In GOCI YAER algorithm, reference channel is the same as 550 nm and retrieval wavelengths are changed as GOCI wavelengths.

GOCI YAER algorithm retrieves AODs at 550 nm using whole GOCI wavelengths reflectance (412, 443, 490, 555, 660, 680, 745, and 865 nm) and aerosol model over ocean. Final selected wavelengths for retrieving aerosol properties over land are those over which surface reflectances are less than 0.15. If the number of selected wavelengths is greater than or equal to 2, AODs at 550 nm are retrieved from those wavelength and aerosol model. The inversion procedure to retrieve AOD is implemented using interpolation from pre-calculated TOA reflectance at LUT dimensions to observed TOA reflectance according to geometries (solar zenith angle, satellite zenith angle, and relative azimuth angle), assumed aerosol model, wavelength, surface reflectance, and terrain height. Then, 3 aerosol models are selected that minimized the standard deviation (σ) of the different AODs retrieved from each wavelength, defined as the square root of the average of the squared deviations of the AODs from their average AOD. Final products of AOD, FMF, SSA, and AE are the σ-weighted average value from 3 selected models as below:

$$\text{Final AOD at 550 nm} = \sum_{i=1}^{3} C_{Model\ i} \times Averaged\ AOD_{Model\ i}$$

$$C_{Model\ i} = \frac{\frac{1}{\sigma_{Model\ i}}}{\frac{1}{\sigma_{Model\ 1}} + \frac{1}{\sigma_{Model\ 2}} + \frac{1}{\sigma_{Model\ 3}}}$$

Final AE between 440 and 870 nm, FMF at 550 nm, and SSA at 440 nm are determined in the same way except that averaged AOD is replaced with assumed AOPs as in Table 3.”

d. The best 3 aerosol types for the final products seems to be determined using the AEs of aerosol models. Please provide the exact AE values of each aerosol model on Table 2 for the readers, or add an additional table if AE varies with AOD change for each aerosol model.

Ans.) AE, FMF, and SSA LUTs for each aerosol model were inserted in Table 3 of the revised manuscript.

e. It is somehow difficult to understand the inversion procedure. Please improve the inversion part of the flowchart in Figure 1 or add a new figure showing more details.

Ans.) More detailed description was presented in the answer of above question (c).

f. Please explain how to get the "stddev weighted average" with an equation.

Ans.) More detailed description was presented in the answer of above question (c).

Pages 9577, lines 2 in 3 Case studies of GOCI YAER products during the DRAGON-NE Asia 2012 campaign: The authors need to discuss briefly about dominant aerosol types around East China Sea in Figures 6 and 7.

Ans) Following sentences were inserted at lines 324 – lines 329 of the revised manuscript.

"Aerosol types of East Asia are very diverse and complicated. Dust occurs sporadically from the Gobi desert and Taklamakan desert of the Continent of Asia and anthropogenic aerosols occur from urban/industrial sites. Highly-absorbing and fine-dominated, non-absorbing and fine-dominated, marine, and dust aerosols are observed similarly over the East Asia (Lee et al., 2014). East China Sea and Yellow Sea are located between the Continent of Asia and the

Korean Peninsula so that the long-range transport of aerosols could be detected clearly."

Pages 9578, lines 25 in 4.2 Inter-comparison condition between MODIS and GOCI: What does "GOCI FOR" stand for?

Ans) The words of "GOCI FOR" means GOCI field-of-regard which is the observation area. Therefore, it was replaced with "GOCI observation area" in the revised manuscript.

Pages 9579, lines 25-27 in 4.3 Validation of AOD: Please explain why the AOD points lower than 0.4 are immediately below EE. Is it attributed to the LUT built up with AERONET SSA data only available when AOD is larger than 0.4?

Ans) Possible cause of underestimation in GOCI YAER AOD compared to AERONET AOD was described as "the minimum reflectivity technique can overestimate surface reflectance due to contamination by the remaining cloud or aerosol, resulting in negative bias at low AOD" in Section 5. And, following sentences were inserted at lines 573 – lines 576 of the revised manuscript was revised as below.

"Main uncertainties in low AOD and high AOD are linked to uncertainties of surface reflectance and assumptions about aerosol microphysical properties, respectively (Sayer et al., 2013). Levy et al. (2010) also described that systematic bias for low AOD results from overestimating the surface reflectance in the visible channels."

Pages 9581-9583 in 4.4 Validation of Angstrom exponent, fine-mode fraction, and single scattering albedo: If possible, please add some validation results from other publications, and compare them with your results.

Ans) Following sentences were inserted at lines 583 – lines 560 of the revised manuscript was revised as below.

"GOCI AE and SSA product qualities could be also compared with other previous studies while the region and period are different. Global MODIS DT Angstrom exponent validation results with AERONET were presented in Levy et al. (2010) and Levy et al. (2013) over land and ocean, respectively. Levy et al. (2010) compared MODIS DT Collection 5 Angstrom exponent between 470 and 650 nm (AE_470_650) and AERONET AE_470_650 over land resulted in R of 0.554 and a linear regression equation with MODIS AE_470_660 = 0.6471 × AERONET AE_470_660 + 0.3342. According to Levy et al. (2013), MODIS DT Collection 6 Angstrom exponent between 550 and 870 nm (AE_550_870) shows more higher accuracy over ocean (R = 0.612 and a linear regression equation with MODIS AE_550_870 = 0.686 × AERONET AE_550_870 + 0.47). MODIS DB Collection 6 Angstrom exponent (over land) shows similar accuracy with GOCI YAER Angstrom exponent (R = 0.45 for all AOD and R = 0.68 when AOD is greater than 0.3). These results are similar with that of GOCI YAER AE validation results (R = 0.594 for all AOD and R = 0.678 when AOD is greater than 0.3).

Aerosol optical properties such as Angstrom exponent and single scattering albedo retrieved from the Polarization and Directionality of Earth Reflectance (POLDER) instrument onboard the Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar (PARASOL) satellite shows more accurate results. Hasekamp et al. (2011) described that AE retrieval using polarization measurement shows higher accuracy (R = 0.85) than using intensity-only retrieval (R = 0.62). Generalized Retrieval of Aerosol &

Surface Properties (GRASP) algorithm using POLDER (Dubovik et al., 2011; Kokhanovsky et al., 2015) shows higher accuracy in SSA (R = 0.93) when AOD is greater than 0.4. These results mean that more information such as polarization and multi-angle observation can improve retrieval accuracy of aerosol optical properties."

Pages 9584, lines 13-14 in 5 Error analysis of GOCI YAER AOD: Please explain why "GOCI AOD is underestimated at scattering angles near 115° and 140° and overestimated at 145° and above 160°".

Ans) Corresponding sentences at lines 587 – lines 608 of the revised manuscript were revised as below.

"Scattering angle is calculated using solar zenith angle, satellite zenith angle, and relative azimuth angle. GOCI is on geostationary orbit so that satellite zenith and azimuth angle is fixed. Therefore, relative azimuth angle between sun and satellite varies according to local standard time only. Solar zenith angle varies according to local standard time and season. Scattering angle contains such complicate error sources so that scattering angle dependency of AOD difference between GOCI and AERONET is difficult to interpret so that AOD error analyses according to solar zenith angle and relative azimuth angle are also presented.

GOCI AOD errors according to solar zenith angle are close to zero at 30, 40, 50, and 60° solar zenith angle, and show fluctuating pattern between them. LUT node points of solar zenith angle are constructed at 10° interval, and linear interpolation to observed solar zenith angles in inversion procedure could cause this error pattern. The fluctuation tendency of error as underestimation at scattering angles near 115° and 140° and overestimation at 145° and above 160° could be also caused by the interpolation error in inversion procedure.

Subdivision of 5° interval for node point of LUT calculation or online calculation could improve this interpolation error (Jeong et al., 2015).

Error tendency according to relative azimuth angle shows less fluctuant shape, and underestimation at low relative azimuth angle. Both conditions of low azimuth angle and high solar zenith angle correspond to the early morning or late afternoon as local standard time. Therefore, errors analyzed according to the fixed local standard time shows underestimation at 09:30, 15:30, and 16:30. Plane-parallel atmosphere approximation or scalar calculation in RTM could result in less accurate Rayleigh scattering calculation for surface reflectance using the minimum reflectivity technique."

Additional references used in this review

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