Response to Reviewer's comment

Substantial issues remain unresolved even after the last major revision. These issues concern the clarity of the description of the AEH retrieval scheme, the content of the analyses presented, as well as the quality of the presentation of the results. A major revision is necessary.

1. The manuscript shows substantial shortcomings in language and clarity. A very large number of sentences are unclear or inaccurate (see detailed comments).

Ans) Thank you for the comments. Based on the reviewer's comments, we revised and modified the manuscript. We revised the manuscript by considering all the detailed comments. In addition, we also checked the language problems. Details are answered in the 'detailed comments' section.

2. The poor correlation with reference data from CALIOP and TROPOMI (Figures 9a and 12 a) and the wide spread of differences (+/- 3 km, Fig 13) is not explained in a satisfactory way. The amplitude of these differences and the absence of correlation across the (~3 km) range of AEH values shown in the scatterplots go beyond what can be explained by the AEH uncertainty estimate of 0.74 – 1.28 km. More work is necessary to identify the root causes for these discrepancies. It seems that improvements to the algorithm are necessary to make the product useful. This should be more clearly stated in the conclusion.

Ans) Thank you for the comments. The AEH retrieval results are largely influenced by the uncertainties of aerosol and surface properties. For this reason, the comparison among the GEMS, CALIOP and TROPOMI have some inconsistencies. From the theoretical study of Park et al. (2016) showed the theoretical error budgets of 0.74-1.28 km. However, this theoretical error is not considered to the aerosol vertical distribution shape.

For the AEH (or ALH from TROPOMI), assumed vertical distribution of aerosol is fixed. However, aerosol vertical distribution in real atmospheric condition is not a fixed shape, and it is hard to assume the climatological (or averaged) shape (as if the total ozone retrieval method assumes the a-priori profiles).

We recognize more work is necessary to identify the causes for discrepancies. Therefore, the manuscript includes the retrieval accuracy analysis according to the aerosol types, AOD, SSA, and surface types. So, we included the focus of further analysis in Section 6 as below:

"Although several fields of study may apply the AEH retrieval results, retrieval uncertainty in AEH remains due to the uncertainty of retrieved AOD and SSA. In addition, the uncertainty in surface reflectance and the discrepancy in O2-O2 SCD values between the simulation results and observations can be affected to the potential error sources of AEH from GEMS. To minimize the AEH retrieval uncertainty, further analysis related to the optimized input parameters of AOD, SSA, and aerosol type information is essential. For this reason, the quantitative analysis of AEH uncertainty due to aerosol and surface property is important for the improvement of AEH retrieval algorithm. In addition, aerosol optical property retrieval by the visible channel will be needed for further study to improve the aerosol type determination. Although the aerosol indices of UV and visible provide the aerosol type information, developing the aerosol type classification algorithm is necessary to make synergy with AEH retrieval. AEH provides representative layer height information as only one variable because of its sole reliance on O2-O2 SCD for direct estimation of aerosol height information. This method is limited to the consideration of aerosol vertical structures (i.e., Gaussian

or exponential vertical distribution structures). To increase the information contents, it would be valuable to combine other oxygen absorption bands from other satellite instruments together with extinction information of aerosols."

3. It is stated that AEH retrieval algorithm takes surface reflectance data from spectral surface reflectance product L2SFC, and AOD data from the L2AERAOD product generated using a different surface reflectance (Line 154 ff). Please clarify whether potential inconsistencies in surface reflectance are problematic for the AEH retrieval. It is recommended to test the AEH algorithm with different input ensuring a consistent treatment of surface reflectance.

Ans) Thank you for the comment. During the revision of this manuscript, the operational algorithm was changed to the surface reflectance estimation method. The GEMS AEH algorithm is now used to the same surface reflectance data as L2AERAOD. Therefore, the revised manuscript does not mention the effect of discrepancy of surface reflectance. However, the AEH uncertainty due to surface reflectance still remained. Therefore, we checked and estimated the intercomparison between GEMS AEH and TROPOMI ALH as categorized to land and ocean.

Detailed Comments

Typo line 133: onboarding ==> on board

Ans) We revised it.

Rephrase line 133-134: "The GEMS is onboarding the Geostationary Korea multipurpose satellite 2B (GK2B) as orbiting at 128.2ºE, …" ==> "The GEMS instrument on board the Geostationary Korea multipurpose satellite 2B (GK2B) located at 128.2ºE, …"

Ans) We revised it.

Use a dash instead of a tilde for ranges throughout the manuscript

Ans) We revised it.

The term "standard spatial resolution" in line 137 is not clear. I guess this is the resolution at a reference location. Rephrase.

Ans) We revised in lines 140-141 in the revised manuscript as below:

"3.5 km (North-South) × 8 km (East-West) for aerosol and gaseous products at 38ºN."

Line 139: Fix the sentence "The spectral resolution and sampling are respectively 0.6 nm with full-width and half-maximum (FWHM) and 0.2 nm with spectral range of 300~500 nm." I suggest something like "The spectral range … is covered with a spectral resolution (as defined by the full-width and half-maximum (FWHM) of the spectral response function) of 0.6 nm and a spectral sampling distance of 0.2 nm".

Ans) We revised it.

Line 142: unclear formulation "with considering the aerosol types". Are AOD and SSA provided for a set of considered aerosol types?

Ans) We revised to "after determining the aerosol types" in lines 145-146 in the revised manuscript.

Line 145: unclear formulation "classification methods based on the UV and visible AIs". I suggest "AI based classification methods exploiting measurements in the UV and visible"

Ans) We revised it.

Line 148: unclear formulation: "Overall, the error for AEH is ranged from 739~1276 m under the AOD error of 0.2, particle size error of 20%, SSA error of 10%, and surface albedo error of 0.02 (Park et al., 2016)." I suggest "Overall, uncertainties of 0.2 in AOD, of 20% in particle size, of 10% in SSA, and 0.02 in surface albedo cause AEH errors in the range 739 – 1276 m in the (Park et al., 2016)."

Ans) We revised it.

Line 150: unclear formulation: "The main variables causing errors for AEH retrieval can be obtained from the L2AERAOD results." Not understood. Remove?

Ans) We removed it.

Line 150: unclear formulation: "Therefore, the L2AERAOD results for AOD at 550 nm and SSA at 443 nm were adopted as input data for aerosol properties" The logic link implied by "Therefore" is not understood. Please state that AOD at 550 nm and SSA at 443 nm are used as input to AEH retrieval. Please justify why these two wavelengths are selected, specifically why parameters at different wavelength are used.

Ans) To explain the detailed explanation of using the AOD and SSA for the radiative transfer calculation, we revised the sentence in lines 153-157 in the revised manuscript as below:

"In this study, the L2AERAOD results for AOD at 550 nm and SSA at 443 nm were adopted as input data for aerosol properties, and the AOD and SSA values were spectrally converted to those values at assumed wavelength for the inversion calculation process after considering the spectral dependence of the aerosol optical properties by the aerosol models."

Line 164 - 169: The discussion of the input surface data is unclear. Please clarify the meaning of "use the minimum reflectance". What is BSR? Is the Black Sky Albedo given in the L2SFC product? Is this parameter taken as the Lambertian equivalent reflectance in the AEH algorithm?

Ans) We removed it due to a change of the version for the GEMS AEH. In addition, all the explanation of algorithm description was revised to the updated version. (i.e., removed the L2SFC explanation, and algorithm flowchart updated)

(Updated version of GEMS AEH was not used to the L2SFC. Instead, the climatological Lambertian

minimum surface reflectance was used. Updated version is the same as the method in the manuscript.)

Instead, we added the sentences to explain the input of the surface reflectance in lines 157-159 in the revised manuscript as below:

"In addition, we also used the minimum reflectance under the Lambertian assumption to retrieve AOD and AEH to coincide with the use of surface information on L2AERAOD and AEH retrieval."

Line 164 – 169: garbled sentence. I suggest something like "The S5P satellite flies on a polar orbit and crosses the equator at 13:30 (local time ascending node)".

Ans) We revised the sentence in lines 164-165 in the revised manuscript as below:

"The S5P is a polar orbit satellite that crosses the equator at 13:30 local time at an ascending node."

Line 176: the "product … provides"

Ans) We revised it.

Line 177: "in THE free"

Ans) We revised it.

Line 179 – 181: garbled sentence. I suggest something like "The spectral fit employs a fast forward model based on a neural network."

Ans) We revised it.

Line 182: "IS used"

Ans) We revised it.

Line 181 – 186: garbled sentence. I suggest something like "After cloud masking, an optimal estimation method is used to retrieve the ALH and AOD. Other aerosol parameters…"

Ans) We revised the sentence in lines 171-174 in the revised manuscript as below:

"After cloud masking, an optimal estimation method is used to retrieve the ALH and AOD by the inversion method from observation. Other aerosol parameters, such as SSA, layer thickness, and scattering phase function, are assumed to be fixed values (Nanda et al., 2020)."

Line 189: "The main purpose ..."

Ans) We revised it.

Line 191: Add "for the layer height and for the associated pressure respectively" when reporting 0.5 km and 50 hPa and 1 km or 100 hPa.

Ans) We revised it.

Line 202 introduce acronym

Ans) We revised it.

Line 206 – 207: garbled sentence. I suggest something like "The CALIPSO satellite flies on a ascending node orbit in the A-train constellation."

Ans) We revised the sentence in lines 195-197 in the revised manuscript as below:

"The CALIPSO is Sun synchronous orbit constellated to the A-train with period of 98.3 minutes. It crosses the equator at 13:30 local time on an ascending node."

Line 213: whitespace between number and unit: 90m ==> 90 m
Ans) We revised it.

Line 222 typo: CLIOP
Ans) We revised to "CALIOP".

Line 224: "Furthermore, the AEH adopted the same method as CALIOP for estimating the ALH, with only changes in the height definition." Is unclear. Please rephrase.

Ans) We revised to "Similarly, the AEH estimation from CALIOP is also used to the extinction coefficient profile."

Line 229 "is THE observation area"
Ans) We revised it.

Line 231-232 "From Park et al. (2020), the spatial scales for AOD validation are 30~40 km." Is unclear. Please rephrase.

Ans) We revised to in lines 218-221 in the revised manuscript as below:

"From Park et al. (2020), the spatial range of highly coincident AOD is 30-40 km. To ensure that the number of retrieved observation pixels that can be analyzed in this study is sufficiently high, we relax the spatial limits for collocation matching."

Line 232: A part of the sentence is missing. Is it "To ensure that the number of retrieved observation pixels THAT CAN BE ANALYSED IN THE PRESENT STUDY IS SUFFICNETLY HIGH, …"?

Ans) We revised it.

Line 233: Please specify to which level the limits were relaxed. Make at least a qualitative statement on the impact of this relaxation on the robustness of the present study.

Ans) For the spatial consistency of aerosol was analyzed by the previous study of Park et al. (2020). To follow this criterion, number of data for the intercomparison is too small to compare. For this reason, this study is relaxed to the criteria of the colocation range. To explain this explanation, we changed the sentences and rephrase it as below: (Lines 217-223)

"In this study, we used data within 75ºE-145ºE for east-west and 5ºS-45ºN for north-south direction, which is the observation area of GEMS. From Park et al. (2020), the spatial range of highly coincident AOD is 30-40 km. To ensure that the number of retrieved observation pixels that can be analyzed in this study is sufficiently high, we relax the spatial limits for collocation matching. For spatial colocation, we selected pixels for which distance between GEMS and CALIOP (or TROPOMI) observations was less than 50 km."

Line 251: garbled sentence. I suggest something like "For this reason, cloud contamination remains a critical source of uncertainty in the retrieved ALH"

Ans) We revised it.

Line 251: I suggest fixing formulation as "the UVAI is used to detect the presence of elevated absorbing aerosol."

Ans) We revised it.

Line 254-256: Sentence makes no sense. Rephrase / remove.

Ans) We revised it.

Line 256: unclear formulation. I suggest "The pixels for which with an AOD at 443 nm taken from the GEMS aerosol product exceed 0.3 are selected for AEH processing. The UVAI is not used for this selection."

Ans) We revised to "the pixels for which with an AOD at 443 nm (AOD_{443} hereafter) taken from the GEMS aerosol product exceed 0.3 are selected for AEH retrieval.". (Lines 247-249)

Line 262: definition is not cleanly formulated. I suggest "…into the aerosol layer. It is defined such that the integral of the vertical aerosol extinction profile from the surface to the AEH is equal to (1-e-1) times the AOD, as defined by Park et al. (2016).

Ans) We revised to "It is defined such that the integral of the vertical aerosol extinction profile from the surface to the AEH is equal to $(1-e^{-1}) \times AOD$, as defined by Park et al. (2016)." (Lines 253-254)

Line 270: Please clarify in which sense the GDF a "modified" Gaussian? The AEC profile shown in Figure 1 looks pretty much like a standard Gaussian without modification.

Ans) We agreed the structure of Figure 1. Figure 1 is purposed on the easy understanding of the difference between ALH and AEH. For this reason, the figure was simplified in this manuscript.

The real structure of the aerosol vertical distribution is not clearly Gaussian structure. For the detailed explanation of GDF, we added the phrase "by considering the range of upper and lower boundary height" on line 261 in the revised manuscript.

Line 272 "..is SET to 1 km." or "…is ASSUMED to be 1 km."
Ans) We revised it.

Line 272 "A schematic .."
Ans) We revised it.

Line 275 – 277 Definition of ALH is not clean. I suggest "the ALH is defined such that the integral of the vertical aerosol extinction profile from the surface to the ALH is equal to 0.5 times the AOD. I assume this is the definition used by Nanda et al. (2016); if confirmed please add this statement.
Ans) We revised it.

Line 277: "is same to the" ==> "equals the"
Ans) We revised it.

Line 288: "for the vertical profile condition as shown" ==> "of the profile in the conditions shown"

Ans) We revised it.

Figure 1: I suggest adding the ALH definition to the figure linking it to the AEC profile. Please introduce acronym AEC.
Ans) We revised it.

Figure 2: Please distinguish on-line processing steps (from L1C to AEH) from off-line processing steps (computation of Look-up-Tables). I recommend splitting the chart in two. There are 2 LUTs: LUT1 SCD = F(alpha, tau, z,…) and LUT2 SCD = F(z). I assume that LUT2 is extracted from LUT1. Please clarify. Is this extraction done on-line during L1C to AEH processing?
Figure 2: The shapes of the flow chart objects are not used in a logic fashion. Please use shapes distinguishing data, data bases, and processes.
Figure 2: Please use arrows in a logic way identifying data that enter processes: Atmospheric profiles must enter the RTM calculation process. The slit function must enter a process (convolution). Cross sections must enter DOAS analyses.
Figure 2: LUTs, AOD and SSA from the GEMS product, and surface reflectance from the L2SFC product must be used in the on-line processing from L1C to AEH.

Answers for Figure 2) We remade the algorithm flowchart for Figure 2. All the reviewer's comments are considered and revised in the modified figure.

Line 285-290 : LUT generation description is unclear. I suggest simplifying to "The AEH algorithm for GEMS employs a look-up table (LUT) that contains O2-O2 SCD values for many scenarios with a variety of … "
Ans) We revised it.

Line 285-290 : LUT generation: I miss the AEH in the list of dimensions of the LUTs. (AEH is included in this list according to Table 3.)
Ans) We revised it.

Line 291: simplify to "the radiance is simulated monochromatically and then convolved with the GEMS instrument spectral response function".

Ans) We revised it.

Line 291: statement is in conflict with the logic of the chart in Fig 2. The DOAS processing provides a O2-O2 SCD, not an AEH. The latter is obtained from the O2-O2 SCD using a LUT. Please clarify, rewrite.
Ans) We revised to the sentence as below:
"Finally, the radiance information is converted to the O2-O2 SCD from differential optical absorption spectroscopy (DOAS) method (Platt, 1994)." (Lines 290-291)

Line 294 ff: the description of DOAS is confusing. Please simplify to the refer to Platt (1994).
Ans) We revised it.

Line 302 ff: The justification of the choice to exploit O2-O2 signatures is hard to understand. I suggest simplifying to "The AEH is retrieved exploiting the O2-O2 absorption signature. The O2 A band signature exploited in ALH algorithms (references) is not covered by GEMS."
Ans) We deleted this sentence and the reason for the choice of O2-O2 at 477 nm is explained in lines 276-281 in the revised manuscript as below:

"For AEH retrieval, the basic idea is the identification of changes in optical path length caused by effective aerosol layer height variation. To measure the optical path length change, O2-O2 SCD retrieved by the DOAS method was used because the spectral coverage is limited to 300-500 nm (Park et al., 2016, Kim et al., 2020). In the GEMS product, the O2-O2 SCD at 477 nm absorption band is the most useful absorption band because this absorption band is strongest absorption band within the GEMS spectral observation range."

Line 325: Conclusion on fit parameters is confusing. I suggest simplifying to "Smallest AEH fitting errors are obtained by a DOAS fit with a 2nd order polynomial and no offset. These settings are used in the GEMS AEH algorithm."
Ans) We revised to "Smallest AEH fitting errors are obtained by a DOAS fit with a 2nd order of polynomial and 'none' offset." in the revised manuscript. (Lines 317-318)

Line 330: Sentence does not swing. I suggest "Park et al () have shown that the largest contributor to the AEH uncertainty is associated with the uncertainty in SSA."
Ans) We revised it.

Line 332: "uncertainty by the aerosol optical properties" ==> "uncertainty due to error in the aerosol optical properties"
Ans) We revised it.

Line 339: aerosol type is DEFINED by the radiative absorptivity and PARTICLE size,
Ans) We revised it.

Line 340 "based on the method from Lee et al. (2010)" not understood. Are aerosol types defined following Lee et al. (2010)?

Ans) We removed it.

Line 341: Absorbing and non-absorbing particles are considered for the fine mode of the size distribution.
Ans) Sure, the absorbing and non-absorbing particles are assumed to the fine mode dominant aerosol types.

Line 344: remove "Otherwise"
Ans) We removed it.

Line 345: "assumed as the fixed value" ==> "assumed to be spectrally constant"
Ans) We revised it.

Line 345 "Although the center of O2-O2 absorption" not understood. Is this about spectral calibration? Are imperfections of the latter ignored?
Ans) We revised to "Although the spectral O2-O2 absorption band is around 477 nm," in the revised manuscript. (Line 336)

Line 348: "we performed the slit response function of GEMS and sampling specification" ==> "the convolution with the GEMS slit response function was applied and the spectra were sampled on the GEMS L1C spectral grid."
Ans) We revised to the sentence in lines 339-341 in the revised manuscript as below:

"the convolution with the GEMS slit response function was applied and the spectra were sampled on the spectral grid of the GEMS radiance data (Level 1C) prior to the DOAS fitting."

Line 350: remove duplication "For O2-O2 absorption, the absorption cross section used for the radiative transfer model calculation is considered the temperature dependent absorption cross section" ==> "Radiative transfer calculations were performed accounting for the temperature dependence of absorption cross sections".
Ans) We revised it.

Figure 3 caption should be "O2-O2 SCD dependence as a function of AOD and AEH for (a)…"
Ans) We revised it.

Line 360: please change "Figure 3 shows … " accordingly.
Ans) We revised to "Figure 3 shows the example of O2-O2 SCD dependence as a function of AOD and AEH from the LUT according to the respective aerosol types and AOD." in the revised manuscript. (Lines 357-358)

Line 368 "Although .. uncertainties " not understood.
Ans) We removed it.

Line 369 – 373 confusing. Rewrite or remove.

Ans) We removed it.

Line 384: "in AOD < 0.4" ==> "in cases with AOD < 0.4"
Ans) We revised it.

Figure 4 caption "uncertainty by the AOD error of 0.2 according to (a)…" ==> "uncertainty due to an AOD error of 0.2 for cases with (a) …"
Ans) We revised it.

Figure 5 caption same as Figure 4 caption
Ans) We revised it.

Line 397: Confusing sentence. I guess what is meant is "On average, the associated AEH bias takes values up to 0.5 km"
Ans) We revised it.

Line 399 ff "Based on the changes … for AEH retrieval" is confusing. Rewrite or remove.
Ans) We revised to "From the sensitivity analysis, aerosol types …" in the revised manuscript. (Lines 397-398)

Line 403: "the L2SFC product is used in operation" ==> "the L2SFC product is produced operationally"?
Ans) We removed it, because the L2SFC product is not used in the updated version.

Line 404: explain why a climatological minimum LER is used instead of the data from the operational L2SFC product.
Ans) We removed it.

Line 406 "The data quality" not understood.

Ans) We removed it.

Line 412: "From Park et al.," ==> "Pixels with low AOD values… due to … (see also Park..) "
Ans) We revised it.

Line 415 – 417 "In addition, the AE" not understood. Is the quality flag from the AOD product copied into the AEH product?
Line 417 what is meant with "significant averaging kernel for optimal estimation for aerosol property retrievals"? significant sensitivity of AEH to AOD?
Answer for above two comments) To clarify the quality flag using, we revised to in lines 411-415 in the revised manuscript as below:

* "For this reason, only AEH retrieval results with AOD greater than 0.3 are shown in this study. In addition, the AEH retrieval results are only shown to the "Reliable" quality flag of L2AERAOD, which is estimated to the aerosol optical properties with significant averaging kernel for optimal estimation in L2AERAOD."*

Line 418 : "During this case study, a dust plume …" ==> "A case was analysed in which a dust plume …"

Ans) We revised it.

423 "shows similar pattern ranging" ==> "shows similar patterns and takes values ranging"

Ans) We revised it.

424 "between 1.0 to 2.0 km" ==> "between 1.0 and 2.0 km"

Ans) We revised it.

Section Case Studies: the repetitive specification "at 443" for AOD and SSA should be avoided. I recommend clarifying upfront that all SSA and AOD values discussed in this section are reported at this reference wavelength.

Ans) We removed 'at 443 nm' in the revised manuscript. Instead, we changed from 'AOD at 443 nm" to 'AOD$_{443}$' and 'SSA at 443 nm' to 'SSA$_{443}$' in the revised manuscript. Also, we mentioned '(AOD$_{443}$ hereafter)' and '(SSA$_{443}$ hereafter)'.

430 "From Rana et al. " ==> "According to Rana et al. "

Ans) We revised it.

431 "clusterS"

Ans) We revised it.

433 "was a result that actually exists, and it was not a result with high uncertainty due to…" ==> "in considered physical rather than an artifact due to …"

Ans) We revised it.

444 "were 0.5~1.5 km" ==> "range between 0.5 - 1.5 km"

Ans) We revised it.

444 – 446 Confusing sentence "Given the difference in definition for the aerosol height parameters between ALH and AEH, relatively high height values were retrieved from GEMS compared to TROPOMI" ==> "AEH values retrieved from GEMS were higher that the ALH values retrieved from TROPOMI. The opposite was expected in view of the definitions of the two parameters".

Ans) We revised to "Given the difference in definition for the aerosol height parameters between ALH and AEH as shown in Fig. 1, AEH values retrieved from GEMS were higher than the ALH values retrieved from TROPOMI." In lines 442-444 in the revised manuscript.

446-449 remove

Ans) Because of the requesting of other reviewer's comment, we are remaining the sentence in the revised manuscript.

It is stated that "A dust plume was transported from China to South Korea during this period" (Line 441) and that this "dust transport case was successfully retrieved" (line 451). Please clarify whether independent data are available that confirm that this dust transport event was real. Only then one can conclude that the dust transport case was successfully retrieved; otherwise, one can only conclude that the AEH signature looks physical.

Ans) Thank you for your comment. To consider the reviewer's consideration, we change the sentence to "Although AEH had higher values than ALH from TROPOMI, the GEMS AEH retrieval provided meaningful physical results for the dust transport case study." (Lines 448-450)

510 "is strong surface type dependence" ==> "exhibits a strong surface type dependence"
Ans) We revised it.

514 A correlation coefficient of 0.993 between GEMS AEH and TROPOMI ALH is reported, which is much higher that what one would expected from the plotted data. Please check/confirm. If confirmed please explain.

Ans) We checked the comparison result and write it that those correlation coefficients are based on the 5-representative points comparison. Because both TROPOMI and GEMS are passive remote sensing and these instruments include uncertainty due to several aerosol properties, we adopted this comparison. Although these correlation scores are not based on the individual data point comparison, the tendency of retrieval is reasonable from the comparison result.

525 Unclear sentence "sensitivity of O2-O2 SCD was weak in cases of high AEH because of the vertical distribution of air molecules". Which sensitivity of O2-O2 SCD is meant? Why past tense? I guess what you want to say is that AEH is weakly sensitive to the true layer height in high layer cases. This is a general feature of the algorithm and is related to the fact that the O2-O2 abundance scales with the square of the pressure.

Ans) Thank you for your comment. We revised these sentences as below:

"Although the GEMS algorithm retrieved AEH in the range of 0-10 km, the sensitivity of O2-O2 SCD to the optical path length was weak in cases of high AEH because the vertical distribution of O2-O2 SCD is related to the square of the air molecule densities. To ensure sufficient quality of retrieved data, therefore, the AEHs from GEMS and CALIOP, and the ALH from TROPOMI were used only in pixels where the AEH from GEMS were lower than 5 km." in the revised manuscript. (Lines 523-528)

666 Rephrase "…, the number of pixels observed at 03:00 UTC was insufficient for the identification of diurnal variation." Observations at one fixed time never allow studying diurnal variation.

Ans) We revised the sentence to "insufficient for the identification of diurnal variation of retrieval uncertainty" in the revised manuscript. (Lines 649-650)