Reply to anonymous referee #1:

We thank the reviewer for the positive feedback on the manuscript. Please find our responses point-by-point below.

Please note: Page, line, figure, table and section numbers in reviewer's comments refer to amtd manuscript. Numbers in authors' reply refer to revised manuscript.

The proposed manuscript presents sensitivity study of aerosol height retrieval as changing aerosol and surface optical properties from radiative transfer model simulation and optimal fitting method. In addition, the model results adopts to the GOME-2A sensors with comparison case study by using ground-based lidar and CALIOP. The text is well written except some paragraphs. However, it needs more explanation for the sensitivity test results.

This study considered the surface and aerosol properties by adopting the parameters for fitting. As the theoretical background of possibility for the aerosol layer height retrieval, this manuscript shows spectral feature difference between finite differences of aerosol and surface optical properties and those of aerosol layer height. However, some contradictions are found during explanation of fitting method. In detail, the manuscript in Section 2 described that surface albedo, aerosol optical depth (AOD) and aerosol model (i.e. aerosol size parameter and single scattering albedo) did not use precise and accurate models, which means these parameter roughly assumed. Otherwise, the article in Section 5.2 explained that individual a-priori information for aerosol properties are necessary for the inversion process.

It is not quite clear to us what exactly the reviewer means. In section 2 we discuss a sensitivity study investigating the effect of inaccurate a priori information about the aerosol model (here: the single scattering albedo) on retrieved aerosol layer height and aerosol optical thickness. (Note that a section further exploring this sensitivity has been added now.) Often, accurate information about the aerosol's optical properties is lacking so it is important to investigate the effect. In section 5.2, the inversion scheme is described but there is no mentioning of aerosol properties. Perhaps the reviewer refers to our remark in section 2 that 'Retrieval of aerosol pressure and optical thickness from the O2 A band requires of course an assumed aerosol model' (p.12). We have now added a clarification to this sentence.

In addition, the feature of spectral sensitivity difference is one of theoretical basis of this study, and front of this manuscript showed that the sensitivity tests of spectral feature is necessary. But this manuscript did not include sufficient sensitivity test of various spectral feature of aerosol parameters: i.e. this manuscript will complement theoretical tests as changing spectral feature change in O2-A band as a function of other aerosol optical properties.

A section with sensitivity studies further exploring the effect of inaccurate aerosol optical properties for realistic aerosol types has now been added (section 3). Note that differences in the spectral shapes of derivatives for aerosol layer mid pressure, aerosol optical thickness and surface albedo have been illustrated in figure 1b because these parameters are intended to be retrieved. Aerosol optical properties on the other hand are not retrieved. A full retrieval simulation is necessary to investigate the sensitivity to errors in assumed aerosol optical properties.

Finally, the aerosol layer mid pressures have realistic values when not fitting the surface albedo than fitting surface albedo on the case study as showing in Section 6's conclusion. However, this Section also showed that successly estimated pixel number is larger when fitting surface albedo than when no-fitting. This is also need to explain the detailed reason.

From the comparison with lidar measurements in section 9 we see that retrieved layer pressures are more realistically representing the actual profile when the surface albedo is not fitted. A possible explanation is discussed in section 10. When we include the surface albedo in the fit, convergence goes up. This means that there are more pixels for which we could reproduce the measured spectrum with a modeled spectrum. The finding is in agreement with the retrieval simulations of section 2 and section 3, which is, in our opinion, clearly explained in section 6, p.24, last paragraph. In brief, when there is an additional fit parameter, the forward model has more freedom to find agreement with the measurement, but this does not mean that the actual retrieval solution is more accurate.

In summary, this paper additionally includes in the revisions as below :
- Additional sensitivity test as changing aerosol optical and physical properties including spectral feautre studies (make some figures as similar to Fig.1)
- Supplement the explanation of discrepancy between conlusions about sensitivity tests and results of case studies.
- Supplement the explanation of case study analysis

See our remarks above, which answer these points. We think that retrieval simulations investigating the effect of inaccurate aerosol properties on the retrieval solution rather than simulations investigating the effect of different aerosol properties on the O2 A band spectrum are more appropriate to answer the reviewer's concerns.

Some detailed comments are listed below, and I suggest that the answer of suggestions would follow after revision.

General Comments:

Section 2: For the fitting procedure, the surface albedo consideration will improve and be stabilize the aerosol layer height retrieval. Does this improvement only correspond in aerosol height retrieval? Does the fitting method in this paper not able to estimate accurate AOD and surface albedo value simultaneously? As see in Fig. 7, AOD value is drastically chaged by adopting fitting method.

Figure 8 refers to the GOME-2A retrievals. Fitting the surface albedo helps to improve convergence. In this sense, the retrieval is indeed stabilized. The retrieval solution however, does not need to be more realistic. As shown in the paper, retrieved pressures become very low. Aerosol optical thickness is also retrieved and since there are correlations between fit parameters, retrieved aerosol optical thicknesses changes as well in response to including the surface albedo in the fit. Particularly, one can see in figure 8 that retrieved optical thicknesses indeed decrease. We hypothesize that this effect is related to the similar decrease in optical thickness found in the retrieval simulations of figure 15. This is explained in section 11. A small clarification has now been added to this section on p.38.

Section 4: For cloud masking method, this paper used AVHRR data and estimate geological cloud fraction by '(number of AVHRR-cloud pixel)/ (number of total AVHRR pixel)' in GOME-2A GSD pixel. However, overpass time difference between GOME-2A and AVHRR makes error of cloud fraction determination. (I think that the cloud fraction error will significantly negligible if overpass time difference has less than 30 minutes.) If overpass time difference time is large, I suggest that the domain of AVHRR pixel will be widen, or the supplements of pixel selection will be added in the manuscript if you have an idea.

There may be some confusion with the reviewer here. There is also an AVHRR instrument on the Metop-A platform. There is thus hardly any time difference between measurements from GOME-2 and AVHRR. Careful collocation of AVHRR and GOME-2A pixels is taken care of by EUMETSAT's operational PMAp processor.

Table 5 : What is exact meaning of 'varying' in the a-priori value of aerosol parameters? Please specify the 'varying' parameter. (e.g., Aerosol layer mid pressure uses 'specific' vertical distribution data from 'specific platform'...)

A clarification has now also been added to the caption of Table 6.

P6067, L18-19: Please add the explanation why the estimation error in case study is larger than expected error from simulation.

We discuss a possible cause for the finding of lower pressures in case the surface albedo is fitted in section 10. So this will become clearer later in the text.

P6067, L20-24: The result is not consist. Focusing on the aerosol layer mid pressure value, the method without surface albedo fitting is realistic. Otherwise the number of successly estimated pixel is relatively small as compared to fitting with surface albedo.

There may be some confusion with the reviewer. Results are consistent, see also our explanations above. Perhaps the confusion is about 'convergence'. With convergence we mean that a fit of the model to the measurement has been found. But this does not necessarily mean that the retrieval solution is the right solution ('successfully estimated'?).

P6067, L26-27: This sentense also concluded that the phase function of aerosol affects aerosol layer mid pressure retrieval. In other words, accurate aerosol optical and physical property model is important factor for aerosol height retrieval. This is inconsistent with the assumption of theoretical sensitivity analysis in Section 2. If aerosol property significantly affects aerosol height retrieval from observation, the sensitivity test for aerosol height retrieval additionally executed as changing other aerosol parameters, such as aerosol single scattering albedo, or types etc.

All assumptions made will affect retrieval, of course. To us, the question is which assumptions will affect retrieval most. Based on the simulations of section 2 and section 3 and the sensitivity experiments with real GOME-2A spectra in figure 9, the effect of aerosol model on retrieved height is moderate. Of all the possible error sources contributing to the total error, this error is not our major concern. Nevertheless, at a later stage, we may very well further optimize the retrieval also with respect to the aerosol model when this proves necessary or when we have gotten other, larger error sources under control.

P6068, L14: How much different of overpass time between Metop-A and Terra? Is overpass time difference sensitive for aerosol comparison? Please add some references related to this issue.

If there are differences in the overpass time, a particular scene observed by the first instrument may have changed, when it is observed by the second instrument. Therefore, aerosol comparisons are sensitive to overpass differences. It would be beyond the scope of the paper to discuss this in detail however because we do not include comparisons between retrieved AOT and MODIS-Terra AOT in the paper for precisely this reason.

- For the sensitivity test, this paper described the effect of surface, aerosol properties, background information (i.e. temperature profiles and gas cross sections) and sensor characteristics, such as stray light. However, hyperspectral sensor also sensitive to the spectral calibration condition. If possible, please add the sensitivity of spectral calibration error.

Detailed sensitivity studies investigating the effect of instrument and calibration errors as well as many other sensitivities are presented in the ATBD, which we expect to be publicly released very soon. See also p.15. Since the present manuscript is already quite comprehensive, we prefer to focus on the specific issues of aerosol model and surface albedo treatment in the present manuscript.

Other comments: Section 1: To add the aerosol height study, please add the reference about guideline for aerosol height accuracy, such as Fishman et al. (2012).

Fishman, J., et al. "The United States' next generation of atmospheric composition and coastal ecosystem measurements: NASA's Geostationary Coastal and Air

Pollution Events (GEO-CAPE) mission." Bulletin of the American Meteorological Society 93.10 (2012): 1547-1566.

Reference has been added (p.9).

P6048, L12 : Please express the example of 'asymptotic solutions'.

When the multiple scattering contribution is large, certain expressions in radiative transfer can be replaced or approximated by their asymptotic equivalent (e.g. in the limit of infinite optical thickness). We feel it is beyond the scope of this paper to further explain this (an asymptote is a rather general mathematical term). One of the cloud retrievals (SACURA) makes use of asymptotic solutions to solve the radiative transfer equation in an efficient way.

P6048, L27 : Move to the full-name of 'GOME' to L16 in 'GOME-2A'.

Done.

P6048, L9-13 : To clarify the meaning, please rewrite the sentense of 'Because of the latter…cannot be used in case of aerosol retrieval'.

Perhaps the reviewer can clarify what exactly is not clear here. Many techniques exist to solve the radiative transfer equation. Depending on the particular problem at hand (e.g. solve the equation for the TOA relectance for a cloudy or an aerosol-laden atmosphere) one or the other technique may be appropriate.

P6051, L12 : Please explain the meaning of 'fixed pressure thickness'

A clarification has been added (p.7).

Fig. 7: For the consistency of figure format, please re-draw these two figures in Fig. 7. Please includes the result of r, p, number of data in revised two figures.

We prefer not to report a linear regression for the right panel of figure 7 for precisely the reason stated. We have, however, redrawn this figure to make the scales of the axis the same for easy comparison.

-Please use abbreviation of 'aerosol optical thickness' and ' aerosol layer mid pressure' in the manuscript.

We feel this is a matter of taste. We prefer to write out terms rather than abbreviate them because in our opinion this makes a text more readable.

- Please add the reason why use the Henyey-Greenstein phase function for aerosol size parameter.

This is explained in section 6.1, p.20-21.