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Atmospheric Measurement Techniques Discussions

Interactive comment on "Error sources in the retrieval of aerosol information over bright surfaces from satellite measurements in the oxygen A-band" *by* Swadhin Nanda et al.

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Reviewer comment (general): This paper presents a comprehensive analysis on the potential error sources in aerosol height and optical thickness retrieval over different surface brightness. By breaking down the top of atmosphere reflectance into contribution from surface (Rs) and from the atmospheric column (Rp), the authors are able to analyze the mechanisms behind the potential retrieval bias/errors. The manuscript is organized and presented very well. It provides the community a detailed documentation on the problems facing aerosol property retrieval with oxygen A-band observations. I definitely recommend publication of the paper. I have several minor comments for the authors to consider.

One general suggestion I have is to add some discussions on TOA reflectance sensitibity to layer height for optically thin aerosols. The manuscript uses thick aerosol layers (tau = 1.0) for this purpose (Figure 3 left panel). Since most aerosol layers are optically thin, a similar figure with aerosol optical thickness of 0.2 maybe more telling. I'm thinking a thinner layer would make the problem even harder.

Author's response: Thank you for your constructive feedback. The sensitivity studies in this paper were designed for the KNMI aerosol layer height algorithm, which primarily focuses on aerosol events with a UV absorbing index greater than 2. These are usually quite optically thick layers in the oxygen A-band. However, the question posed is a very valid one - How does the optical thickness determine the accuracy of retrieving aerosol layer height over bright surfaces?

To answer this, we have repeated the sensitivity analyses presented in Figure 7 (bottom left) for retrieval behaviour in the presence of model error in the surface albedo over a bright surface with a surface albedo 0.25 at 760 nm. The simulations are conducted for an aerosol optical thickness of 0.2, 0.5, 0.8 and 1.0. These are more realistic scenarios over Europe in terms of the presence of model errors and the amount of aerosols (see the plot in Figure 1). The caption of the figure is described as follows (the AMT online response editor's figure caption text box does not have enough space for the full caption):

'Bias in retrieved aerosol layer mid pressure (for different aerosol loads) versus introduced model error in the surface albedo relative to the truth (expressed in %) over a scene with a surface albedo of 0.25, viewing at a relative azimuth angle of 0°, solar zenith angle of 45°, and viewing zenith angle of 20°. The aerosols are represented by a single layer present at 650 hPa over a scene with surface pressure of 1013 hPa. The aerosols have a single scattering albedo of 0.95, and the scattering phase function is described by a Henyey-Greenstein model with an anisotropy factor of 0.7. The aerosol optical thickness is described in the figure legend. Plot points represented with a cross represent non-convergences, i.e., no aerosol layer was retrieved in these cases. The bias is defined as the retrieved aerosol layer height minus the true aerosol layer height — a positive bias suggests that the retrieved aerosol layer is below the true aerosol layer.'

Optically thin aerosol layers will allow more photons to pass through and interact with the surface, leading to an increase in R_s, and hence an increase in the cancellation between R_p and R_s. With an increase in the aerosol optical thickness, less photons pass through the aerosol layer; consequently, biases in the retrieved aerosol layer height reduce as observed in Figure 1.

Changes to the manuscript: We will include the discussion presented here into the manuscript in Section 4.4 as a continuation from line 18 as - 'Retrieving height of optically thin aerosol layers can also be quite challenging, owing to the fact that these layers will allow more photons to pass through and interact with the surface, leading to an increase in R_s, and hence an increase in the cancellation between R_p and R_s. As a result of this, large biases in the retrieved aerosol layer height can be expected for optically thin layers over bright surfaces.'

Reviewer comment (specific 1): P8, Line 31: Figure 2 does show Rs is more significant than Rp, but that's for albedo = 0.4, not for a dark surface. Maybe just remove "(Figure 2, blue line)".

Author's response: Agreed.

Changes to the manuscript: Removed '(Figure 2, blue line)' from page 8, line 31.

Reviewer comment (specific 2): Figure 6: What would be the physical reasons for the retrieval algorithm getting a positively biased optical thickness over brighter surfaces.

Author's response: The bias in the minimum of the cost function, in the case of Figure 6, need not be positive. It is also possible for this bias to be negative. In the calculation of the cost function (Equation 2 in the submitted manuscript), the synthetic measured spectrum **y** (or the 'truth' in this case) is at 600 hPa, whereas the modeled spectrum **F(x,b)** has an aerosol layer at 700 hPa. Because the aerosol layer in the modeled spectrum is lower than the same in the measured spectrum, the modeled atmospheric column that the photon passes through is longer, which increases the amount of absorption by molecular oxygen. Because of this, the aerosol optical thickness in the retrieval forward model is automatically adjusted (in this case, increased) in the minimum in order to compensate for the residual absorption. If the aerosol layer in the model is higher in the atmosphere than the same in the 'measured' (synthetic truth) spectrum, the minimum will appropriately shift to a lower value, in order to compensate for a deficit in the absorption in the spectrum generated by the retrieval forward model.

Changes to the manuscript: We have changed Page 9 line 9 (second paragraph) from 'Also, as Rs increases, the global minimum shifts away from the true τ. This is predominantly observed in Figure 6 (left, red line) over the bright surface for a viewing angle close to nadir, where R_s is more dominant. For the same angle, the global minimum over a dark surface is situated at the true τ value. As the viewing angle increases over the bright surface, R_p increases and the global minimum of the cost function moves closer towards the true τ.' to the following:

'Also, because of a model error (described in Figure 6) in the aerosol layer height between **y** and **F(x,b)**, (in Equation 2) the global minimum of the cost functions shifts away from the true τ. This shift is baised higher than the truth if the aerosol layer is lower in the atmosphere in comparison to the aerosol layer in the synthetic true spectrum, because the model has to compensate the extra absorption by molecular oxygen. If the aerosol layer is higher in the atmosphere, the minimum of the cost function is situated at a τ lower than the true τ. As observed in Figure 6 (left, red line), this shift of the cost function minimum from the true τ is larger over bright surfaces for a viewing angle close to nadir, where R_S is more dominant. For the same angle, the global minimum over a dark surface is situated at the true τ value, even with the presence of a model disagreement with the simulated 'true' spectrum. As the viewing angle increases over the bright surface, R_p increases and the global minimum of the cost function moves closer towards the true τ.'

Reviewer comment (specific 3): P11, Line 15: "larger over land than the over the ocean" may be "larger over land that over ocean".

Author's response: Agreed.

Changes to the manuscript: Page 11, Line 15: changed 'larger over land than the over the ocean" changed to 'larger over land than over ocean".

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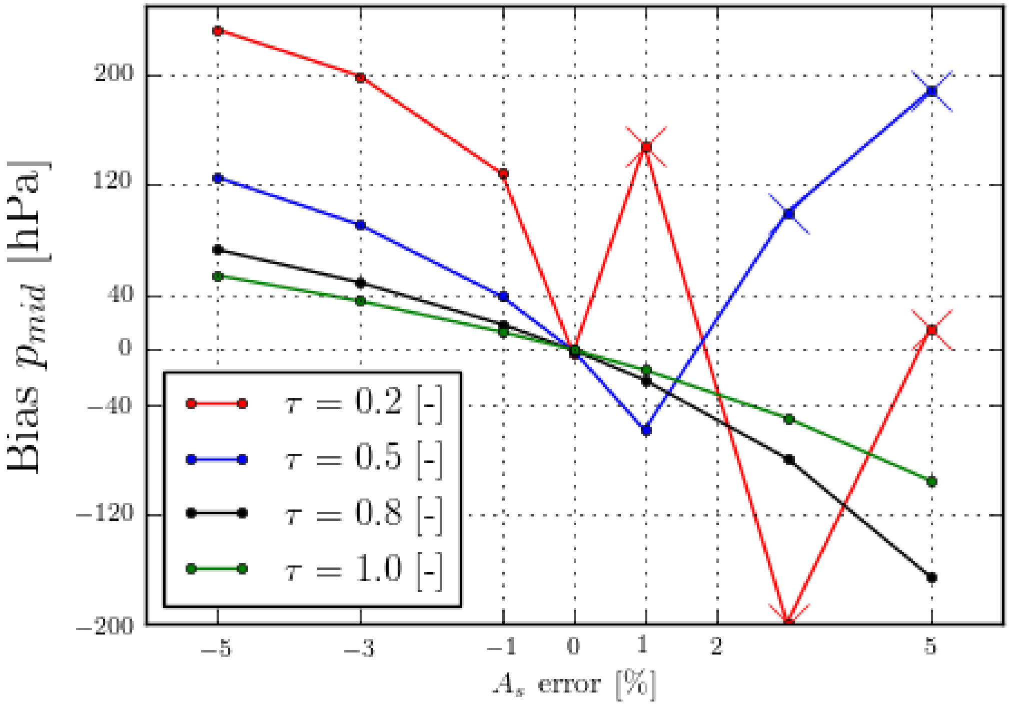

Fig. 1. Please check text for the caption.

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Discussion paper