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Atmospheric Measurement Techniques Discussions

Interactive comment on "A weighted least squares approach to retrieve aerosol layer height over bright surfaces applied to GOME-2 measurements of the oxygen A band for forest fire cases over Europe" *by* Swadhin Nanda et al.

Swadhin Nanda et al.

nanda@knmi.nl

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Response to RC1:

Thank you for your comments. Our response to your suggestions and questions as well as incorporated changes (in line with your suggestions) are detailed point-by-point in the following:

Page 4, line 6: It is stated that Raman scattering is ignored. The impact of rotational Raman scattering in the O2-A band has been quantified by Vasilkov et al. (2013).

Please justify why you omit Raman scattering considering their results. Specifically, may Raman scattering significantly impact your dynamical scaling method?

The primary reason for ignoring RRS is due to its computational requirement, which is significant. RRS is also dependent on the amount of Rayleigh scattering, which has a low cross section in the near-infrared. As such, RRS can be ignored for ALH retrievals.

Regarding the effect of RRS on the dynamic scaling method, we performed a synthetic experiment wherein spectra were generated with a 3-polynomial approximated RRS, and the retrieval forward model ignored RRS. We did this for 195 spectra, generated with randomly varying input parameters. The experiment excludes Ring spectrum and a differential ring spectrum, for simplicity.

The results are as follows.

The average bias in the retrieved aerosol layer height from the formal (unscaled) approach was approximately -7 hPa, whereas the same from the dynamic scaling approach was -11 hPa. The standard deviation of these biases were similar. So, ignoring RRS does affect dynamic scaling, just not to the degree that we can term significant, especially since including RRS will result in computational times doubling, sometimes tripling, the time from runs that ignore RRS. As such, ignoring RRS is a logical step.

Amendment to the manuscript:

Replaced 'To that extent, rotational Raman scattering is also ignored in the forward model.' with 'Because of the low Rayleigh Scattering cross section in the near-infrared, Rotational Raman Scattering can also be ignored.'

Page 9, line 2: Please define LER.

Accepted.

Amendment to the manuscript:

Replaced 'monthly LER database' with 'monthly database of Lambertian Equivalent

Reflectivity (LER) values'.

Page 9, line 14: Please remove 'seems to'. The formal approach does not 'seems to' retrieve more pixels, it actually does so. Accepted.

Amendment to the manuscript:

Replaced 'The formal approach seems to retrieve ...' with 'The formal approach retrieves ...'

Page 10, line 13: Please quantify 'majority of the cases', for example by giving the percentage.

Accepted. In order to comply, we calculated biases for retrievals with the formal approach, and compared their absolute value for the same with the dynamic scaling method. We found that, out of 2000 experiments, 1727 (or about 86%) of the retrievals had a lowered absolute bias value from using the dynamic scaling method.

Amendment to the manuscript:

Replaced 'However, the method is able to improve both convergence and retrieval biases for a majority of the cases.' with 'However, the dynamic scaling method improves convergence from 89.3% to 92.3%, and reduces bias for 86.4% of the cases.'

Page 11, lines 22-24: These numbers are provided in Table 4 and need not to be repeated here. If you choose to repeat them, include a reference to Table 4.

Accepted.

Amendment to the manuscript:

Replaced 'The algorithm assumes a cloud fraction of 0.0, and aerosols homogeneously distributed over the entire pixel. The a-priori aerosol optical thickness chosen is 0.8 at 760 nm, the aerosol layer top and bottom pressures are 775.0 hPa and 825.0 hPa, the aerosol single scattering albedo is 0.95 and the aerosol phase function is a Henyey-

Greenstein model with an anisotropy factor of 0.7.' with 'Algorithm settings are detailed in Table 3'.

Page 11, line 32: Table 3 is first referenced after Table 4. Please rearrange.

Accepted.

Amendment to the manuscript:

Replaced referencing of Tables 3 and 4: Table 4, containing algorithm settings, will be referenced before Table 3, which contains validation data location and GOME-2 colocation.

Page 13, line 5: What is your reason for stating that the 'values are not realistic'? The Moscow station may not be representative as the plume is thick and nonhomogeneous (manuscript page 12, line 14.) Have you compared the retrieved AOT values with MODIS AOT? That might shed light on how realistic the retrieved values are.

The retrieved AOT value using the dynamic scaling method over Moscow is 6.60 at 760 nm. With the formal approach, the retrieval does not converge. We did not check with the MODIS AOT value, and instead relied on the AERONET AOD values, which report AOD values of approximately 1.0 at 870 nm and 1.5 at 675 nm (meaning that AOT retrieved at 760 nm must lie in this range).

Amendment to the manuscript:

Please check our response to point 8.

Page 13, line 6: Please give the retrieved AOT values for the Moscow station pixel.

Accepted.

Amendment to the manuscript:

Replaced 'These values are not realistic, since aerosol optical thickness retrieved from the AErosol RObotic NETwork (AERONET) station in Moscow, which falls within one

of the GOME-2A pixels, on the same day observed values between 1.0 at 870 nm and 1.5 at 675 nm between 09:00 UTC and 10:00 UTC.' with 'These values are not realistic - the AErosol RObotic NETwork (AERONET) station in Moscow observed, on the same day, values between 1.0 at 870 nm and 1.5 at 675 nm between 09:00 UTC and 10:00 UTC, whereas our retrieval estimates an AOT of 6.60 at 760 nm over Moscow using dynamic scaling.'

Page 14, line 4: I would replace 'still unrealistic' with 'still high', but see also comment above for Page 13, line 5.

Accepted.

Amendment to the manuscript:

Replaced '... retrieved AOT values are still unrealistic to the scene, the spatial distribution is consistent with the biomass burning plume ...' with '... fitted AOT values are still high to the scene, the spatial distribution is consistent with the biomass burning plume ...'

Page 14, line 18: Please include reference to Table 5, that is, the sentence should end with: ' the 2010 fires is 0.19, see Table 5.'

Accepted.

Amendment to the manuscript:

Replaced ' On average, the LER of this scene from the 2017 fires is 0.15 at 760 nm, whereas the same for the 2010 fires is 0.19.' with ' On average, the LER of this scene from the 2017 fires is 0.15 at 760 nm, whereas the same for the 2010 fires is 0.19, see Table 5.'

Page 15, line 3: Please change 'is to profiles from a' to 'to profiles from a'.

Accepted.

Amendment to the manuscript:

Replaced '... is to profiles from a ground-based ceilometer in De Bilt ...' to '... to profiles from a ground-based ceilometer in De Bilt ...".

Page 16, line 23: Please change 'demonstrated over real' to 'demonstrated for real'.

Accepted.

Amendment to the manuscript:

Replaced 'The dynamic scaling method is also demonstrated over real spectra by using GOME-2A and GOME-2B oxygen A band' with 'The dynamic scaling method is also demonstrated for real spectra by using GOME-2A and GOME-2B oxygen A band'

Page 16, line 29: Please change 'improves' to 'increases'.

Accepted.

Amendment to the manuscript:

Replaced 'The dynamic scaling method, on the other hand, improves the number of converged pixels by 60% in comparison to the formal approach' with 'The dynamic scaling method, on the other hand, increases the number of converged pixels by 60% in comparison to the formal approach'.

Page 16, lines 31: Maybe change 'not realistic' to 'too high'?

Accepted.

Amendment to the manuscript:

Replaced 'The retrieved aerosol optical thickness is still not realistic, but the spatial ...' with 'The fitted aerosol optical thickness is still too high, but the spatial ...'

Page 17, lines 19-22: Your algorithm retrieves AOT and ALH. Here you state that the AOT is not necessarily a realistic value, but rather a diagnostic quality measure. If

the AOT is of diagnostic quality only, how can then the ALH be a realistic value when they both come from the same retrieval? The discussion about AOT over these lines is rather unclear and maybe it is better to just leave it out.

The question about the AOT being a diagnostic quantity compromising the realism behind ALH can be challenged by the fact that the retrieval of ALH depends more on the amount of light absorbed by oxygen, whereas the retrieval of AOT depends on the amount of light scattered back by aerosols. AOT does affect ALH, no doubt, and your concern regarding our discussion of AOT in these lines are well founded. To that extent, we accept to remove discussions of AOT in these lines.

Amendment to the manuscript:

Replaced 'However, the goal of the aerosol layer height retrieval algorithm is to estimate a diagnostic aerosol optical thickness rather than a realistic value. In this case, the dynamic scaling method improves the retrieved aerosol optical thickness's representativity of the aerosol plume over the 2010 Russian wildfires, and hence it's overall diagnostic quality.' with 'In any case, the dynamic scaling method improves the representativity of the fitted aerosol optical thickness of the MODIS Terra observed smoke plume.'

Page 23, Fig. 3, caption: Please include overpass times for the MODIS images.

Accepted.

Amendment to the manuscript:

Replaced '(a) MODIS RGB composite on August 8, 2010 of the 2010 Russian wildfires. The white line represents an approximation of CALIPSO's ground track. (b) Portugal wildfire plume over Western Europe on October 17, 2017. Blue dots represent 12 ceilometer locations.' with '(a) MODIS RGB composite on 08:50 UTC, August 8, 2010 of the 2010 Russian wildfires. The white line represents an approximation of CALIPSO's ground track. (b) Portugal wildfire plume over Western Europe observed

by MODIS Terra on 11:00 UTC, October 17, 2017. Blue dots represent 12 ceilometer locations.'

Pages 24 and 27, Figs. 4 and 7: Please change colour scale range in Figs. 4b,d and 7b,d so it agrees with the height ranges in Figs. 5b and 5d, respectively. As they are, Figs. 4b,d and 7b,d do not show the height structure.

Accepted. We also changed the color map of AOT to distinguish it from ALH.

Amendment to the manuscript: Replaced Figures 4 and 7 with images 1 and 2 included in this response.

Fig 1 (for Figure 4)

Fig 2 (for Figure 7)

Page 26, Fig. 6, caption: Please change 'attenated' to 'attenuated'.

Accepted.

Amendment to the manuscript:

Replaced '... ground track (using great circle distance), plotted over attenated backscatter . . .' with '... ground track (using great circle distance), plotted over attenuated backscatter ...'

Page 28, Fig. 8, caption: The following sentences are repeated twice: 'The red and blue dashed line represents retrieved aerosol layer height using the formal approach and the dynamic scaling method, respectively. The red and blue shaded boxes represent the aerosol layer from the respective retrieval methods.'

Accepted.

Amendment to the manuscript:

Replaced 'The red and blue dashed line represents retrieved aerosol layer height using the formal approach and the dynamic scaling method, respectively. The red and blue

shaded boxes represent the aerosol layer from the respective retrieval methods.' with 'The red and blue dashed line represents retrieved aerosol layer height using the formal approach and the dynamic scaling method, respectively.'

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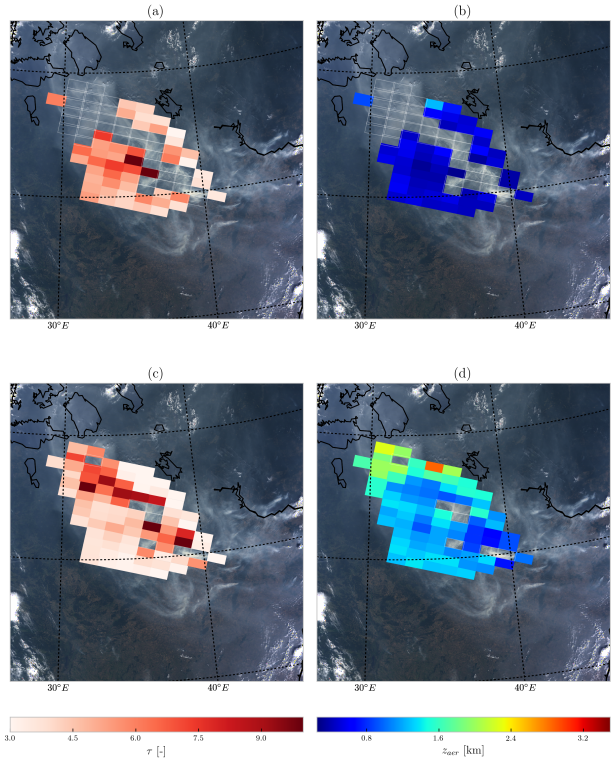

Fig. 1.

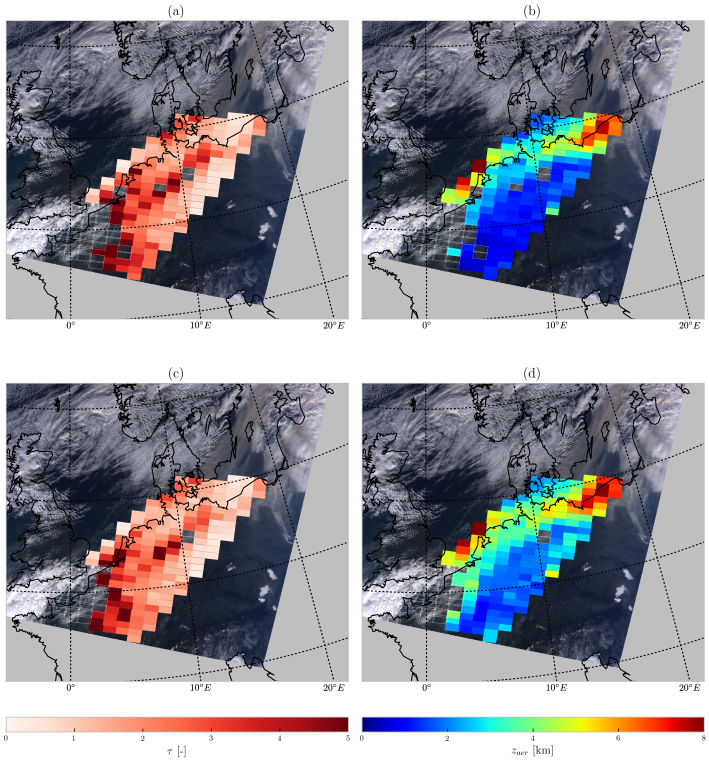

Fig. 2.