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Author response to reviews

Mok et al., “Comparisons of spectral aerosol absorption in Seoul, South Korea”

[Reviewer comments are in black, responses in red]

Anonymous Referee #1

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This manuscript by Mok et al., "Comparisons of spectral aerosol absorption in Seoul, South Korea", presents a comparison of SKYNET-retrieved SSA in the UV with the SSA derived from a combination of AERONET, MFRSR, and Pandora retrievals in Seoul, South Korea in spring and summer of 2016. There have been only a limited number of measurements / measurement campaigns focusing on absorption at UV wavelengths, therefore, the topic of this study is of great interest and relevance. The scope of the paper is both concise and specific, and my minor comments are mainly related to the need to clarify some of the issues.

We thank the reviewer for the positive assessment and summary

Before publication, the following points should be addressed:

GENERAL COMMENTS:

I was missing some more information and details about the measurements, for instance

regarding the following two points.

1. Figure 5 (and 7) shows a large variability for each SKYNET mean value, so apparently it is shown based on several measurements within 32 minutes, but what is the temporal resolution of SKYNET measurements? I think this was never mentioned.

Like the AMP retrievals, we used the same temporal resolution of the SKYNET measurements, which are averaged within ±16 minutes from the AERONET retrieval time for consistency.

For the clarification, we added the following statements at Page 3, Line 22:

"are retrieved every 10 minutes using standard processing software SKYRAD.pack"

The data shown in Fig. 5 and Fig. 7 are ±16 minute averages around AERONET inversion time for both MFRSR and SKYNET.

We clarified in the caption of Figure 5:
"Figure 5. Comparisons of AMP-retrieved with SKYNET-retrieved SSA (±16 minute average)"

2. Page 9, Line 25, here solar aureole corrections are mentioned. Please include few sentences to explain this correction in some detail. Also, this same issue applies also, to some extent, to Cimel measurements (diffuse light in FOV). Could you discuss the relative importance of this kind of uncertainty in both measurements?

We agree with suggestion. We added the following sentences on page 9 after line 26:

"The aureole correction is less important to the AERONET measurements because of the small FOV ~ 1.2^{o} (Sinyuk et al., 2012) than to the shadowing measurements from MFRSR (Krotkov et al., 2005a). The empirical MFRSR aureole correction (Harrison et al., 1994) tends to underestimate aureole contribution to the diffuse irradiance for coarse aerosol particles and cirrus clouds (Min et al., 2004; Yin et al., 2015)."

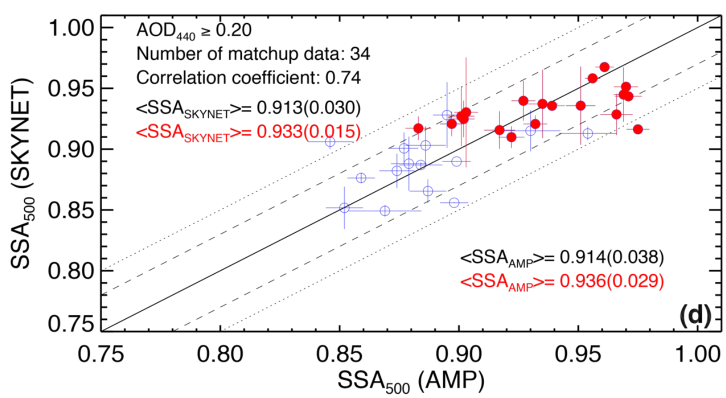
Sinyuk, A., Holben, B. N., Smirnov, A., Eck, T. F., Slutsker, I., Schafer, J. S., Giles, D. M. and Sorokin, M.: Assessment of error in aerosol optical depth measured by AERONET due to aerosol forward scattering, Geophys. Res. Lett., 39, L23806, doi:10.1029/2012GL053894, 2012.

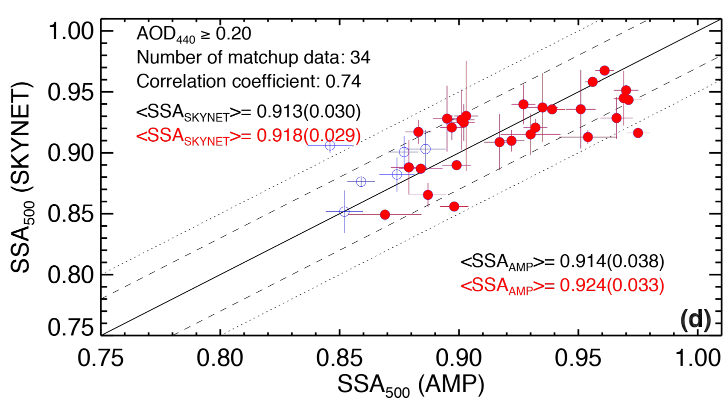
Min, Q. L., Joseph, E. and Duan, M.: Retrievals of thin cloud optical depth from a multifilter rotating shadowband radiometer, J. Geophys. Res., 109, D02201, doi:10.1023/2003JD003964, 2004.

Yin, B., Min, Q. and Joseph, E.: Retrievals and uncertainty analysis of aerosol single scattering albedo from MFRSR measurements, J. Quant. Spectrosc. Radiat. Transf., 150, 95-106, doi:10.1016/j.jqsrt.2014.08.012, 2015.

3. The focus of the paper is on UV wavelengths and thus one should not perhaps concentrate too much on the longer wavelengths, however I cannot help wondering about the comparison in the Figure 5 and at the wavelengths > 400nm. Now the explanation was given that the larger scatter is due to the lower AOD and related larger uncertainty. However, it is not only the larger scatter, but also the systematic behavior that stands out, e.g. at 500 nm for largest AOD (red points) SKYNET is showing very little SSA variability. SKYNET value is close to 0.93, when AERONET SSA varies from 0.88 to 0.98. AOD is not very low in these cases at 500nm, when it is larger than 0.4 at 440nm. Is there any idea why this happens?

As a reviewer mentioned, the SSA_{500}(SKYNET) values are ~0.909 to ~0.968, whereas the SSA_{500}(AMP) values are ~0.883 to ~0.975 in Figure 5(d), thus SKYNET SSA values show less variation compared to AMP SSA at 500 nm. However, the amount of data for comparison with $AOD_{440} \geq 0.4$ is only 19. Therefore, it is difficult to determine if this variation is significant with such a small number of data points. For example, if we change the AOD threshold from 0.4 to 0.3 and comparisons have more matchup samples, the SKYNET SSA shows similar variations as below.





(upper panel) original Figure 5(d). Red dots are filtered using $AOD_{440} \geq 0.4$.

(lower panel) same with Figure 5(d) except red dots are filtered using $AOD_{440} \geq 0.3$

Similar pattern and poor agreement seems to be true also at 675nm. Also, the vertical error bars are sometimes strikingly large. In your Figure 8 you show that AODs match well, so what could be the main reason to cause a variability this large SSA variability within a short period of measurements?

The horizontal bars in Fig. 5 and 7 show estimated uncertainties of the AMP SSA mean values (i.e. excluding natural variability) within ±16 minute time window. Because SKYNET retrievals do not provide SSA uncertainties for the individual retrievals, the vertical bars show one standard deviation of the SKYNET retrieved individual SSA values within ±16 minute time window (i.e. including natural variability). Natural SSA short-term variability makes vertical bars typically larger.

We added clarification in the captions of Fig. 5 and Fig. 7.

"The horizontal bars show estimated uncertainties of the AMP SSA mean values (i.e. excluding natural variability) within ±16 minute time window. The vertical bars show one standard deviation of the SKYNET retrieved individual SSA values within ±16 minute time window (i.e. including natural variability)."

4. Page 9, Lines 14-26. Here are several possible explanations given for a larger scatter between AERONET and MFRSR-based SSA (Figure 3b and 3c), if compared to UV-MFRSR and VIS-MFRSR (in Figure 3a). Could you please discuss the potential sources of absolute difference as well. For instance, your points 1 and 2 would both contribute so that MFRSR SSA is larger than AERONET SSA. Now, the scatter includes mainly points when MFRSR SSA is smaller than AERONET SSA. So a quantitative discussion about the possible sources of systematic biases, which differ between these measurements, would be helpful for the reader to better understand not only the scatter, but also the mean overall differences.

We agree with suggestion. We added the following quantitative discussion at the end of page 9:

"The aureole correction is less important to the AERONET measurements because of the small FOV ~ 1.2^{o} (Sinyuk et al., 2012) than to the shadowing measurements from MFRSR (Krotkov et al., 2005a). The empirical MFRSR aureole correction (Harrison et al., 1994) tends to underestimate the aureole contribution to the diffuse irradiance for coarse aerosol particles and cirrus clouds (Min et al., 2004; Yin et al., 2015). The aureole undercorrection causes systematic underestimation of the diffuse irradiance and retrieved SSA by the MFRSR. Quantitatively, the bias varies for different locations: e.g., from +0.004 at the Santa Cruz, Bolivia (Mok et al., 2016) to -0.005 in Greenbelt, Maryland with fine mode dominated aerosols (Krotkov et al., 2009). We estimate that aureole SSA bias should be less than ~0.01 at Seoul."

5. Related to the above point and to your first point (fractional clouds). Would you see a reduced scatter between MFRSR and AERONET SSA, if you narrowed the 32 minutes averaging window? Given your arguments there, it should happen, so perhaps the role of this effect can be estimated?

Although the MFRSR can provide 1-miniute retrievals of SSA, the AERONET standard (Dubovik) algorithm requires 32 minutes of the almucantar scan time to retrieve SSA. So, it is not possible to narrow the 32 minutes averaging window for comparison between MFRSR and AERONET SSA.

SPECIFIC COMMENTS:

6. Figure 7, you list the wavelengths there in the caption, 673/675nm is missing.

We do not include 675 nm in the caption on purpose. As L4 in Page 11, the spectrally invariant SKYNET-assumed surface albedo~0.1 is close to the AERONET surface albedo at 675 nm (Figure 6). Thus, we do not re-process the SKYNET inversion at 675 nm.

For the clarification, we added the following sentence in the caption of Figure 7:
SKYNET SSA at 675 nm is the same with Figure 5(e).