Response to Referee #3:

The authors greatly appreciate the helpful comments of the two referees. In the following, we present our point-by-point responses to the Referee #3. The referees' comments are in blue italic and our responses are in black. We have made appropriate changes in the revised manuscript by taking the comments into account.

Overall evaluation:

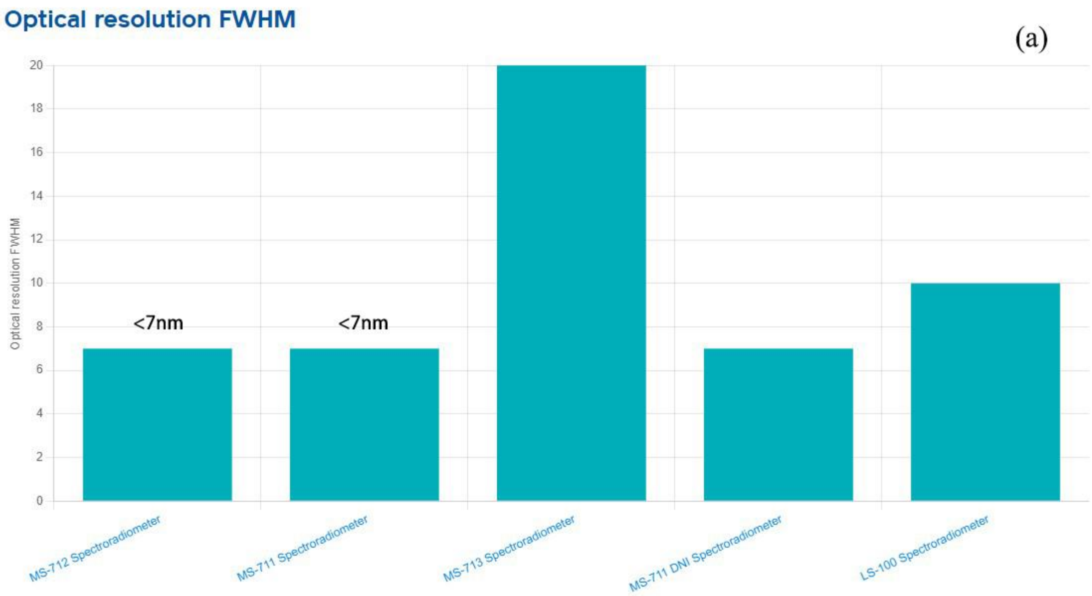
The work of Qiao et al., focuses on the PWV and AOD retrievals of EKO MS711 and MS712. The method presented is based on methods of other instruments, but it is novel and since the spectral measuring instruments are becoming more popular, will become valuable in the future and fits the scope of AMT. However, the manuscript is poorly written, a lot crucial information for the reproducibility of the methodology are missing and the validation of the retrievals is very shallow. Hence, I suggest to be considered for publication after major changes.

Responses: We greatly appreciate your valuable comments on our submitted manuscript. According to your comments, we have carefully revised the manuscript. The item-to-item responses to your comments are as follows.

Specific comments

1. The two instruments are considered as one for most of the manuscript. I think it should be separated and make clear what is the performance of each one. Since the area around 940nm is overlapped by both them, the comparison of the measurements should be presented. Also, the different spectral steps and FWHM will result to very statistics in the validation process. It is crucial to present that, since the instruments are usually sold and installed separately and also in case of parallel operation, a decision should be made for the overlapping region. Finally, in section 2 more details should be mentioned such as the calibration of the instruments, the reported uncertainty and their measuring schedules. Specially, the calibration of the spectral bands is very *important and could lead to high deviations for the algorithm. Is there any wavelength shift? How are the spectral channels characterized?*

Response: Thank you for your comment. We reconfirmed that the radiometric measurements used in the 900-990 nm band are from MS711 recorded data. We found the relevant descriptions of the FWHM and wavelength accuracy of MS711 and MS712 from EKO Instruments official website. As can be seen from Figure 1(a) and (b), the full width at half maximum of both is <7nm, and the wavelength accuracy of both is ±0.2nm, so the wavelength drift hardly affects the inversion results. In addition, we contacted EKO in Japan and obtained the calibration certificates of MS711 and MS712. From the certificates, we learned that both instruments were accurately calibrated in Japan in 2018. The uncertainty of calibration is shown in Table 1. we performed a specific analysis of the inversion uncertainty due to the calibration uncertainty in Sect. 4 of the submitted manuscript.



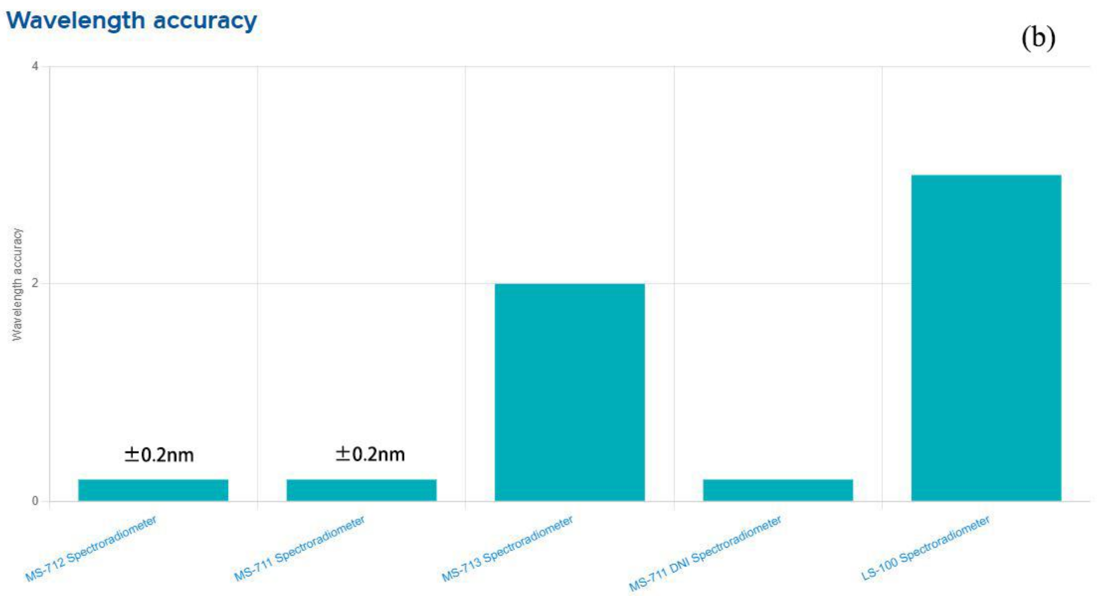


Figure 1 FWHM (a) and wavelength accuracy (b) of MS711 and MS712 (https://www.eko-instruments.com/us/categories/products/spectroradiometers/ms-711-spectroradiometer)

Table 1 MS711 and MS712 calibration uncertainty

Spectroradiometer	Wavelength range	Uncertainty
MS711	300nm – 350nm	±17.4%
	350nm – 450nm	±5.1%
	450nm – 1050nm	±4.2%
	1050nm – 1100nm	±5.3%
MS712	900nm – 950nm	±4.52%
	950nm – 1600nm	±4.84%
	1600nm – 1700nm	±23.67%

2. L75-80 More details should be provided on the cloud screening procedure. How effective was it? Give a figure showing the cloud screen data and discuss the results.

Response: Thank you for your comment. We have added details related to cloud screening in Sect. 3.1 of the manuscript, drawn the graphs of cloud detection instances, and discussed the detection effect.

3. It is implied that the radiative transfer model used is MODTRAN. Please, add a section in 2, about the model, the setup, the selection of variables and the bibliographical accuracy.

Response: Thank you for your comment. We added the detailed parameter settings of the mode and the corresponding bibliography as the table 2 in the Sect. 3.2. (Lines 145-149)

Table 2 The input parameters to the MODTRAN mode used in this work.

Parameters	Input	Reference
Boundary Aerosol Model	No aerosol or cloud attenuation	——
Atmosphere profile	US Standard Atmosphere	NOAA. (1976)
Altitude	0.05 km	——
Slit function	Gaussain function, with FWHM of 6.5 nm	——
Radiative transfer	DISORT	Stamnes et al. (1988)
Solar flux	Kurucz (0.1 nm resolution)	Kurucz (1994)

4. In general the 1370 absorbing window is more sensitive to PWV changes, but the Direct Irradiance signal at this spectral range is a lot lower. Hence, before using it, signal to noise ratio for the instrument should be discussed and the expected uncertainty should be estimated.

Response: Thank you for your comment. We use MODTRAN mode to simulate and find that when the PWV is greater than 3cm(SZA=0°), the water vapor transmittance at 1370nm is zero, so theoretically the measurement value of the instrument at 1370nm should also be zero, if not, it is considered to be the measurement noise of the instrument at 1370nm. Therefore, we use the mean value of the measurements at 1370nm corresponding to the PWV inversion value greater than 3.5cm as the background noise signal and estimate that the SNR of the band near 1370nm used for inversion of PWV in a dry environment is greater than 60. In addition, uncertainty analysis for water vapor inversion in the band around 1370 nm is added in Sect. 4 of the manuscript.

5. L103/figure 4. This approach should be discussed thoroughly and the results need to be evaluated.

Response: Thank you for your comment. We have added a description of the method in the manuscript (lines 131-153), and then the water vapor inversion efficiencies of the two water vapor absorption bands were compared and analyzed. (lines 154 -164)

6. L117 Results showed in figure 5 are not enough to prove that one band is more efficient than the other. We don't know what is the testing sample, how representative is and all other effects on the measurements are already eliminated. A discussion leading to figure 5 is clearly missing.

Response: Thank you for your comment. I am very sorry that our explanation of this part is not clear enough in the previous manuscript. In order to test the PWV retrieval efficiency of BAND1 and BAND2, the spectral curves used in our test are based on MODTRAN simulations with random noise added afterwards. In spectral simulations, the US standard atmospheric model was used with random PWV between 0-0.5 cm, and solar zenith angle between 0°-30°, regardless of cloud and aerosol. Then the simulated spectral was superimposed a random noise of ±5 % on each wavelength to generate the test spectral curves. Figure 2 shows the results of the inversion test using the two bands, the PWV retrievals of the band near 1370nm are closer to the input PWV when the spectrum is simulated, and it is more stable, which demonstrates that the band around 1370 nm may be more suitable for water vapor retrieval in dry atmosphere than the band around 940 nm for the water vapor inversion using the method in Sect. 3.2.

The result plot of the inversion test is different from Figure 5 in the previous manuscript because noise was previously added to the overall spectrum of the MODTRAN output. When checking the manuscript, considering that this was not reasonable, we redid the inversion test and added noise on each wavelength of the mode output spectrum.

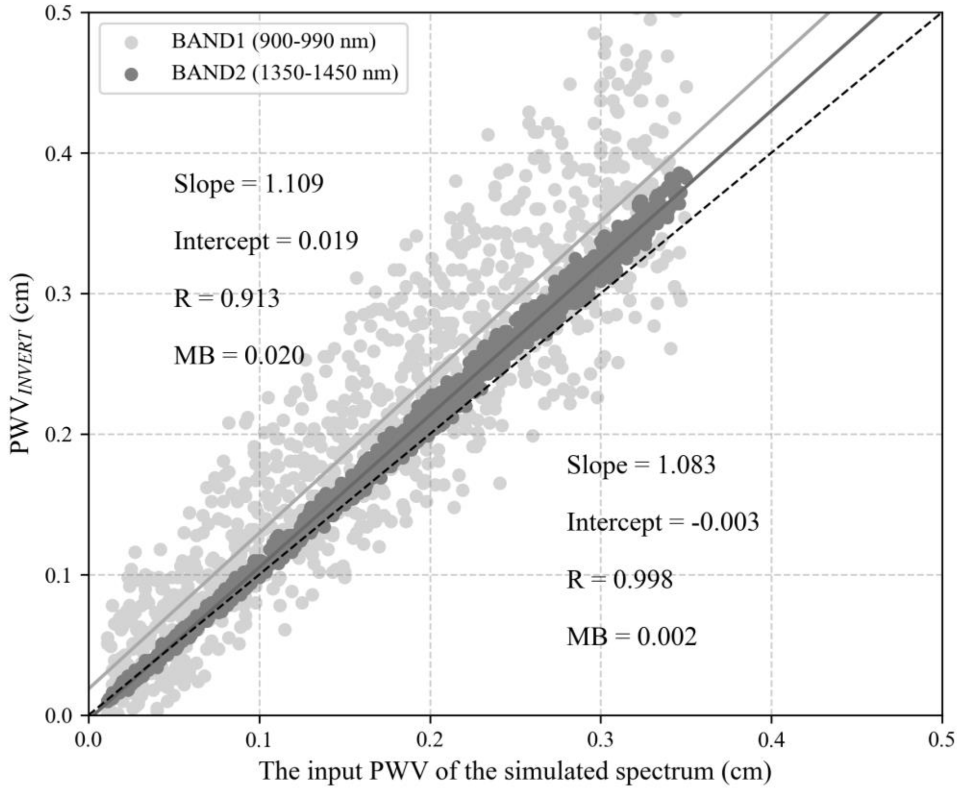


Figure 2. Scatter plot of the water vapor retrievals obtained from BAND1 and BAND2 of the test spectrum versus the input PWV of the simulated spectrum and their linear fits.

7. 3.2 It is not clear at which wavelengths this inversion will be used. It is a odd to name this aod inversion in general, since it is not valid for the most wavelengths (where other gases absorb). I suggest to focus in water vapor bands and close bandwidths and just calculate aod for those and keep the full aod inversion for future work that will include more trace gases.

Response: Thank you for your comment. We have added Figure 3 to Section 3.3 of the manuscript, marking the wavelengths used for AOD inversion, specifically those with transmittance greater than 0.999 excluding Rayleigh scattering and continuous absorption by water vapor. The AOD for other wavelengths are obtained by high-order fitting. In addition, thanks for your suggestion, we have stated in the article that the EKO instruments have the potential to provide spectral AOD, and we are also considering your suggestion to use the spectral AOD of this instrument for ohter trace gases retrieval.

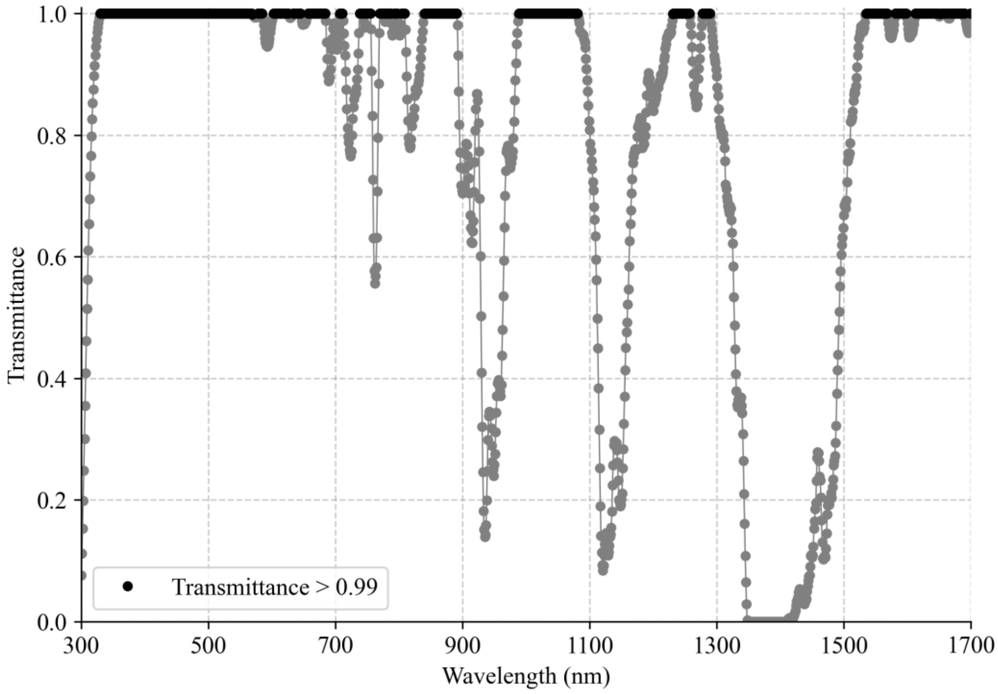


Figure 3. The transmittance without Rayleigh scattering and continuous water vapor absorption in the EKO band simulated by MODTRAN, where the transmittance value greater than 0.999 is marked in black, and the rest are marked in grey.

8. L139 these uncertainties should be discussed and estimated in a separate section. Also, the fact that is compared with CIMEL retrievals, which was found in other studies to drift above 70º sza.

Response: Thank you for your comment. We have added a section to the manuscript to estimate the uncertainties of water vapor and aerosol retrievals. Since we use the physical method for inversion, it is not convenient to use the conventional error propagation method to measure the uncertainties, therefore, we use another approach to estimate the uncertainties, which is described in Sect. 4 of the manuscript. In addition, some explanations are added for the increase of the difference between the EKO PWV retrievals and the CIMEL PWV retrievals when the zenith angle is greater than 70°. (Lines 223-226)

9. "here we say", I don t understand this phrase.

Response: Thank you for your comment. The phrase has been removed, and the article has been carefully checked for grammar and expression.

10. Figure 7 discussion. It is clear that band 2 is underestimating PWV constantly. It is more like a constant bias of 0.02 between the two bands. So this seems more a calibration issue (between the model and the instrument) than a systematic error of the method.

Response: Thank you for your comment. We also found such an underestimation. From the calibration certificate provided by EKO Instruments, we see that the calibration uncertainties for the two bands used for water vapor inversion are not very different, which are ±4.2% and ±4.84%, respectively. In addition, when using EKO data, the PWV retrievals of BAND2 is lower than that of BAND1, which is consistent with the result of the inversion test using the test spectrums, however, the added uncertainties on BAND1 and BAND2 of the test spectrums are the same. Therefore, we speculate that such underestimation is not caused by the calibration differences, and certainly cannot be completely excluded from differences in MS711 and MS712.

11. Figure 2.L82 This figure does not show water vapor absorption windows. It is just two random measurements. Do we know that there was different PWV at these days? Figure 3 Clearly shows the windows, but the figure 2 has no use at this version of the manuscript.

Response: Thank you for your comment. This figure has been deleted from the manuscript.

12. Figure 3. I don't understand the purpose of visualizing cimel filters. Also, the aerosol line, corresponds to a specific AOD (which will change the transmittance). Please change the legend to the actual AOD value. Also, move the legend to a position that does not hide the drop at 1300-1500nm.

Response: Thank you for your comment. Referring to your suggestion, we have changed the original Figure 3 to Figure 4. The spectral response curves of the CIMEL filters in the figure are drawn to show the position of the CIMEL measurement band more intuitively.

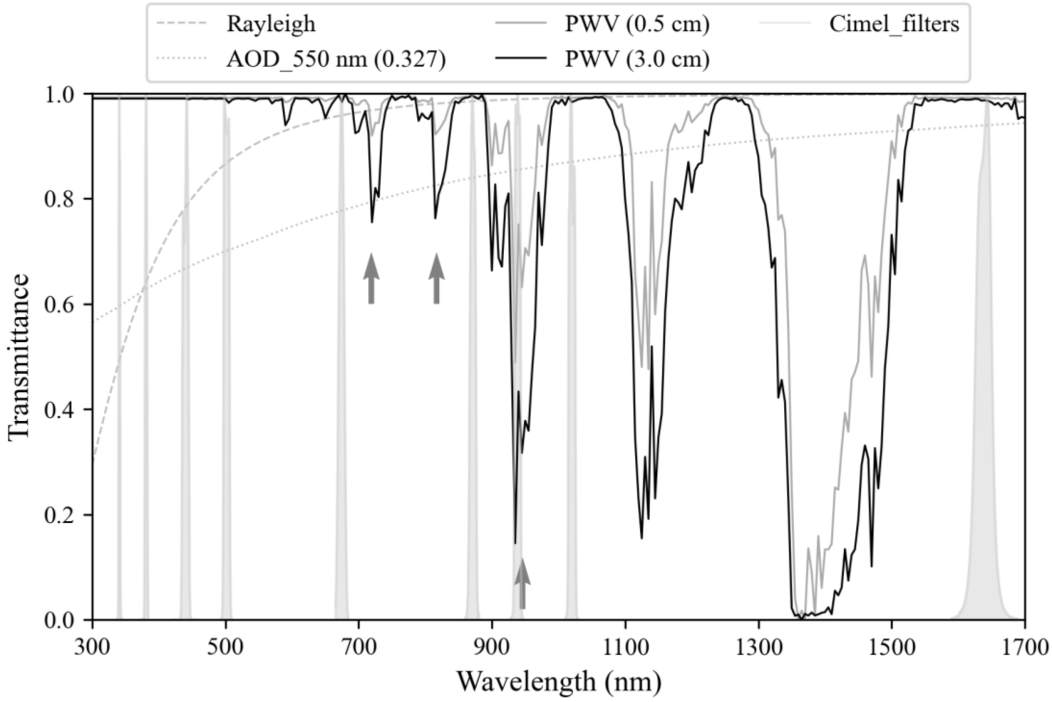


Figure 4. The spectrum response curves of CE-318 photometer's filter wheels, and the transmittance of water vapor, aerosols and Rayleigh scattering in the spectral range of 300–1700 nm, which are calculated by MODTRAN4.3 at SZA=0°, PWV=0.5 cm, PWV=3.0 cm and Boundary Aerosol Model=Rural extinction(spring-summer), VIS=23 km. The wavelengths pointed by the grey arrows represent WMO recommendations for PWV retrieval.

13. Figure 4. Describe better at the caption. Information on how these spectra were retrieved.

Response: Thank you for your comment. We have changed the original caption **"Figure 4. Direct normal solar irradiance reaching the surface, I, the irradiance after removing water vapor absorption, I_1, and the solar irradiance at the top of the atmosphere, I_0."** to **"Figure 4. Direct normal solar irradiance reaching the surface (I), the solar irradiance at the top of the atmosphere (I_0), and the irradiance after approximately removing the water vapor absorption by interpolating the baseline points outside the water vapor band (I_1)."**

14. Figure 5. What are the "real values"? If it is CIMEL retrievals, keep in mind that previous studies showed that CIMEL was the most erroneous from all the methods (GPS, radiosondes, microwave radiometer).

Response: Thank you for your comment. Figure 5 in the original manuscript shows the results of examining the water vapor inversion efficiency of BAND1 and BAND2 using the test spectrums. Here "real values" refers to the water vapor input values when simulating the spectrums. Considering the inappropriate use of the language, we made a change from "real values" to " The input PWV of the simulated spectrum".

15. Figure 8. It is not wise to provide spectral AOD, when all the trace gases but the water vapor are ignored.

Response: Thank you for your comment. It is indeed unreasonable to provide the AOD of the spectrum ignoring the absorption of gases other than water vapor, so we have added some clarifications to the manuscript in conjunction with your suggestion and changed Figure 8 in the previous manuscript to the following figure. (Lines 240-247)

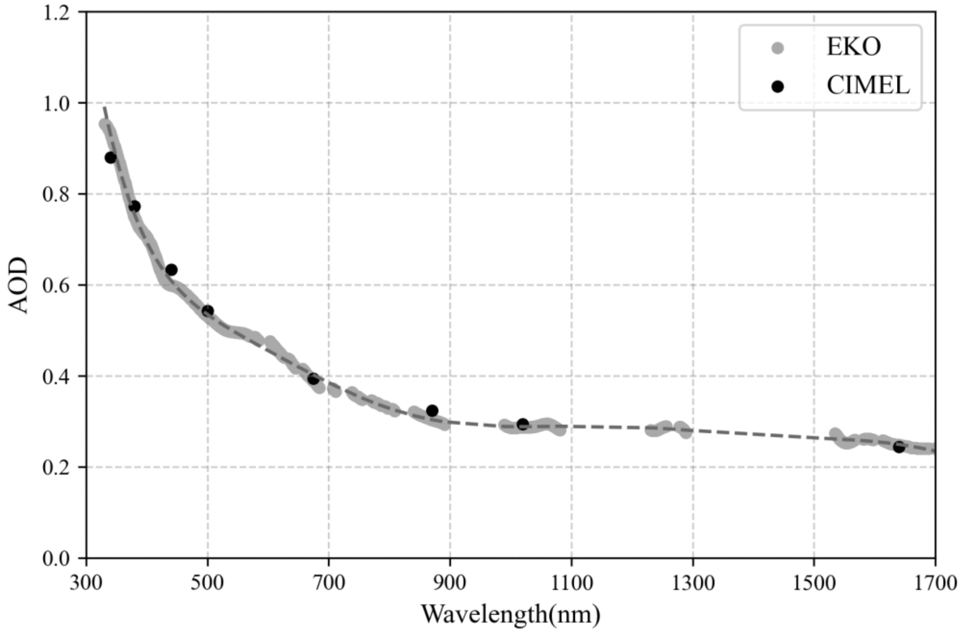


Figure 5. The AOD was retrieved by EKO and provided by AERONET-CIMEL on 06 June 2020 (15:22 UTC+8), the dashed line is the spectral AOD obtained by the AOD_{EKO} high-order fitting.