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Supplement of

Effect of water vapor on the determination of aerosol direct radiative effect based on the AERONET fluxes

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Sect. S1 Comparison of the analysis with measured and the AERONET-modeled fluxes

In order to confirm that the AERONET-modeled fluxes are adequate to the purpose of our study, we additionally conducted the analysis in two sites, Alta-Floresta and Goddard Space Flight Center (GSFC), by using pyranometer measurements. The maximum time difference between the AERONET fluxes and the measured fluxes is 5 minutes, otherwise the thresholds are the same as described in the study. The analysis here is done for GSFC and Alta-Floresta in 2006 and for SZA=60±1.5 degrees. The results are shown in Figs. S1 and S3; ADRE is approximately the same for the measured and the AERONET fluxes, with no significant difference and therefore same conclusions can be drawn from both analysis. In Fig. The lower panel of S1, the average AERONET F^0 is shown for GSFC with the red cross. The intercept term of the linear regression gives a result that is close to the red cross, thus giving ADRE in a close agreement with the AERONET based ADRE, demonstrating the WVC effect. Indeed, as Fig. S2 shows (from GSFC data set) WVC increases with increasing AOD and the change is significant; from below 0.5 cm to above 4 cm, while AOD changes from below 0.1 to above 1.0. Fig. S3 shows the analysis for Alta-Floresta, providing essentially the same conclusion.

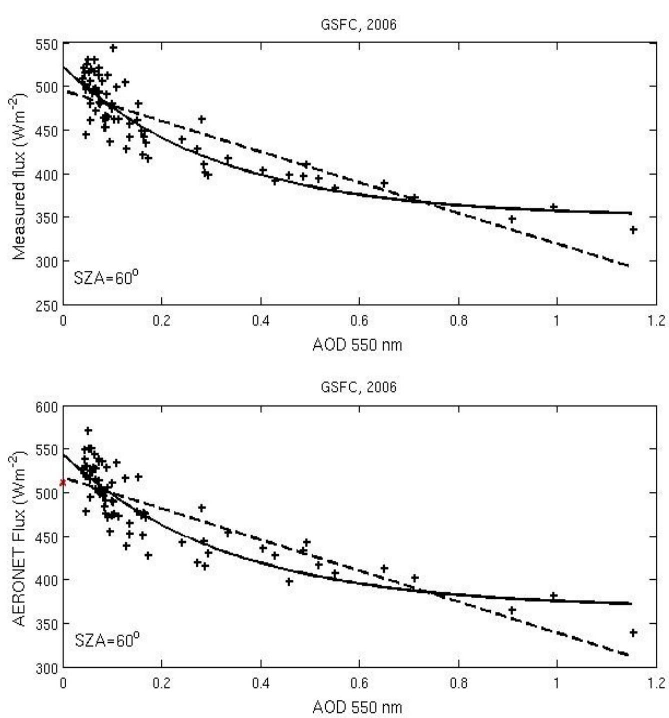
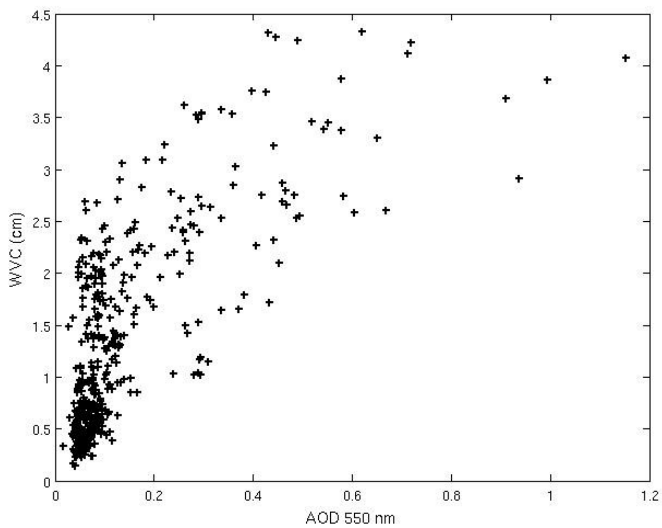


Fig. S1: Measured fluxes (upper sub figure) and the AERONET fluxes (lower sub figure) as a function of AOD with the regressions (nonlinear and linear) in GSFC 2006.



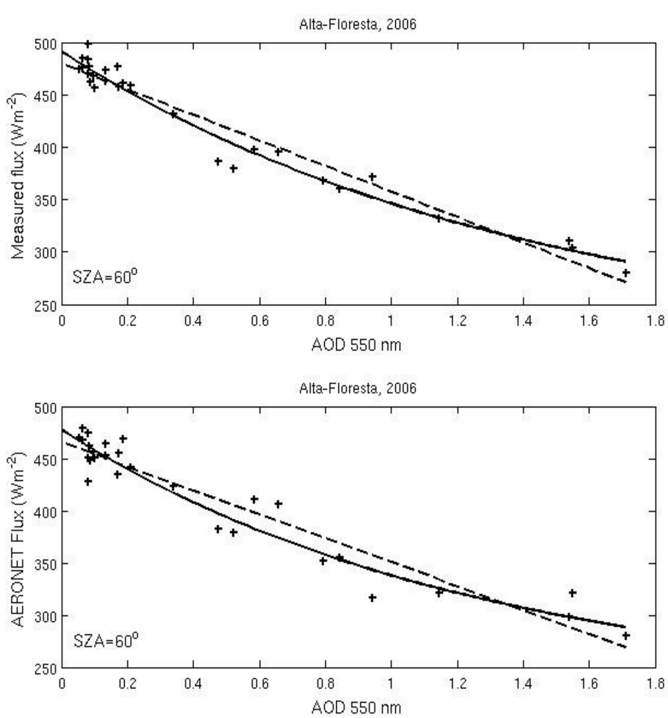


Fig. S2: AOD and WVC observations from GSFC data set.

Fig. S3: The same as in Fig. S1, but for Alta-Floresta.

Sect. S2 The results divided by the main aerosol optical properties and surface reflectance

We extended the analysis by dividing the results by aerosol optical properties and surface reflectance. First, we want to clarify that our Figures 3 and 4 do not cover the same sites; Figure 3 includes the sites in our analysis, while the Figure 4 shows the WVC and AOD correlation and we created it by including all the AERONET sites. By applying our criteria, the high latitude sites were not included, likely due to our requirement to have AOD range of 0.1 – 0.3. Thus, unfortunately we could not focus in more detail on the sites with high surface reflectance in the selected data set. Nevertheless, we investigated the possible AOD and albedo correlation of all the sites, by relaxing our requirement of 0.1-0.3 AOD range and found that albedo does not change significantly as a function of AOD. From the extreme cases (out of entire AERONET data set) we estimated the largest albedo change to be from 0.10 to 0.25 as a function of AOD, while WVC can vary from 5 to 25 mm as a function of AOD. Then we calculated F^0 with varying albedo (0.10-0.25) by libRadtran (Mayer and Kylling, 2005) and got a change of 5 Wm^{-2}. At the same, varying WVC (5-25 mm) resulted in a change of 40 Wm^{-2} (these estimates were modeled for SZA=60 degrees). Thus, we argue that in addition for being rare, the cases of AOD vs albedo changes would not induce a significant bias in the ADRE estimation. Our purpose was to investigate the possible correlations between AOD and any other variable that could influence the method to estimate ADRE, which assumes that the conditions stay stable and only AOD is changing. We found significant correlations only between AOD and WVC, not e.g. between AOD and surface reflectance. Figs. S4 and S5 show our results classified by the following parameters, SSA, ASYM, AOD and albedo (shown by the color bars, otherwise the figures are as the Figure 3), for the nonlinear and the linear method. It is evident that none of the other parameters separates the results as clearly as WVC in the Figure 3. In addition, Fig. S6 shows the results divided into surface reflectance (albedo) below 0.3 and above 0.3.

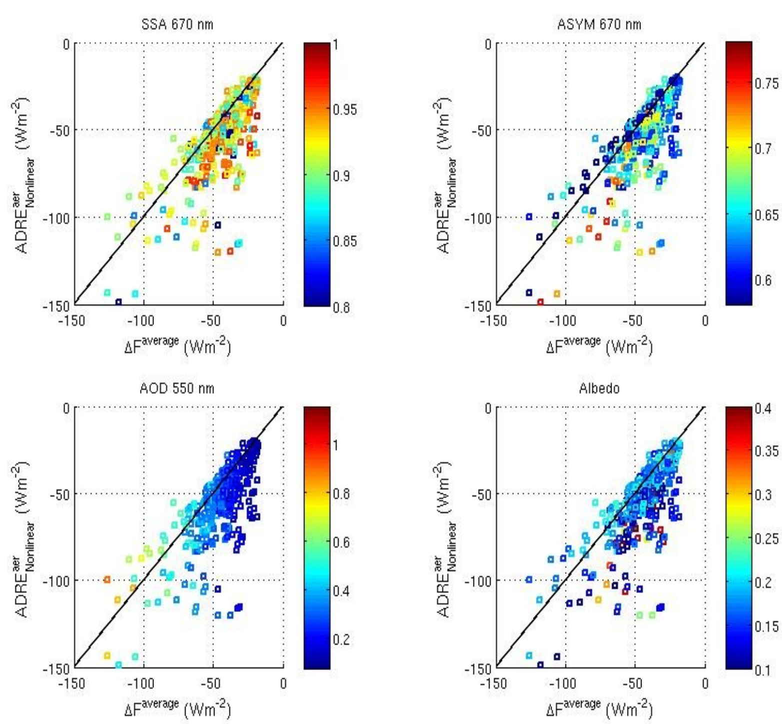


Fig. S4: ADRE

estimated with the nonlinear decay compared with the baseline for the main optical properties (AOD, SSA and ASYM) and surface albedo indicated with color bar.

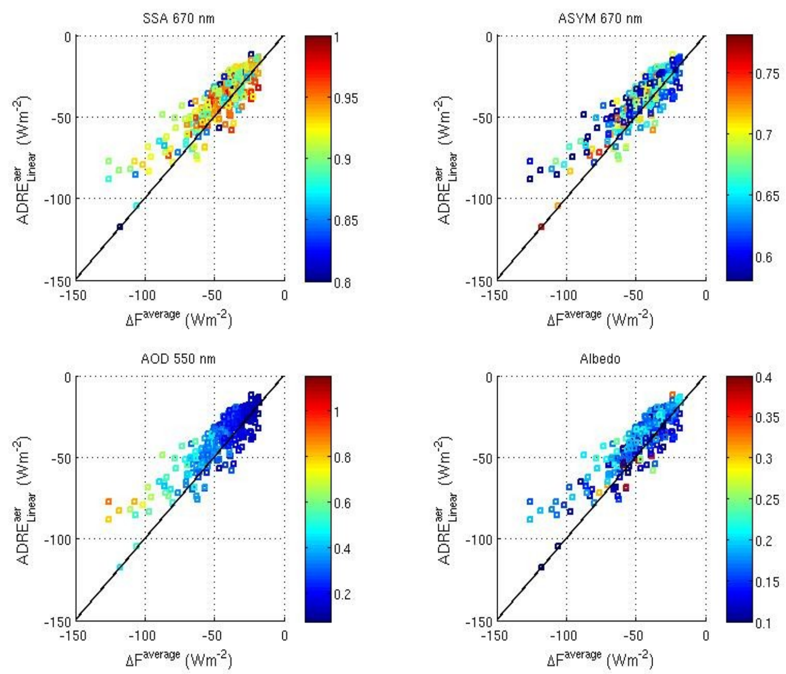


Fig. S5: The same as in Fig. S4, but for the linear regression.

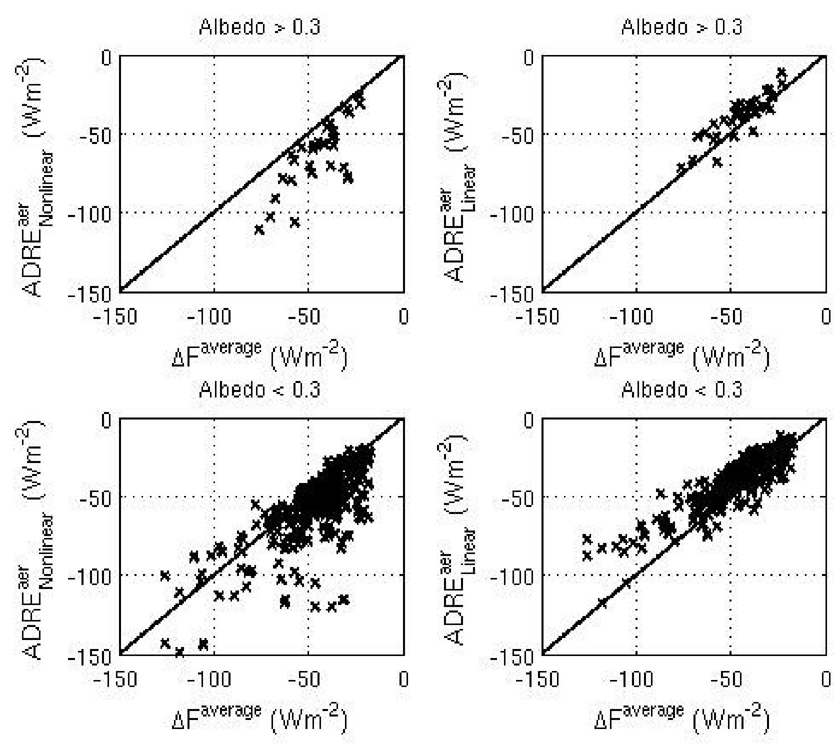


Fig. S6: The results of the study divided by albedo; above 0.3 and below 0.3.

Sect. S3 Corresponding ADRE analysis with limited wavelength range

We estimated the possible WVC effect by limiting broadband flux to the wavelength range containing no significant water vapour absorption. This was done with libRadtran code. In these RT model runs the following input was assumed: NewGuey's 2003 solar file (Gueymard, 2004), the correlated-k Kato method, the atmosphere profile for mid-latitude summer conditions, constant albedo of 0.15, altitude was set to 0 km, aerosol-default from libRadtran for the aerosol setup, varying AOD from 0 to 1.4 (constant as a function of the wavelength) and varying WVC from 0.5 cm to 1.9 cm, increasing 0.1 cm with each change of 0.1 in AOD. This was done for the broadband flux range 310 nm -2800 nm (as e.g. pyranometer measures) and for short wavelength only, 310 nm -500 nm, thus without significant water vapour absorption. For each simulation, also F° was calculated. Figs. S7 and S8 show the results for SZA varying from 0 to 75 degrees with 15 degree interval including fits by the nonlinear and linear method; if the broadband flux (310-2800 nm) is considered (Fig. S7), the WVC effect exists. On the other hand, Fig. S8 shows the analysis with limited wavelength range; the WVC effect is now removed and the nonlinear regression method finds the baseline F° better than the linear method, while the linear approach systematically underestimate F°. Thus, the WVC effect vanishes by limiting broadband flux to wavelength ranges containing no significant water vapour absorption.

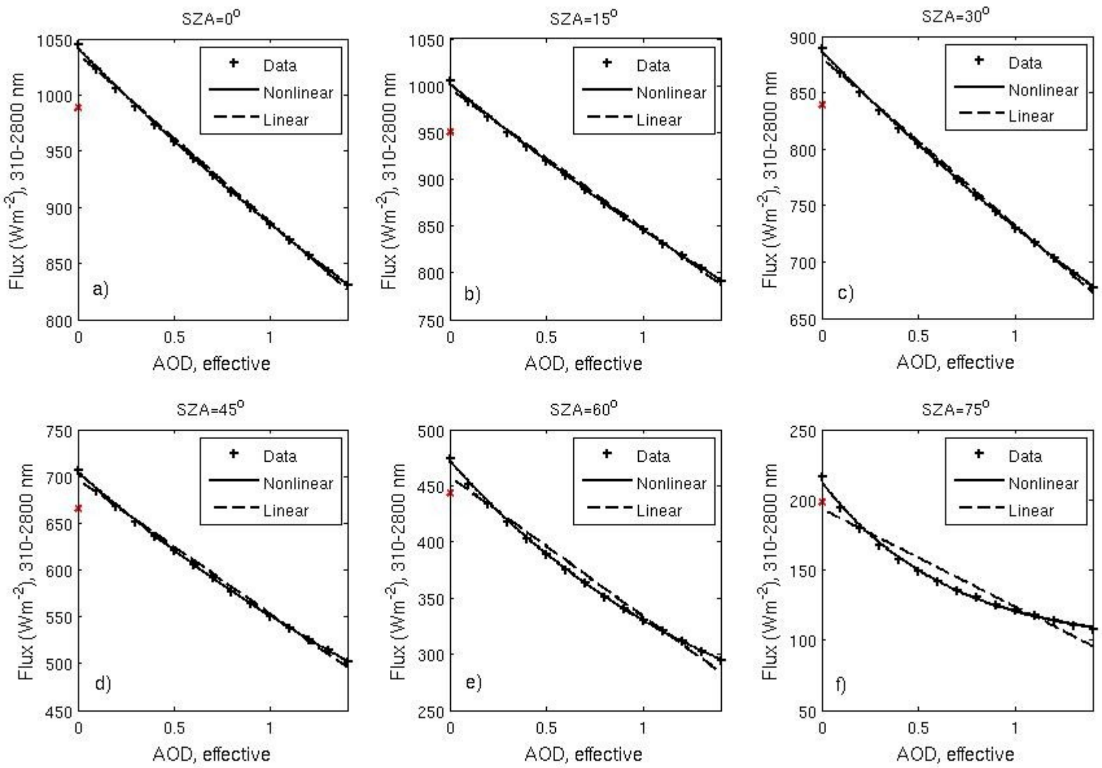


Fig. S7: Surface solar flux as a function of AOD for varying SZA. Red crosses indicate simulated, baseline, F° averaged over AOD range for subplots. The fits represent the nonlinear(continuous) and the linear method (discontinuous).

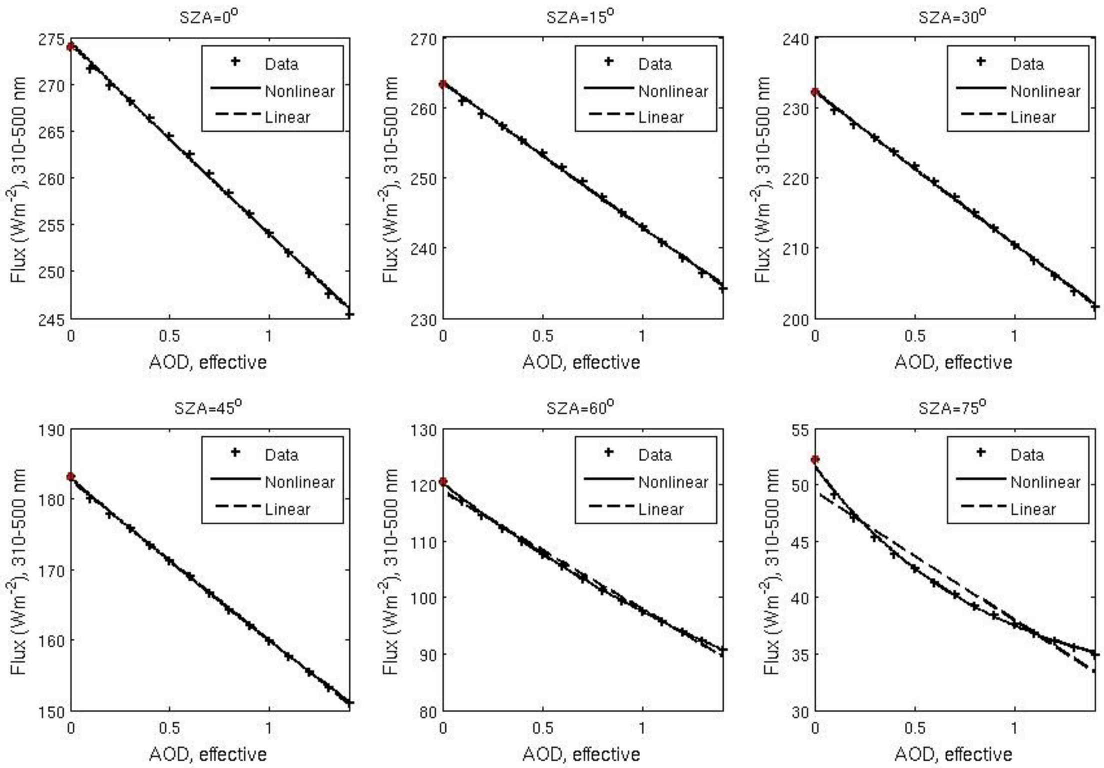


Fig. S8: The same as Fig. S7, but solar flux is limited to the range 301-500 nm without significant WVC absorption.

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