Author response on “Effect of water vapour on the determination of Aerosol Direct Radiative Effect based on the AERONET fluxes” by J. Huttunen et al.

First of all, the authors express thanks for the comments. Changes to the paper based on the comments are marked in the revised reviewers' version with blue. The response is below with the reviewer comments in italics.

Anonymous Referee #1

1.) *My main concern for this sensitivity study of calculations of ADRE is the fact that all modeling work of the study is not described in detail since it is AERONET based. There, a number of assumptions about spectral dependence of aerosol extinction, absorption, profiles, extraterrestrial spectrum used e.t.c. that are not described and more or less are assumed that include no uncertainties (investigating some systematic ones here) on the AERONET Fzero calculations. In addition to the previous comment, since the paper discusses absolute solar radiation differences, the absolute uncertainties of AOD, SSA, WVC AERONET retrievals should be discussed in such a study.*

1.) Indeed, the AERONET-based modeling approach was not discussed in much detail. Therefore, in the revised version we have added more details both on the RT modeling and on the uncertainties of AERONET products.

As an example: AERONET radiative transfer model utilize a certain extraterrestrial spectrum (ET) for calculating solar radiation, individual wavelength direct sun Langley calibration include an uncertainty translated in AOD (or AO Thickness to be more precise) uncertainty. So in theory CIMEL Langley air mass zero values at one wavelength should represent the (spectral weighted due to non monochromatic direct sun measurement) ET at the same wavelength.

We agree that it would be interesting to look at the ET spectrum assumed in the modeling vs. that effectively applied by Cimel after its calibration. However, it is clearly out of scope of our study, where

the goal was to look at the sources of systematic bias and that by WVC and AOD correlation in particular, to estimate ADRE using solar flux and AOD measurements. So our situation tries to be as identical as possible to the conditions when pyranometer and sunphotometer measurements are combined for this purpose. And then the consistency of calibration in these two measurements is not typically considered. And in any case, this issue would not influence the main findings of our study.

2.) *It would be an interesting exercise to use a radiative transfer model in order to calculate ADRE's at a shorter (limited, e.g. PAR) wavelength range (excluding wavelength ranges with high WVC effects), in order to see if there can be a closure on the (even limited in wavelength range) ADRE approaches.*

2.) This is an interesting point, if limited wavelength range is considered instead of the broadband solar fluxes. We tested this by simulating solar fluxes either with broadband range covering the same wavelength response than e.g. pyranometers (310-2800 nm) or with limited range (310-500 nm) without significant WVC absorption, and then applying the method into these simulations. As a result, the WVC-effect vanishes if wavelength is limited to non-WVC-absorbing ranges. The test is described below with its result figures. We also added couple of sentences about this into the paper.

<u>A brief test considering the WVC-effect with limited wavelength range:</u> We demonstrate the WVC effect by limiting broadband flux to ranges containing no significant water vapour absorption. This was done with libRadtran code and the test is brief but effectively shows that the WVC effect holds only for wavelength bands including water vapour absorption, thus mainly IR. In this test some assumptions were used; NewGuey's 2003 solar file, the correlated-k Kato method, the afglms-conditions, albedo was assumed to be a constant with 0.15, altitude was set to 0 km, normal conditions for temperature and pressure, 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 by forcing AOD to zero. Figs. 1 and 2 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, the WVC effect exists as stated in the paper. Evidently from Fig. 1, the both extrapolation methods (nonlinear and linear, continuous and discontinous curves/lines) provide larger F° than the baseline (red crosses), and also the estimated ADRE is larger than the baseline, in magnitude. The linear method ADRE approaches the baseline ADRE while SZA increases. This is due to the fact of the multiple scattering of solar flux which cannot be predicted by the linear approach, but is compensated by the WVC effect. The nonlinear method overestimate the F°. Fig. 2 shows the analysis with limited wavelength range; visibly the WVC effect is now removed and the nonlinear regression method finds the baseline F° better than the linear method, the linear approach systematically underestimate F°. Hopefully this test provides the information you were looking for.

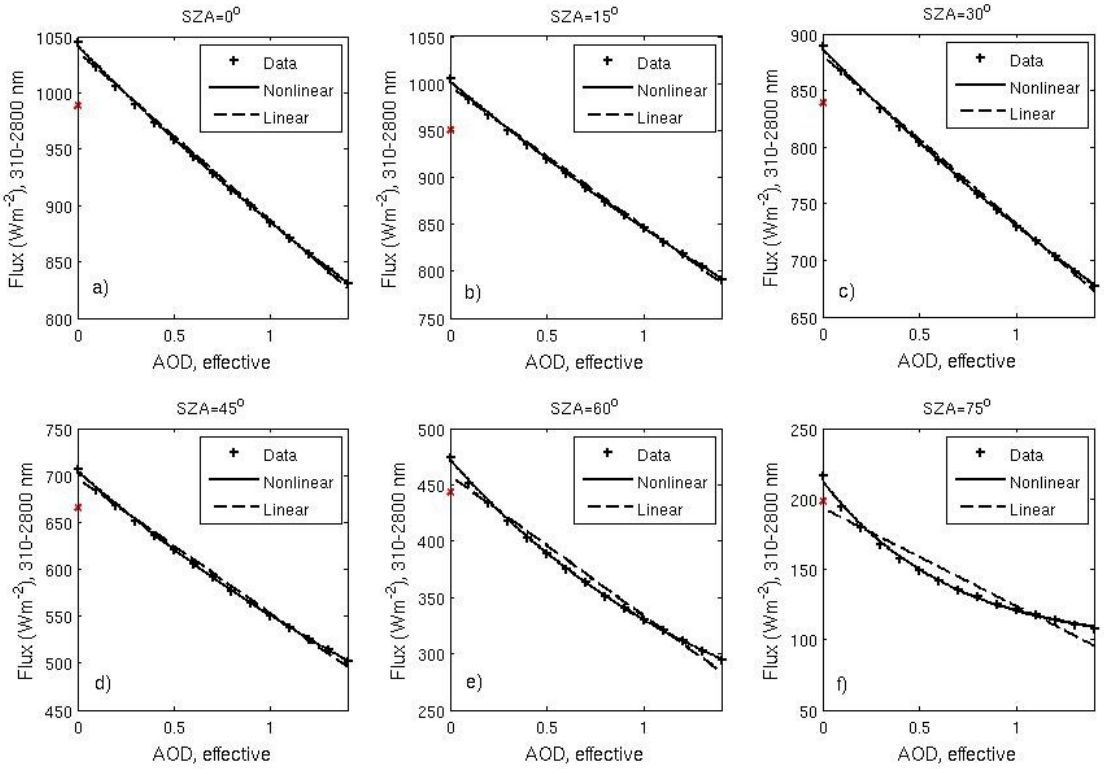

Fig.1: Solar flux as a function of AOD for varying SZA. Red crosses indicate simulated, baseline, F° averaged over AOD range for subplots. The fits represent the nonlinear(continuous) and the linear method (discontinuous).

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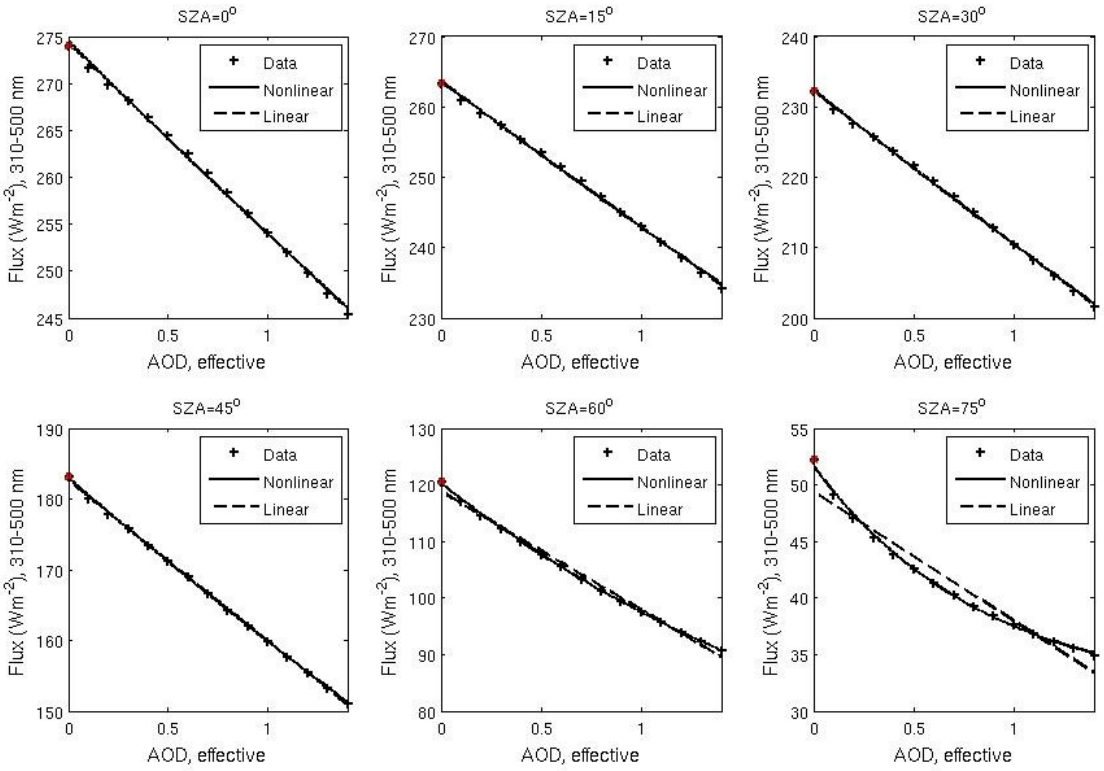

73 Fig. 2: The same as Fig. 1, but solar flux is limited to the range 301-500 nm without significant WVC
74 absorption.

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76 3.) *In addition, the dependence of WVC and AOD as described is a complex issue. In a part of the*
77 *document there is a short discussion on seasonal characteristics of AOD and WVC (that look like an*
78 *interdependence, but still it is not a direct one) that needs more elaboration.*

79 3.) We added the global WVC, AOD-correlation map also for other three month seasons (Dec-Feb,
80 Mar-May, Jun-Aug and Sep-Nov). Also more description added and stronger link with Fig. 3, which
81 shows the results of the methods.

82

Figure 2 is kind of misleading as currently it contains 5 figures (four are mentioned in the caption and the text) and also with different axis limits, making the visual comparison of the datasets difficult.

Figure 2 is updated and contains now only four subplots as indicated.

The solar zenith angle correction mentioned at p 754 line 27 has to be clarified

We meant flux correction, not SZA as in the paper's previous version. This is clarified in the new version.

P 752 line 13 WVC acronym was not defined

Added.

4.) *P 756 line 10. The reason of not using all available pyranometers is explained. However I would suggest to add at least one station (e.g. figure 1 station) pyranometer data in the analysis, since they are the "real" measurement for solar radiation. And can point also to one direction towards linear and non linear results.*

4.) We agree. Still in this paper, use of the AERONET fluxes with the explanations is justified. This is motivated with a result (below) in where no significant difference was found between the AERONET and measured fluxes. We added some text about this into the paper as well.

A brief test considering the analysis with measured and the AERONET fluxes: Here, the WVC effect is considered with measured solar fluxes (pyranometer fluxes from SolRadNet) side by side with the AERONET fluxes. The maximum time difference between the AERONET fluxes and measured fluxes is 5 minutes, otherwise the thresholds are the same as described in the paper. The analysis here is done for GSFC and Alta-Floresta in 2006 for SZA=60±1.5 degrees. The results are shown in Figs. 3 and 5; the ADRE is the approximately the same for the measured and the AERONET fluxes, with no significant difference. Thus, we can state that the conclusion of the paper is holding also for measured fluxes. In Fig.3, the lower subfigure, the average AERONET F^0 is shown with the red cross. The linear regression's intersection with the y-axis is close to the red cross, thus giving the ADRE in a close

agreement with the AERONET's ADRE, demonstrating the WVC effect. Fig. 4 shows AOD and WVC from Fig. 3, indicating that WVC is increasing while AOD increases 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.

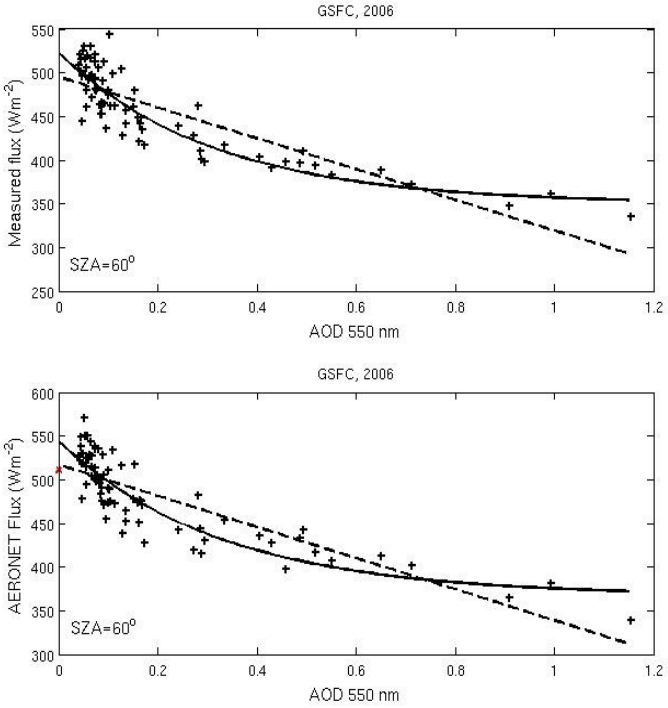

Fig. 3: Measured fluxes (upper subfigure) and the AERONET fluxes (lower subfigure) as a function of AOD with the regressions (nonlinear and linear) in GSFC 2006. There is no significant difference between the measured and the AERONET fluxes. Also the ADRE is close to the same for the both fluxes.

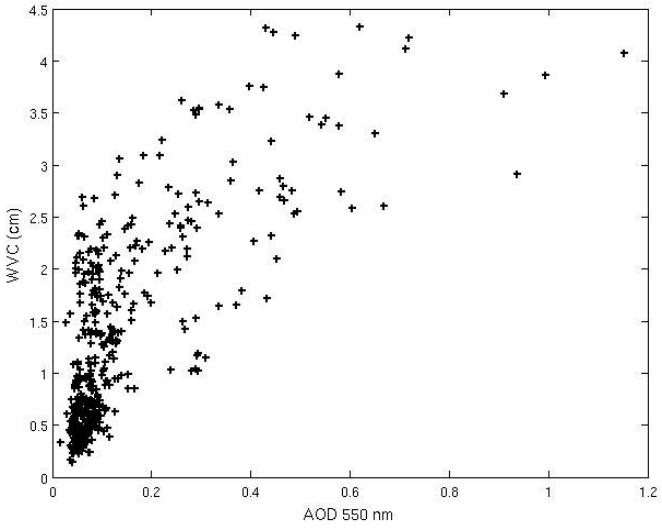

Fig. 4: AOD and WVC observations from Fig. 3. A significant positive correlation between the parameters.

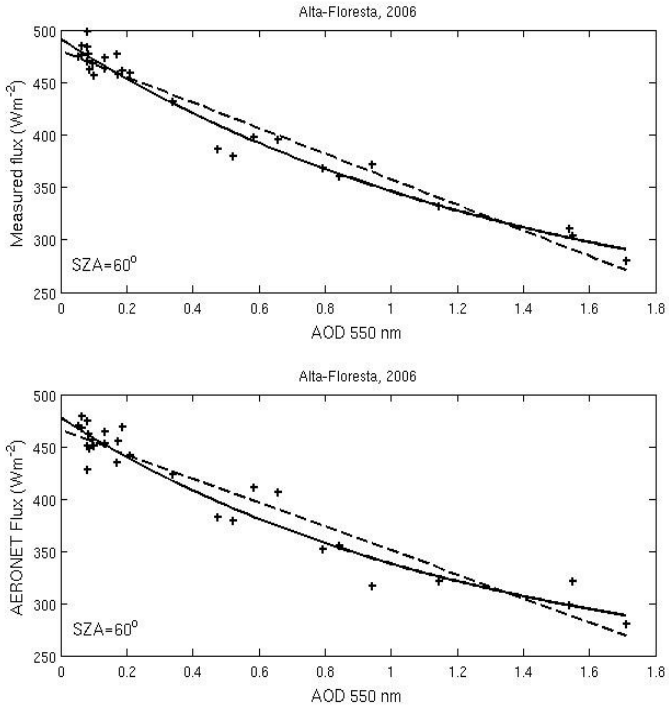

Fig. 5: The same as in Fig. 3, but for Alta-Floresta. The conclusion is the same as in the previous case.

What I am missing in the conclusions is a suggestion from the authors, on possible users of such data, in order to use them for ADRE calculations.

We added some text to conclusions- section.