EXPLOITING UV RANGE IN SMAC ATMOSPHERIC CORRECTION FOR SAL PRODUCT OF CM-SAF

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Abstract

For the surface albedo product SAL the atmospheric correction is currently carried out by using SMAC algorithm. A constant value of 0.1 is used for one of its main parameters, Aerosol Optical Depth (AOD) at the wavelength 550 nm. A better solution is needed and using the AOD value, which is estimated from the AOD value at the UV range, may provide one. Results of case studies are quite promising.

INTRODUCTION

The surface albedo product SAL, processed by the CM-SAF project, is based on NOAA/AVHRR and METOP/AVHRR instrument data. In order to estimate the surface albedo, the effect of the atmosphere has to be removed from the observed surface reflectances. Currently the atmospheric correction is carried out using the SMAC (Simplified Method for Atmospheric Correction) algorithm, which is especially useful when huge amounts of data have to be processed. Its technique is based on a set of equations with coefficients, which depend on the spectral band of the sensor (Rahman and Dedieu, 1994). The main input parameter needed is the aerosol optical depth at wavelength 550 nm. Unfortunately, reliable AOD values are not available globally for the time range of interest from the climate point of view. Therefore the current CLARA-SAL time series 1982-2009 was calculated using a constant τ_{550} = 0.1 assumption, which permits a postprocessing correction by reverse engineering (Manninen et al, 2013).

A better solution for atmospheric correction estimation is needed, because τ_{550} = 0.1 is a poor assumption in some areas (e.g. rainforests and deserts). One possibility is to use AOD value, which is estimated from AOD at the UV wavelength range. We carried out a few case studies using various values as input for the AOD at 550 nm wavelength (τ_{550}) required by the SMAC algorithm. The applied values are 1) AOD values, which are calculated on the basis of the AOD values in the UV range ($\tau_{550\text{-}UV}$), 2) AOD values at the wavelength 500 nm ($\tau_{550\text{-}500}$) and 3) the constant value 0.1 used in the current SAL processing ($\tau_{550\text{-}0.1}$).

STATIONS

Case studies have been carried out for two stations of different type (*Table 1*). The aerosol values in Petrolina are mostly small, but there are also some higher individual values. The aerosol values at Tamanrasset vary in a large range and they are in most occasions quite high. The chosen stations represent also diverse land cover classes: rainforest (Petrolina) and desert (Tamanrasset). In addition, data availability affected the choice of test stations. The needed AOD for calculations are from the AERONET (AErosol RObotic NETwork) website. There are available several measured AOD values at different wavelengths, and from these measurements we chose those which are measured at the wavelength 500 nm and those which are closest to the UV range. For Petrolina the chosen AOD values in the UV range were measured at the wavelength 380 nm and for Tamanrasset at 340 nm.

Station name	latitude, longitude	Surroundings
Petrolina_SONDA (Brasil)	9.38330° S, 40.50000° W	rainforest
Tamanrasset_TMP (Algeria)	22.790000° N, 5.530000° E	desert

***Table 1*: Station information**

METHOD

We did 30 atmospheric correction simulations for both stations. They were carried out using three different kinds of τ_{550} values: 1) calculated from the AOD values in the UV range, 2) calculated from the AOD values at the wavelength 500 nm and 3) constant value 0.1. The τ_{550} values estimated from the UV range or from the 500 nm were calculated using the formula (Kokhanovsky and de Leeuw, 2009)

$$\tau_{\mathrm{Aer}} = \tau_{\mathrm{Ref}} \left(\frac{\lambda_{\mathrm{Aer}}}{\lambda_{\mathrm{Ref}}} \right)^{-\alpha}$$

where τ_{Aer} is the AOD value at the desired wavelength λ_{Aer}, τ_{Ref} is the AOD at the reference wavelength λ_{Ref} and α is the Ångström exponent. As a reference AOD we used values which are measured at 500 nm and the other wavelength used was either 380 nm (Petrolina) or 340 nm (Tamanrasset). For the Ångström exponent we used values obtained from the AERONET from the range 440-675 nm. The τ_{550} values, which are calculated using Eq.1 with the AOD values at the 500 nm, are shown in *Figure 1*. The AOD values of Petrolina are typically small, but there are also a few higher ones. Most of the AOD values of Tamanrasset are smaller than unity, but also markedly higher ones are common. The AOD do not correlate with the sun zenith angle (SZA). The derived AOD values at 550 nm were then used in calculating the atmospheric correction with the SMAC algorithm.

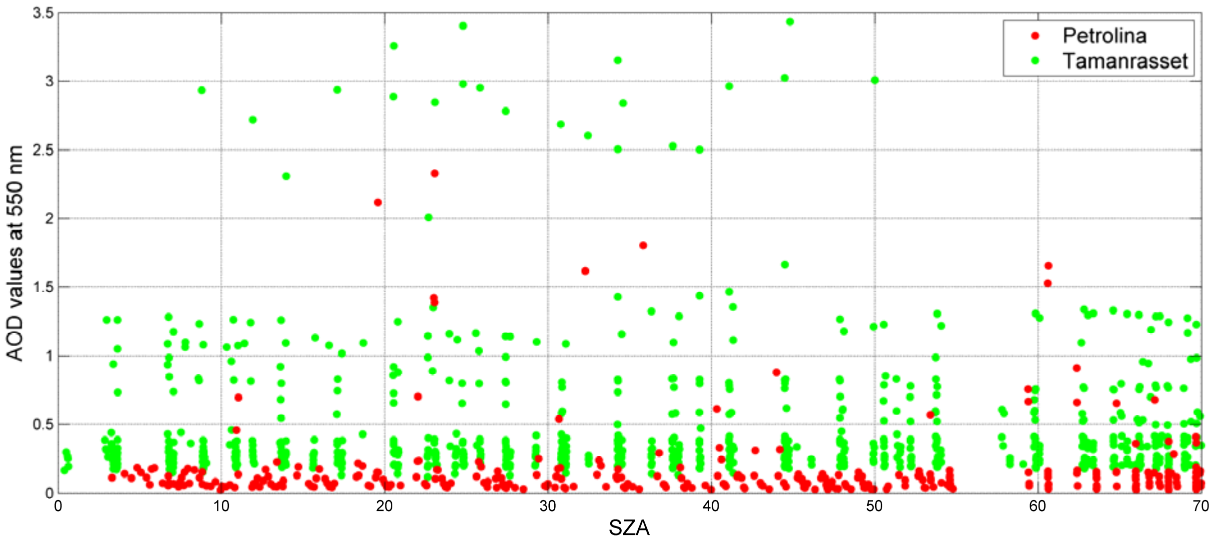

***Figure 1:* AOD values at the wavelength 550 nm for both stations calculated from the AOD value at 500 nm.**

As an atmospheric correction we used the formula

$$C_{\mathrm{ATM}} = \frac{\hat{R}_{\mathrm{surf}}}{R_{\mathrm{TOA}}}$$

where $\hat{R}_{\mathrm{surf}}$ is the estimated surface reflectance calculated by SMAC algorithm and R_{TOA} is the TOA (top of the atmosphere) reflectance.

Hence we mark atmospheric correction values, which are calculated using SMAC algorithm with different AOD values as τ_{550}, with $C_{ATM}(\tau_{550-UV})$, $C_{ATM}(\tau_{550-500})$ and $C_{ATM}(\tau_{550-0.1})$.

RESULTS

To grasp the effect of varying AOD on the atmospheric correction properly, we varied also other input parameters of the SMAC algorithm, such as TOA reflectance, zenith view angle and azimuth view angle. The values used for TOA reflectance were 0.1, 0.25, 0.5, 0.75 and 1.0, the zenith view angle was either 20 or 50 degrees and the azimuth view angle was 0, 90 or 180 degrees. For the sun zenith angle we used real values which were found from the AERONET website and hence they corresponded to the AOD values in the UV range and the AOD values at the 500 nm. The sun azimuth angle values were calculated from the zenith angle and the coordinate of the station. For other parameters needed by the SMAC algorithm, ozone amount and pressure at surface level, were given constant values 0.35 atm–cm^2 and 1013 hPa, respectively. Water vapour content varies by location, so both station had its own value for that. For Petrolina it was 5 g/cm^2 and for Tamanrasset it was 1.5 g/cm^2.

We compared the atmospheric correction value $C_{ATM}(\tau_{550-UV})$ to the value $C_{ATM}(\tau_{550-500})$ to see how well the AOD at 550 nm can be estimated on the basis of the AOD value at UV range. The atmospheric correction value $C_{ATM}(\tau_{550-0.1})$ was compared to the $C_{ATM}(\tau_{550-500})$ value to assess the difference between the true atmospheric correction and the currently used constant value. The calculated $\tau_{550-500}$ is very close to the real AOD at the 550 nm so it was used here as the true τ_{550} value. Also only the AOD values below unity were used, because SMAC algorithm can’t process the higher ones.

PETROLINA

In either comparison, comparing $C_{ATM}(\tau_{550-UV})$ to the $C_{ATM}(\tau_{550-500})$ or $C_{ATM}(\tau_{550-0.1})$ to the $C_{ATM}(\tau_{550-500})$, the ancillary parameters did not have a significant effect on the results. In the former case the absolute errors are small, as can be seen in the histogram in *Figure 2*. The mean error value is 0.0002 and the median is 0.000305. In the latter comparison the absolute errors are still small, but slightly larger than in the previous case (*Figure 3*). The mean error value is -0.0050 and the median is 0.00259.

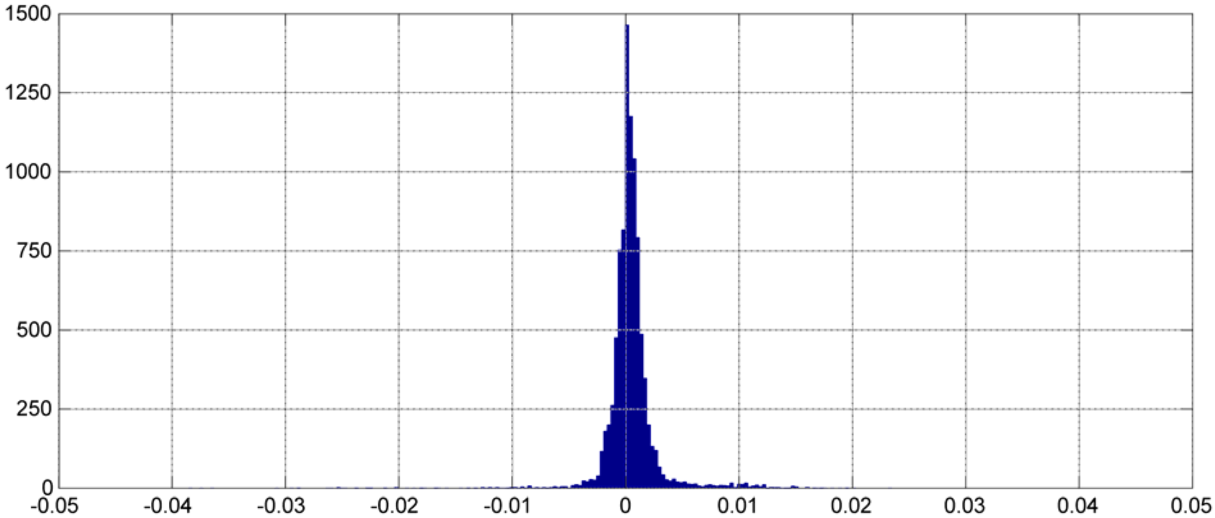

***Figure 2*: The histogram of absolute errors of [$C_{ATM}(\tau_{550-UV})$ - $C_{ATM}(\tau_{550-500})$] at Petrolina, March 2008.**

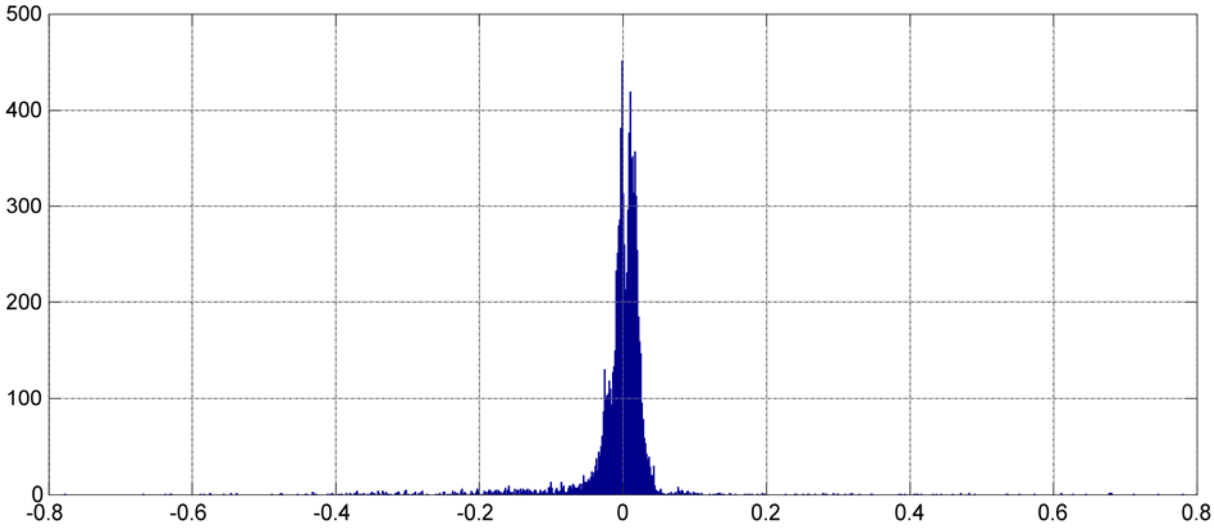

***Figure 3*: The histogram of absolute errors of [$C_{ATM}(\tau_{550-0.1})$ - $C_{ATM}(\tau_{550-500})$] at Petrolina, March 2008.**

The relative errors of the first comparison are also small, as can be seen in *Figure 4*. The red horizontal lines indicate the range between -10 % and 10 %. Most of the relative errors, 98.2 %, are below 1 % of all values and already 99.7% of relative errors are smaller than 5 %. The mean error value is -0.0048 % and the median is 0.0285 %.

In the latter comparison the results are slightly weaker (*Table 2*). The relative errors scatter more, which can be seen in *Figure 5*. Again the red lines indicate the range between -10 % and 10 %. Only 42.6 % of the relative errors are smaller than 1%, but still 91.4 % of the errors are below 5 %. The mean error value is -0.598 % and the median is 0.268 %.

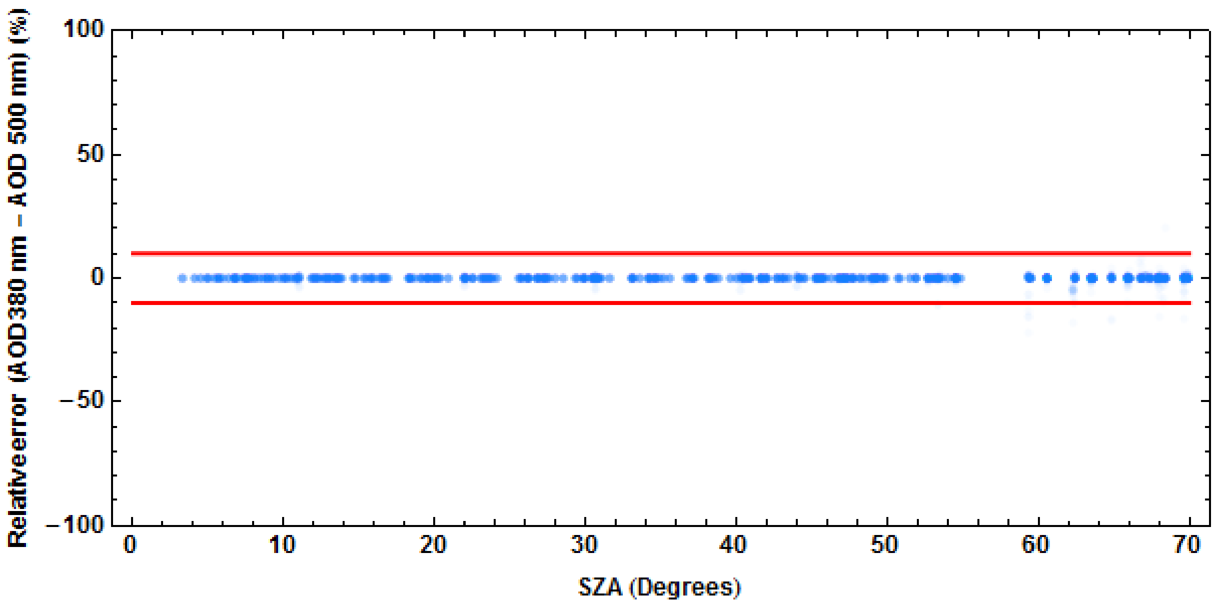

***Figure 4*: The relative errors of [$C_{ATM}(\tau_{550-UV})$ - $C_{ATM}(\tau_{550-500})$] / $C_{ATM}(\tau_{550-500})$ at Petrolina, March 2008.**

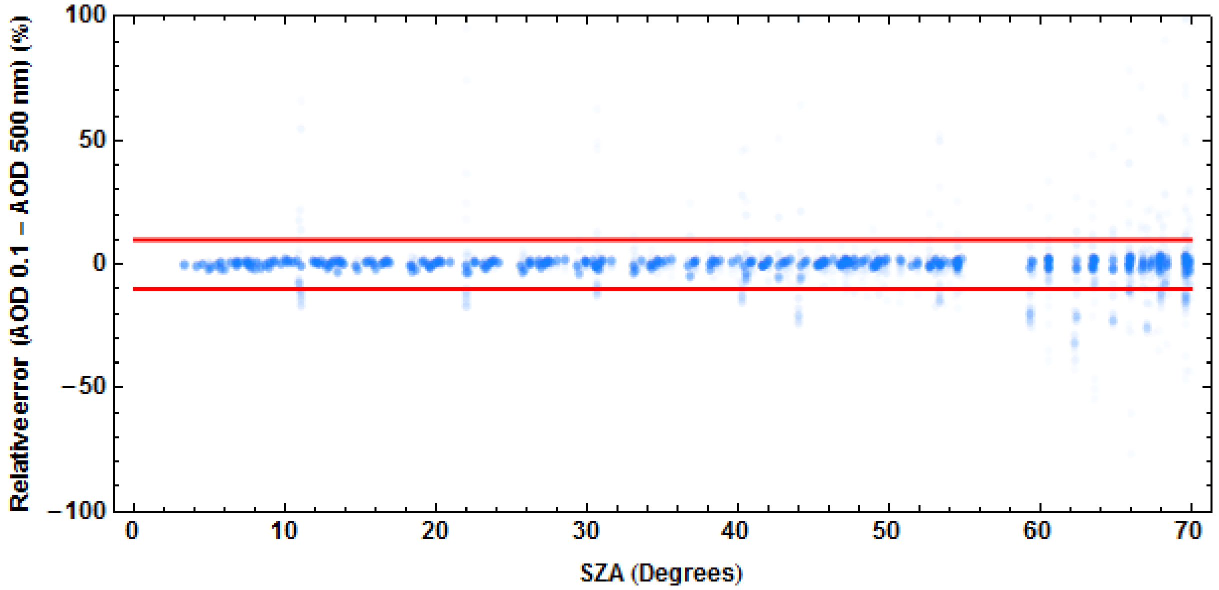

Figure 5: **The relative errors of [$C_{ATM}(\tau_{550\text{-}0.1})$ - $C_{ATM}(\tau_{550\text{-}500})$] / $C_{ATM}(\tau_{550\text{-}500})$ at Petrolina, March 2008.**

		$C_{ATM}(\tau_{550\text{-}UV})$ - $C_{ATM}(\tau_{550\text{-}500})$	$C_{ATM}(\tau_{550\text{-}0.1})$ - $C_{ATM}(\tau_{550\text{-}500})$
Abs. errors	**the mean value**	0.000212	-0.00502
	the median	0.000305	0.00259
Rel. errors	**the mean value**	0.00408 %	-0.598 %
	the median	0.02847 %	0.268 %
	| 1% |	98.2 %	42.6 %
	| 5% |	99.7 %	91.4 %
	| 10% |	99.9 %	94.4 %

Table 2: **Statistical numbers of absolute and relative errors of both comparisons, $C_{ATM}(\tau_{550\text{-}UV})$ to $C_{ATM}(\tau_{550\text{-}500})$ and $C_{ATM}(\tau_{550\text{-}0.1})$ to $C_{ATM}(\tau_{550\text{-}500})$, at Petrolina, March 2008.**

TAMANRASSET

No significant difference in the atmospheric correction values calculated for Tamanrasset was observed when varying the ancillary parameter values in either comparison, $C_{ATM}(\tau_{550\text{-}UV})$ to the $C_{ATM}(\tau_{550\text{-}500})$ and $C_{ATM}(\tau_{550\text{-}0.1})$ to the $C_{ATM}(\tau_{550\text{-}500})$. The absolute errors are small in both cases as can be seen in the histograms in *Figure 6* and *Figure 7.* In the first comparison the mean error value is 0.0017 and the median is 0.0222 and in the latter one the mean error value is -0.0123 and the median is -0.028.

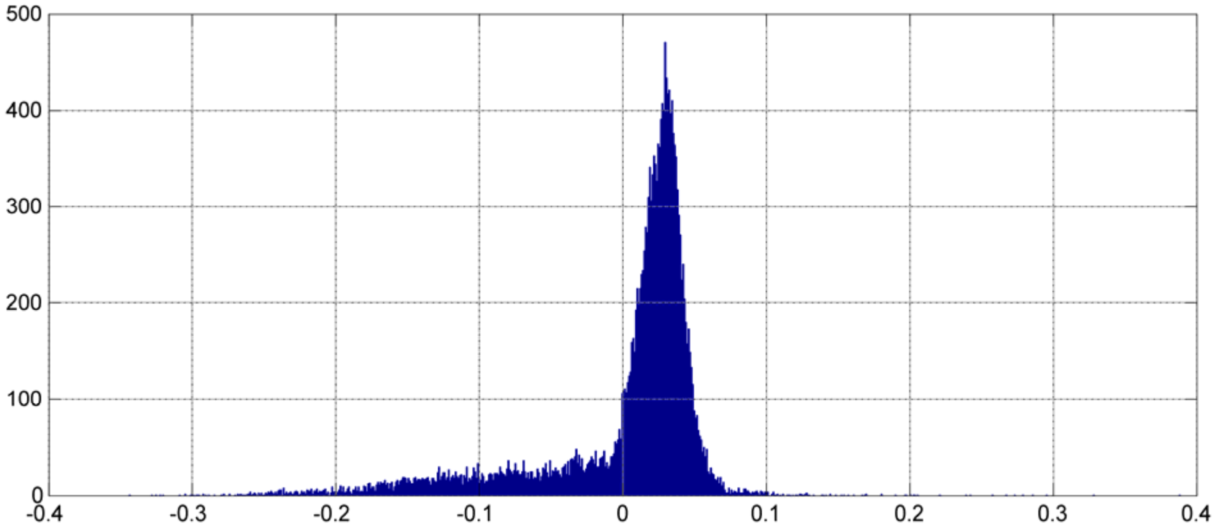

***Figure 6*: The histogram of absolute errors of [$C_{ATM}(\tau_{550\text{-}UV})$ - $C_{ATM}(\tau_{550\text{-}500})$] at Tamanrasset, June 2006.**

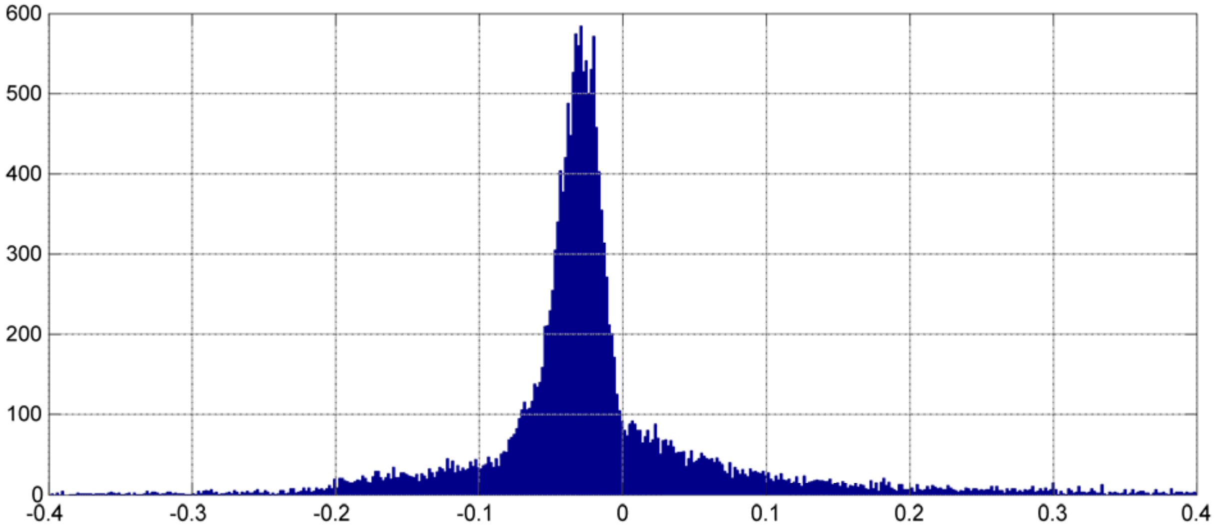

***Figure 7*: The histogram of absolute errors of [$C_{ATM}(\tau_{550\text{-}0.1})$ - $C_{ATM}(\tau_{550\text{-}500})$] at Tamanrasset, June 2006.**

The relative errors of the first comparison are mostly small, 11.5 % of the values are below 1 %, 82.3 % are smaller than 5 %. Most of the values, 88.4 %, are below 10 % as can be seen in *Figure 8,* where the red lines indicate the range between -10 % and 10 %. The mean error value is -1.25 % and the median of the values is 1.989 %.

In the latter comparison the relative errors scatter slightly less, as can be seen in *Figure 9*. Only 6.9 % of the errors are below 1 %, and 67.2 % of the values are below 5 %. Still, 82.7 % of the relative errors are between -10 % and 10 %. The mean error value is 4.17 % and the median is -2.51 %. All the important statistical numbers are displayed in *Table 3*.

In both comparisons, the higher relative errors occur, when the $C_{ATM}(\tau_{550\text{-}500})$ (determinator) is small.

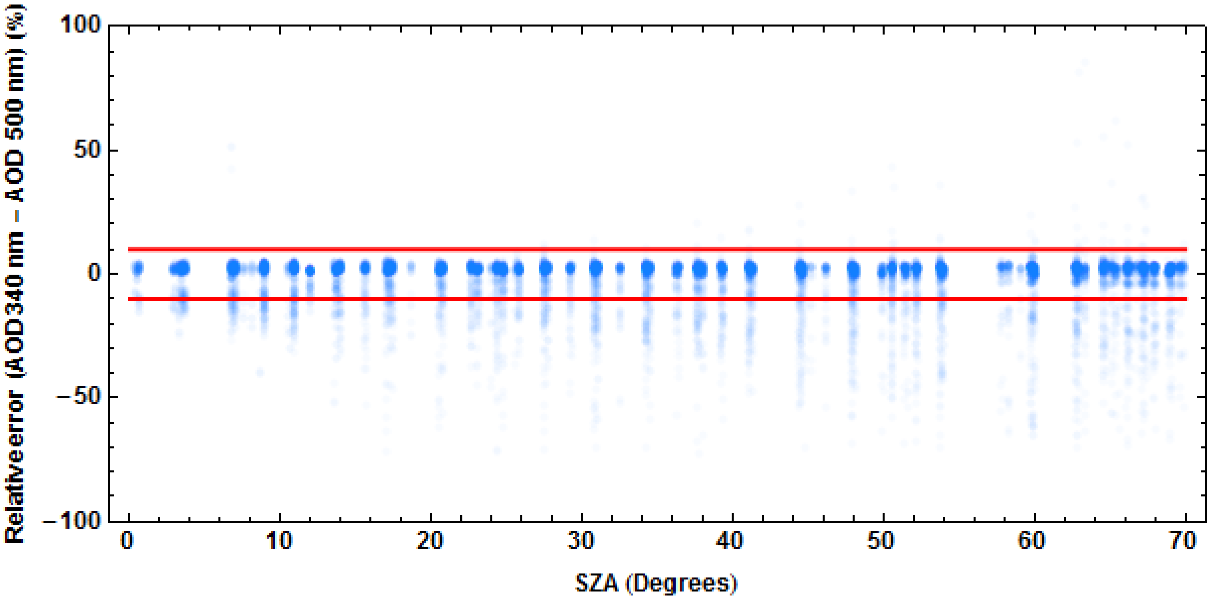

Figure 8: **The relative errors of [$C_{ATM}(\tau_{550\text{-}UV})$ - $C_{ATM}(\tau_{550\text{-}500})$] / $C_{ATM}(\tau_{550\text{-}500})$ at Tamanrasset, June 2006.**

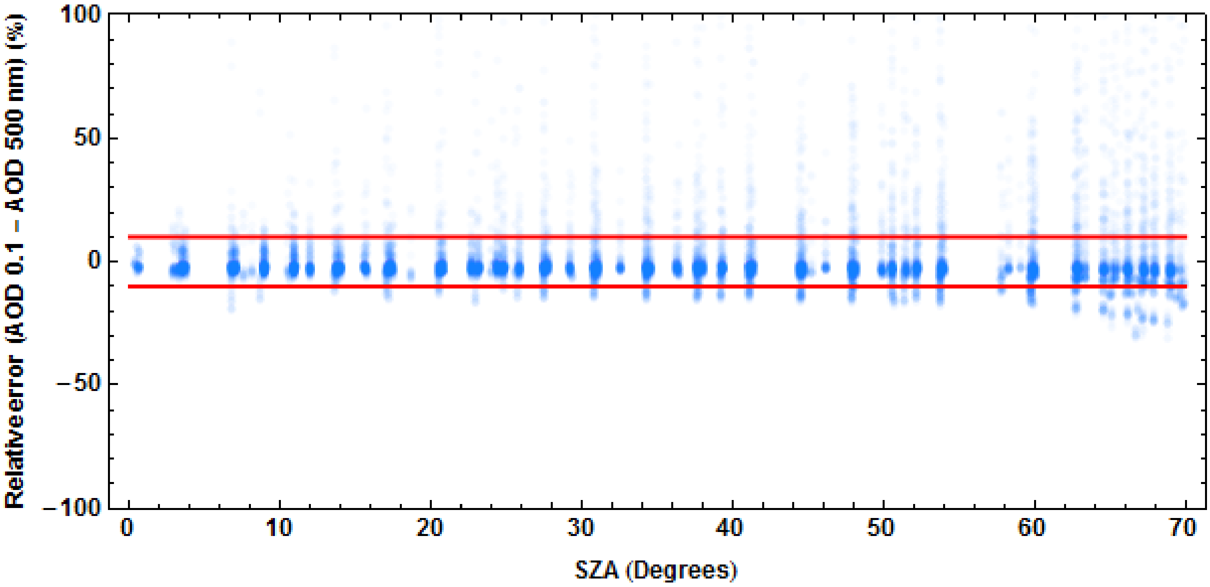

Figure 9: **The relative errors of [$C_{ATM}(\tau_{550\text{-}0.1})$ - $C_{ATM}(\tau_{550\text{-}500})$] / $C_{ATM}(\tau_{550\text{-}500})$ at Tamanrasset, June 2006.**

		$C_{ATM}(\tau_{550\text{-}UV})$ - $C_{ATM}(\tau_{550\text{-}500})$	$C_{ATM}(\tau_{550\text{-}0.1})$ - $C_{ATM}(\tau_{550\text{-}500})$
Abs. errors	**the mean value**	0.00170	-0.0123
	the median	0.02219	-0.0280
Rel. errors	**the mean value**	-1.251 %	4.172 %
	the median	1.989 %	-2.513 %
	| 1% |	11.5 %	6.9 %
	| 5% |	82.3 %	67.2 %
	| 10% |	88.4 %	82.7 %

Table 3: **Statistical numbers of absolute and relative errors of both comparisons, $C_{ATM}(\tau_{550\text{-}UV})$ to the $C_{ATM}(\tau_{550\text{-}500})$ and $C_{ATM}(\tau_{550\text{-}0.1})$ to the $C_{ATM}(\tau_{550\text{-}500})$, at Tamanrasset, June 2006.**

CONCLUSIONS

Using the $\tau_{550\text{-}UV}$ values for the AOD parameter values for the SMAC algorithm in calculating the atmospheric correction seems to work well for Petrolina. The absolute errors are small and most of the relative errors are below 5 %. Using the constant value 0.1 for AOD at 550 nm provides weaker results, which is manifested in larger relative errors. The difference in the atmospheric correction caused by using the UV based AOD estimate instead the true value is almost always below 1 %, but the atmospheric correction calculated using the constant 0.1 at 550 nm instead of the true value produces only in about 43 % of the cases a relative error smaller than 1%.

For Tamanrasset the use of $\tau_{550\text{-}UV}$ values for the AOD parameter values for the SMAC algorithm in calculating the atmospheric correction seems to work well too. It provides smaller relative errors, almost 12% of the relative errors being smaller than 1 % and 82.3 % being smaller than 5 %. In comparison, the use of the of constant value 0.1 for AOD at 550 nm inflicts, that only 6.9 % of the relative errors are smaller than 1% and only 67.2 % are smaller 5 %.

The estimation of the AOD value at 550 nm on the basis of the value at the UV range seems a useful method for the past, when no AOD satellite products were available for visible wavelengths, but UV AOD products exist.

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