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Atmospheric Measurement Techniques Discussions

Interactive comment on "Fast and simple model for atmospheric radiative transfer" *by* F. C. Seidel et al.

F. C. Seidel et al.

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Reply to referee 3
We thank this referee for his / her review. Our replies and changes to be made to a revised manuscript are listed below.

General Comments

Comment 1 *"The first question that arises when taking the side of a potential user is whether the described RTM will be made available to the public or on request?"*
Reply SMART is still under development and therefore not yet available to the public. For the time being, we offer an executable IDL for interested parties upon request, which can be run using an IDL Virtual Machine.

Specific comments

Comment 2 *"Abstract, line 12: The word 'uncertainty' is somewhat confusing here, as the reference is unclear. From later parts of the manuscript, this turns out to be the difference between SMART and 6S. This is not immediately clear from this sentence even though 6S is mentioned in the preceding sentence."*
Reply We will change lines 6 to 15 on page 2226 (Abstract) as follows "The relative difference between SMART and 6S is about 5% for spaceborne and about 10% for airborne computations of the atmospheric reflectance function. The combination of a large solar zenith angle (SZA) with high aerosol optical depth (AOD) at low wavelengths leads to relative differences of up to 15%." As a consequence, we also adjust the sentence on the page brake from 2235 to 2236 to: "As an indicator of the accuracy, we calculate the relative difference or percent error of the reflectance function to the benchmark 6S"

Comment 3 *"p. 2229: g is used without explanation"*
Measure Corrected.

Comment 4 *"Section 2.1: τ_{mlc} is used without explanation"*
Measure Corrected.

Comment 5 *"p.2230, line 2-3: the parameters and 'associated constants' (which?) provided with respect to g: Why do these parameters depend on g, and on nothing else? A little more than a mere reference to Kokhanovsky et al. (2005) should be offered."*
Measure Corrected. We extended this part by writing down the equations in full as follows:

The downward total transmittance $T_\lambda^{l\downarrow}$ is the sum of the downward direct transmittance $T_\lambda^{l\downarrow\,\mathrm{dir}}$ and the downward diffuse transmittance $T_\lambda^{l\downarrow\,\mathrm{dfs}}$:

$$T_\lambda^{l\downarrow} = T_\lambda^{l\downarrow\,\mathrm{dir}} + T_\lambda^{l\downarrow\,\mathrm{dfs}} = e^{-\frac{\tau_\lambda^l}{\mu_0}} + \tau_\lambda^l e^{\left(-u_0 - v_0\tau_\lambda^l - w_0\left(\tau_\lambda^l\right)^2\right)} . \quad (4)$$

$T_\lambda^{l\downarrow\,\mathrm{dfs}}$ is approximated by using a fast and accurate parameterization suggested by Kokhanovsky et al. (2005) for $\omega_\lambda = 1$, where

$$u_0 = \sum_{m=0}^{3} h_m \mu_0^m , \quad (5)$$

$$v_0 = p_0 + p_1 e^{-p_2\mu_0} , \quad (6)$$

$$w_0 = q_0 + q_1 e^{-q_2\mu_0} . \quad (7)$$

The constants p_0, q_0, p_1, q_1, p_2, q_2 and h_m are parameterized using polynomial expansions with respect to g_λ, e.g.

$$p_0 = \sum_{s=0}^{3} p_{0,s} g_\lambda . \quad (8)$$

$p_{0,s}$ and all other expansion coefficients are given in Kokhanovsky et al. (2005). The upward transmittance $T_\lambda^{l\uparrow}$ is defined according to Eqs. (4) to (8) by substituting μ_0, u_0, v_0, w_0 for μ, u, v, w, respectively.

Comment 6 *"line 3: Should the transmittance not be the same for upwelling and downwelling radiation? Does the principle of reversibility not hold here?"*
Reply The up- and downwelling transmittance are the same, as long as the viewing and the solar zenith angles are equal and g remains constant. It is noted that $T_{nadir} > T_{off-nadir}$ due to the different distance in the scattering atmosphere, which the light has to travel through.

Comment 7 *"line 13: omega = 1: so molecular absorption is entirely neglected, which leads to the restrictions of the wavelength range in which this RTM is stated to be useful. How large is the effect of neglecting the 500–700 nm ozone absorption band?"*
Reply Results of calculations with 6S are given in Tables 1 and 2 below, which may help to answer this question. We found that neglecting ozone leads in the worst-case (600 nm, SZA=70°) to an overestimation of 0.007 in reflectance units, whereas for typical SZA the effect is about 0.003 to 0.004 in reflectance units. We conclude, that calculating ozone absorption is of minor concern as compared to other simplifications used in SMART and this overestimation, as a function of SZA, may compensate some of the underestimation in the aerosol multiple scattering.

Comment 8 *"Section 3.1.2: So far I had had the impression that SMART uses only the HG function. Apparently, use of a full Mie phase function is implemented but not recommended as HG is much faster?"*
Reply A Mie phase function needs to be pre-calculated, taking more time than using the simpler HG approximation. Once a Mie phase function is available, there is no significant difference in calculation time. At the moment, SMART has no subroutine to compute a Mie phase function and uses therefore the HG approximation by default. It would be possible to use Mie phase functions with a look-up-table, but we prefer to use the more flexible HG approximation approach for now. On the other hand, the HG limitations are well known, especially for aerosols with a strong forward- and/or backward scattering (see AMTD-Fig. 1).
Measure We will rewrite lines 18 to 22 on p. 2236 to make this point more clear in the

final paper.

Comment 9 *"p. 2237, line 1: Please state the value of the third quantity for each plot. For example, plot 4 shows the wavelength dependence of the error for different SZAs. But what was the AOD? Etc."*
Measure Corrected.

Comment 10 *"Section 3.2, p.2238, line 2: Yes, the accuracy was within 5 % for each single test. This sentence seems to imply that if SMART does not exceed 5 % for any single test, it does not exceed 5 % at all. Although the remainder of this section clarifies this, this sentence should be worded more strictly."*
Measure Corrected. We change the sentence to: "The previous Sect. 3.1 demonstrated that the approximations used in SMART are adequate. Each approximation remains within the desired accuracy of $\pm 5\%$ for the investigated conditions as defined in Table 2." Table 2. refers to the AMDT-Table 2 in the paper.

Comment 11 *"Section 3.2: The test is performed at TOA and at 5.5 km altitude. 5.5 km is well above the boundary layer in most cases. What about airborne measurements at lower altitudes? Presumably the simple layer structure of the model atmosphere is a severe limitation when comparing the SMART results to measurements at such altitudes, as the model does not account for any vertical structure within the aerosol layer. Any vertical inhomogeneity would affect measurements within the layer much stronger than one performed at higher altitudes. If this is relevant for SMART, this is another limitation for potential users that should be mentioned in the summary.*
Reply We agree that 5.5 km is above the boundary layer. We have set this altitude, since typical Earth Observation imaging spectrometers are operated at this altitude. These instruments are not capable of differentiating within columnar measurements. However, if SMART is to be used to do so, then this reviewer comment is to be taken into account.
Measure We add the following sentence after line 23 on p. 2241: "It is also recommended to use SMART for computations with a sensor above the PBL to avoid uncer-

tainties in the vertical distribution of the aerosols."

Technical corrections

Remark 1 *"p. 2227, line 13: 'rely', not 'relay' "*
Measure Corrected.

Remark 2 *"line 19: uncertainty range of up to 5–10 %"*
Measure Corrected, as well as the same correction on p. 2241, line 17.

Remark 3 *"p.2229, line 6: Angstrom's law – no article"*
Measure Correcteds.

Remark 4 *"Eq.(4): lambda missing in the last-but-one term"*
Measure Corrected.

Remark 4 *"p.2237, line 17: Figure 7–9, not 4–6"*
Measure Corrected. We will add up corresponding figures (2,3), (7–9), (4–6), (7–9), (10–12), (14–19) and (20–25) together and label them as subfigures for the revised manuscript for AMT.

Table 1. Total ozone transmittance under different SZA and wavelength conditions with sensor at TOA, surface at MSL, $\mu = 1$(nadir viewing) and a high ozone concentration (O_3 = 0.35 cm/atm = 350 Dobson)

Total ozone transmittance	SZA, deg.	Wavelength, nm
0.989	0	500
0.958	0	600
0.992	0	700
0.970	70	500
0.882	70	600
0.978	70	700

Table 2. Absolute difference between the atmospheric reflectance factor with- and without ozone ($R^{\mathrm{atm}}_{\mathrm{O3=350Dobson}} - R^{\mathrm{atm}}_{\mathrm{O3=0Dobson}}$ under same conditions as for Table 1. above

ΔR^{atm}	SZA, deg.	Wavelength, nm
0.002 (0.056 - 0.054)	0	500
0.002 (0.026 - 0.024)	0	600
0.000 (0.014 - 0.014)	0	700
0.003 (0.084 – 0.081)	70	500
0.007 (0.042 – 0.035)	70	600
0.001 (0.023 – 0.022)	70	700

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 2225, 2010.