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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 1
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 *"What was the spectral resolution for plots errors vs. wavelength? Is it correct to assume, that the only difference between different wavelengths was changing Rayleigh and aerosol optical depths as well as aerosol asymmetry factor and single scattering albedo?"*
Reply Yes, the above mentioned parameters are all wavelength dependent. We per-

form monochromatic calculations using a spectral sampling interval of 10 nm.

Specific comments

Comment 2 *"The examples provided in the manuscript are all for black surface. The accuracy of the model needs to be discussed also for bright surface. In other words, the accuracy of parameterization for spherical albedo is not discussed; in this case, Eq. (14) is irrelevant here."*
Reply We decided to focus the accuracy assessment on the atmospheric part of SMART in this paper, because our treatment of the surface follows standard practice. Nevertheless, we think that Sect. 2.3 with Eq. (14) is still needed for the sake of completeness describing SMART. A bright surface would decrease the relative error of SMART due to the larger signal, as long as we use homogeneous lambertian targets. Therefore, we decided to assume a black target, representing a 'minimum' scenario. We agree, that a solid coupling of atmospheric radiative transfer with non-lambertian surfaces would be very interesting. This soild coupling within the planetary boundary layer, however, might be a topic for another contribution.
The accuracy of the spherical albedo parameterization is discussed in Kokhanovsky, A. A., Mayer, B., and Rozanov, V. V.: A parameterization of the diffuse transmittance and reflectance for aerosol remote sensing problems, Atmos. Res., 73, 37–43, 2005. We refer to this paper in Sect. 2.3.

Comment 3 *"Equation (11) is valid for any viewing angles; though the results are shown for only nadir directions. How does the model behave for μ different from 1"*
Reply The behaviour of the modelled atmospheric reflectance function at TOA as a function of μ and μ_0 is shown here in Fig. 1.
The scattering approximations are generally valid for any viewing angles between 0° to approx. 78° (see Kokhanovsky, Mayer and Rozanov 2005). The findings in the paper (for $\mu = 1$) are also valid for μ and μ_0 being any number, between 0 and 1, as long as $2 \geqslant (\mu + \mu_0) > 1.5$ and $\theta_0 = \theta$ are fulfilled (eg. $\mu = 0.601$, $\mu_0 = 0.9$

or $\mu = 0.8$, $\mu_0 = 0.701$). This is also true for the phase function, which depends on the scattering angle (p. 2230 line 16). It is obvious, that the accuracy of SMART is generally decreasing for larger zenith angles, where $(\mu + \mu_0) < 1.5$, due to the simple two-layer structure of the underlying atmospheric model.
However, $\mu < 0.97$ is rare when using typical airborne nadir instruments (assuming a field of view of less than 30°), for which SMART was developed. Fig. 1 quantifies the change in the reflectance function for such a field of view. For this reasons, we decided not to discuss the case of $\mu < 1$, but acknowledge its importance for instruments operating outside the above boundary conditions.

Comment 4 *"I am confused with the "numerical artifact" shown in Fig. 3. I would recommend to illustrate other SZAs smaller than 10 or to remove it."*
Reply We much appreciate this comment. We couldn't explain this error at SZA=0°. We have re-run the simulations and found an issue in the MODTRAN tape5 handling, which was used to calculate the Rayleigh scattering at SZA=0° and leading to an erroneous correction factor for Rayleigh multiple scattering.
Measure We have updated the correction factor at SZA=0° with a proper MODTRAN calculation and present the corrected AMTD-Fig. 3 here in Fig. 2.

Comment 5 *"pg. 2237, Sect. 3.1.3. Replace 'Figs. 4, 5 and 6' by 'Figs. 7, 8 and 9'."*
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.

Comment 6 *"pg. 2240, Sect. 4. I would delete the last sentence: the number '5500 times' is irrelevant. One cannot compare the computational efficiency speed of 6S with a method that calculates only single scattering."*
Reply Aerosol multiple scattering is also approximated in this case by assuming a given a spectral ratio between single and multiple scattering (correction factor). We agree that the presented comparison is based on different grounds and therefore out of scope.

Measure We will change "Smart runs more than 5500 times faster than 6S." to "in the presented configuration, SMART runs 220 times faster than by solving numerically Eq. (11)."

Comment 7 *"Fig. 5. Please explain why for some SZAs, the relative error increases with AOD while for others decreases. The thicker AOD the stronger the contribution from multiple scattering is. I thought that SMART would underestimate the reflectance function for thicker AOD. However, this is true only for SZA=60. Why?"*
Reply We appreciate this comment. We recalculated the relative error of SMART due to aerosol scattering. For SZA<30°, we still get a very small overestimation of the aerosol scattering for low AOD (ca. 0.0005 absolute reflectance values). Reasons are: SMART has a much simpler atmospheric model (only two layers) compared to 6S and the single scattering approximation is less accurate for absorbing aerosols ($\omega < 1$). The water soluble aerosols used in the paper assume $\omega \approx 0.96$.
Measure We will update the AMTD-Figs. 4 to 9 for the revised paper. Figs. 3 (the new AMTD-Fig. 5) and 4 (the new AMTD-Fig. 8) are given here as examples for this update.

Comment 7 *"Fig. 13. I got confused here. Please clarify."*
Reply This surface plot shall visualize the output array of SMART [wvl,AOD] together with an corresponding independent calculation of 6S. It shall give the readers with less experiences in RTM a feeling on the behaviour of the atmospheric reflectance as a function of wavelength and AOD. Further, it shall give an impression of the fit between SMART and 6S in at-sensor reflectance.
Measure We will replace AMTD-Fig. 13 by a simpler graph (here Fig. 5) and adapt the description in the revised paper accordingly.

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

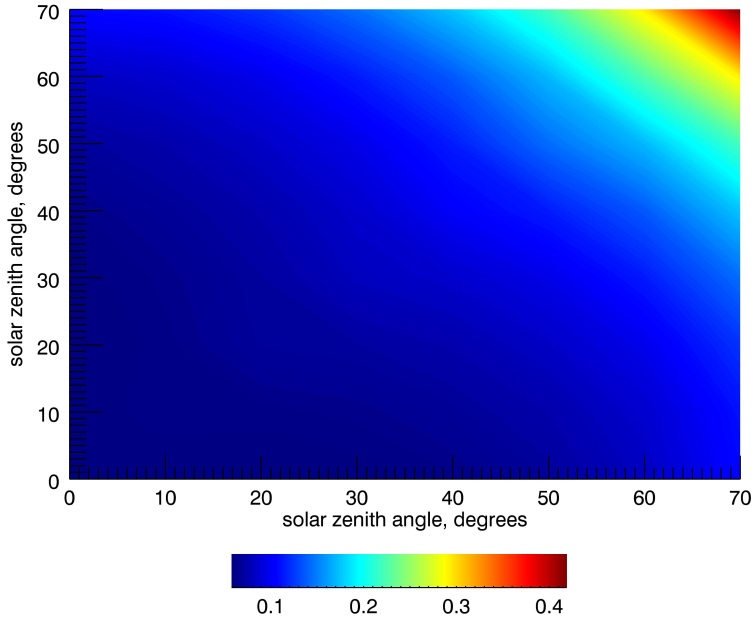

Fig. 1. Atmospheric reflectance function at TOA as a function of $\mu 0$ and μ at 550 nm, AOD=0.3, solar- and viewing azimuth = 180deg.

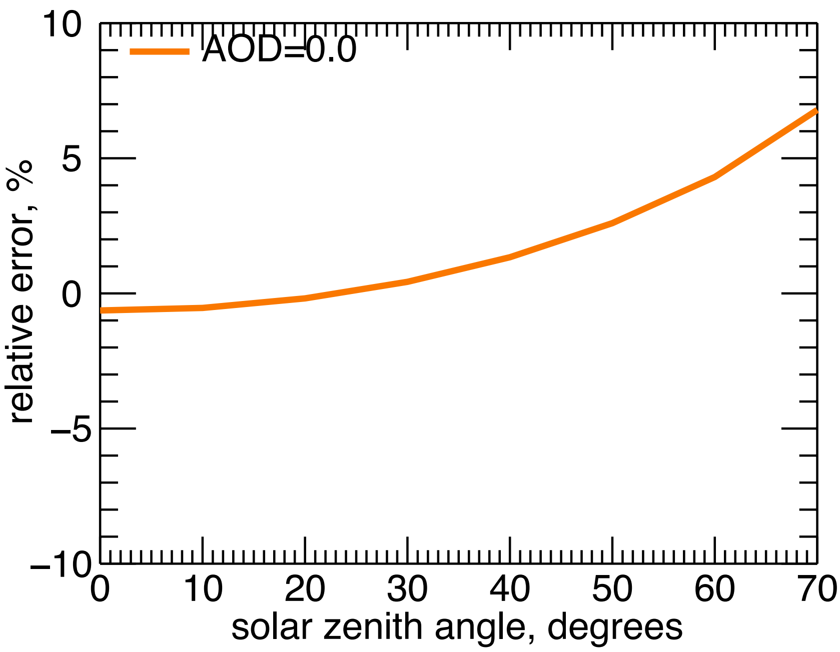

Fig. 2. (new AMTD-Fig. 3) Percent error at 550 nm due to Rayleigh scattering and polarisation with respect to solar zenith angle (SZA).

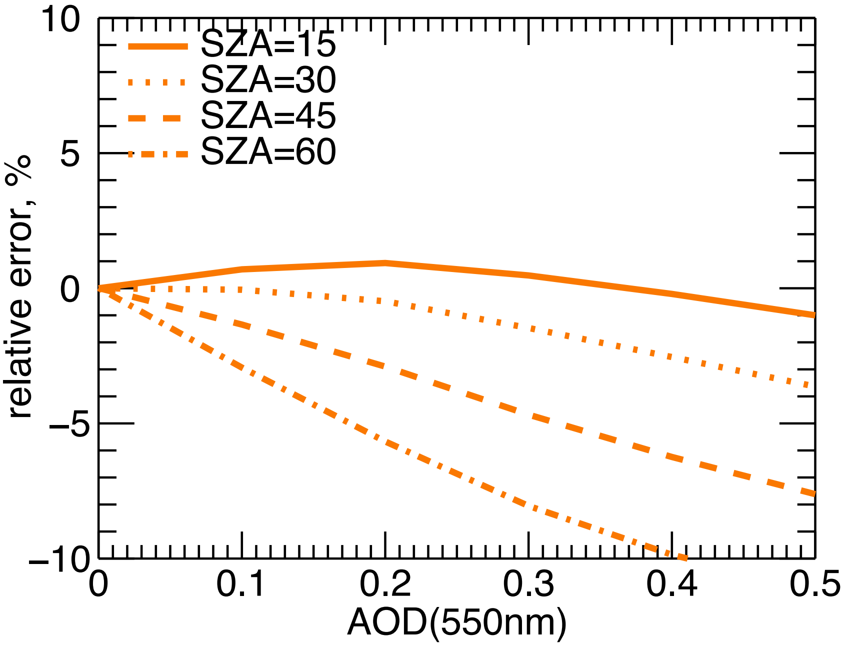

Fig. 3. (new AMTD-Fig. 8) Percent error at 550 nm of the SMART reflectance function due to aerosol scattering with respect to aerosol optical depth (AOD). Same phase function used in SMART and 6S.

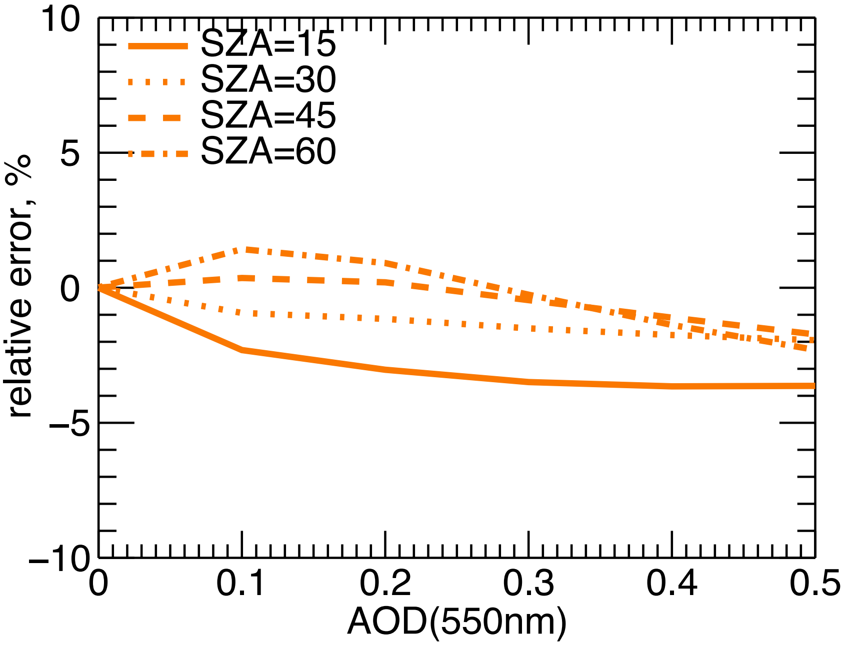

Fig. 4. (new AMTD-Fig. 5) Percent error at 550 nm of the SMART reflectance function due to aerosol scattering with respect to aerosol optical depth (AOD). SMART with HG and 6S with Mie phase function.

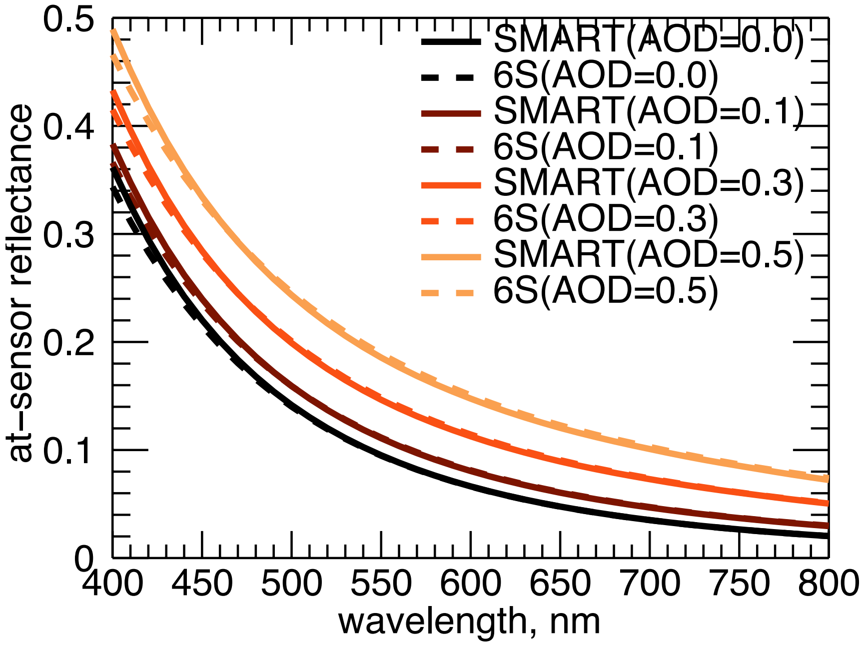

Fig. 5. (new AMTD-Fig. 13) At-sensor reflectance function computed by SMART and 6S (dashed).