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www.atmos-meas-tech-discuss.net/8/C1250/2015/

Atmospheric Measurement Techniques
Discussions

Interactive comment on "High resolution and Monte Carlo additions to the SASKTRAN radiative transfer model" *by* D. J. Zawada et al.

D. J. Zawada et al.

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We would like to thank the referee for their helpful comments and suggestions. Included below are the referee's comments (italics) followed by our reply. We have also attached our proposed changes to the manuscript as a supplement.

Responses to Anonymous Referee 1

Sect. 2.1

"All SASKTRAN engines treat the planet and atmosphere in a fully spherical geometry." Could you clarify what this statement means? I believe you're making a distinction between SASKTRAN and explicitly "pseudo-spherical" models. Many flavors of "pseudospherical" models exist, but that's a separate discussion... do you mean that all path lengths and angles are computed using a spherical geometry?

Reply: That is correct, all path lengths and angles are calculated using a spherical geometry. This has been clarified in the text.

Some sort of illustration would be useful to define the angles, directions and points referenced in equations (1) – (3) more clearly.

Reply: Figure 1 has been added defining the geometry.

I thought it was curious to call the quantity defined in equation (2) the "optical depth". This usually connotes a vertical coordinate, while the quantity in this case is the optical path length along a general line of sight. The k variables are defined with names such as "extinction" and "scattering extinction", but I've more commonly heard this quantity defined as the "extinction coefficient" or "scattering coefficient".

Reply: We think these terms are fairly standard in general radiative transfer theory, and have chosen to follow the same conventions as in the original SASKTRAN paper (Bourassa et. al. 2008).

The following 2 sentences are confusing: "Line segments bounded by shell intersections are called cells. Inside the cells bounded by the spherical shell intersections the extinction and source function are assumed to be constant, allowing for numerical evaluation of the line integrals."

Reply: We have rewritten this paragraph to better explain what we mean by cell, hopefully the added Fig. 1 will help here as well. The relevant section now reads "We approximate the line integral by splitting the ray into segments where the extinction and source function are assumed to be constant. We call these segments *cells*. The successive orders model finds the cell boundaries by calculating intersections of the line of sight with a set of spherical shells (Fig. 1), which by default are spaced uniformly in altitude with a separation of $1\,\mathrm{km}$, but can be placed on any user defined grid. An additional cell boundary is added at the tangent point to ensure that the start and end of a cell are not at the same altitude."

Could you clarify how a cell that is not bounded by spherical shell intersections occurs? I think this can happen if a line segment exits the cell through a vertically-oriented boundary (rather than the spherical shells), but in that case I don't understand the definition given for a cell.

Reply: For the successive orders engine an additional intersection is added at the tangent point which causes this to happen, this is now explicitly stated in the text. This is done to ensure that the bounding points of any cell are not at the same altitude. For HR, additional cell boundaries are added with adaptive integration and 2 3 dimensional ray tracing which may not lie on spherical shells. We hope that the new explanation of cell clarifies this.

The text in this section also inappropriately uses the word "all" several times: "Solar rays are attenuated to all points..." "...once again, scattered at all points..." "...the diffuse field calculated for all local look directions and all altitudes..." This is strangely interspersed with text that describes the (finite) discretization of solar rays, altitudes, etc. that is used.

Reply: The first two uses of all were intended to be part of a section developing the intuition of the successive orders method, this has been clarified in the text. The third use of all has been changed to "for a discrete set of local look directions and altitudes"

Finally, a picture illustrating the directional interpolation triangle would also be helpful.

Reply: Figure 2 has been added which shows the grids used for the two and three dimensional atmospheres, part of this figure shows the interpolation triangle.

2.3.1

How is the "start" of a cell defined? Again, an appropriate illustration would clarify this section greatly.

Reply: In the text we have explicitly stated that the start of a cell is s_j and hope that the added figure will help here as well.

Reference should be changed to "Loughman et al. (2015)".

Reply: Done

2.4.1

This section mentions that the scalar radiative transfer equation is used "for brevity" — has a vector implementation of SASKTRAN been added? I don't see it mentioned elsewhere, so I assume not, but this should be clarified in any case.

Reply: Good question. Polarization has been added to both MC and HR since the paper was written. A paper is planned for the near future to explain how this was done, especially for HR, where the memory burden of polarization may be very large. A sentence was added to indicate that polarization will be the subject of future work.

In equation (16), is s_{end} still < 0, as it was in equation (1)? And how is s (the limit of the integral that computes the extinction) defined? I can somewhat appreciate the logic of reversing the direction of the path integral for the Monte Carlo section, but overall I find both versions of the path integral (equation 1 and equation 16) confusing as presented. Again, a picture would help.

Reply: That was a typo, the variable s in this equation has been corrected to t. A sentence explaining the reason for the change of variables is added for clarification.

How does the definition of J_n^θ (the second line of equation 20) connect to the earlier equations? That symbol never appears before or after equation (20).

Reply: J_n^θ is defined on a separate line because equation (20) is quite long when written all in one line and would be difficult to read. The intention of separating the sampling of ϕ from the sampling of θ has been clarified in the text.

Sect. 2.4.2 *The following sentences create some confusion for me: "If the ray intersects the ground it is terminated with transmission zero." I think this simply means that photons are not allowed to penetrate the solid Earth. But the question of how surface reflection is handled is not clearly addressed (except that the other text mentions simulations for non-zero surface albedos). Or is the sentence below meant to describe surface reflection? "If the ray hits the ground and the target 15 transmission is smaller than the ray's transmission through the atmosphere, the scatter is said to happen at the ground intersection."*

Reply: Thank you. The Earth is currently treated as a Lambertian sphere – We hope we have clarified this in the text.

Sect. 5 *A passing reference to cirrus clouds appears in this section — could you say more about this adaptive integration step, as well as the representation of these clouds overall? Are they spherical shells, or do they have "edges"? And how is the non-Mie scattering by such clouds modeled?*

Reply: The reference made to cirrus clouds was intended to be an example of a situation where the adaptive integration technique may be useful. We feel that a full treatment of clouds is out of scope, however, we have added a reference to Wiensz et al. (2013) where subvisual cirrus clouds were modeled with SASKTRAN.

Fig. 2 *The axis labels are extremely difficult to read as presented.*

Reply: Thank you, this has been fixed.

References

Bourassa, A. E., Degenstein, D., and Llewellyn, E.: SASKTRAN: a spherical geometry radiative transfer code for efficient estimation of limb scattered sunlight, J. Quant. Spectrosc. Ra., 109, 52–73, doi:10.1016/j.jqsrt.2007.07.007, 2008.

Wiensz, J. T., Degenstein, D. A., Lloyd, N. D., and Bourassa, A. E.: Retrieval of subvisual cirrus cloud optical thickness from limb-scatter measurements, Atmos. Meas. Tech., 6, 105-119, doi:10.5194/amt-6-105-2013, 2013.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/8/C1250/2015/amtd-8-C1250-2015-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 8, 3357, 2015.

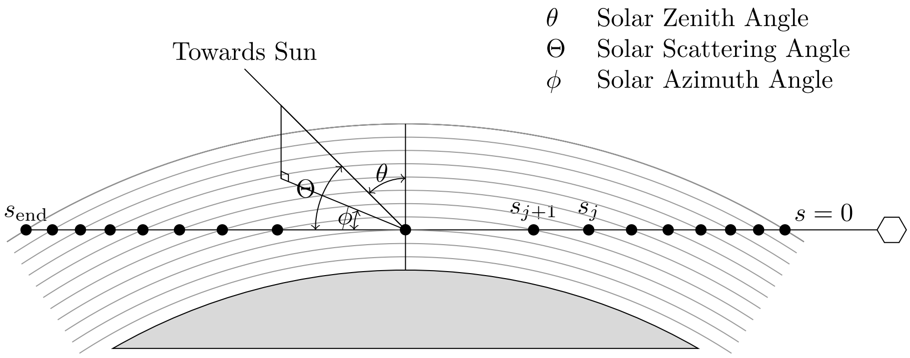

Fig. 1. The limb scatter geometry used in SO, HR, and MC. The solar viewing angles are defined at the tangent point.

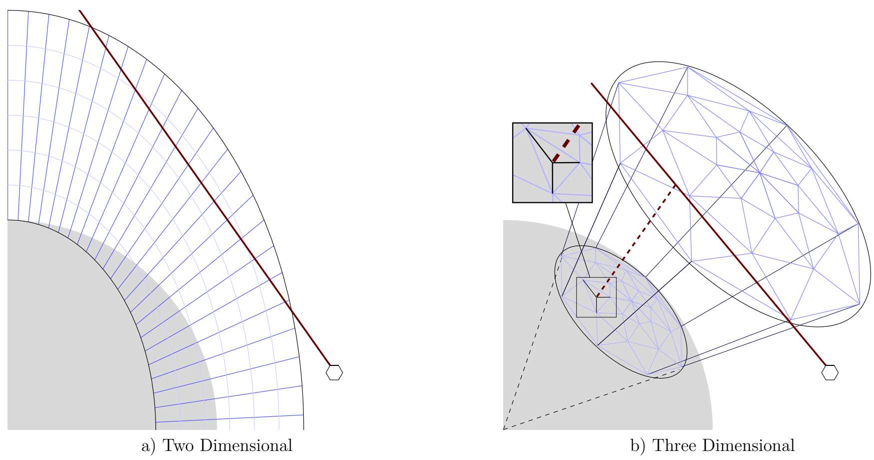

Fig. 2. The two and three dimensional atmospheric grids used in HR. a) A grid is shown consisting of altitude and angle along the line of sight direction, however, the plane can be placed in any direction