Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-81-RC1, 2019

Atmospheric Measurement Techniques Discussions

Interactive comment on “A Fast Visible Wavelength 3-D Radiative Transfer Procedure for NWP Visualization and Forward Modeling” *by* Steven Albers et al.

Anonymous Referee #1

Received and published: 20 June 2019

The manuscript presents a fast, approximate 3D radiative transfer procedure for visualization of numerical weather prediction and forward modeling of ground-, aircraft-, and satellite-based camera and imager. Reflection by optically thick cloud or aerosol layer is parameterized. The scattering phase function of cloud and aerosol is approximated by the double Henyey-Greenstein function. The model is capable of produce true-color images composed of radiances at three wavelengths in the visible spectrum. While the authors emphasized the usefulness of the model in data assimilation in weather models, future works are needed to actually apply to data assimilation. Technical details of the calculation method should be clarified. I believe that important improvements are needed in the manuscript. My recommendation is therefore to make major revisions.

Please find below my detailed comments.

General comments

1. A lot of technical details are missing. For example, a) authors mentioned about a combination of single and multiple scattering components of radiance and some interpolation method between optically thin and thick regimes, but the methods for the combination and interpolation are not given. b) Actually, what equations are used to calculate the total radiance? It is unclear how radiances are calculated when interactions between clouds and surface reflection is present. Please show equations of total radiance that accumulates all contributions from the atmosphere, clouds, aerosols, and surface. c) The method for determining “a single scattering phase function that is equivalent to the net effect of the multiple scattering events” is missing in the current manuscript. With unknown methods, I cannot judge the validity and values of the “approximations”. I have raised more points in the “specific points” below.

2. This is probably because the technical details are obscured, I cannot evaluate the model’s accuracy, validity and limitations. How accurate is this model? What approximations are used? These should be clearly stated in Abstract and Conclusions.

3. As indicated in Fig. 2, the model possibly uses the bidirectional (dual-path) ray tracing along lines of sight and paths from radiation source (i.e. typically the sun) to scattering points. However, actually, it is not clear how to compute the radiance. There is no description on evaluation of the integral of scattering contributions from segments of the line of sight. Or, maybe, the model does not actually compute the integral, but instead scattering contributions from aerosol and cloud elements are approximated to be from some single point within cloud or aerosol layer. Even if so, that “point” is unknown.

4. The adjoint of this radiative transfer model is not available, and more works are needed for data assimilation. I understand the adjoint is not necessary in some frameworks. However, this paper’s focus is not data assimilation, anyway. Subsection 4.3

just suggests possibilities and outlook by lengthy descriptions lacking any evidence and results. I recommend to greatly shorten this part and merge into the last paragraph of Section 5.

5. Lens flare: Lens flare effects appear in actual total-sky images, which should be discussed if comparing the model simulations with camera images. The lens flare is significant in forward scattering directions and modify the appearance of solar aureole by aerosol particles. This is critical in determining aerosol properties from total-sky images.

6. Subsection 3.2 describes the optional characteristics of the model, which is interesting. However, it is not clear whether the authors are first presenting new modeling of this complicated modeling such as moonlight, city lights, and spherical atmosphere. Are there any previous papers regarding to things presented in this section? If so, the details should be found in those papers, and this paper should just cite the references. In the current form, the descriptions are too short to fully describe the complicated radiative sources such as city light, while no results of demonstration and verification are presented in this paper. If this section should be presented in this paper, supporting information including some examples of nighttime scene and Belt of Venus as the authors mentioned in the text. Anyway, this paper does not focus on such nighttime and twilight cases. I recommend to remove this subsection and to leave them for some separate papers. I hope to see example result, validation, and applications in the future.

Specific points

Title: Does the use of acronym of “NWP” conform to the regulation of AMT?

P1, L16: In my understanding, the proposed procedure is not intended for a radiation scheme in “weather and climate” models. The first paragraph of abstract loses focus.

P5, L20, “This is a unique feature that allows. . .”: The methodology is standard in the

field of atmospheric science, optics and computer vision. For example, MYSTIC, as used in Klinger et al. (2017), uses that standard method. The authors should give appropriate references.

P6: Eqs. (1) and (2) are identical, and there is no reason to present both.

P6, L6, Fig. 2 and Table 1: A method for radiance integration is not clear. In my understanding, the radiance should be an integral of contributions coming from many small segment of line of sight (from camera). Each contribution is a function of irradiance from radiative source, which should be calculated by the forward path using some spatial interpolation or directly tracing a ray from the scattering point to the radiative source. This kind of integration should be explained in detail. Without such a description, the readers cannot understand the relationship between forward and backward rays.

P6, L22, “615nm. . .”: Please give a reason for selection of these 3 wavelengths. Is there any references?

P7, L1, “The light. . .”: The same sentence is given previously.

P7: Eqs. (3) and (4) are identical, and there is no reason to present both.

P9, L4, “A two-stream approach is used to incorporate the backscatter fraction. . .”: This sentence is not clear. There are several two-stream approaches. References should be given. Or, is this paper presenting a new two-stream approach for rendering? The definition of backscatter fraction should be clarified. How is the backward fraction used to determine the total downward illumination? What is “illumination”? Is it equal to the irradiance?

P9, L24: Why are HG functions used? Why not Mie theory? The reason should be explained in the text.

P10, Eq. (6): Explanations of i and theta are missing.

P10, Eq. (7): An explanation of ci is missing.

P10, L4: "When τ « 1": Please give an exact definition of tau. In Eq. (2), tau is optical depth integrated along the beam path. The definition of "beam path" is not clear because there are two paths: from camera to target and from the sun to target. In Eq. (8), how is tau defined? Is it the optical thickness along line of sight, along the direct source beam, or some combination of them? For volumetric object (i.e. cloud), there are infinite number of forward paths (from sun) corresponding to small path segments along the backward path (from camera).

P10, L15-17, "more efficient approximation that arrives at a single scattering phase function...": This approximated phase function is not given in Subsubsection 3.4.2. I also failed to find any description in the manuscript. I guess the phase function should be modified to represent multiple scattering effects. How are they modified from the original single-scattering phase function?

P10, L17-18: The interpolation scheme is not actually given in Subsubsection 3.4.2. I also failed to find any details of this interpolation in the manuscript. What interpolation scheme is actually used between optically thin and thick clouds? Please show it using equations if possible.

P10, L26: Does "heavy overcast sky" mean sky with 100% cloud cover? How is the radiance parameterized as a function of cloud cover? How is the radiance computed when the sky is not overcast?

P11, L7, "Intermediate values of tau_0 are given empirical phase functions": How are tau_0 and the empirical phase functions related?

P11, L28, "A simple bidirectional. . .": How is the BRDF developed? Is it based on any measurements or theoretical calculations using rigorous radiative transfer models? It is better to show equations of the ARF.

P12, L9: Actually, what and how is interpolated? Is the cloud albedo (or BRDF) interpolated? Is it linear interpolation with respect to tau? It is better to explain the method

with equations and references (if present).

P13, L25: This paragraph mentioned about single-scattering albedo (for single scattering radiance), but previous explanations say that scattering contributions by aerosols do not depend on the single-scattering albedo (Eq. (8)). In P10, L7, single-scattering radiance is insensitive to the single-scattering albedo: "This relationship applies to hydrometeors as well as aerosols". If so, why single-scattering albedo is discussed in P13.

P14, L6, "The first row in Table 2 was derived semiÂ■empirically for relatively dusty days": How was the camera radiometrically calibrated? Were all pixels of camera image used? Was the circumsolar region excluded or obscured by shadow band or anything? Of course, saturated pixels should be excluded. Are there any references?

P14, L11, "AERONET": References are needed.

P15, L3-7, "As with cloud multiple scattering, a rigorous approach such as MonteÂ■-Carlo would consider each scattering event explicitly, though this would be computationally inefficient. . . . multiple scattering events.": These 2 sentences are almost identical as previously shown in the hydrometeor subsection. Please make a point clear.

P15, L10 and L21, "eq. 6": The equation number seems wrong.

P15, L11: What are CIRA, RAMS, and WRF? They are explained at page 18, but it is too late. Also, references are needed.

P16, L6, "these quantities are merged together to provide the combined radiance": How are they merged? Is the combination simply a sum of radiance components by clear sky and aerosol/cloud? How does the model implement the transmissivities between the sun and cloud/aerosol and between the cloud/aerosol and the camera? Please show equations if possible.

P17, L2-5: A lot of details and references are missing. What is "relatively simple analytical function"? How is the f "modified"? What a sun glint model is chosen from many previously proposed models? How is "scattering from below the water surface" modeled? If there are references, please cite them. If there is no reference, described the details.

P18, L3, "3x3 transfer matrix": Please provide this matrix explicitly or show a reference. This is because there are several variants of RGB color space.

P19, L2, "A more complete. . .": This sentence is not clear. Is this confirmed by tests or just a guess by the authors? Is there any evidence?

P18, L31, "we've" → "we have"

P18, L31: "Simulated Weather Imagery (SWIm)" → "SWIm" (This is already written at P4, L7 and should not be repeated)

P20, L23, "Local Analysis and Prediction System Â■ LAPS, Toth et al., 2014)" This should be presented earlier because LAPS appears at P19, L9.

P20, L25, "METAR": What is METAR?

P21, L8, "High Resolution Rapid Refresh (HRRR)" → "HRRR". HRRR first appeared earlier. It should be explained when presented first.

P21, Subsubsection 4.2.1: In this comparison of simulated observed imagery, strong direct sun beam can cause lens flare, which should be taken into account. The lens flare may be significant particularly when strong direct beam is incident to the camera as in Fig. 11. The camera image cannot be directly compared with the simulated image.

P21, L26, "The brightness scaling...": This should be primarily influenced by the lens flare.

P22, L7, "GFS": What is GFS?

P22, L17, "uncertainty in the brightness scaling of the DSCOVR imagery" : Why is it uncertain? If the radiance data are from the EPIC product, the brightness scaling should be the same as for simulated imagery.

P23, L32, "One approach would entail developing SWIM's Jacobian or adjoint, while other techniques employ recursive minimization.": This sentence is not clear. Please give references. The authors stated that "SWIm can be used as a forward operator in a variational minimization". However, the derivatives are required in the variational minimization, while derivative calculations are not in scope of the current manuscript. This is confusing. It is not very clear whether he current SWIM be used for data assimilations or further works are needed.

P23, Subsection 4.3: This section seems to be the authors' outlook. The problem is that it is not clear whether it is outlook or not. It is better to shorten this part and move to Section 5.

P24, L1: There are no references of GSI, Joint Environment for Data Integration (JEDI), variational LAPS (vLAPS).

P24, L9, "We are. . .": This paragraph briefly presents an ongoing work without any evidence, results, and detailed explanations. I recommend to delete this paragraph and leave it for future papers.

P25, L18, "to assimilate observed imagery via a comparison of such with simulated imagery produced by SWIM from first guess NWP forecasts" : In my understanding, the current SWIM cannot be used for data assimilation, and the improvement is left for future works. This sentence is wrong, or it is just the authors' outlook.

P25, L33-: This and subsequent paragraphs mainly describes the author's outlook, using more spaces than pure conclusions of this paper. I think the authors have too much emphasis on the outlook.

Figure 1 presents a copy from a paper. Does this conform to the copyright? Is there no problem to reuse the copy of the figure of Klinger et al. (2017)?

Figure 1 summarize few selected radiative transfer models, while there are significantly more 1D and 3D models over the world. The objectives of them are very different, and the purpose of presentation of this figure is not clear. It should be clarified how the models are selected. For example, are they candidates used for data assimilation in NWP, or can they all produce color imagery?

The table in Fig. 1 should be separated and presented as a table (not in a figure).

Figure 2, "...and used for subsequent calculations to estimate the radiance": tau_s should vary by location on the line of sight. How is the radiance actually calculated using tau_s and tau_o? The details should be explained in the main text possibly with equations.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-81, 2019.