Reviewer #1

General Comments:
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1. More details on the forward light rays and 3D irradiance field are now discussed in Section 3.4.

a) the method of interpolating between the single & multiple scattering cases is now given in section 3.4.2

b) The final combination of clear and cloudy contributions to the radiance is now specified in section 3.6, with the individual steps described in earlier sections. Surface albedo is discussed in section 3.7.

c) the procedure for handling multiple scattering with an effective single scattering phase function was elaborated upon for cloud liquid. Similar formulations (not shown) are used for cloud ice, rain and snow.

2. Additional equations have been added in various sections to more completely describe the total (and solar relative) radiance. The overall accuracy of SWIm is now summarized in Table 4, and the items within this table are discussed in the conclusion and elsewhere in the manuscript.

3. Computation of radiance is now given in greater detail throughout the manuscript (e.g. section 3.4.1).

4. We believe section 4.3 gives a useful review of related 3D assimilation methods that include the use of visible light wavelengths and cameras. We now provide some results (Figure 14) that illustrate preliminary steps we are taking to develop a SWIm based assimilation. We agree there is much more to be done.

5. Lens flare is now mentioned in a more general context at the end of section 4.2.3.

6. Details on moonlight, city lights, and spherical atmosphere will be deferred to a future paper and this has been clarified in the text.

Specific points

Title: "NWP" is now spelled out

P1, L16: The first paragraph of the abstract provides context about the importance of visible wavelength radiation in modeling and we believe the 3rd paragraph of the abstract discusses the more focused role of SWIm in a reasonable manner.

P5, L20: The last paragraph of section 2 along with parts of section 3.8 have been modified to reflect the reviewer's suggestions.

P6, Eqs. (1) and (2) are indeed identical. We now only show the second equation.

P6, L6: The method for radiance integration, with Step 2 (clear sky) ray tracing as an example, is now shown in Eq. 3.

P6, L22: The rationale for wavelength selection was elaborated upon.

P7, L1: The redundant sentence was removed

P7, Eqs. (3) and (4) are indeed identical. We now only show the second equation.

P9, L4: This line and section has been revised to improve clarity. "Two-stream" isn't mentioned now since we use a different relatively simple approach. "Illumination" has also been replaced by "irradiance" in this section.

P9, L24: Rationale for using HG functions is now given in sections 3.4.1 and 3.4.2

P10, Eq 6: Definitions of i and theta are now in place

P10, Eq 7: c(i) was changed to f(i) and is now defined as a summation

P10, L4: Tau is now more clearly defined in this context

P10, L15-17, 17-18: The phase function is now more completely described for the case of cloud liquid, though the formulation isn't yet detailed for cloud ice, rain, or snow.

P10 L26: In the context of this section, "heavy overcast" means the 3D irradiance field (eq. 8) at the location of the portions of the cloud along the line of sight closest to the observer is ~<0.4. This definition of overcast is independent of cloud fraction and related quantities.

P11 L7: The intermediate phase functions are now described in section 3.4.2.
P11 L28: A simple ARF parameterization was developed with references and equations now given in section 3.4.3.

P12, L9: It is now stated that linear interpolation with respect to cloud albedo is used to approximate the reflectance between the low τ and high τ regimes.

P13 L25: Single scattering albedo is now included in eq. 11 since this is considered for aerosols with the single scattering radiance calculation.

P14, L6: The items mentioned by the reviewer are now clarified in the text within section 3.5.2.

P 14, L11: An AERONET reference was added in section 3.5.2.

P15, L3-7: These two sentences are now condensed for clarity and to avoid repetition.

P15, L11: These chemistry models are now better explained here, including references.

P16, L6: More details and equations are now given in section 3.6.

P17, L2-5: A reference was added that we base the ocean reflectance upon. Brief descriptions are given for the handling of land anisotropic reflectance.

P18, L3: The transfer matrix is now explicitly supplied

P18, L31: Wording adjusted to follow both suggestions

P19, L2: "A more complete" appears in the text on P18, L25. A more specific reference to Rayleigh correction is being added for the satellite example. For everyday photography this is more of a general comment that images often have more saturation, or may suppress the atmospheric brightness with polarizing filters and the like, all for the purpose of making the image look more appealing.

P20, L23: The LAPS reference was moved to section 4.1 and the LAPS description was clarified in section 4.2.

P20, L25: A more general description is now used for the METAR observations

P21, L8: The HRRR acronym is now expanded upon its first use.

P21, sec 4.2.1: We agree and lens flare is now mentioned there in the text.

P21, L26: In a camera image, the regions that are saturated (hence not useful for quantitative brightness comparison) can reach that brightness from either lens flare or sunlight scattering by aerosols and clouds, depending on the situation and quality of the camera. A clarifying sentence was added here.

P22, L7: GFS is now defined

P22, L17: The strategy for producing figure 12 is now explained in more detail to address the reviewer questions, within section 4.2.2.

P23, L32: We state that "One approach would entail developing SWIm's Jacobian or adjoint". This should clearly imply that it has yet to be done.

P24, L1: References for vLAPS, GSI were added. JEDI is now referenced with a website since this appears to be unpublished at this time.

P25, L18: The revised text now describes a simple camera assimilation technique we performed that can serve as an introduction to the other methods mentioned in our roadmap.

P25, L33: As now mentioned in the last paragraph of Section 1, this study is intended to introduce SWIm, and describe what has been done so far, and suggest a roadmap for the future.

Figure 1: We are no longer using the image from another paper. This has now been converted into Table 1. The table is intended to show a variety of RT packages and for context to illustrate which ones have similar capabilities as SWIm. The other questions are now addressed in section 2 of the text.

Figure 2: Section 3.3 now has an equation illustrating how radiance is computed as an integral from the rays traced in the figure. In this section, the simple example of Rayleigh or Mie single scattering is illustrated. Additional equations relating to multiple scattering are given in section 3.4.

Reviewer #2

General Comments:

The authors are glad the reviewer appreciates the relevance and value of SWIm. We appreciate the major concerns and would like to respond both generally and specifically. Data assimilation is now mentioned mainly in the context of future work. However even with significant approximations in the radiative transfer it is possible to perform simple types of assimilation with metrics like the correlation coefficient as now described in the text. Evaluation of the 1D radiative transfer has been performed in the context of the distribution of reflectance values at the red wavelength in DSCOVR / EPIC imagery for both clear and cloudy regions. Oceanic clear areas are in the expected range of 5-6% reflectance factor with the bright tops of tropical convective clouds between 1.0 and 1.1.

Specific points

P 5, L32: As now discussed in Section 5, specific comparisons with other radiative transfer packages (e.g. CRTM, MYSTIC) is a good topic for future work. Thus far we've focused mainly on comparisons with ground-based cameras, pyranometers, and DSCOVR imagery, even though they typically include the LAPS cloud analysis used for SWIm input in the evaluation pipeline.

P 5, L35: The forward-backward ray-tracing procedure has now been clarified in section 3 of the text.

P 7, L18: The zenith angle weighting is now mentioned in the text.

P 7, L21: A simple calculation of this was performed and now summarized in the last paragraph of section 3.1.

P 7, L31: We would like to investigate this further in the literature and report in a followup paper. Thus far the authors have only seen information about this in the form of an online solar spectrum calculator used within the solar power industry.

P 8, L 7: The statements about the moon's brightness came from a literature search about the "opposition effect". It is now made clear in the manuscript that details about the moon's brightness will be deferred to a future paper.

P 9, L 4: The "two-stream" term was used too loosely and the description has now been updated to make the detailed procedure more clear.

P 9, L11: The density is based on the hydrometeor type and the effective radius as now mentioned in the text.

P 9, L18: “bilinear” is now replaced with “trilinear” since light rays are traced in 3D space.

P9, L24: The linear combination of HG functions is now introduced in section 3.4.1 and further described in section 3.4.2 and Appendix B. The HG function terms provide for both forward and backward scattering.

P9, L24: Rationale for using HG functions is now given in sections 3.4.1 and 3.4.2, particularly with the convenience of being able to raise “g” to an exponent to approximate multiple scattering.

P 10, L 27: This was chosen empirically, partly since it averages to 1 with respect to zenith angle. We will try your formulation since it will probably help improve the pyranometer comparisons with overcast conditions, camera image comparisons with partly cloudy conditions, and have better theoretical footing as you suggest.

P11, L15: The procedure for calculating the backscatter fraction is now given in section 3.4.3.

P12, L6: We would suggest the increasing optical path of the sunlight through optically thin cloud or aerosols shouldn’t affect the observed radiance (technically the reflectance factor), since we are in a single scattering regime. The path length from the observer through the medium is remaining constant.

P12, L12: The HAALE-MURI history has been removed, while this project is represented in the Acknowledgements section.

P12, L16: 1-D aerosol calculations are faster than 3-D aerosols as now clarified in the text.

P12, L27: Eq. 11 represents a pair of DHG functions from eq. 10 as now explained further in the text.

P14, L7: The semi-empirical procedure is now explained in more detail in the text.

P16, L5: SWIm is designed to work even in cases when the NWP grid is limited in horizontal or vertical extent. This helps save computing resources and allows SWIm to work with limitations in NWP systems.

P17, L3: A reference was added that we base the ocean reflectance upon - this is the same one the reviewer suggested.

P17, L6: A reference was added that we base the ocean reflectance upon. Brief descriptions are given for the handling of land anisotropic reflectance.

P17, L21: The Bell et al. reference describes some experiments that help show the value of having a more complete spectrum to get the best chromaticities and color rendering. The interpolation procedure we describe will by design produce a more accurate spectrum and hence chromaticity, compared with simply inserting three narrowband wavelengths into the CIE color matching functions. We also in the text now give the rationale for selecting the three reference wavelengths used within SWIm.

P20, L1: In addition to image correlation, subjective evaluation of the 1D radiative transfer has been performed in the context of the distribution of reflectance values at the red wavelength in DSCOVR / EPIC imagery for both clear and cloudy regions. Ground-based comparisons of global horizontal irradiance (GHI) have also been done. A more rigorous comparison of SWIm with another 3D radiative transfer model (e.g. MYSTIC, SHDOM) is planned for a future paper..

P20, L17: The solar irradiance (GHI) comparisons are now being done with case studies of clear and partly cloudy conditions (e.g. section 3.1 - Fig. 2, section 4.2.1 - Figs 2,10), and overcast skies though not yet in a more systematic manner.

P23, L32: We have clarified in the text that the adjoint has yet to be developed. We think it is feasible to do in the future. Minimization methods that do not require an adjoint would also be possible.