

Interactive comment on “A generalized method for discriminating thermodynamic phase and retrieving cloud optical thickness and effective radius using transmitted shortwave radiance spectra” by S. E. LeBlanc et al.

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Response to Anonymous Referree #2: Review of the Manuscript by LeBlanc et al. (2014):

- (i) In my point of view, the method is not a “generalized method”, as implied in the title of the manuscript and the text. What I mean here is that it remains unclear why in particular these 15 parameters, as defined in the manuscript, are cho-

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sen for the retrieval. I guess even more than 15 parameters could be proposed; maybe less than 15 would do a similarly good job. The sensitivity of the chosen particular parameters is well introduced; however, this makes the approach not a general one. I would consider the method general if the parameters are determined by an objective algorithm (e.g., principal component analysis, or other procedures) which is not the case here. Therefore, I suggest omitting the term ‘general’ in the title and the respective text.

The method presented here is general in the sense that it can be applied to clouds spanning a wide range of optical thickness and effective radius for ice and liquid water clouds. The wording “Spectral” will be substituted for “Generalized” in the title, and reference to general will be removed.

- (ii) For a mixed-phase cloud the retrieval of tau and reff seems not meaningful. You can clearly decide from the retrieval if there is some ice in the cloud, but there is no way to tell how much. Therefore, if you want to retrieve tau and reff you have to assume the cloud consisting of either liquid water drops, or pure ice only, which both cannot reproduce the mixed phase cloud normalized transmitted radiances.

The purpose of using a mixed-phase cloud as a measurement case is to illustrate the extent to which this retrieval can be used, and to what extent do this cause differences in transmitted radiances. However, at this stage, the retrieval can only be used to retrieve thermodynamic phase, and not the ratio of the two phases. This will be made clearer in the revised manuscript in the retrieval methodology section. In addition the following sentence will be added to line 6, p. 5317: “This mixed-phase case is also used to present the extent of disagreement between retrieval methods when the thermodynamic phase is neither pure ice nor pure liquid water.”

- (iii) I feel the paper is too long, and the number of figures could considerably be reduced (e.g., Figs. 1-3 could be omitted, also Fig. 4 is not crucial for the paper)

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without much loss of information. Therefore, I ask the authors to shorten their paper.

To shorten the paper, an annex was created to include Figs. 1-3. The corresponding Section 3 and Section 4.2 were moved to this annex.

Detailed comments:

- For the title (and elsewhere in the text), I suggest to change the term 'shortwave' to 'solar'. Short is always relative, solar is much more specific.

Shortwave has been replaced by either the combination of solar shortwave or solar, where appropriate.

- Page 5294, line 21: I guess the 53 W m⁻² are annually averaged too.

Added annually averaged.

- Page 5295, line 2-5: I suggest adding the reference Ehrlich et al. (2008) here, which also deals with cloud thermodynamic phase retrievals using spectral reflectivity.

Reference added in revised manuscript.

- Page 5295, line 19-21: It could help to explain what 'additional information' means.

Expanded to include: "[...], such as if the cloud is optically thin (lower than 4) or optically thick (higher than 4)."

- Page 5297, line 13: The terminology used for 'spectral zenith radiance' is not consistent. For example, on Page 5300, line 21-22, it is 'zenith transmittance'. This is a little confusing.

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Corrected occurrences of zenith transmittance to zenith radiance when referring to measurements taken directly with SSFR.

- Page 5297, line 13: I suggest changing 'radiance light collector' to 'optical inlet'.

Modified.

- Page 5297-5298, line 21-13: Was a calibration performed in the field? It seems the calibration factors were obtained from laboratory measurements, which might change due to disconnection of the optical fibers for the transport to the measurement site.

Calibrations bracketed the field deployment, and great care was taken when transporting and reinstalling at the field site, which was above the building containing the calibration laboratory. The manuscript was modified to indicate this.

- Page 5299, line 2-9: The pixel size of the satellite products should be specified.

Included in the manuscript the pixel sizes for GOES: 16.0 km and MODIS: 500 m.

- Page 5301, line 23-24: Have inherent uncertainties of surface albedo, cloud base altitude/extent, and atmospheric state profiles been considered in the final uncertainty analysis?

It is beyond the scope of this paper to investigate uncertainties in ancillary inputs, but is within the reach of the future analysis involving the GENRA algorithm, presented briefly on Page 5296, line 17-19. This line was expanded slightly to indicate that it encompasses an uncertainty and sensitivity analysis of ancillary inputs.

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- Page 5302-5303, line 25-3: If my understanding is correct, you calculated one LUT for each of the presented three case studies?

Yes. That will be specified in the revised manuscript.

- Page 5303, line 11: Please see previous comment on terminology ('cloud-transmitted radiation').

Unlike the previous terminology comment, this does not specifically refer to a measured value, but is inherent to the cloud, thus it is not changed. A small clarification sentence is added at the end these lines.

- Page 5303, line 15 and line 16: I suggest changing 'asymmetry parameter' to 'asymmetry factor'.

Asymmetry parameter is chosen to match the terminology used by Baum et al. 2011.

- Page 5303, line 21: Typo, replace 'Fig. 4' by 'Fig. 5', please reduce the size of the huge axis labels of Fig. 5.

Typo fixed, and axis label sizes reduced.

- Page 5304, line 26-27: Why do you use the term 'transmittance' in a way that is inconsistent with common definitions? Call the quantity what it actually represents: normalized transmitted radiance. The reader gets confused otherwise.

Transmittance will be substituted by normalized transmitted radiance

- Page 5305-5306, lines 18-3: This is nice; you might consider a cross-reference to Brückner et al. (2014, submitted to JGR).

This reference will be added.

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- Page 5308, line 27 (and following): The terms in brackets could be avoided (also later in the text), since the detailed definitions are introduced in Table 1.

The terms in bracket are used as a shorthand definitions and are kept.

- Page 5312, line 16: The phase discrimination for mixed-phase clouds is not really clear. It is obvious that only-ice cases can clearly be distinguished. However, how pure liquid water cases can be discerned from mixed-phase clouds? The ice content in mixed-phase clouds cannot be quantified, which does not become clear from the text. There seem to be two ranges of optical thickness (larger and lower 10). For the range of $\tau > 10$, it is possible to determine thermodynamic phase using one single parameter 1, 2, 4, 9, 10, or 13. Which one do you use? For $\tau < 10$ all 15 parameters are required to determine thermodynamic phase. Anyway, this means you have to use the combination of all 15 parameters, since the range of optical thickness is unknown. Is this the main point of the paragraph? In a similar way, what is the resolution of τ and reff used in the model to discriminate whether it is a liquid water or ice cloud? Please elaborate.

The thermodynamic phase that most closely match the 15 parameters is determined to be the representative phase, either pure ice or liquid. The ice content is not retrieved for mixed phase clouds, the manuscript will be revised to clarify this. Will add to line 21, p.5312: "If any of these 6 parameters have values unique to ice clouds with $\tau > 10$, the cloud thermodynamic phase is therefore ice, and the retrieval process moves on to the second step." The LUT used for determining the thermodynamic phase where these parameters are non-unique, is the same presented in Section 4.3. The manuscript will have this noted right after reference to the LUT.

- Page 5313, line 15-16: Can a threshold or number in certain parameters be given beyond which the retrieval is still valid? Or is this the predefined value of 0.69?

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Since the threshold is related to the signal to noise value, this will be reported, with added examples for particular parameters. The predefined value of 0.69 defines the largest value of the minimum χ^2 for a retrieval that is valid.

- Page 5313-5314, line 23-10: While Section 5.1 discusses only the retrieval uncertainties due to measurement errors, there are other uncertainties as well. For example, uncertainties caused by multi-layer clouds or uncertainties of the model input. Therefore, lines 23 to (next page) 10 should be reworded to clarify that while other uncertainties can also occur, this section discusses only those due to measurement uncertainties.

This section will be reworded to clarify that it is indeed only referring to measurement uncertainties, not uncertainties in ancillary inputs, or other factors described above. Will add: "While uncertainties in ancillary inputs or multilayered clouds may occur, this section only refers to uncertainties related to known variations in measurements linked to calibration stability and noise variance." To line 24 p. 5313.

- Page 5315, line 8-19: It makes no sense to compare to reff time series retrieved from the two wavelength method which cannot be used to derive reff.

The 2-wavelength method can be actually used to derive reff, but it does so with increased uncertainty as compared to the other methods. For completeness of comparison and for tying back this new retrieval method to a 'standard' retrieval, the comparison of effective radius derived from the 2-wavelength method to others is kept. A note on the increase of uncertainty will be added here to emphasize the large uncertainty.

- Page 5317, line 1-19: 'Although we have not addressed the applicability of the 15 spectral parameters to mixed phase clouds in this work, we investigate the results

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of the thermodynamic phase discrimination, and the residual of least squares fit of the retrieval to measured transmittance under conditions of concurrent ice and liquid absorption.' Then I would suggest to show only the results for the thermodynamic phase. To compare the results for tau and reff from all 3 methods, at least the ice cloud LUT should be used for the slope and 2-wavelength method in the start of case B (as GOES retrieves also ice phase). Using a liquid cloud LUT cannot result in a reliable retrieval (values of reff > 30 μm represents the upper limit of reff in the LUT). Furthermore, I don't think, that the overall trend is reproduced with all 3 methods.

We will apply an ice LUT in addition to the liquid LUT to case B. To illustrate the case of the overall trend better, we will add a trend line on top of each retrieved properties, and emphasize the trend for the latter portion of the time series. Wording will be changed accordingly.

- Page 5318, line 3-14: I suggest adding a discussion concerning the influence of different ice crystal shapes on the 3 retrieval methods. As reported by several studies, this could have a huge influence on the retrieved cloud parameters.

Added small description on the effect of ice crystal shape with examples of change to LUT from reflectance based retrievals (e.g. Baum et al. 2011).

- Page 5319, line 28: 'Lastly, The presence' to 'Lastly, the presence'

Changed.

- Fig. 13: The dashed dark green line in case B is very hard to distinguish from the solid colored lines. I suggest changing the color and line style of the presented data.

Line color changed.

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