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Interactive comment on "The Community Cloud retrieval for CLimate (CC4CL). Part II: The optimal estimation approach" *by* Gregory R. McGarragh et al.

Anonymous Referee #1

Received and published: 16 November 2017

This paper describes the optimal estimation algorithm for the retrieval of cloud top pressure (CTP), optical thickness (COT), and effective particle radius (CER), namely the Optimal Retrieval of Aerosol and Cloud (ORAC) algorithm, used in ESA's Community Cloud retrieval for Climate (CC4CL) system. The theoretical basis and methodology of the retrieval are described in great detail. Also presented is an evaluation of the retrieval itself and the fast forward radiative transfer model, each using simulated TOA radiances under a variety of assumptions.

This is a very detailed paper, and is generally well written. I do think revisions are necessary, however. My detailed comments are below. Note that there appear to be

line number issues within the available pdf, e.g., line 10 towards the bottom of pages – I try to remain consistent with what appears in the file. Also, there appear to be font inconsistencies within Figs. 6-13 that caused missing text labels in my downloaded version (viewing online was fine) – please check these figures for portability.

Comments

p 3, line 5: I'm not sure this statement on CO2-slicing is correct. It is my understanding that you need at least two channels within the 13-15μm region, as the technique relies on ratios of two channels having differential CO2 absorption. It is indeed not applicable to the AVHRR record, though, as the authors correctly state.

p 3, lines 20-22: Do the authors have references showing that this difference in simulated vs observed radiances is indeed the case? For the solar retrievals, as long as the thermal cloud top is used consistently throughout the retrieval (e.g., for above-cloud atmospheric corrections), then any solar radiance bias due to using the thermal cloud top is essentially "built in" to the retrievals themselves.

p 3, lines 33-35: It's not clear to my why other "traditional" algorithms cannot also be applied in the same consistent manner? Can the authors elaborate?

p 4, lines 5-6: This statement is true for many "traditional" retrieval algorithms as well; for instance, the Nakajima-King approach will produce simultaneous COT and CER retrievals that are radiatively consistent over both wavelengths used in the inversion.

p 4, lines 7-8: Yes, this may be an advantage of optimal estimation generally speaking, but it is immaterial here since active sensors are not used.

p 4, lines 13-14: This is not unique to optimal estimation – see, e.g., the MOD06 retrievals which use mathematics analogous to optimal estimation to calculate retrieval uncertainty estimates.

p 4, lines 15-16: This is certainly true!

p 4, lines 17-19: The authors might want to add the Wang et al. papers (2016a,b, JGR, doi:10.1002/2015JD024528, doi:10.1002/2015JD024526) that detail a MODIS IR-based optimal estimation retrieval of ice phase COT, CER, and CTH.

Section 3.2.2: Did the authors verify that the Baum general habit mixture for ice clouds yields consistent COT retrievals from independent solar and thermal IR retrievals? When combining observations from different spectra, it is important to use assumptions that can provide consistency between both. Refer to the Holz et al. (2016, ACP, doi:10.5194/acp-16-5075-2016) paper for further discussion.

p 11, lines 9-11: Why extend the retrieval space beyond the $60\mu m$ maximum CER of the ice cloud scattering properties? What does this gain?

p 12, line 23: Remove "look-up" from the beginning of this line, as that is already included in the acronym LUT.

p 12-13, DISORT approximation list: I would also add that the analytical solution requires approximating the scattering phase function, through some use of expansion terms, in which case some special scattering angles (e.g., liquid cloud rainbow region, glory) may not be well resolved depending on the number of terms used.

p 13, lines 11-13: Can the authors provide a statement on any errors incurred by fixing the cloud top for above/below-cloud Rayleigh scattering, given that cloud top is part of the state vector?

p 13, last paragraph: Can the authors provide evidence that the errors due to not accounting for the response functions are small? In some spectral regions cloud scattering properties may have significant variation with wavelength such that characterizing channel placement is critical (e.g., I believe, ice crystal absorption around $3.7\mu m$, among others). Regardless, if the calculations are done offline and stored in LUTs anyways, why not go ahead and account for instrument response functions?

p 20, line 10: Lbc should also depend on surface emissivity, correct?

p 21, lines 23-24: To clarify, the Jacobians are calculated via mathematical formulations rather than, say, perturbing each parameter and re-calculating the radiances?

p 21, lines 32-33: Perhaps reference Zhang et al. 2012 (JGR, doi:10.1029/2012JD017655) or another of his papers here.

Section 3.8, p 22: I again might add the representation of the phase function in the radiative transfer calculations, which can introduce large errors at special scattering angles if not adequately resolved. Backscatter peak calculations are also known to be deficient in some cases, e.g., the Yang et al. ice crystal database – see Zhou and Yang (2015, Opt Express, doi: 10.1364/OE.23.011995).

p 23, line 23: Since you're including Hale & Querry here, you might as well add the Palmer & Williams and Downing & Williams references as well.

Section 3.9: Why not use DISORT as the reference model, since that is what is used for the cloud calculations? This would eliminate potential differences in the radiative transfer solution due to different model approaches. Why are errors with respect to angle space not shown for $3.7\mu m$, which has a large solar component?

Tables 3, 4: I notice that the CER limits for liquid and ice retrievals, with the exception of the maximum liquid value, are outside of the pre-calculated cloud LUT ranges. How can that be the case?

p 28, lines 25-26: In many cases assuming uncorrelated errors is inappropriate. Are there plans to include error correlation in the future? I would suggest the authors refer to Wang et al. (2016a, JGR, doi:10.1002/2015JD024528) for a detailed treatment of error covariance matrices in the IR.

p 28, line 12 (bottom of page): Is COT really normally distributed? See, e.g., Fig. 15 in King et al. (2012, IEEE TGRS doi:10.1109/TGRS.2012.2227333) – here it seems this assumption is more valid for CER.

p 28, line 13 – p 29, line 16: I think the authors are confusing individual crystal sizes

within an observed size distribution with the effective radius that is more of a "bulk" quantity.

p 29, line 19: Are uncorrelated a priori standard deviations appropriate given non-orthogonal solution spaces (e.g., COT-CER space at small optical thickness)?

p 29, lines 21-23: Assuming large a priori standard deviation, thereby eliminating its constraint on the retrieval solution, is somewhat at odds with an earlier statement in the paper implying that a priori assumptions are important (p 25, last paragraph).

p 30, lines 19-20: Did the authors verify that including Ts in the state vector reduces its uncertainty relative to ECMWF?

Section 4.4: I'm curious how close the first-guess CTP is to the final CTP solution. I assume relatively close for optically thick clouds. Have the authors looked at this?

p 34, lines 36-37: I'm surprised to see small CTP errors at small COT, though I guess the difference between the surface and cloud temperatures are small enough that surface contamination does not significantly bias the results.

Section 5: Since Ts is fixed in the simulations but is part of the state vector, have the authors looked at differences between the retrieved Ts and its fixed value? I'm wondering if this is playing a role in some of the differences observed here.

p 35, lines 27-28: Did the authors verify that the microphysical information does in fact improve the CTP retrievals? An easy test might be to simply remove CER from the state vector.