The manuscript discusses the retrieval of vertical droplet size profiles from multispectral solar reflectance observations with high radiometric accuracy using a constrained optimal estimation inversion technique applied to MODIS observations. The study leverages VOCALS-REx field campaign data to develop the forward model constraints, which improves retrievals from, in particular, the lower optical depth levels of moderately thick liquid phase clouds. The high radiometric accuracy and spectral sampling follows from the design specifications for the upcoming CLARREO Pathfinder (CPF) instrument to be flown on the ISS in the 2026-27 timeframe. The findings highlight the value of high radiometric accuracy compared with current state of the art satellite imagers, as well as the challenges in comparing retrievals against *in situ* measurements in heterogenous clouds due to the profound differences in sampling volume.

The study contributes to a better understanding of future cloud microphysical profile retrieval information content from solar reflectance observations and nicely expands on previous efforts. The manuscript is very well-written, successfully capturing the history of previous studies as well as appropriate details of the author's work. I characterized one comment as major but all others are minor.

<u>Major comment</u>

Fig. 4: This is a very important figure in terms of the study findings but I was confused.

(1) I interpret the y-axis to be absolute reflectance, not relative reflectance like the accuracy specs for MODIS or CPF. If that's correct, the choice of r_bottom and dr_bottom will scale the y-axis value Jacobians without changing the MODIS or CPF lines. If that's the case, I don't know how to interpret the results (e.g., if dr_bottom is effectively zero, all bars will be zero on the y-axis). If not the case, please elaborate.
(2) While the text mentions the spectral dependence of the Jacobians, it's not clear which channel(s) are being used in the figure.
(3) The y-axis for the Jacobians should be labeled delta reflectance, delta reflectance/drbottom, or something similar unless I'm mistaken about (1).

<u>Minor comments</u>

L34: "effective droplet radius" or "effective droplet absorption" is proportional to 1-ssa? While it's true that kr_e ~ 1-ssa for an absorbing wavelength, it's an ill-defined definition for r_e when ssa=unity (i.e., reduces to r_e = 0/0).

L49, 60: While Twomey and Cocks (1982) provides a nice overview of the retrieval theory, a more focused retrieval study was done in the follow-up Twomey and Cocks (1989, *Beitr. Phys. Atmosph.),* which used 5 spectral channels simultaneously in the retrieval (not bi-spectral) and presented the solution space in terms of residual contour plots similar to your Figs. 7, 8.

I'm not suggesting you include the following relevant historic τ, r_e retrievals references but just for awareness: Other airborne retrievals (Foot (1988), Rawlins and Foot (1990)); AVHRR (Arking and Childs, 1985), Platnick and Twomey (1994).

L60: suggest adding the qualifier "nearly independent from one another for optically thicker clouds ..."

L64: "... radius, cloud optical depth, and various surface spectral reflectance assumptions."

L123, Sect. 4.2: As a simulation, it doesn't make a difference for present purposes, but I'm curious why the simulations were done for EMIT spectra instead of CPF, which is mentioned prominently as the motivation for the study (including the abstract). Was it in anticipation of doing EMIT retrievals as a follow-on? It would be useful to explain the rationale.

L184: What effective variance (v_e) is used? The alpha "width parameter" is mentioned on L294 but would be helpful to put it in terms of v_e. Are the same value(s) used for all 100 layers?

L188, 193: Eq. 5 is an approximation, though a reasonably good one, for the retrieved r_e since an exact weighting function is confounded by multiple scattering. I.e., suggest "represents the approximate retrieved ..."

L91: A nice summary of the previous work. Platnick (2000) also did an information content study for MODIS-like imager, including the effect of calibration uncertainty, to help understand the number of independent parameters that can be retrieved for vertical profile inversions. Hard to make apple-to-apple comparisons but do your results seem somewhat consistent? Similar question with respect Fig. 8 accuracy sensitivity.

Fig. 1: Please try to add some contrast to the line plot colors as some are hard to distinguish (esp. for color blind readers).

L253, 254: Good idea.

L295: The MODIS retrieval wouldn't correspond exactly to the upper boundary r_e according to Fig. 1. Likely a small difference but worth a comment.

L361/Sect. 4.1: For further context on the confounding effects that uncertainties in situ probes have on retrieval validation, including sampling issues associated with vertical and horizontal heterogeneity, I suggest looking at the recent Meyer et al. ORACLES study (amt.copernicus.org/articles/18/981/2025/). The paper discusses airborne spectral retrievals compared against two in situ cloud probes (CAS, PDI) having different measurement approaches in addition to some retrieval forward model errors. Retrieval evaluation with airborne probes continues to be an inherently challenging problem for the community. Nice discussion here and in Sect. 4.1.

L377: Not sure that the cloud-top r_e retrievals "validate" use of the 2.1 μm MODIS bi-spectral retreival as a prior as much as demonstrates consistency with its use as a prior. I.e., much of the upper cloud r_e information content is coming from the 2.1 μm channel, regardless of which algorithm is used.

Fig. 3a and 3c have the same MODIS retrieval values (blue dashed lines). One must be incorrect.

L409: I think this often gets lost on those who use gradient searches as part of inversion algorithms, especially in higher dimensional spaces. So, good to make this point, as obvious as it may seem. Is there an example solution contour plot associated with Fig. 3 that you could show to illustrate this point (i.e., similar to Figs. 7, 8)?

L440: suggest "… approximately 1 km^2". The effective pixel shape in the across track direction suffers from the finite integration time and so has a ~2 km triangular wide spatial weighting function for most MODIS channels though a bit less so for "1 km" channels aggregated from the native 250 m (bands 1, 2) and 500 m (bands 3-7) detector arrays. That said, L462 is correct that the across track sampling is 1 km.

L446: Interesting number. Thanks for making the calculation.

Fig. 5 caption, L454, 455, and later text/captions.: Constant altitude flight lines aren't usually considered a "profile" in airborne sampling vernacular (at least in the cloud and aerosol community). Also, elsewhere in the manuscript profiles is used, without qualification, to describer vertical sizes only so it will be a source of confusion. Try "horizontal legs" or just "legs". I realize that constant altitude across three different clouds during the campaign may end up sampling different depths relative to cloud top and so have some verical profile information (e.g., the yellow curve in Fig. 5).

L458: "… and 6 μm (yellow)"

Figs. 7, 8: Nice demonstration of more channels v. better accuracy, with the latter being the only way to dramatically reduce the delta radius solution space uncertainty. That's an important result. (1) Initially, I didn't notice that the y-axis had both positive and negative values. Would be helpful to add a horizontal line to the zero value so readers can quickly appreciate that a large region of the space is outside the constraint. Or add a slight shading to the negative regions. (2) Add a point on the plots to indicate the modeled cloud optical depth and delta effective radius that was used in the simulation (didn't see it mentioned in the text, nor the cloud top effective radius).

Data Availability: If MODIS L2 cloud data was used, please also mention that these files were obtained from LAADS. I strongly suggest providing a doi for both the L1B and L2 files, which should be available on the LAADS product information pages.