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Interactive comment on "Liquid marine cloud geometric thickness retrieved from OCO-2's oxygen A-band spectrometer" *by* Mark Richardson et al.

Anonymous Referee #1

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This manuscript presents a method for the joint retrieval of cloud optical thickness, top pressure and geometric thickness from passive hyperspectral shortwave IR measurements combined with lidar observations. Overall the paper is well written and the presented methodology appears sound. The retrieval of the cloud geometric thickness from O_2 A-band measurements is an important novel element of this method, even though it must be acknowledged that the validation of cloud geometric thickness looks much less robust than that of the other parameters. In particular, I find it difficult to understand what is the additional added value of the retrieved cloud geometric thickness compared to a reasonably chosen prior. Below are my complete comments.

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[Discussion paper]

MAIN COMMENTS

- The validation of the retrieved quantities is mostly focused on discussing biases and their most likely sources, but it would be also nice to see how well do the retrieved cloud optical thickness correlate with MODIS.

- While correlative data are available for the validation of cloud optical thickness (MODIS) and cloud top pressure (CALIPSO), the only available verification for cloud geometric thickness is a comparison to the adiabatic prior. I know that independent measurements of cloud geometric thickness are difficult to obtain, but nevertheless don't you feel that just comparing the retrieval with the prior limits somehow our capability of assessing the added value of the retrieval? After all, if you carry out a retrieval it is because you would like to get better estimates than the prior. What I see from the paper is that your Delta P_c retrievals are sensitive to the choice of the prior. As you say at page 13, scaling the prior Delta P_c by 0.5 or 2 leads to posterior Delta P_c that are, in your own opinion, unrealistically small and unrealistically large respectively. Absent a dataset of independent measurements, though, it is difficult to corroborate this opinion. Would an experiment with synthetic data (running the retrieval on synthetic cloud scenes of which you know the geometric thickness) be of any help? And are there any instruments (e.g., ground-based lidars) available from which marine cloud base heights can be determined and combined with CALIPSO cloud top heights? Wouldn't that help you understand more precisely how your Delta P_c retrievals behave?

MINOR COMMENTS

- P4, L14. Try to avoid the repetition in "A term-by-term error analysis estimated H could be estimated..." (replace one of the two "estimated" with a synonym)

- P7, L7. "each I" -> "each I_i (i=1,...,75)"

- I think the description of the optimal estimation principles at page 7 is a bit too terse, and may not be help a non-expert reader to understand what this all is about. No

context is provided for the invocation of Bayes' theorem. In my opinion, the following points should emerge from the description:

1. It is assumed that the state vector follows a Gaussian distribution with mean x_a and covariance matrix S_a

2. It is assumed that the measurement error is additive and follows a Gaussian distribution with zero mean and covariance matrix S_epsilon

3. The Bayes theorem is applied in order to express the posterior probability density of the state vector given the observations

4. The estimation procedure looks for the maximum of such probability density

- P7, L16. Please clarify that x_i is the iterate solution, and that K_i is the Jacobian matrix of the forward model evaluated at x_i

- P7, L20. What convergence criterion did you adopt?

- P8, L31. Please specify what you mean by "correct for mu_0". I guess you divide I by mu_0, but it would be better to make this explicit.

- P9, L4. Could you explain the reason for applying a low cloud top pressure threshold? Is it because you assume ice clouds if p_top < 680 hPa?

- P11, L1. I may have missed where I_wk and I_O2 are defined. If they weren't, please specify their meaning (I guess they represent radiances in the weak CO2 band and in the O2-A band respectively, but it should be made explicit).

- P11, L8-20. I had some difficulties trying to link the text with what is shown in Fig. 4. The subfigures (c) and (d) contain four plots each. In the legend, two plots are marked with "& flag" and two are not. Does the "& flag" mark mean I_wk/I_O2<0.28? It would be handy to have this information readily available in the figure caption (now you only mention a "radiance ratio warn flag"). Furthermore, at L13 you say that "for the full sample the median bias is 0.02 times the MODIS uncertainty and the 14-86% range is

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-1.15 to 0.99". Are you then referring to panel (b) of Figure 4? If so, there the 14-86% range reads -1.12 to 1.02. A similar question holds for the last sentence (L18-20). Are you referring to panel (d) of Fig. 4? If so, the numbers mentioned in the text seem slightly inconsistent with those reported in the figure. This is of course a minor issue, but it does not help readability.

- P15, L4. "we Section 5.3.3 linked" -> "in Section 5.3.3 we linked" ?

- Wouldn't the material presented as supplement be more suitable as an appendix inside the manuscript?

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