General response to reviewer 3
We have responded to each of your points below, with your text in red and ours in blue. We have made changes to address all of your technical comments. After playing around with the organisation and ordering of the text, we decided to keep the current structure but change section titles to help readers follow.

We have found that we get pretty good match with the MODIS cloud flag by using a simple brightness threshold, and similarly get a good match (~93 % agreement) on cloud phase using a simple derived Nakajima-King diagram. Our retrieval is now running through the OCO-2 data record but we haven't finalised thresholds for warning levels etc. For SZA < 60° We can match when MODIS is confidently cloudy in 93—96 % of cases depending on the orbit, for a set of test orbits we have done. We can also increase the thresholds to do fewer retrievals, but be more likely to retrieve when MODIS also obtains cloud properties (the numbers differ since MODIS retrieval does not provide e.g. τ for every confidently cloudy scene).

We feel that adding these preliminary results would clutter the paper and the thresholds may change before product release so have just expanded the discussion to address your points.

Your suggestion of adding degrees of freedom for signal and adding a comparison versus lower spectral resolution results has clearly improved the paper. Fortunately we easily replicated the Schuessler et al. GOME-2 results and they fit very neatly into the narrative in our introduction.

Thanks for your time and helpful review.

NOTE: our page and line numbers refer to the new version. With our greatly expanded introduction and other minor corrections it became very messy otherwise. New Figure 6 is appended to end of this document.

Interactive comment on "Information content of OCO-2 oxygen A-band channels for retrieving marine liquid cloud properties" by Mark Richardson and Graeme L. Stephens

Anonymous Referee #3
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Review comments on manuscript "Information content of OCO-2 oxygen A-band channels for retrieving marine liquid cloud properties"

Authors: M. Richardson and G. L. Stephens

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MS Type: Research article

General comments:
This paper presents a theoretical study on retrieving marine boundary layer cloud optical thickness, pressure thickness, and top pressure, using the OCO-2 oxygen A-band measurements. The method is well defined and the results are of interests to the community. The topic is suitable for publication in AMT, but I do have some concerns for the authors to consider.

1) Marine boundary layer clouds are targets that we have pretty good a priori knowledge; hence it's not surprising to have good retrieval accuracy, but since the goal of the research is to apply the method to OCO-2 retrievals, one question would be how to decide when to retrieve? I would suggest adding at least some discussions on how to identify the clouds that are suitable for applying this method.

- ➔ **Response:** We are preparing a paper and Algorithm Theoretical Basis Document to explain our full implementation in practice and didn't want to clutter this paper. However, we understand that readers may be interested in some of the general principles we will apply so have made the changes listed below. Some further justification: the OCO-2 preprocessors provide cloud flags, but they are optimised for glint only over ocean (e.g. Taylor et al. 2016, cited in the text for its collocated data) and we found we could not use it in nadir. Instead, we use a simple brightness threshold after accounting for solar zenith angle. Initial tests show >90 % agreement with MODIS cloud flags, depending on the orbit.

➔ **Changes made:** Text added to discussion: "Cloud identification is relatively simple for nadir A-band reflectance measurements over ocean, as for most solar zenith angles the surface is dark and cloudy scenes may simply be identified when reflectance exceeds some threshold, which depends on the viewing geometry".

2) The literature review should have been more complete. There have been studies on retrieving cloud pressure thickness plus cloud top pressure in the past, especially for thick clouds over dark surfaces (e.g., Ferlay et al. 2010, Yang et al. 2013, Merlin et al., 2016, reference given below).

➔ **Response:** Agreed, the introduction has been changed.

➔ **Changes made:** The introduction has been rewritten and substantially lengthened with citations to Hanel (1961), Yamamoto & Wark (1961), Deschamps et al. (1994), Ferlay et al. (2010), Desmons et al. (2013), Merlin et al. (2016), Yang et al. (2013), Rozanov & Kokhanovsky (2004), Schuessler et al. (2014), Heidinger & Stephens (2000) and O'Brien & Mitchell (1992). These support a new summary of various A-band cloud studies and then justify our new work as applying hyperspectral approaches that are useful for low clouds. We cite Bony & Dufresne (2005) and Zelinka et al. (2012) to support the importance of low clouds that are poorly sampled by the multi-angular approaches, and explain our advantages for geometrical thickness relative to other work that used instruments with lower SNR and spectral resolution.

3) I found the structure of the paper makes understanding the contents difficult. I would suggest some re-arrangements. For example, Section 2 is titled "The OCO-2 satellite and its instruments", I couldn't see how the two subsections fit there: " 2.1 OCO-2 radiative transfer calculations" and "2.2 Optimal estimation and information content". My suggestion would be to use one section to describe forward modeling issues and another section for retrieval related issues.

➔ **Response:** We looked into moving things around but decided that we prefer the current organisation, but agree that the titles are confusing. Our separation is (Section 2) general information and techniques introduced and (Section 3) Specific techniques and samples used in this paper. Going for (Optimal Estimation) followed by or leading (Forward model) also seemed somewhat confusing given it leaves no obvious place to put the synthetic retrievals, and aspects needed for the optimal estimation (e.g. our sampling methodology) require understanding of the forward modelling and vice versa. We think that whichever way could confuse some readers, but think that after modifying Section 2 and 3 titles things are clearer this way.

➔ **Changes made:** Section 2 title changed to "Data sources and analysis techniques"

4) I would suggest converting the information content shown in the article to how many pieces of information can be retrieved. For example, it's not clear to me what information content = 16 means (the red line in Figure 4(a)) physically.

➔ **Response:** We had thought that the low posterior errors were sufficient to indicate that the degrees of freedom or signal approached 3, but agree that there isn't actually that clear. We have therefore added d_s to our figures and discussion.

➔ **Changes made:** degrees of freedom for signal introduced in Section 3 along with the equation we use to calculate it. Figures 4 and 5 now have it, and legend of new Figure 6 includes example values.

References:

Ferlay, N., and F. Thieuleux, C. Cornet, and A. B. Davis, 2010: Toward New Inferences about Cloud Structures from Multidirectional Measurements in the Oxygen A Band: Middle-of-Cloud Pressure and Cloud Geometrical Thickness from POLDER-3/PARASOL. J. Appl. Meteor. Climatol., 49, 2492–2507. doi: C2 http://dx.doi.org/10.1175/2010JAMC2550.1.

Merlin, G., Riedi, J., Labonnote, L. C., Cornet, C., Davis, A. B., Dubuisson, P., .Parol, F., 2016: Cloud information content analysis of multi-angular measurements in the oxygen A-band: Application to 3MI and MSPI. Atmospheric Measurement Techniques, 9(10), 4977-4995. doi:http://dx.doi.org/10.5194/amt-9-4977-2016.

Yang, Y., A. Marshak, J. Mao, A. Lyapustin, J. Herman, 2013: A Method of Retrieving Cloud Top Height and Cloud Geometrical Thickness with Oxygen A and B bands for the Deep Space Climate Observatory (DSCOVR) Mission: Radiative Transfer Simulations. J. Quant. Spectrosc. Radiat. Trans. 122, 141-149,

http://dx.doi.org/10.1016/j.jqsrt.2012.09.017.

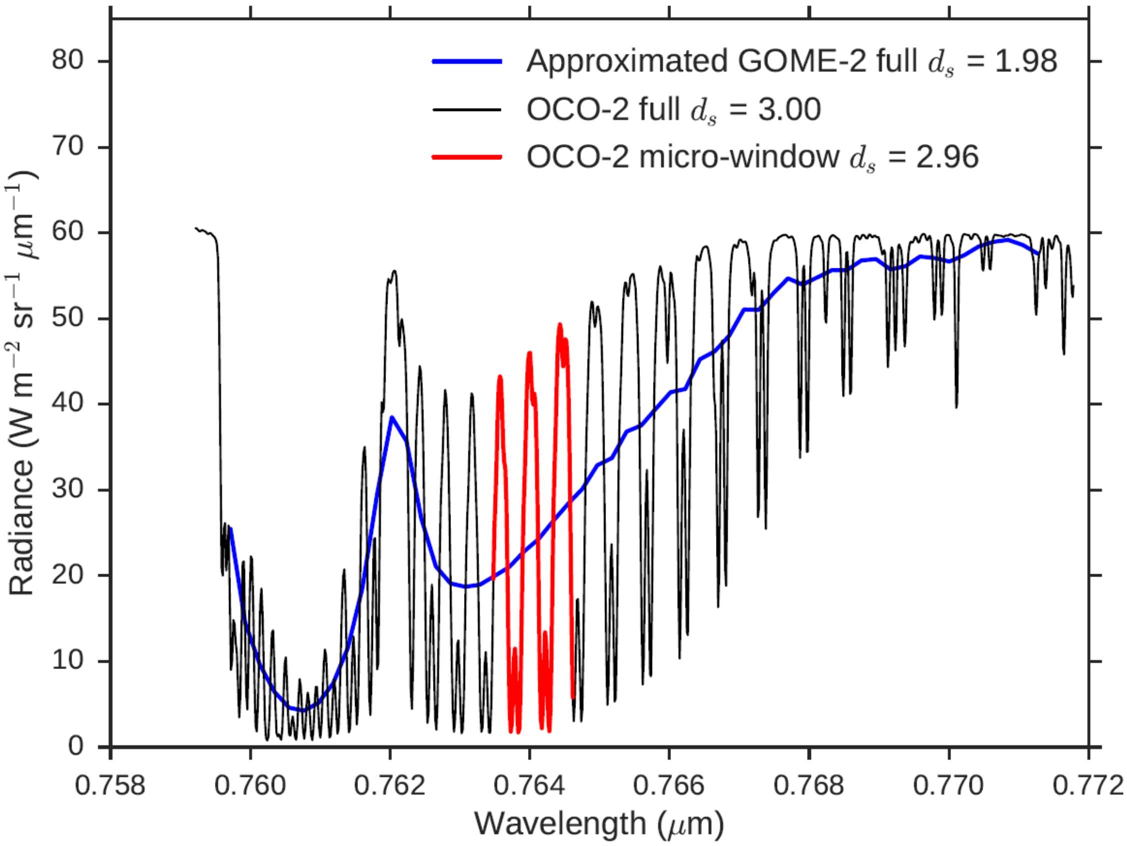

Figure 1 Example simulated cloudy scene A-band spectrum, for a τ = 10, P_{top} = 850 hPa cloud in a tropical atmosphere with a solar zenith angle of 45°. The black line shows the full OCO-2 simulated spectrum, the blue line is the black line resampled using approximate GOME-2 instrument line shapes and the red line is the selected 75 channel micro-window for OCO-2 cloud retrievals. The legend also reports the d_s for each spectrum with the GOME-2 instrumental uncertainty based on an SNR of 100 as in previous work (Schuessler et al., 2014).