General response to reviewer 2
We have responded to each of your points below, with your text in red and ours in blue.

Firstly, we haven't specifically mentioned airborne data, although some of our citations and text now refer to instruments that have airborne versions (e.g. MSPI). We're definitely interested in seeing the outcome of more airborne campaigns and comparing our functioning retrieval with available airborne data including non-A-band sensors. A next step is to look at ORACLES data to assist with our validation since they have some flights designed to underpass CloudsSat, which has the same reference ground track as OCO-2

The ORACLES example brings us neatly to the issue of aerosols: our current radiative transfer implementation has had some problems with adding above cloud aerosol. We have plans to transfer the code to optimise for scattering atmospheres but we believe that sufficient caveats mean that this paper is still justified (after all, other recent cloudy information content papers have worked on single layer cloudy scenes too!). We have added text and citations regarding aerosols and highlight that it is a source of uncertainty that we must address.

Your suggestion of using the multi-layer mask from MODIS is excellent and we are considering and testing it now. We are currently running our retrieval with CALIPSO priors as well, but MODIS has the advantage of a longer expected time in the A-train. Ultimately we would like to identify multi-layer cases with OCO instrumentation alone so that our retrieval could be applied to e.g. potential OCO-3 measurements even if no other MODIS-like or CATS-like instruments are available to identify multi-layer cases. However, CloudSat-CALIPSO and MODIS multi-layer data are vital to allow us to develop and test this technique.

Thanks for taking the time to review our paper, you spotted several unclear points or typos that we have now fixed.

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. Please scroll to end for new Figure 6.

Review of Richardson & Stephens paper:

This is a very interesting and valuable study. I would be very interested to know how this study could transfer to airborne spectrometers like AVIRIS and PICARD that also have high spectral resolution and lack IR channels for cloud top retrieval. We've done a similar thing with ASTER: used an instrument that was previously only for clear-sky work and created a product from unused data. The paper is overall well written and methods are clearly described and understandable.

Major comments:

Marine SCu frequently have some kind of aerosol sitting on top of them especially off the coast of Africa (Sahara dust and Namibia smoke) and to a lesser extent the US Pacific Coast (mostly smoke). Have you tried inserting above-cloud aerosol layers into your simulations and seeing what happens? I'm not saying that you have to correct for aerosols but some idea as to uncertainty introduced by absorbing aerosols would be nice.

- ➔ **Response:** We have added some discussion about aerosols and indicated that we do not consider them in this study. There have been some technical problems implementing aerosol layers into our modified cloudy-scene radiative transfer model. Much other A-band work has considered clear-sky cases and we have discussed the prevalence of aerosol in the new text, and note that we should be able to flag heavily polluted cases using collocated data. Future work will look in more detail at overlying aerosol, and speculatively I expect an effect on the residual spectral fits from the retrieval which may allow identification based on OCO-2 alone.
- ➔ **Changes made:** p3L10—12 now reads: "Our current analysis considers aerosol-free cases as aerosols have not yet been properly implemented in our modified cloudy-sky version of the radiative transfer model, this is an avenue for future work and will be discussed in Sect. 5."

P13L32—p14L9 now reads: “Alternatively, since OCO-2 flies in the A-train it would also be possible to use other sensors such as CALIPSO (which is now leaving the A-train) or MODIS to identify multi-layer cloud cases, or scenes in which there is heavy aerosol loading. Cases of heavy aerosol loading are most common over the Namibian stratocumulus region with common occurrence in June-July-August (JJA) and a peak in September-October-November (SON). A combination of CALIPSO, CloudSat and International Satellite Cloud Climatology Project (ISCCP) data imply that in the SON Namibian stratocumulus region, approximately one-third of low clouds have overlying aerosol, and approximately half of these cases are smoke (Devasthale and Thomas, 2011; Winker et al., 2010). Scattering layers overlying a marine cloud tend to reduce in the effective retrieved cloud layer pressure due to the reduced mean path length of those photons reflected from the overlying layer (Vanbauce et al., 1998). Assessment of aerosol effects will be necessary in future work.”

Please be consistent in definition of micro-window. You use “pixels” in the first 8.5 pages of the paper and then switch to “channels” for the rest of the text. I personally would prefer you use “channels”, but you can use whichever you see fit as long as it’s consistent throughout.

- ➔ **Response:** Agreed, this was a legacy from our use in a previous paper and some OCO-2 documentation but is confusing.
- ➔ **Changes made:** We now use the correct term “focal plane array elements” when discussing damage to the sensor, and “channels” for all spectral properties.

Minor comments:

Figure 3 caption should read $\mu_{0\text{-}2}=\cos_{\text{-}2}(SZA)$, μ is normally used to indicate sensor zenith angle.

- ➔ **Response:** Oops.
- ➔ **Changes made:** Labels changed throughout, $\mu \rightarrow \mu_0$

Page 1 Line 1: please expand CALIPSO acronym, first use

- ➔ **Response:** Done.
- ➔ **Changes made:** CALIPSO is now introduced on p2L13 following our major changes to the introduction, its acronym is expanded.

Page 2 Line 21: should read “equator crossing time near 13:30”

- ➔ **Response:**
- ➔ **Changes made:** Done.

Page 7 Line 25: please clarify what the micro-windows are measured in: 500 of what? Later in the text, on page 9 it becomes clear that the units of the micro-window size are channels. For folks that don’t normally use something like OCO, it might help giving a bit more information, like what a 75-channel micro-window translates into as far as a wavelength range goes. It would make the research more transferable to other instruments as this is a potentially very valuable retrieval approach.

- ➔ **Response:** This was unclear on our part. We have now clarified throughout, adding “channels” after 500. The 75 channel wavelength range is given. The new Figure 6, made in response to reviewer 1, also hopefully clarifies things.
- ➔ **Changes made:** p10L9—10 now reads: “To make this problem tractable, we select micro-windows of the following size: 5, 10, 25, 50, 75, 100, 150, 200 and 500 neighbouring channels.” (note added word “channels”)

  p12L17—28 text includes: “By contrast, the 75 channel micro-window...reduces the full wavelength range from 759.2—771.8 nm to 763.5—764.6 nm.”

  Figure 6 added to visualise this.

Page 9 Line 3: please use θ_0 and μ_0 as is generally customary for solar zenith angle and its cosine

- ➔ **Response:** Agreed.
- ➔ **Changes made:** Done.

Page 9 Line 20: "highest mean information content2. " A typo?

- ➔ **Response:** Good catch.
- ➔ **Changes made:** 2 deleted.

Page 10 Line 26: OCO is in the constellation with Aqua, so you may be able to use the MODIS multilayer cloud map in order to stay away from cirrus. That's just what that map is for.

- ➔ **Response:** We have done some preliminary analysis using this for validation of the retrieval and it makes a difference (same as multiple layers from CALIPSO). This was helpful in our discussion, thanks.
- ➔ **Changes made:** See aerosol response text, we now mention the multi-layer map.

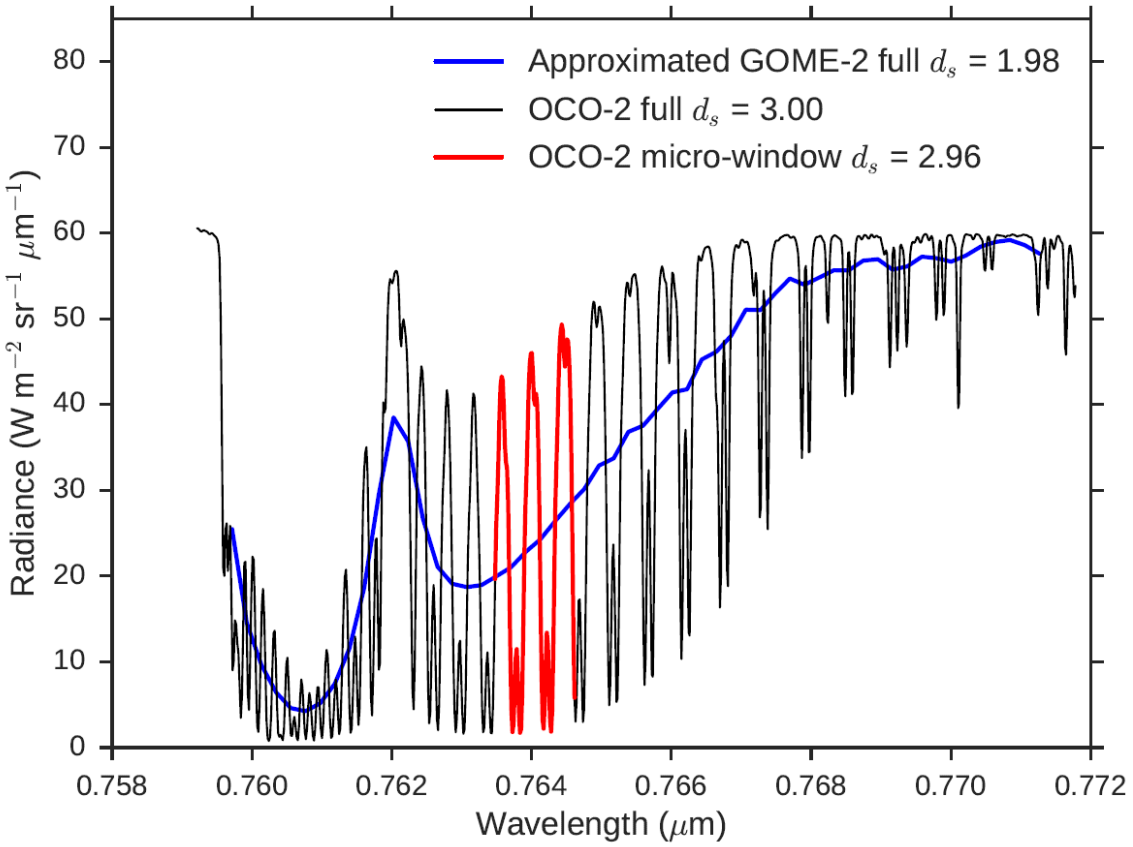

Figure 1 Example simulated cloudy scene A-band spectrum, for a τ = 10, P_{top} = 850 hPa cloud in a tropical atmosphere with a solar zenith angle of 45°. The black line shows the full OCO-2 simulated spectrum, the blue line is the black line resampled using approximate GOME-2 instrument line shapes and 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).