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

Anonymous Referee #2

General comments:

This paper introduces the new OCO2CLD-LIDAR-AUX product and its algorithm theoretical basis. The algorithm adopts the optimum estimation principles to retrieve cloud properties, including optical thickness, cloud top, and geometrical thickness for marine boundary layer clouds using the OCO-2 hyperspectral A-band measurements. Performance evaluation is also conducted. The paper is well written and this new product provides new information for further understanding the properties of marine boundary layer clouds. The topic is suitable for publication in AMT. I recommend publication after some minor revisions. Some concerns for the authors to consider:

Comments: Firstly, thanks for reading our paper, we appreciate that you clearly thought about relevant physics throughout and are gratified that you recommend publication after minor revisions. We have addressed your comments below, and the manuscript with tracked changes is part of the file in response to RC1.

Changes: See below.

1) I actually don't find the physics of cloud phase detection method used here straight-forward. What is the general value range for Iwk/Io2? How strongly does it depend on other factors in addition to cloud phase (e.g., cloud optical depth, height etc)?

Comments: We have flipped the order of Figures 2 and 3 and lengthened the description: it's a "traditional" Nakajima-King approach relying on how ice absorbs relatively more strongly for the longer wavelength band.

There is little sensitivity to cloud top pressure since we are using continuum bands with little above-cloud absorption. There are sensitivities to the droplet/crystal size, but these are summarized in the Nakajima & King reference, and the relationship to τ can be inferred from the lookup table that is the black line in the phase lookup table figure.

Changes: The final paragraph of Section 4.3 has been changed to:

"If both of these tests agree on a cloud, then the continuum A-band and weak CO_2 $\mu_0 I$ are used to estimate cloud phase via a lookup table that exploits how ice absorbs more strongly than water in the weak CO_2 band relative to the A-band (Nakajima and King, 1990). A lookup table is also used to estimate the prior cloud optical depth from the continuum A-band radiance, since more optically thick clouds tend to be brighter, and Figure 2 shows both the phase and τ lookup tables."

Figures 2 and 3 order switched.

2) The differences in performance for thin and thick clouds (Fig. 6) makes me wonder the role of surface reflectance. How is the sea surface reflectance handled?

Comments: We use a Cox-Munk scheme with ECMWF surface winds, tests showed little response of the retrieval to scaling the albedo because the oceans are typically so dark in the nadir anyway, and any signal is dominated by clouds. We now comment more on this, and for further illustration: median clear-sky nadir view $\mu_0^{-1}I$ is about 4 W m-2 sr-1 micron-1. Our threshold for any cloud is 15 W m-2 sr-1 micron-1. Our changes below explain this.

Changes:

Text added to Section 4.3 when discussing meteorology:

"which provides temperature and humidity profiles along with surface wind speed for the Cox-Munk sea surface reflectance model (Cox and Munk, 1954)"

Text added to Section 4.3 when discussing cloud flags:

"This threshold is equivalent to just over 15 W m^{-2} sr^{-1} μm^{-1}, compared with the median $\mu_0^{-1}I$ near 4 W m^{-2} sr^{-1} μm^{-1} in clear sky conditions, according to the OCO-2 A-band preprocessor."

Text added to Section 5.3.1 in discussion of Figure 6 (now Figure 8):

"This shift fits with aerosol layers above the cloud shortening photon path lengths, and is inconsistent with a dominant role for increased surface reflection in scenes with a low value of retrieved cloud τ. The secondary peak near 0 hPa in low-τ clouds might be related to signals returning from the surface with a longer path length counteracting the upward shift, but these only represent a small fraction of the total retrievals."

Specific comments:

P8 L19: It is mentioned that the L2RTM input includes meteorology. I assume this include temperature profile?

Comments:

Changes: Text added to the same paragraph:

"which provides temperature and humidity profiles along with surface wind speed for the Cox-Munk sea surface reflectance model (Cox and Munk, 1954)"

P9 L8: Cloud phase determination is brought up here, but the details are given in P11; suggest either move the details here or add something like “detailed discussion in Section5.1”.

Comments: We hope that our response to comment 1) covers this.

Changes: See above

Figure 4: Does “&flag” in the legend mean “Quality_flag =2”?

Comments:

Changes: We have changed the legend to explicitly state the ratio used and the final sentence of the caption has been lengthened to link these values to the Quality_flag.

Figure 8: there are typos in the caption: there are two panel “c” descriptions (the second should be for panel d) but none for panel “f”.

Comments: Thanks for catching this.

Changes: Caption corrected.