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Atmospheric Measurement Techniques Discussions

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Interactive comment on "Characterization of the OCO-2 instrument line shape functions using on-orbit solar measurements" *by* Kang Sun et al.

Anonymous Referee #1

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General comments

This study is an accurate characterization of the OCO-2 ILS function from on-orbit solar calibration measurements. The OCO-2 preflight ILS was provided in tables because typical line shape functions cannot fit well (Frankenberg et al., 2015). Authors analyzed on-orbit solar spectra fitting by several analytical functions and stretch/sharpen preflight ILS. They showed the ILS fitting result of several solar lines in spectral micro-windows and the temporal variations of ILS FWHMs.

They found the derived O2A ILS sharpen term was changed but the ILS FWHM of O2A band was stable. The sharpen term decreased in time but recovered after decontamination operation. On-orbit ILS is estimated the center is sharper, but the wing is broadened than preflight ILS. They discussed that this O2A ILS wing broadening was related to the reflection from the FPA with ice layer accumulation (Crisp et al., 2016). The reflection might be affected to SIF retrieval in earth observation spectra. They showed the O2A band had an offset radiance in the SIF retrieval from solar spectra, which have no chlorophyll fluorescence. Temporal variation of on-orbit stretch/sharpen ILS for solar spectra can explain the SIF offset. They concluded an accurate knowledge of the ILS on-orbit variation might be useful for precise XCO_2 retrieval.

Overall, this study showed the OCO-2 ILS on-orbit assessment method. This result is very useful for precise retrieval in long-term observation. In future study, XCO_2 is expected to become much better accuracy with reducing spectral residual by applying the long-term ILS change. This paper is well written with sufficient detailed explanation in the scope of AMT. I recommend publication with some revisions for further clear explanation.

Specific comments

I have some comments and recommendations from Section 2 to Section 7.

1. Introduction

Authors briefly address the OCO-2 mission introduction and ILS calibration importance for precise XCO_2 retrieval. They also introduce previous studies on on-orbit ILS investigations by other atmospheric spectroscopic missions.

2. Instrument and data analysis

In this section, authors show the OCO-2 sensor specification, on-orbit solar calibration, ILS fitting analysis method focused on Fraunhofer lines by using several analytical functions and modified preflight ILS. They briefly explain how the preflight ILS table was constructed in previous studies.

In the following Section 6 (Page 16, L 2- 3): As such, the “stretch/sharpen” fit-

ting appears to be the best way to capture the on-orbit behavior of OCO-2 ILS.
The “stretch/sharpen” fitting is important in this paper result as shown in the above sentence. However, in Section 2.2 (Page 6, L19-21) the definition appears only in sentence explanation. I recommend you show the equation in Section 2.2.

3. Wavelength calibration of solar spectra
In this section, authors show the temporal variation of the wavelength shift and the squeeze term from solar spectra of O2A, WCO2 and SCO2 bands.

Page 7
Is your study comparable to the wavelength shift and squeeze term of Crisp et al. (2016) result? You can compare with peak-to-peak variations of the shift and the squeeze. Derived consistency or difference between Earth radiance spectra and Solar radiance spectra is an important information.

4. Spectrally resolved ILS calibration
In this section, authors show FWHMs and spectral residuals using several analytical ILS functions derived from solar spectra. Analyzed parameters are compared with the preflight ILS at each wavelength window.

Page 9
L10-12: This sentence is not correct.
L11: at the first fitting window in the O2A band (Fig. 5a) -> at the fitting window 2 in the O2A band (Fig. 5a and Fig. 6a). Correct the corresponding figure number for the inconsistent FWHM.
L12: at the last fitting window in the SCO2 band (Fig. 5c) -> at the fitting window 3 in the SCO2 band (Fig. 5c and Fig. 6i). Correct the corresponding figure number for the good match FWHM.

L13-14: The “stretch/sharpen” and “stretch only” fitting results are very similar to and essentially overlap with the preflight ILS in Fig. 6.
If the sharpen term < 1 appears in Fig. 6, I recommend you mention wing broadening briefly after the last sentence in Section 4 to become consistent with the following Section 6.

5. The impact of spectral sampling on derived ILS using analytical functions

In this section, authors make a sensitivity test for the ILS estimation to the spectral sampling.

Page 10
L 3: The first fitting window (0.76-0.764 μm) -> The fitting window 1. Correct as a definition.

By stretching ILS analysis, temporal variations of wavelength shift (Fig. 4) and ILS FWHM (Fig. 8) for each footprint are the same in order. However, by hybrid asymmetric Gaussian ILS analysis, temporal variation of FWHM for each footprint is not in order especially in the fitting window 1. One candidate cause is the ILS FWHM strongly relates to the wavelength shift in the fitting window 1 as shown in Fig. 9. How is an example of the other windows like Fig. 9?

Page 11
In Fig. 9, the variation of ILS FWHM of asymmetric Gaussian is 0.001nm (0.0425 $\sim$ 0.0435nm), and the corresponding variation of wavelength shift is 0.004nm (-0.018 $\sim$ -0.014nm). However, Fig. 11a simulation (in blue) shows slightly larger ILS FWHM variation as 0.002nm (0.042 $\sim$ 0.044nm) corresponding to wavelength shift 0.004nm (0 $\sim$ 0.004nm). Why are they different?

6. Temporal variation of OCO-2 on-orbit ILS

In this section, authors show temporal variation of OCO-2 on-orbit ILS features in FWHM, sharpen term, and wing width. They discuss that this O2A ILS wing broadening up to 0.5 $\%$ between decontaminations is related to the reflection from the FPA with ice layer accumulation.

Page 15

L 15-16: A smaller value of this term -> A smaller value (less than 1) of this term. To become clear.

Figures 13c and 13d show that monthly solar Doppler spectra is slightly sharper and narrower than daily regular solar spectra. Why do the sharpen term and the wing width have differences between the two solar calibrations?

Figure 3b shows the derived hybrid Gaussian is composed of flat-top Gaussian (ILS center) and standard Gaussian (ILS wings). This figure looks the ILS width at 1/e maximum comes almost from the flat-top Gaussian part. Is it consistent with Fig. 13d?

7. Verifying solar-derived ILS with Earthshine spectra

In this section, authors retrieve SIF and radiance correction offset from solar spectra, which have no fluorescence. They compare radiance correction offset of earth's barren surface spectra, solar spectra using preflight ILS and solar spectra using “stretch/sharpen” preflight ILS.

Figure 14 shows the SIF correction of earth radiance (black) from 758nm line is almost zero, but 770nm has an offset. However, the SIF corrections of solar radiance (both blue and red) are almost the same offset at both wavelengths. What is the cause candidate? It might be corresponding to the spectral residual (Fig. 5g).

Is the SIF retrieved stretch/sharpen term in Fig. 14 the same as Fig. 13?

8. Conclusions

Authors summarize this paper results of OCO-2 on-orbit ILS analysis by using solar spectral calibration. They propose this ILS corrections are tested on XCO_2 retrieval for L2 v8 algorithm for improvement.

Technical corrections

Page 5

L 4: In Eq. (1), $\bar{\lambda}$ definition does not appear.

Page 7

L 6: ILS functions used in this study first appear as a list. So, “listed above” -> “listed below”. Or revise/add as a list in Section 2.2.

Page 8

L 5- 6: “the FWHM of the ILS fitted using five different functions, defined in Section 2.2”

Five analytical functions are addressed and defined in Section 2.2, but apparently listed in Section 3.

Page 11

Figure 7 caption: at the O2A band -> in the O2A band.

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