Response to Reviewer

Reviewer's comments:

"Although the author added GOSAT in the results section, no discussion of GOSAT findings was added in the discussion or conclusion sections."

Author's Response:

Thank you for pointing out this omission. We have now added to the discussion: "OCO-2 and GOSAT showed reasonable agreement (Fig.4) in northern and southern hemisphere tropical zones (0-20°), although there were some notable phase differences during the strong 2015 El Niño for GOSAT compared to the other timeseries in both the northern and southern extratropic regions. In contrast, OCO-2 shows good temporal agreement with the ground-based observations from MBL and TCCON."

Reviewer's comments:

"I suggest the author re-write some parts of the abstract to convey the main findings in the manuscript better. In line 40, the author says that 'similar zonal patterns of OCO-2 XCO_2 IAV timeseries compared to ground-based in situ observations and with column observations from the Total Carbon Column Observing Network (TCCON) and the Greenhouse Gases Observing Satellite (GOSAT) provide validation that OCO-2 observations can be used reliably to estimate IAV'. Here the author uses the word "validation" when comparing OCO-2 and GOSAT."

Author's Response:

We made changes to the Abstract: "Similar, but smoother, zonal patterns of OCO-2 XCO_2 IAV timeseries compared to ground-based in situ observations and with column observations from the Total Carbon Column Observing Network (TCCON) and the Greenhouse Gases Observing Satellite (GOSAT) show that OCO-2 observations can be used reliably to estimate IAV."

Reviewer's comments:

"In the discussion, the author starts this section by saying: the good agreement among the OCO-2 XCO_2 IAV timeseries, TCCON XCO_2 IAV timeseries, and the MBL surface CO_2 IAV timeseries in broad zonal belts improves our confidence that we are able to quantify reasonable IAV timeseries from the satellite record. I can't entirely agree here with the author. Looking at Fig.4, I can clearly see that OCO-2 IAV is much smaller than TCCON and MBL surface data."

Author's Response:

We rephrase the sentence to read: "The temporal agreement of the OCO-2 and TCCON XCO_2 IAV timeseries and the MBL surface CO_2 IAV timeseries in broad zonal belts improves our confidence that we can quantify IAV timeseries from the satellite record. We note that amplitude differences remain among the timeseries, owing to two major factors: first, compared to MBL surface observations, we expect XCO_2 timeseries to have smaller amplitudes of variability since it integrates over the entire atmospheric

column (Olsen and Randerson 2004), and second, the fact that the OCO-2 timeseries averages around a full latitude circle rather than a few discrete sites reduces some of the IAV contained in site-level records."

Reviewer's comments:

"As mentioned at the beginning, there is no discussion about GOSAT here or in the conclusion section. Looking at Fig.4b and Fig4.c OCO-2 and GOSAT seem to agree well in the northern (20N-0) and southern hemisphere (0-20S), but with some differences in the northern (60N-20N) or southern extratropic (20S-60S). How well GOSAT compares to TCCON and MBL surface measurements at site level? I couldn't find this analysis in the result section or supplementary. Suppose GOSAT shows a poor agreement with TCCON in the extratropical bands. In that case, OCO-2 better characterizes the IAV in these zonal bands compared to GOSAT and provides more accurate results to study IAV."

Author's Response:

Based on the reviewer's helpful comments above, we have added the following text to the discussion section, "OCO-2 and GOSAT showed reasonable agreement (Fig.4) in northern and southern hemisphere tropical zones (0-20°), although there were some notable phase differences during the strong 2015 El Niño for GOSAT compared to the other timeseries in both the northern and southern extratropic regions. In contrast, OCO-2 shows good temporal agreement with the ground-based observations from MBL and TCCON."

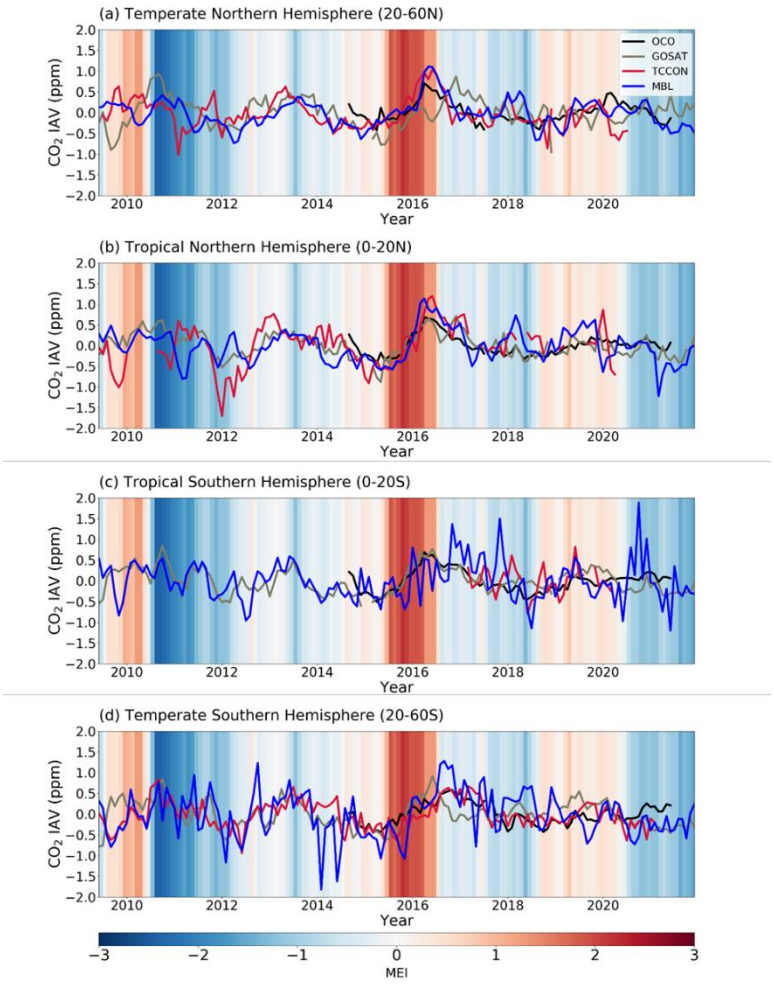
Our Fig. 7 shows that the IAV amplitude can be reliably calculated over a smaller fraction of the extratropic for GOSAT compared to OCO-2 (Figure 6), and we hypothesize that the lower number of observations and lower coverage leads to reduced agreement with GOSAT. We further note that the site-to-site TCCON and OCO-2 comparisons showed only modest agreements. Given that the focus of our paper is to understand IAV in the OCO-2 timeseries, not the GOSAT timeseries, and given the timeframe suggested by the editor for these revisions, we respectfully decline to perform site-level analyses with GOSAT or to state that the OCO-2 data are superior to GOSAT.

Minor editorial changes

Reviewer's comments:

Add to Fig.4 the description of the zonal bands. For example, (a) northern hemisphere extratropical (60N-20N), (b) northern hemisphere (20N- 0), (c) Southern hemisphere (0-20S), (d) Southern hemisphere extratropical (20S-60S). I would also suggest to change the black color of the OCO-2 time series to a more notorious color.

Author's Response:



We add the description for zonal bands - Caption becomes "IAV timeseries averaged for zonal bands between 60 °N and 60 °S from four different observing strategies: Space-based OCO-2 XCO_2 (Black), Surface CO_2 observations from NOAA's marine boundary layer (MBL) sites(Blue), Ground-based TCCON XCO_2 (Red), Space-based GOSAT XCO_2 (Gray). (a) temperate northern hemisphere (20°N-60°N), (b) tropical northern hemisphere (0° - 20°N), (c) tropical southern hemisphere (0°-20°S), (d) temperate

southern hemisphere (20°S-60°S). For all panels, the background shading indicates the Multivariate ENSO Index (MEI), which is positive during El Niño phases."

We change the boldness of the Black lines for OCO-2 timeseries to make it clear to see and easy to compare with other observations.

Reviewer's comments:

Line 252. Which figure? I would write: the southern hemisphere extratropical region (Fig.1d). Remove the 's' at the end of regions. Here, I guess the author is referring to one zonal band.

Author's Response:

We corrected as the reviewer suggested: "The Southern Hemisphere extratropical region (Fig.1d)…"

Reviewer's comments:

"Line 255. Why refer to Fig.4 only. If you are comparing Fig.4d to the other panels, you should write (fig.4a to c)."

Author's Response:

We clarify that we are comparing the OCO-2 of Southern Hemisphere extratropical region shown in Fig. 4d to other regions shown in Fig. 4a to c. "At this time, the XCO_2 IAV timeseries(Fig. 4d) had an anomaly nearly twice as large as that of other latitude belts (Fig. 4a to 4c)."

Reviewer's comments:

"The caption of Figure 8 needs to be clarified. Is this figure showing lag correlations? If so, please indicate and add the description to label (a), (b), and (c) panels."

Author's Response:

We changed the captions to "Correlation coefficient between local grid cell OCO-2 XCO_2 IAV timeseries and MEI, for (a)synchronous timeseries,(b) with 3-month lags,(c) with 6-month lags."

Reviewer's comments:

"Line 257, We assess the spatial correlation patterns… should it says, we assess the spatial 'lag' correlation patterns"

Author's Response:

We change the sentence in to "we assess the spatial correlation patterns with no time lag, 3-month, 6-month lag".

Reviewer's comments:

"Line 440, 452 : Again. El niño instead of El ñino. 'Ñ' goes in the second n. Check throughout the whole manuscript"

Author's Response:

We checked through whole manuscripts and made the missed correction for "El Niño"

Reviewer's comments:

"Line 273 the high XCO_2 in early 2020 around 60°S. Which Figure?"

Author's Response:

We specify that we are looking at Fig. 5a when saying "...the high XCO_2 in early 2020 around 60°S…"

Reviewer's comments:

"Figure 10: (page 15) I suggest to indicate that the IAV timeseries come from XCO_2 OCO-2"

Author's Response:

We changed the captions to "Correlation coefficient between local grid cell IAV timeseries and the corresponding 5° zonal mean OCO-2 XCO_2 IAV timeseries".

Reviewer's comments:

"Line 431. Fix the typo in the word timeseries^are"

Author's Response:

We deleted the wrong typo '^'.

Reviewer's comments:

"Line 124 fix typo (1sigma) to 1-sigma"

Author's Response:

We corrected the typo from (1sigma) to 1-sigma