General comments:

Reviewer's comments:

Given that the IVA at MBL sites is almost double the IAV in the OCO-2 time series (Fig. 4a and 4b), Has the author tried to estimate XCO_2 at the lower layer of the troposphere? Some studies (e.g., Kulawik et al., (2017)) split the XCO_2 GOSAT column into two partial columns (lower <25 km elevation) and above 25 km., and found that the lower tropospheric CO_2 partial column compares well to the independent surface CO_2 data at oceanic sites. I wonder whether doing something similar here could improve the IAV comparison between OCO-2 and MLB.I also agree with reviewer 1, and a comparison with GOSAT XCO_2 satellite data will also be beneficial.

Authors' Response:

We agree with the reviewer that it would be interesting to compare upper and lower partial column IAV with that of the MBL, but feel this is outside the scope of our analysis. We are not necessarily interested in perfect comparisons between OCO-2 IAV and that of the MBL, but rather showing that IAV signals from OCO-2 emerge from sources of error, given that IAV and error are of comparable magnitude for OCO-2 (Mitchell et al., 2023). We have added the following text to the discussion section: "In the future, as partial column retrievals (e.g., Kulawik et al., 2017) mature, intercomparisons of lowermost tropospheric partial columns may provide a useful bridge between variations in surface MBL observations and total column observations."

Both of the reviewers point out we could apply the method to GOSAT, with 4 years more data from 2009 to 2014. We added analysis based on GOSAT, which shows the similar patterns as OCO-2, and we are able to see that OCO-2 has the big improvements in terms of the data quality issue, as expected. We have added revised text to Section2.1.4 to describe the GOSAT dataset that reads "We compare patterns of XCO_2 IAV from OCO-2 with those from GOSAT. Also known as Ibuki, GOSAT is the world's first satellite dedicated to greenhouse gas monitoring, measuring global total column CO_2 and CH_4 since 2009. With the Thermal and Near infrared Sensor for carbon Observation (TANSO) - Fourier Transform Spectrometer (FTS) onboard for greenhouse gas monitoring using three SWIR bands and one TIR band (Cogan et al., 2012; Yoshida et al., 2013). Column-averaged dry mole fraction are obtained at a circular footprint of approximately 10.5 km. GOSAT has a regional biased of about approximately 0.3 ppm and 1.7 ppm single observation error versus the TCCON (Kulawik et al., 2016). We utilize the FTS SWIR Level 3 data global monthly 2.5° resolution mean CO_2 mixing ratio products from 2009 June to 2021 December to generate IAV and make comparisons with OCO-2. L3 products are generated by interpolating, extrapolating, and smoothing the FTS SWIR column-averaged mixing ratios of CO2 and apply the geostatistical calculation technique Kriging method. GOSAT observation datasets are available to public at NIES GOSAT website (https://www.gosat.nies.go.jp/en/about_5_products.html)."

We also added new Fig. 7 showing the GOSAT XCO_2 IAV amplitude, determined as the standard deviation of the IAV timeseries, with revised text in in section 3.2: "We carried out comparisons between the global spatiotemporal pattern of XCO_2 IAV between OCO-2 and GOSAT, since GOSAT has data beginning in 2009. The XCO_2 timeseries from OCO-2 provides higher coverage over mid-latitude oceans and tropical rainforests (stippling in Fig. 6, 7). The IAV amplitude of OCO-2 is generally smaller than that of GOSAT worldwide (Fig. 6, 7), which may be due to greater data volume and reduced noise in the OCO-2 dataset (Wu et al., 2020)"

Specific comments:

Reviewer's comments:

Line 221: When averaged into broad zonal belts representing the tropics and mid-latitudes, the OCO-2 XCO_2 IAV time-series anomalies range between -0.5 to 0.75 ppm (Fig. 4). Does the author mean Fig.4a? Please indicates the results of Figs 4b and 4c are described in 3.2. For a moment, I thought that author was going to include the findings of MBL and TCCON in this section.

Authors' Response:

Thanks for the opportunity to clarify the text. We specify that we are discussing Fig4.a, only referring to OCO-2 instead of MBL and TCCON. The revised text reads "When averaged into broad zonal belts representing the tropics and mid-latitudes, the OCO-2 XCO_2 IAV timeseries anomalies range between -0.5 to 0.75 ppm (Fig. 4a).".

Reviewer's comments:

As an opinion, I believe that it would be better to only have one figure in this section (Fig 4a), and later in Section 3.2, I would include Fig 4a-4c as 4 different panels. For example, (a) (20-60S), (b) 0-20S, (c) 0N-20N and (d) 20-60N, where each panel should only contain the IAV time-series of OCO-2, MBL and TCCON together. By doing this, it would be easy for the reader to see how different the temporal-spatial variation is between these products.

Authors' Response:

Thanks for offering this idea for the alternative way of timeseries comparison. We replotted the figure 4 and extended the time range of MBL/TCCON back to 2009 and remade the zonal mean timeseries following the reviewer's comments. The new version (as below) is still clear to see that MBL surface IAV is larger than TCCON/OCO-2/GOSAT, each type of observation is differentiable from another, and we can see the peak time changes from south to north.

With this new timeseries Fig.5 with GOSAT XCO_2 IAV included, we added the analysis in section 3.2, "OCO-2 and GOSAT zonal mean IAV timeseries generally share the same feature from 2014 to 2021, with an increasing trend during El Niño and decreasing trend during La Niña, however the GOSAT XCO_2 shows a delayed response in the northern midlatitudes, by almost 9 months, to the strong 2015 El Ni*ño* compared to the other datasets. Generally, GOSAT IAV timeseries are nosier, from month-to-month, compared to those from OCO-2. "

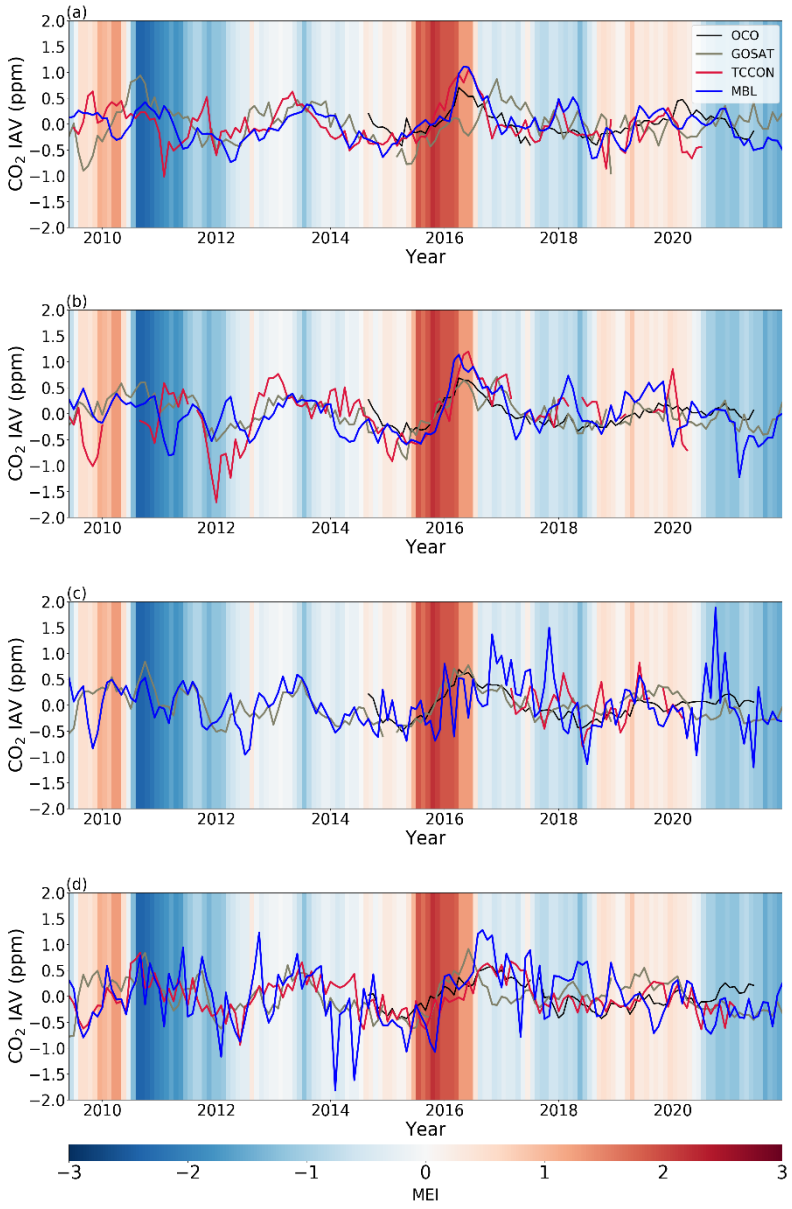


Figure 4. IAV timeseries averaged for zonal bands between 60 °N and 60 °S from three different observing strategies. (a) Space-based OCO-2 XCO_2, (b) Surface CO2 observations from NOAA's marine boundary layer (MBL) sites, (c), Ground-based TCCON XCO_2, (d) Space-based GOSAT XCO_2. For all panels, the background shading indicates the Multivariate ENSO Index (MEI), which is positive during El Ñino phases.

Reviewer's comments:

Line 225: The Southern Hemisphere extratropical regions have larger and more rapid response in the IAV associated with ENSO compared to other zones, especially for a second. What does the author mean by saying: especially for a second?

Authors' Response:

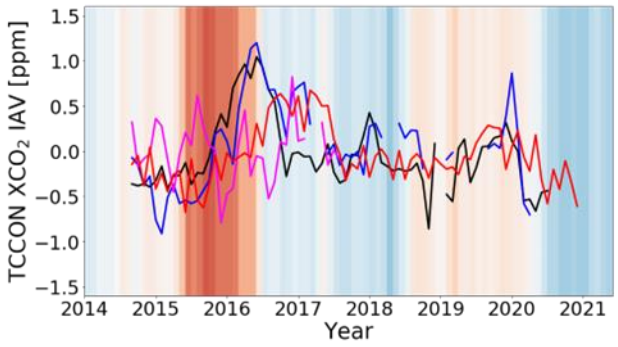
There is something problematic with the expression here, and we revise the sentence to make it clear we are talking about the time in the beginning of 2020. The revised text reads "The Southern Hemisphere extratropical regions have larger and more rapid response in the IAV associated with ENSO compared to other zones, especially for the smaller El Niño that peaked at the beginning of 2020. At this time, the XCO_2 IAV timeseries had an anomaly nearly twice as large as other latitude belts (Fig. 4)."

Reviewer's comments:

The author also mentions that TCCON has a similar IAV amplitude to OCO-2. Is this true? Looking at Fig 4.c, TCCON has more IAV than OCO-2 (zonal belt (20-60S)). What happened in 2019? It seems that TCCON has an IAV of about 1.5 ppm compared to OCO-2 (no variability).

Authors' Response:

We checked that there are only two sites: Lauder and Reunion Island in the 20-60°S belt. The spike is from the signal from Lauder. We didn't see this pattern from other nearby New Zealand NOAA ESRL sites, and we would suggest this spike could be due to limited TCCON sampling and data quality issue during wintertime and shouldering season, therefore we filtered out the IAV spike at zonal belt 20-60°S. The new timeseries is as below:



IAV timeseries averaged for zonal bands between 60 °N and 60 °S based on Ground-based TCCON XCO_2

Reviewer's comments:

We note a slight low bias in OCO-2 relative to TCCON for all five sites in the Southern Hemisphere, which lie below the one-to-one line. How does the author know that OCO-2 has a lower bias than TCCON? I am a bit confused here; the author calculated standard deviations in Fig.10 and then discussed biases. Please clarify.

Authors' Response:

The word 'bias' is used by mistake here. Just as the Reviewer points out, we are not talking about bias, but calculated the standard deviations of the timeseries for both OCO-2 and TCCON, so as to get the IAV amplitudes, and would like to the compare the amplitudes. The text now reads: 'We note a slight low

IAV amplitude in OCO-2 relative to TCCON for all five sites in the Southern Hemisphere which lie below the one-to-one line.'

Reviewer's comments:

Line 427: When using IAV time series for flux inference, it will be crucial to account for non-flux imprints on the time series since spurious attribution of IAV will lead to biased fluxes. What does the author mean when he says: non-flux imprints on the time series? Flux or XCO_2? Spurious attribution of IAV in XCO_2 data?

Authors' Response:

We give more explanation of the mentioned 'non-flux imprints on the timeseries,' which roughly refers to the imprints apart from fluxes, including atmospheric transport, random errors, systematic errors, and remote geophysical coherence. The revised text now reads "When using IAV timeseries for flux inference, it will be crucial to account for non-flux imprints such as imprint from atmospheric transport, random errors, systematic errors, and remote geophysical coherence on the timeseries (e.g., Torres et al., 2019; Mitchell et al., 2023), since spurious attribution of IAV will lead to biased fluxes."

Editorial comments:

Reviewer's comments:

Table 1 and Table 2 should also be included in the appendix and not in the main text. Please be aware that TCCON locations must be placed correctly on the map. For example, reunion Island is over the Australian continent.

Authors' Response:

We made corrections in the locations map Figure 1, confirming that TCCON sites in right places.

Reviewer's comments:

Line 227: that of other latitude belts. Remove 'that of' from the text; it seems unnecessary in this sentence.

Authors' Response:

We remove the redundant 'that of', now the sentence reads 'The Southern Hemisphere extratropical regions have larger and more rapid response in the IAV associated with ENSO compared to other zones, especially for the time of smaller El Niño at the beginning of 2020 when the MEI peaked, the XCO_2 IAV timeseries had an anomaly nearly twice as large as other latitude belts. During both El Niño events, the IAV timeseries in the NH tropics zone peaks nearly six months after the maximum MEI value. '

Reviewer's comments:

El Niño instead of El Nino. Please be aware that El Niño is a Spanish word that must be written with 'Ñ'

Authors' Response:

We went through the whole paper and changed all the miswritten '*El Nino'* into *'El Niño'.*