

Atmos. Chem. Phys. Discuss., referee comment RC1  
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## Comment on acp-2021-185

Anonymous Referee #1

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Referee comment on "Spatial distributions of  $X_{\text{CO}_2}$  seasonal cycle amplitude and phase over northern high-latitude regions" by Nicole Jacobs et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-185-RC1>, 2021

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This study examines spatial variability in the seasonal cycle of column-averaged dry-air mole fractions of CO<sub>2</sub> ( $X_{\text{CO}_2}$ ) across the arctic-boreal zone. This analysis is performed with  $X_{\text{CO}_2}$  retrievals from ground-based instruments and OCO-2, as well as simulated  $X_{\text{CO}_2}$  using two chemical transport models. The authors find that the amplitude of the seasonal cycle is largest and half drawdown day is earliest over eastern Eurasia due to a combination of surface fluxes and transport. The carbon cycle of the northern latitudes is an important area of research, and this analysis furthers our understanding of this region. However, there are a number of major issues with the analysis and manuscript that need to be addressed before I can recommend publication. I have outlined my concerns below.

### General comments

- Many of the seasonal cycle fits shown in Fig. S4-S11 appear to be quite unphysical. Thus, it is unclear if the analysis is really capturing accurate SCA estimates. There should be uncertainty quantification in the SCA fits, perhaps using bootstrap resampling or another technique. Ideally, the analysis could also be performed fitting truncated Fourier series, to test the impact of the functional form on the results.
- I was not able to understand if the SCA analysis accounts for temporal sampling differences between OCO-2 and the model simulations. It appears that the models are sampled daily throughout the year. I think that it is quite likely that the SCA fits will be quite sensitive to the observational sampling. The sensitivity of SCA estimates to temporal sampling should be quantified.
- The contact tracer analysis was insufficiently described. I could not understand what this analysis was telling us. When are the tracers released? And what amount? How long is the simulation run? What precisely is being shown in Figure 10 (tracer was plotted at what time? for simulation starting on what day? that released what quantity of tracer? And released it over what spatiotemporal window?)?

- The manuscript is quite hard to follow in places. It would help to explicitly describe the subpanels in the figures, for example, "(a) Quantity Y versus quantity X with Z processing". Please also ensure that the main results from the figures are described in the text when the figure is referenced.
- I think that the impact of this study would be improved if the OCO-2 retrievals with the standard bias correction and filtering were presented throughout the main text in addition to the high-latitude focused bias correction and filtering. As a potential user of these data, I am very interested in understanding the impact of differences in bias correction and filtering. From Fig. S1, it appears that differences are substantial. Furthermore, it would be of interest to determine if differences between different QC/bias-correction result in larger SCA differences than between the models.

### Specific comments

P1L12: It is a little confusing to refer to a GEOS-Chem run with CT2019 fluxes as "GEOS-Chem". It would be better to use a specific acronym such as "GC-CT2019" to make clear that it is GEOS-Chem run with CT2019.

P1L16-17: This is only for >50N that is examined here. The meridional gradient is still greater from ~0 ppm at the equator to >10ppm at the North pole.

P1L16-17: Reads strange to use "Longitudinal" and "meridional". I suggest using "zonal" instead of "longitudinal".

Sec 2.4: I do not see how XCO<sub>2</sub> is calculated. Is an averaging kernel applied or is it the true XCO<sub>2</sub>?

Sec 3.1: I found the main points of Sec 3.1 quite unclear. It would be helpful to walk the reader through the results. The section starts by stating that differences in spatial sampling may impact the results, but from reading the rest of the section I am not clear on the impact of spatial sampling on the results. It would be helpful to explicitly state the results of this comparison, and what are the implications for the analysis that follows. In particular, I'm having a hard time understanding what Fig. 2 and Fig. 3 are telling us (please explicitly state what the sub-panels are showing). What does Fig. 3 show us that Fig. 2 does not? And why are there TCCON symbols for the OCO-2 vs model comparison?

P10L9-10: "Results in the supplement (see Fig. S30) indicate that SCA derived from clipped time-series of OCO-2 and CAMS (restricted to 2014-2016) were only marginally different from SCA derived for the full time (2014-2019)". Figure S30 does not really support this claim. The figure shows difference in SCA of ~0.5 ppm and up to 10 days in

HDD for TCCON sites. These do not seem marginal.

P10L20: What does "systematic distribution" mean?

P10L31: What does it mean for a gradient in North America to be "consistent" with a gradient in Eurasia?

Sec. 4.1 & Sec 4.2: These are both results sections, and the methods for this analysis need to be fully described. I suggest moving Sec 4.1 and Fig. 8 to supplementary materials, as it is well known that terrestrial biosphere fluxes drive seasonal variations in XCO<sub>2</sub>.

Fig 4.: What exactly is being plotted? Is this an instantaneous field? And after a simulation of what length?

P13L32: I do not understand what is being correlated, and what is the correlation coefficient?

P14L12-18: This seems out of place; this should be in the methods section.

P14L20: Why are the CT2019 fluxes being referred to as "GEOS-Chem". This analysis is only looking at CT2019 fluxes, GEOS-Chem is not used here.

P15L20-21: "The dominance of terrestrial biospheric exchange in the GEOS-Chem model is likely an intentional quality built into the model" – What does this mean?

P15L24: "15 or 30 lifetimes"?