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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Sources of variations in total column carbon dioxide" *by* G. Keppel-Aleks et al.

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We would like to thank Dr. Feist for his careful review of our manuscript. Below is a response to each of the suggestions he makes in his review.

I find Sec 3.2 rather unclear, there are many figures and only very short explanations to some of them.

We will include more explanation to the figures in Section 3.2, but feel that the figures are crucial to illustrate the benefits and limitations of the method of using covariations in $\langle CO_2 \rangle$ and θ.

There are many plots: 19 figures containing 46 individual subplots. Some of them could be left out without sacrificing the results.

We feel that the figures in the paper illustrate clearly the sensitivity of variations in $\langle CO_2 \rangle$ to perturbations in surface fluxes and are necessary to show how $\langle CO_2 \rangle$ responds to flux variations as well as to illustrate the utility of the methods we suggest to quantify these variations.

The conclusions should be more concise. Also the results should be discussed in the same order as they appear in Sec. 3.

We will reorganize the conclusions section to better reflect the results presented in Section 3.

A large part of the total column is contained in the stratosphere. How good is the AM2 model at altitudes above the tropopause?

We have analyzed the seasonal gradients in stratospheric CO_2 against those determined by Sawa et al., 2008, who obtained upper troposphere/lower stratosphere CO_2 data aboard commercial aircraft traveling between Europe and Japan. The vertical and horizontal stratospheric gradients in AM2 agree qualitatively with the patterns shown in Figure 7 of Sawa et al., 2008, and the CO_2 contrasts across the northern hemisphere agree quantiatively to within $\sim$1ppm. The seasonal cycle amplitude at the midlatitude TCCON sites at altitudes higher than 200 hPa is 0.9 ppm at Bialystok and Orleans, and 1.3 ppm at the North American sites; the vertical resolution in AM2 in the stratosphere is relatively poor ($\sim$80 hPa), so precisely defining a tropopause is difficult. Since it is variations in column CO2 that we are studying, it is the mass-weighted error in simulated stratospheric variations that matter.

Table 1: no tropical site was selected even though there is an operational one (Darwin) and a planned one (Ascension Island) in TCCON. So what would we see at a tropical site?

We did not include a tropical site in our analysis because the dynamics governing variations in tropical $\langle CO_2 \rangle$ are quite different than those in the midlatitudes. The focus

here is on non-tropical ecosystems and their imprint on the column.

Hovmöller-diagram: when you mention the name you might also want to add the reference Tellus, Volume 1, Issue 2, pages 62–66, May 1949 to honour the inventor Ernest Hovmöller.

We will add a citation to Ernest Hovmoller's paper.

Table 1: why are the acronyms not consistent with the usual TCCON site IDs?

We will remove the acronyms from the manuscript and only use the site names in the text and in figure labels.

Order of figures: Figs. 1b/2b are not discussed in the text until after Fig. 3a

We will mention Fig. 1b and 2b in the text prior to introducing Fig. 3a.

Fig. 4: why where these locations locations chosen? They do not correspond to the stations in Table 1. Fig. 4: we chose these locations as they were all in northern hemisphere and covered a range of latitudes that illustrates the difference in column $\langle CO_2 \rangle$ owing to latitude. All of these sites are productive, forested ecosystems. Of currently operational TCCON sites, we do not have a high northern latitude site, or a tropical site, in forested ecosystems. We will include a sentence in the revised manuscript as explanation for how these sites were chosen.

Fig. 7 is hardly explained in the text, could it be left out completely?

We believe Fig. 7 is necessary in the paper because it clearly illustrates regions where local fluxes have an impact on the column. We refer to this figure in section 3, when it is introduced to show that there are only small differences in the column when using zonal vs CASA net ecosystem exchange. We will refer to it again in the conclusions when we discuss that when $\langle CO_2 \rangle$ is plotted against meridional displacement, the impact of more local fluxes can actually be discerned (Fig. 15). The $\sim$1 ppm offset of Park Falls during August can be explained by the difference caused by local fluxes in Fig. 7.

Fig. 9 and following plots: you only selected 5 of the 6 sites from Table 1. Why these? Also the choice of colors is not ideal. Especially BIK is very hard to distinguish from ORL.

We will change the shade of orange used to represent Orleans in the figures, while still keeping the general color scheme of warm colors further north, cool colors further south. We do not plot variations in Lauder, New Zealand because we focus on northern hemisphere $\langle CO_2 \rangle$ and the dynamical connections that exist between midlatitude sites within one hemisphere.

Fig. 11: what is the difference between contrast and actual contrast? The explanation in the text is also not very clear.

We will change the language we use to discuss the estimated and actual contrast in reference to Fig. 11.

Page 30585, last paragraph: the AM2/TM5 comparison and Fig. 19 should not appear in the middle of the conclusions.

We will move the AM2/TM5 comparison to the results section, and broaden the discussion of vertical mixing to include all model-specific parameterizations. This section will include Dr. Rayner's suggestion to mention the results in Chevallier et al., (2010), who find that inversions of $\langle CO_2 \rangle$ are sensitive to transport.

Page 30581: it is awkward to have the discussion of Fig. 8b appear at this position in the text.

We will move the discussion if Fig. 8b to the section that relates synoptic scale variability to the underlying flux (Section 3.3).

References

Chevallier, F. , L. Feng, H. Bosch, P. I. almer, and P.J. Rayner: On the impact of transport model errors for the estimation of surface fluxes from GOSAT observations, Geo-

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Sawa, Y., T. Machida, and H. Matsueda: Seasonal variations of CO_2 near the tropopause observed by commercial aircraft, J. Geophys. Res., 113, doi: 10.1029/2008JD10568, 2009.

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