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Interactive comment on "Gradients of Column CO_2 across North America from the NOAA Global Greenhouse Gas Reference Network" *by* Xin Lan et al.

Anonymous Referee #3

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Review of: Gradients of Column CO2 across North America from the NOAA Global Greenhouse Gas Reference Network, by Lan et al.

This paper computes total column dry-air mole fractions of CO2 (XCO2) from NOAA aircraft profiles, combined with tower measurements and capped with CT2015 stratospheric CO2. From these computed XCO2 values, they then investigate spatial gradients in 8 regions spanning most of the US and one site in Canada. The main results of this paper are that there are large north-south spatial gradients in XCO2 in summer, which are significantly influenced (~50%) by large-scale circulation patterns.

These results are interesting, and this paper approaches the total column analysis in

a new way. One particularly interesting part of this study was the "masked" run of CT which turned off the Eurasian boreal flux and reduced the North American N-S gradients by 50%. The results corroborate some of the existing literature that looks at gradients in XCO2 from ground-based remote sensing instruments that are capable of measuring CO2 in the entire column (e.g., Keppel-Aleks et al., 2011; Keppel-Aleks et al., 2012; Wunch et al., 2013).

My major comment is that this paper is begging for a direct comparison between the aircraft-derived XCO2 quantity and those measured via remote sensing at coincident TCCON stations. The obvious two sites would be at LEF (Park Falls) and SGP (Lamont) for which TCCON measurements exist since 2004 and 2008, respectively. There is also a TCCON station at ETL, but it has been measuring for less than one year and would therefore be less useful for this study. It would significantly strengthen this paper if the authors could show that their method of integrating the aircraft and extending the profile into the stratosphere with CT compares well with, or improves upon, the total column measurements from TCCON. The authors could average the TCCON XCO2 within an hour or so of the aircraft profile times for an apples-to-apples comparison. They could then use the remaining TCCON data (or at least the near-noon data) to investigate any biases or missing information caused by the relatively infrequent aircraft measurements. As part of this comparison, a more rigorous error analysis of the aircraft-derived XCO2 would be necessary.

Other comments:

L19: What does a "stronger summer drawdown" mean? Larger amplitude? Lower minimum?

L20: This sentence is contradicted by the conclusions:

"The spatial gradients of total column XCO2 across North America mainly reflect large-scale circulation patterns rather than regional surface sources and sinks."

Conclusions:

"By comparing the spatial gradients of ΔXCO2 with wind vectors across North America, we find that total column ΔXCO2 patterns are equally affected by large-scale circulation patterns as by regional surface sources and sinks."

Your paper seems to corroborate the sentence in your conclusions and not your abstract. Please modify the abstract accordingly.

L55: in-situ observations are sparse in global and regional coverage, and, with the exception of AirCore measurements are limited in vertical extent - most cannot measure more than 80% of the atmospheric mass.

L73: What are the uncertainties of total column XCO2 calculated from in situ measurements? According to Wunch et al. 2010, given the lack of measurements above the aircraft ceiling, the total column aircraft uncertainty is ~0.4 ppm, which is similar to the TCCON measurement uncertainty. I would expect the errors for the profiles discussed in this paper to have larger uncertainties, since the altitude coverage for the NOAA flights is significantly smaller than the profiles used in the Wunch et al., 2010 paper.

L190: As you mention, nine AirCore profiles is inadequate to evaluate CT2015 stratospheric CO2. Perhaps you could use the other, (much) older balloon-borne or ER-2-borne stratospheric CO2 measurements (e.g., BOS (https://espoarchive.nasa.gov/archive/browse/bos/Balloon), STRAT (https://espo.nasa.gov/strat/content/STRAT_Science_Overview), ASHOE, etc.), or the more recent HIPPO and ATom aircraft profiles that often reach above the tropopause altitude, especially in wintertime.

L201: It's not clear to me why you compute the high CT bias by using the partial column comparisons. Why don't you integrate the entire CT and AirCore profiles and compare those values?

L206: This is unclear: if the stratosphere doesn't matter for your analyses, why include

it at all?

Fig 3 caption: What are the black dots?

L250: I don't understand why this sentence does not end after "It demonstrates that there is a lot of important information in the vertical profile."

Fig. 7: It seems strange that you would not include de-trended averaged TCCON XCO2 for comparison in regions that have long-term TCCON measurements (i.e., MW and SM). Additionally, Figure S1 would be an ideal place to show the SGP TCCON total column measurements.

L338: What does "deepest drawdown" mean? The lowest minimum value? The largest amplitude?

L337-339: "It is interesting that the deepest drawdown is seen in region NM, not in region MW that encompasses the very intensive agricultural activities in the U.S. midwest, which suggest the possibility of strong upwind influence in the NM region." I agree this is interesting. Could the authors say something more about possible causes of this effect?

L343: Again, what does "strength of summer drawdown" mean here?

L373: This sentence is misleading, regarding Keppel-Aleks et al., 2012: "Thus they also propose that the variations in column CO2 are mainly driven by large-scale flux and transport." In Keppel-Aleks et al., 2012, they also state (in the abstract): "Rather than obscure the signature of surface fluxes on atmospheric CO2, these synoptic-scale variations provide useful information that can be used to reveal the meridional flux distribution."

L373: That large-scale circulation drives almost half (~40%) of the N-S gradient in XCO2 was also shown in Wunch et al. (2013) through the interannual variability of the seasonal cycle amplitudes.

Fig 9: Why do the aircraft measurements appear to disagree significantly with CT in panel (c) in the SGP/Colorado region, and the site just south of lake Michigan?

L443: I would call 4 ppm a large difference. Please remove “only” from this sentence and quantify the “large spatial gradients” observed below 2 km.

Technical comments

L44: space after “sinks” and spurious semicolon

L90: source*s* and sinks

L154: *The* long-term trend of CO2 *measured at* this site is removed. . .

L258: . . ., which may *be* due to the sea-breeze. . .

References:

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