Review of “A climatological description of atmospheric CO2 concentrations” by Bréon et al.

General Comment

This study presents a method to produce climatology of atmospheric CO2 distributions based on the atmospheric inversion model outputs (CAMS) constrained by the worldwide observations. The authors assessed their method against AirCore and TCCON measurements. They also discussed limitation and possibility for use of their product as a prior of a satellite retrieval.

My overall assessment is that this manuscript concisely documents technical methodology, but its scientific validation could be improved. With its concise and well-structured descriptions, this manuscript would be a practical publication that supports a satellite CO2 observation mission and overall direction and discussion are sound. In this regard, I realized that this study is more like a technical paper. This is also because of limited novelty in terms of the method and scientific finding. In my opinion, additional validation is needed for this study to be considered for ACP.

As the authors acknowledge in the manuscript, historical efforts have been made for mathematical representation of atmospheric CO2 variations (e.g., Thoning et al., 1989; Nakazawa et al., 1997; Pickers and Manning, 2015, reference therein). In addition, the Mauna Loa data have been used as the CO2 reference to demonstrate climatology of CO2 variations horizontally and vertically, because CO2 concentration at the site gives approximation of the global average, though slightly northern hemisphere biased (Sweeney et al., 2015; Umezawa et al., 2018). The authors take the approach similar to these earlier studies, but it does not seem to me that this study provide a new scientific insight into CO2 variations.

I also note that guidance to the conventional understanding from the earlier studies is insufficient, by which it is likely difficult for readers to understand underlying scientific consideration about why the authors took the approach in this study. For instance, the authors could explain why the site Mauna Loa is chosen in the scientific context with the aforementioned earlier studies. This is also the case for the sites American Samoa and Amsterdam Island mentioned in the manuscript.

Another component that could enhance this study is validation for the other regions. The AirCore dataset over France is an excellent contribution. As the authors explain, however, the data are from an area over which atmospheric CO2 undergoes typical mid-latitude seasonal variation with a moderate amplitude. While the authors write that longitudinal variations in the atmospheric CO2 are relatively small (in introduction), I think that, throughout the manuscript, they tend to simplify atmospheric variations and underestimate the spatial variability. Aircraft observation studies have reported large variations in atmospheric CO2 in latitude, longitude and altitude (Sawa et al., 2012; Sweeney et al., 2015; Umezawa et al., 2018). The magnitude of variability in the northern hemisphere is also large enough (> 2 ppm) to be considered in this study. In the northern hemisphere, variability (or deviation from the climatology) is likely larger over eastern North America (Sweeney et al., 2015), over East Asia and South Asia (Umezawa et al., 2018) and over Siberia (Lloyd et al., 2002; Sasakawa et al., 2013) than over France. Considering this, comparison to the AirCore over France data would not provide validation at the continental to hemispheric scales. It should be also noted that the AirCore measurements were made over the area where the data density is high and CAMS are relatively well constrained. Nevertheless, discussion goes to use of the approach for satellite retrievals, where global coverage is the key. Here I see a significant gap to justify value of this study. Additional validation could be made by using available aircraft data: NOAA (Sweeney et al., 2015), CONTRAIL (Umezawa et al., 2018) and IAGOS (Filges et al., 2015).

Regarding the limitation of this study in terms of spatial representativeness, title of this manuscript reads too general. I would suggest that it could be more objective specific. I have to point out that general scientific interpretation of the atmospheric CO2 climatology has been discussed in more detail in earlier studies than in this study.

Specific comment

Section 2.3: If this is the first publication after the methodological paper (Membrive et al., 2017), presentation of the monthly AirCore data in more detail might interest readers. Given that the data plays a central role in this manuscript, it would be interesting and helpful to see the variation characteristics (e.g., seasonality) and comparison to the CAMS and climatology.

P7 L156: “STDDEV” is not consistent with that in Figure 3 (“StDev”).

Figure 3: I am curious to see how the bias and standard deviation vary with season.

Section 3.5 and Figure 7: I am afraid that the term “error” could be misleading and I would use a more neutral term like “difference” or “deviation.” The CAMS output and the climatological fit behave differently by definition. A small value is obtained by coincidence. In this sense, Figure 7 shows areas where the climatological fit has difficulty for follow-up use (where “errors” are high), as the authors also discuss later.

P12 L231: As in my earlier comment, it would be interesting to see season-specific comparisons.

P16 L323: The use of Mauna Loa as a reference site has a history. A bit more explanation about the site's advantage in latitude, altitude and geography could be mentioned somewhere in the manuscript. This comment applies to American Samoa and Amsterdam Island, but I wonder what kind of improvement is expected by replacing Mauna Loa with American Samoa or Amsterdam Island.

Reference

Filges, A., Gerbig, C., Chen, H., Franke, H., Klaus, C., & Jordan, A. (2016). The IAGOS-core greenhouse gas package: a measurement system for continuous airborne observations of CO_2, CH_4, H_2O and CO. *Tellus B: Chemical and Physical Meteorology*, *68*(s1). https://doi.org/10.3402/tellusb.v67.27989@zelb20.2016.68.issue-s1

Llyd, J., R. L. Langenfelds, R. J. Francey, M. Glorr, N. M. Tchebakova, D. Zolotuokhine, W. A. Brand, R. A. Werner, A. Jordan, C. A. Allison, V. Zrazhewske, O. Shibistova, E.-D. Schulze (2002) A trace-gas climatology above Zotino, central Siberia, Tellus B, 54, 5, 749–767, https://doi.org/10.1034/j.1600-0889.2002.01335.x

Nakazawa, T., Ishizawa, M., Higuchi, K., and Trivett, N. B. A. (1997(Two curve fitting methods applied to CO2 flask data, Environmetrics, 8, 197–218, https://doi.org/10.1002/(SICI)1099-095X(199705)8:3<197::AID-ENV248>3.0.CO;2-C

Pickers, P. A. and Manning, A. C. (2015) Investigating bias in the application of curve fitting programs to atmospheric time series, Atmos. Meas. Tech., 8, 1469–1489, https://doi.org/10.5194/amt-8-1469-2015

Sasakawa, M., T. Machida, N. Tsuda, M. Arshinov, D. Davydov, A. Fofonov, O. Krasnov (2013) Aircraft and tower measurements of CO2 concentration in the planetary boundary layer and the lower free troposphere over southern taiga in West Siberia: Long-term records from 2002 to 2011. Journal of Geophysical Research Atmospheres, 118, 16, 9489–9498, https://doi.org/10.1002/jgrd.50755

Sawa, Y., Machida, T., and Matsueda, H. (2012) Aircraft observation of the seasonal variation in the transport of CO2 in the upper atmosphere, J. Geophys. Res., 117, D05305, https://doi.org/10.1029/2011JD016933

Sweeney, C., Karion, A., Wolter, S., Newberger, T., Guenther, D., Higgs, J. A., Andrews, A. E., Lang, P. M., Neff, D., Dlugokencky, E., Miller, J. B., Montzka, S. A., Miller, B. R., Masarie, K. A., Biraud, S. C., Novelli, P. C., Crotwell, M., Crotwell, A. M., Thoning, K., and Tans, P. P. (2015) Seasonal climatology of CO2 across North America from aircraft measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network, J. Geophys. Res.-Atmos., 120, 5155–5190, https://doi.org/10.1002/2014JD022591

Thoning KW, Tans PP, Komhyr WD (1989) Atmospheric carbon dioxide at Mauna Loa observatory: 2. Analysis of the NOAA GMCC data, 1974–1985. J Geophys Res 94(6):8549–8565. https://doi.org/10.1029/JD094iD06p08549

Umezawa T, Matsueda H, Sawa Y, Niwa Y, Machida T, Zhou L (2018) Seasonal evaluation of tropospheric CO2 over the Asia-Pacific region observed by the CONTRAIL commercial airliner measurements. Atmos Chem Phys 18:14851–14866. https://doi.org/10.5194/acp-18-14851-2018