

Review on “A climatological description of atmospheric CO₂ concentrations” by François-Marie Bréon et al.,

This manuscript presents a concise and operationally useful climatological description of atmospheric CO₂ variability. The core idea is to decompose the global CO₂ field into (i) the long-term growth rate derived from the Mauna Loa record and (ii) a spatially varying seasonal cycle represented by two harmonics. Using the CAMS high-resolution reanalysis (1979–2022), the authors derive only five coefficients per grid point and pressure level, and validate the resulting climatological product against 80 independent AirCore profiles over France and global TCCON column retrievals. The results show that the fit captures the dominant variability with typical errors of ~1–1.5 ppm in the free troposphere, with vertically correlated error structures, and it significantly outperforms the existing GGG2020 prior model (Laughner et al., 2023). Overall, the manuscript is well structured, the validation is thorough, and the discussion openly acknowledges limitations and possible improvements. The quality is high, and the paper is suitable for publication in ACP after addressing the following comments:

We thank the reviewer for this assessment

Major comments:

1. The core validation relies exclusively on 80 AirCore profiles from a single region (central France), where the CAMS reanalysis is tightly constrained by a dense surface network and may not be representative of the global performance. The authors themselves acknowledge this in the discussion. However, the authors can add at least one additional independent dataset from a contrasting region (e.g., NOAA AirCore flights over North America, or the regular Sodankylä profiles in Finland) to show whether the error statistics are broadly similar or not.

In the revised version, we have added a figure that shows the comparison of the climatological product against all NOAA Aircore profiles acquired in North America, Finland and Australia. We discuss the comparisons which appear consistent with the results obtained over France

2. The authors note that the inter-hemispheric exchange time (~1 year) suggests using American Samoa or Amsterdam Island data for the southern extratropics, yet the main product still relies solely on Mauna Loa. Here, I would suggest the authors make a sensitivity test: where the Mauna Loa trend is replaced by the American Samoa record for grid points south of, say, ~20S, and comparing the resulting XCO₂ errors against TCCON stations such as Wollongong, Lauder, or Reunion.

In the revised manuscript, we analyze the difference between the smoothed Mauna Loa and American Samoa time series and discuss in quantitative term the impact on the climatology when using one versus the other. The differences are on the order of a few tenths of ppm with a trend component (increasing difference due to increasing emissions in the northern hemisphere. The impact on the climatology is visible but small with respect to the other uncertainties.

3. In Section 4.5, the authors mention "For the comparison against TCCON, we did not account for averaging kernels. While acceptable for a first-order assessment, this simplification may slightly bias the interpretation of TCCON comparisons. A more precise evaluation of the precision of CAMS and its climatological fit should account for the variations linked to the averaging kernels." But I am still curious about the effect of the AK. Can you make a sensitivity test and add a figure as well?

In the revised version, we have modified Figure 4 to show both the statistics obtained when using the unweighted total column (as in previous version) and the statistics when using the AK for the weighting. The differences are very small.

Minor comments:

1. P12, 3.5 Vertical Covariance -> 3.6 Vertical Covariance

Corrected

2. TCCON citation (data DOI) is missing. Although the acknowledgement includes the TCCON, please check with the TCCON community/PIs if this is enough.

We have been in contact with the TCCON community to make a proper acknowledgment that is acceptable to them. We have added a reference for each of the TCCON sites individually