

RC2

We thank the reviewer for his/her positive appreciation of our manuscript. Below, we detailed our answers to his/her specific comments and describe how they have been accounted for.

- 1. L11: "... continuous in-situ surface measurements have been conducted since 2015" – Please state which ones.**

More details and references are given in the introduction.

- 2. L17: "(EM27/SUN instruments)" – Please define or state while mentioning the FTIR instruments earlier.**

Specified in L12.

- 3. L19: "Observed" to "The observed"**

Modified.

- 4. L20: "Correlations" to "The correlations"**

Modified.

- 5. L31: denoted by "X"**

Modified.

- 6. L33: "... and industry" – Please cite**

There is already a reference to an IPCC report.

- 7. L35: ".. greenhouse gas" – Please cite.**

We do not feel there is really a need for a reference for this fact that is very well known in the community. The IPCC reference (next sentence) is also relevant.

- 8. L47: Please define ICOS before the first use.**

ICOS-Cities is the name of the project supported by the ICOS research infrastructure. The ICOS acronym is defined in the same line : Integrated Carbon Observation System.

- 9. L57: "... mitigate this issue" – How?**

The use of in situ surface measurements with modelling is constrained by the model's ability to accurately reproduce the vertical mixing of the species. Total column measurements are therefore, by nature, much less sensitive to this limitation than in situ surface measurements. A comment has been added in the main text.

- 10. L 58: "...observed by satellites" – Please cite.**

We do not feel there is really a need for a reference for this fact that is very well known in the community.

- 11. L68: "NE-SW" – Please define before first use.**

Modified.

- 12. L79: "...in spring" à "in the spring"**

Modified.

13. L87: Please check if the EM27s operate continuously or continually. The EM27s other than SN061 make sporadic measurements at Munich.

According to Dietrich et al., 2021: « We present the Munich Urban Carbon Column network (MUCCnet), the world's first urban sensor network, which has been **permanently** measuring GHGs, based on the principle of differential column measurements (DCMs), since summer 2019. ».

According to Zhao et al., 2023: To aid in reaching the goal of climate neutrality and track emissions in Munich, our group has established a novel automated urban sensor network (MUCCnet; Munich Urban Carbon Column Network, accessible via <https://atmosphere.ei.tum.de/>, last access: 10 September 2023; Dietrich et al., 2021) for **continuous**, long-term monitoring of GHGs in and around Munich.

14. L92: "...poor agreement" – Please state the number.

The correlation appears to be close to zero. So « poor agreement » provides all the information.

15. L96: Please check the EM27s at Mexico City. There are six, not seven of them (see the KIT COCCON data page). SN038 is used to measure at Alzomoni and Boxo.

The Mexico campaign described in Che et al., 2020 (October 2020 to May 2021) had six EM27/SUN and one IFS 125 HR (involved in the NDACC network). This one is actually located 60 km away from the city center but is still part of the campaign in the Mexico City Metropolitan Area (MCMA). In L96, it is already written « seven FTIR instruments » and not « seven EM27/SUN ».

16. L97: "...high-resolution site in continuous operation" – Please state which one.

It is the Alzomoni Atmospheric Observatory. This precision is actually important and has been added to the main text.

17. L98: "St. Petersburg and Tokyo" instead of "St. Petersburg or Tokyo"

Modified.

18. L105: Please define "WRF" before its first use while mentioning WRF-GHG. Please define GHG as well.

Precision added.

19. L110: "Origins.earth emission" instead of "origins.earth emission"

Modified.

20. L115: "This provides a time series of more than 10 years..." – It isn't clear what "This" refers to here.

Precision added.

21. Table 1: Please define LSCE before first use.

Reference to author's affiliations added.

22. L133: Please provide references for CamTracker and OPUS – either papers that discuss them, or a link to a user guide so the reader can learn more about them.

CamTracker :

<https://amt.copernicus.org/articles/4/47/2011/>

OPUS:

<https://www.bruker.com/en/products-and-solutions/infrared-and-raman/opus-spectroscopy-software/downloads.html>

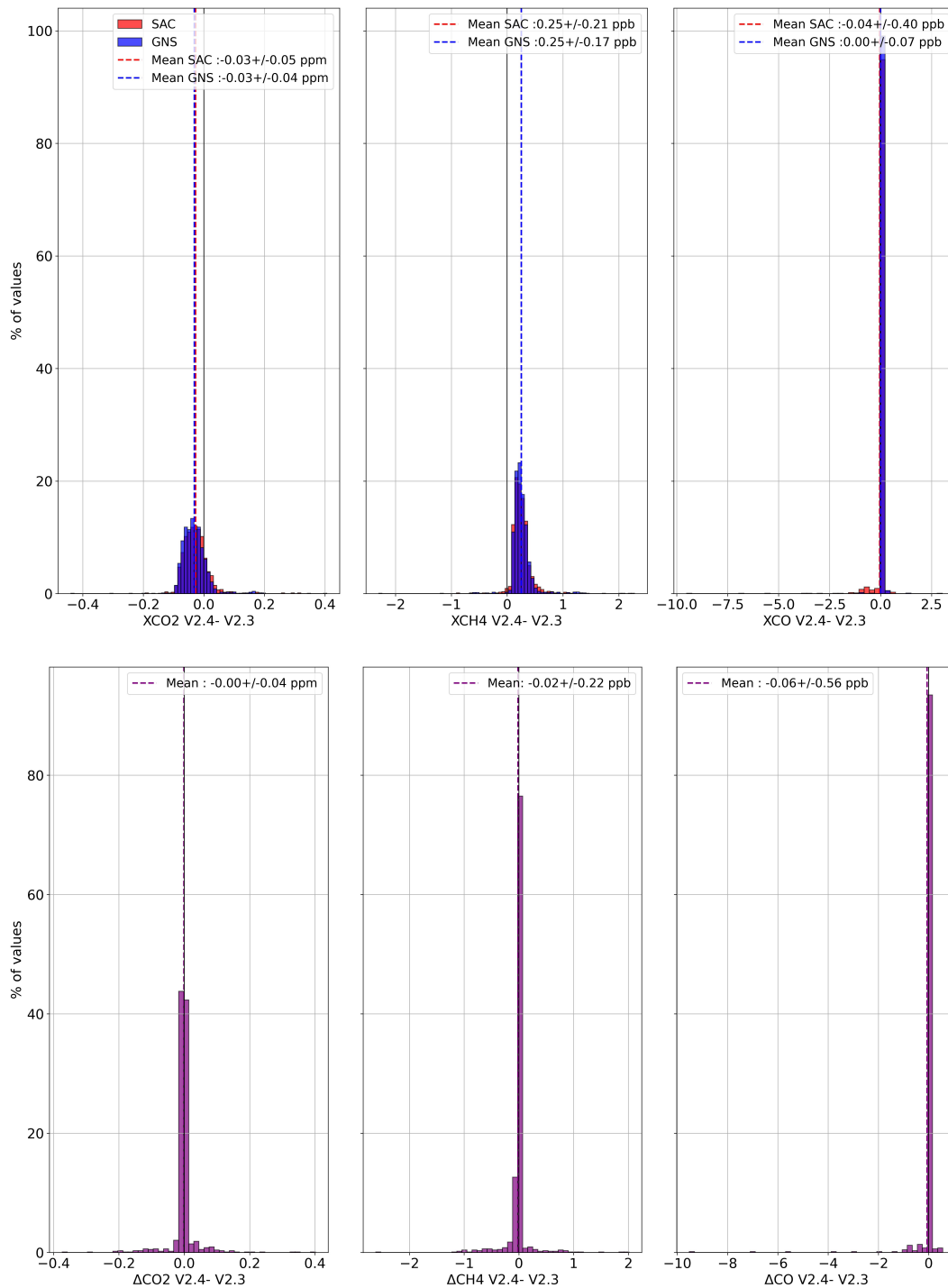
23. L134: MONARIS – Please expand if this is an acronym. If not, please state so.

Reference to author's affiliations added.

24. L136: Please explain what the travel/travelling standard EM27 refers to. It would also be nice to have an image of the station/deployment set up.

As explained, the travelling EM27/SUN is a mobile instrument dedicated to side-by-side comparisons. A reference is made to section 2.3 for more details on the comparisons.

25. L140 – PROFFAST 2.4.1 is the latest version and PROFFASTpylot is at v1.3. Why are older PROFFAST/PROFFASTpylot versions being used in this analysis? I suggest the authors update the PROFFAST/PROFFASTpylot versions for this analysis, if possible. (Or provide an estimate of how much the results would vary upon using the latest PROFFAST and PROFFASTpylot versions.)



Using the two figures above, the following comment has been added to the main text:

Between versions 2.3 and 2.4 of PROFFAST, the XCO₂ estimates differ, on average, by -0.03 ppm with some dispersion around this mean value: 90% of the XCO₂ differences are between -0.08 and 0.03 ppm. There are a few outliers (up to 0.4 ppm) but we have not been able to identify how these outliers differ from the typical case. The XCO₂ differences (between the two versions) of PROFFAST are correlated between the two ICOS stations so that the dispersion in term of ΔXCO₂ is lower than the dispersion on XCO₂. Indeed, 90% of the ΔXCO₂ changes (between two versions of PROFFAST) are between -0.03 and 0.03 ppm. These differences are relatively small in comparison to the other sources of errors. They are therefore neglected in the following.

- 26. Please also state that PROFFAST is not an acronym but the actual name of the retrieval tool. It would also be helpful if the authors could briefly state the updates between the various PROFFAST 2 subversions.**

PROFFAST is actually used as a retrieval software and updates between various sub-versions of PROFFAST V2 consist in processing details. As explained in the first part of this comment, differences between retrieved results from V2.3 and V2.4 are neglectable. For more informations, please contact the KIT.

- 27. L147: Please define CAMS first and use the acronym later.**

As clearly written on L147, CAMS stands for « Copernicus Atmospheric Monitoring System ».

- 28. L151: Please define PAUL.**

Precision added.

- 29. L154: Please define and explain NUBICOS.**

Precision added.

- 30. L156: "...while also ensuring long-term traceability" – Please provide references.**

Reference added.

- 31. L166: "...where *NMesDays* is the number of days with valid data" – Or with valid "Measurement" data?**

Modified.

- 32. L186: "The uncertainty is given by $\sigma/(N)^{0.5}$ "- Please consider writing as an equation.**

Done.

- 33. L188: Please change "after that date" to "following which"**

Modified.

- 34. L191: " not "the" absolute truth**

Modified.

- 35. L192: lower "than" about**

Modified.

- 36. L196: What are the uncertainty values for XCH₄ and XCO.**

Precision added.

- 37. L199: Please start a new sentence after "average".**

Modified.

38. Figure 3: Please explain the green strip in the figure caption.

Precision added to the figure's caption.

39. L209-210: "For the Jussieu IFS 125 HR, days with more than 200 spectra are fewer because the site alternates usually between 210 NDACC and TCCON measurements." – This sentence is hard to follow. Please rephrase.

Rephrased.

40. L210: Please state how the 0.55 ppm estimation was made?

We obviously use the same method than for EM27/SUNs. A precision has been added in the text.

41. L213: "due to" a known issue

Added.

42. L220: "low SZA" – Please start a new sentence after this instead of using “;”.

Modified.

43. L227: "noon SZA < 50°" – Why was this value used.

The value of 50° was determined empirically to eliminate days when the sun does not rise high enough in the sky while still retaining enough days for a representative statistical study.

44. L227: "...assume no large geophysical trend between midday and early/late hours" – How much uncertainty would this add to the analysis?

The geophysical variations of XCO₂ between midday and early/late hours are responsible for the variation (grey area) around the mean trend. The variations are then included in the analysis. There would be an impact if there was a systematic variation correlated with the solar angle.

45. L237: "We detect no systematic drift up to ~60°. Beyond ~65-70°, a drift emerges that grows with SZA and differs by gas: for XCO₂, it becomes noticeable above ~75° (> 1 ppm) and reaches up to 3.5 ppm for 80-85°; for XCH₄, it remains smaller (< 2 ppb up to 80°, up to 5 ppb between 80-85°); for XCO, it is negligible." – It might be nice to put this in a table.

We can only provide order of magnitudes which can be extracted from the figure.

46. L258: "X_{comp} GAS, the_GAS" – Please remove the underscore between "the" and "GAS".

Removed.

47. Figure 5: Please update the axis language to English.

Modified.

48. L268: Please remove "however"

Removed.

49. L271: "a_priori" – Please remove the underscore and italicize the words here and for all instances of occurrence.

Done.

50. L272: "(slightly)" – Please put the word in parentheses.

Modified.

- 51. L278: “...alternate station 2 km away” – Please state if this introduced any uncertainty in the analysis and if so, how much.**

The altitude correction calculated as the difference between usual pressure measurements at the EM27/SUN station and pressure measurements at the other station is mostly constant. It allows a correction with no additional uncertainty.

- 52. L280: “XAIR” – Please use a subscript for “AIR” – here and everywhere else in the paper.**

Modified.

- 53. L292: Please define ILS.**

ILS stands for Instrumental Line Shape. This meaning has been added to the text.

- 54. L293: “An empirical tolerance of $\pm 4.10^{-3}$ around 1 is typically accepted” – Please state why. Please use a multiplication sign (“ \times ”) instead of a period (“.”) here: $\pm 4.10^{-3}$.**

« . » modified to « * ».

The value of 0.004 does not correspond to clearly defined quantitative criteria. It is an empirical criterion accepted on the basis of studies on data stability and reliability such as Herkommer et al., 2024.

- 55. L312: “Assuming independence” – How much uncertainty does this add to the analysis?**

It is impossible to say. If all errors are correlated, their sum is larger than with our hypothesis. But there is no reason to believe that they are correlated, rather than anti-correlated.

- 56. L329: “CCGvu algorithm” – Please expand if this is an acronym. If not, please state so.**

CCGvu is not an acronym, it is the name of the algorithm. « CCG » stands for « Carbon Cycle Group » (NOAA) that published the algorithm first.

- 57. L343: “It is important to note that seasonal and long-term signals are very similar at the regional scale” – Please cite relevant publications.**

Reference added.

- 58. L347 – “that are clearly geophysical”- Please explain how.**

On an hourly scale, with amplitudes corresponding to those observed in other studies (see introduction) and with wind directions carrying the urban plume towards the measuring stations, these observations are considered to be very likely geophysical phenomena linked to the Paris urban plume. An explanation has been added to the main text.

- 59. Figure 7. – Please consider writing “Total” instead of “TOT”. It looks like an acronym.**

Modified.

- 60. L358 – “Saclay shows no enhancement” – Do we know why the WRF-Chem model didn’t see the enhancement, even though modest?**

No, we do not. One hypothesis is that the simulated CO₂ “dome” over Paris is not large enough to reach Gonesse because it disperses too early toward the northeast. This corresponds to what can be seen on the maps presented in the same figure and would explain why no slight increase is observed in the modeling at Saclay, even though it is clearly visible in the measurements.

- 61. L266 – “Errors in transport fields can dominate apparent source mismatches. Therefore, caution is required when interpreting model–measurement differences solely as inventory biases” – Are there similar studies that draw this inference? If so, please cite them.**

Reference added.

62. L402: “depending on the month.” – Please clarify which values are associated with which months.

Precision added.

63. L409: Please change “will use” to “we used”. Please remove “to finally”. Please change “compare” to “and compared”.

Modified.

64. L444: Please change “(temperature, solar irradiation, precipitation, ...)” to “(temperature, solar irradiation, precipitation, etc.)”

Modified.

65. L488: “Noth-East to South-West” – Please be consistent in the use of NE-SW and the full forms. Since NE-SW has been used earlier, please define it at the first instance and use the acronym form throughout the paper.

Modified.

66. L492: “The background concentration should be very similar in the whole domain at any given moment, so we could expect a narrower distribution of background gradients between SAC and GNS.” Please change this to “The background concentration should be very similar in the whole domain at any given moment. Thus, a narrower distribution of background gradients between SAC and GNS can be expected.”

Modified.

67. L494: “However, occasional episodes with larger differences between the background at the two stations do occur and must be taken into account when interpreting the total gradient in relation to urban emissions.” – How much will this impact the uncertainty?

These events contribute to the statistical uncertainty. The point we want to make is that background difference of more than 0.3 ppm do occur and explain some of the scatter.

68. L509: Please capitalize the “O” in origins.earth.

Modified.

69. L520: “XCO₂;SAC < XCO₂;GNS” – Here and for all similar occurrences in the manuscript, please consider using underscore instead of semi-colon.

Modified.

70. L554: “The best fit slope is also lower than 1 555 (0.72 for JUS-GNS and 0.44 for SAC-JUS). The best linear fit indicates a statistical error that are relatively small (0.005 for SAC-GNS, 0.015 for JUS-GNS, and 0.017 for SAC-JUS), so that a slope significantly smaller than 1 is a result that is statistically robust.” – I wonder if it would be better to put these numbers in a table.

A table has been added to summarize these values.

71. L615: “That study, published in Lian et al., 2023 [14], concluded that emissions were underestimated by 2 to 20 %, depending on the month.” – Please state the approximate values typically associated with the months.

Precision added in the main text.