RC1

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

Specific comments :

1. **L21 : What is the basis for an overestimation in emissions of 35%? This figure is not mentioned in the main text. In addition, the Conclusion section states that emissions are overestimated by 44%.**

The 35% overestimation of emissions is based on the slope of the best linear approximation in Figure 11. We consider the gradient signal to be a leading indicator of emissions when the wind direction is parallel to the axis between these stations.

44% is a mistake (now corrected) and should have been 34%.

2. **Table 1: Please include the serial numbers (#88, #103, and #179) of the EM27/SUNs used at each station, along with the corresponding periods.**

The information is now available in Table 1 for each station and each instrument until 2024/12. Please note that all stations were still in operation after 2024/12 but our study period ends on 2024/12/31.

3. **Figure 2: Regarding XCO_2, instrument #88, which was deployed at SAC before 2023-05-19 and at GNS after 2023-05-19, appears to have a low bias, while instrument #103, which was deployed at SAC after 2023-05-19, has a high bias. Thus, there seems to be device-specific biases. Can the effect of the exchange of instruments be considered negligible? Additionally, Paris TCCON data are biased low by approximately 0.5 ppm, compared with other EM27/SUN data. Is it acceptable not to consider this bias?**

For this reason, we use the average bias between the two instruments in calculating the overall uncertainty. This takes into account the specific biases of each instrument and the effect of the change between the two stations.

For the Paris TCCON site, we consider this bias in calculating its uncertainty as showed in Table 3.

4. **Figure 4 and L233: Could you please clarify whether the ΔXCO_2 values were calculated for each instrument, as indicated in the legend of Figure 4, or for each station, as described in the main text?**

This precision is indeed important. The ΔXCO_2 values have been calculated for each instrument. A clarification is made in the main text.

5. **L294–295: According to Table 2, a 0.0015 change in XAIR corresponds to a 0.14 ppm change in XCO_2. Which is correct?**

According to Table 2, a change of 4.10^{-3} in XAIR may create a variation of 0.37 ppm in XCO_2. A correction has been done in the main text.

6. **L331: Is the observed growth rate the same at the three stations?**

In order to maximise the number of points used to calculate the growth rate over this period, we use measurements from Saclay (clarification added in the text). The growth rates calculated at Gonesse and Jussieu are slightly different (2.89 and 2.84 ppm/yr, respectively). The difference in growth rate remains small and can be explained by the limited time period and the under-sampling of the time series, in particular during the winter months.

7. **L465–478: Please add discussion of the differences between the simulations and observations, especially why the measured XCO_2 values at Gonessa were, on average, larger than those at Saclay, contrary to the simulations.**

We do mention in the text that the measured gradients appear larger (positive) than the modeled values. We do not have a demonstration for the main cause of this discrepency. Our best hypothesis is that some emissions in the proximity of GNS are not accounted for in the simulation. A mistake has been identified in Figure 9. We modified the figure and wrote the text again, with the required precisions and modifications due to the new figure.

8. **L579: What is the emission inventory used by CAMS? This information would be helpful in understanding the differences between the WRF-Chem and CAMS simulations.**

It is the CAMS-GLOB-ANT, a global inventory produced by the ECMWF for CAMS simulations. We added a reference to a paper published in 2024 describing this inventory.

9. **L587–588: Because the errors in the slopes for JUS-GNS and SAC-JUS are almost the same between CAMS (9 km resolution) and WRF-Chem (1 km resolution) simulations, the difference in the spatial resolution seems to be irrelevant.**

Yes, we deleted the part of this sentence about the spatial resolution.

10. **L589–590: Why is underestimation in the emissions inventory considered more reasonable than overestimation?**

Another study published in 2023 (Lian et al., 2023) indicates that emissions in the Greater Paris region (Paris and its inner suburbs) are underestimated. This study uses in-situ surface measurements taken in this region over a six-year period and has a complete atmospheric inversion framework. Our study assesses the potential of using total column measurements in a possible atmospheric inversion. In view of the results demonstrated previously in the article on measurement uncertainty, which is of the same order of magnitude as the measured signal and the contribution of vegetation in the model, and having demonstrated the limitations of model-measurement comparison, we consider that the underestimation assessed by Lian et al. 2023 is more reasonable than the very significant overestimation that appears to be indicated here.

11. **L615–619: In L402–404, it is stated that emission estimates using in situ surface measurements are subject to significant uncertainty due to the difficulty of modeling the vertical mixing, whereas column measurements are insensitive to this modeling. Could you discuss which approach is more accurate?**

The approach using surface measurements involves a degree of uncertainty due to the modelling of vertical atmospheric transport. This is not (or only slightly) the case for total column measurements. For this reason, total column measurements provided an interesting perspective in the optimisation of emissions inventories. However, other reasons mentioned in this paper (high uncertainties, anthropogenic signal comparable to biogenic signal, and horizontal transport errors) demonstrate the impossibility of using these measurements in a complete atmospheric inversion process as with surface measurements. This comment has been added to the main text.

Technical corrections:

1. **L64: Are the EM27/SUN data at JUS used in this study? Otherwise, it would be better to either state that fact or delete it to avoid confusion.**

No EM27/SUN measurements from JUS are used in this study due to the late installation of the instrument at the station. We deleted the mention to this instrument in the main text.

2. **Table 1: What is the QUALAIR platform?**

QUALAIR is a multi-instrument experimental research platform for observing chemical and dynamic variability in the atmosphere. See http://qualair.aero.jussieu.fr/ (link added to Table 1).

3. **L147: "to be used" is unnecessary?**

Removed.

4. **L157: the radiative transfer code GGG2020 package -> the retrieval software GGG2020**

Modified.

5. **L159: TCCON framework -> TCCON archive**

Modified.

6. **L225–226: we define a reference as the mean XCO_2 over 10:00-14:00 local time. -> we define the mean XCO_2 over 10:00-14:00 local time as a reference.**

Modified.

7. **L240: modelled radiative -> modelled radiative processes**

Modified.

8. **Equations (3.1)–(3.3): What do the double arrows means?**

Here, double arrows mean « equivalent ».

9. **Figure 5: Please change the x-axis label to English.**

Modified.

10. **L266: r_{SAC} = 0.76 et r_{GNS} = 0.75 -> r_{SAC} = –0.76 and r_{GNS} = –0.75**

Modified.

11. **L312: This sentence is almost identical to L314–315, so it is redundant.**

Modified.

12. **Table 3: What is the difference between "-" and "X"?**

No difference, it is a mistake from our side. Modified to « X » only.

13. **L324: According to Section 2.2, TCCON spectra were analyzed with GGG2020.**

Modified.

14. **L392: CO_2 plus -> CO_2 plumes?**

Modified.

15. **L420: Figure 10 is cited before Figure 9 in the main text. Figure 10 should be changed to Figure 9 and vice versa.**

We consider it appropriate to present the upper and lower panels of Figure 10 together (rather than in two separate figures). However, Figure 10 cannot be placed in Section 5.1 because it also presents results simulated by WRF-Chem, and this section precedes the presentation of WRF-Chem. For this reason, Figure 10 is placed after Figure 9.

16. **L504 and 507: et -> and**

Modified.

17. **L560–564: Please add the slopes of the fits as well as the correlation coefficient.**

Added in the text with the Pearson's correlation coefficients.

18. **L584: discrepancies in the simulation of emissions or atmospheric transport -> discrepancies in the atmospheric transport simulations or emissions**

Modified.

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.

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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 realy 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 realy 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 Altzomoni 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 Altzomoni 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

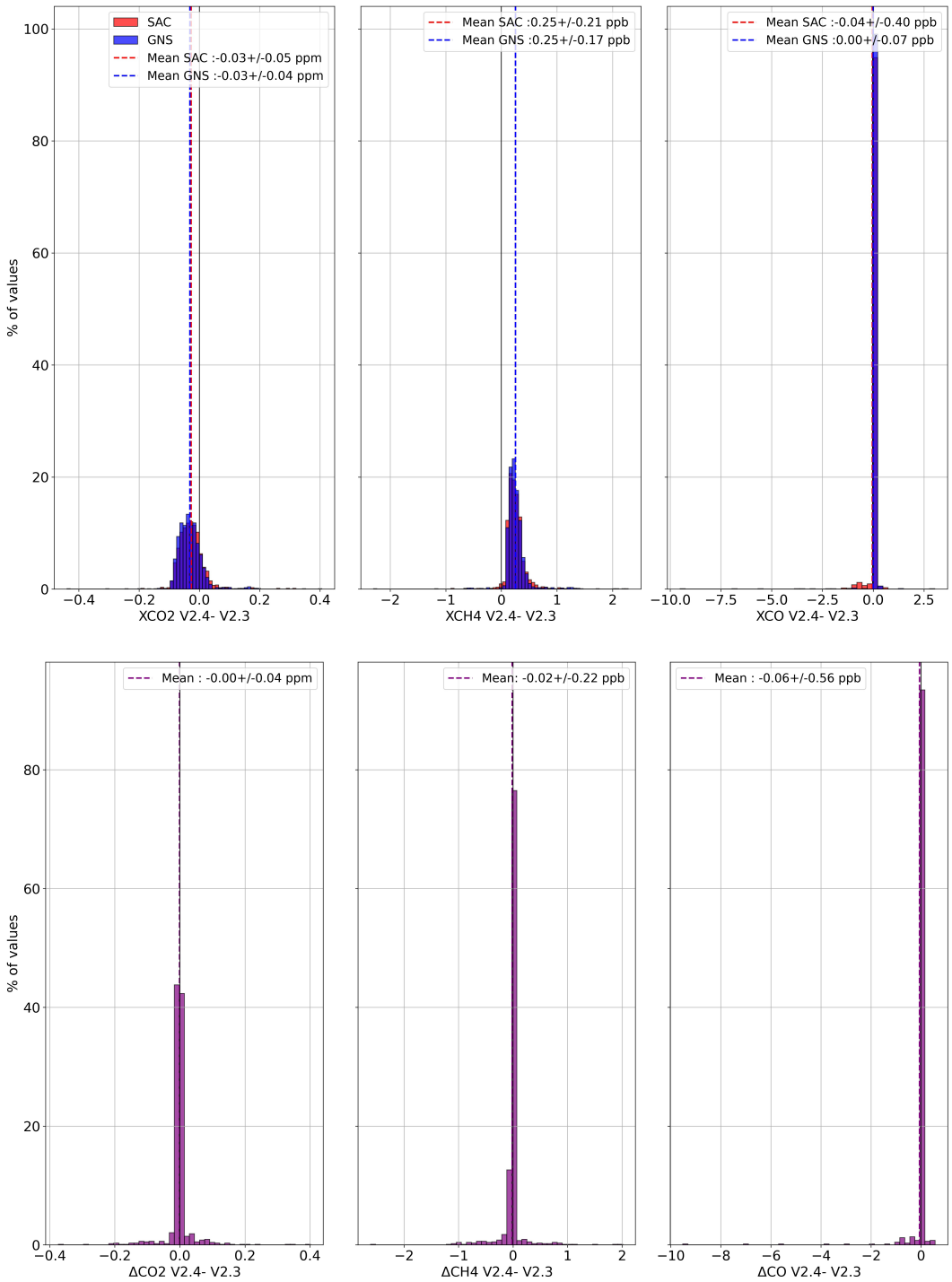
23. **L134: MONARIS – Please expand if this is an acronym. If not, please state so.**

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 PROFFASTpyplot 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 XCO_2 estimates differ, on average, by -0.03 ppm with some dispersion around this mean value: 90% of the XCO_2 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 XCO_2 differences (between the two versions) of PROFFAST are correlated berween the two ICOS stations so that the dispersion in term of ΔXCO_2 is lower than the dispersion on XCO_2. Indeed, 90% of the ΔXCO_2 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. Is 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 ("×") 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 error are correlated, they 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 CO_2 "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.