Answers to the comments of "Anonymous Referee 2"

First of all, we would like to thank you for the valuable feedback and comments.

In the following we will reply to your questions and comments point-by-point. Your questions and comments are given (sometimes a bit shortened) in bold font, and our answers in normal font. Extracts of the paper are added in italic font.

Note that two errors were discovered by us in the meanwhile which also have been corrected:

1. In Table 1 and Table A2 there were wrong numbers. Fortunately, only the numbers in the manuscript were erroneous but not the ones used for the calculation of the final result. Hence, nothing changed in Table 4 due to these corrections.
2. We discovered an error in the Excel table used to calculate the final corrections factors for the Tsukuba time-corrected data. This error is corrected now, causing that the relative deviation for the XCO_2 TK-LR-tcorr data is now similar to the XCO_2 TK-LR data.
   This caused the values for "TK t-corr -44s" to be changed in Table 4 and Table A2:
   a. Table 4:
      XCO_2: 0.16401 ± 0.00830 − 0.06318 → 0.11387 ± 0.00829 − 0.06314
      XCH_4: −0.1115 ± 0.00873 + 0.06690 → −0.18343 ± 0.00871 + 0.06685
      XCO: 1.46537 ± 0.0487 + 0.05470 → 1.16653 ± 0.04870 + 0.05454
   b. Table A2:
      XCO_2: 0.99836 ± 0.00008 + 0.00063 → 0.99886 ± 0.00008 + 0.00063
      XCH_4: 1.00112 ± 0.00009 − 0.00067 → 1.00185 ± 0.00009 − 0.00067
      XCO: 0.98556 ± 0.00047 − 0.00053 → 0.98847 ± 0.00047 − 0.00053
   This also caused changes in Figure 16 (which is the visualization of Table 4) and the main text in Section 7.3:

Furthermore, we corrected grammatic and spelling errors as well as the wrong naming of the colors and shapes in the main text.

Specific Comments

1. **Is there a time series of the transport logger?**

   - No, only shocks are recorded, however, including a timestamp. To make this clearer, we described this in the manuscript and added the start and stop dates of the logging as well as the timestamp of the detected shock events.
   - We added in the manuscript in Section 2.2.1:
     "The loggers do not record a continuous time series but only log shocks with a duration and acceleration larger than a certain threshold. Furthermore, the sensors are saturated a 16 g. Hence, all shock events larger than that are truncated to 16 g."
     "On its way to Wollongong, the record was started on 2022-10-22 at 07:59 (this and all following times are given in UTC) and stopped on 2022-12-06 at 09:35. The events were recorded on 2022-11-25 08:23 and 10:34 as well as on 2022-12-06 at 09:26. On its back, the record started on 2023-01-26 at 21:27 and stopped on 2023-11-07 at 11:32. The event was recorded on 2023-02-15 at 03:40."
     "On its way to Wollongong the logger attached to the EM27/SUN was started on 2022-10-20 at 7:59 and stopped on 2022-12-06 at 09:40.

It recorded one shock event on 2022-12-06 at 09:40 with a maximum acceleration of 14.4 g. Since this record was just before stopping the record, this was probably caused by putting the logger hardly on the desk before reading it out."
"On its way back the record starts on 2023-01-26 at 21:35 and stopped on 2023-03-07 at 11:33. Two shock events were recorded both on 2023-01-26 at 21:38 and a maximum acceleration of 16 g. Here, as well the record was shortly after the start and therefore is most probable caused by a drop of the logger itself without being attached to the instrument."
"The fact that the enclosure experienced such extreme shocks, but the logger attached to the EM27/SUN did not record them indicates that the packing in foam of the EM27/SUN helps to cushion the shocks".

2. **Comparison with Saturn V is misleading as rocket launch acceleration is a steady state acceleration.**

    - Agreed, we removed the comment. (Very high variable accelerations seem to have resulted from extreme vibrations especially during the first stage burning of the Saturn V, according to Apollo mission astronauts' reports)

3. **Lines 20-23: Not clear if the comparisons described refer to TCCON HR-LR or TCCON-TS.**

    - These are the final deviations calculated (visited TCOCN site relative to the reference in Karlsruhe), so TCCON versus TS.
    - We reformulated these lines to make that clear:
    "For Tsukuba and Wollongong the agreement with the reference in Karlsruhe found for XCO_2 is…"

4. **Why not compare directly to the KA-TCCON site but to the COCCON reference EM27/SUN?**

    - As correctly stated by you, Sha et al. (2020) found a seasonal bias between HR and LR FTIR remote sensing measurements. This is triggered by the different vertical sensitivity of high-resolution and low-resolution measurements. Therefore, whenever the a-priori gas profile deviates from the actual profile, a difference between the XGas result occurs. The most prominent effect are the aforementioned seasonally varying biases.

    - However, for the TS characterization measurements conducted before and after each campaign we need to avoid these variable biases, because they would result in a time-dependent bias in the TS's calibration, which would propagate to the comparisons to the TCCON stations. Hence, we compare with low-resolution FTIR measurements.

    - A more direct approach would be to use LR measurements of the TCCON-KA site. However, the TCCON-KA spectrometer collects alternating HR and LR measurements and follows a measurement pattern which also involves the collection of mid-infrared spectra. As consequence, LR TCCON data are available only every 20 minutes. In contrast, we approximately collect one measurement every minute with the reference COCCON spectrometer. Hence, we can achieve significantly better statistics from the comparison of the TS with the COCCON reference spectrometer. The COCCON reference, operated in Karlsruhe continuously, can be compared to the TCCON-KA station record with much lower statistical uncertainty as it can be compared over a longer time interval.

    - The calibration factors within the PROFFAST retrieval software are determined such, that on average the COCCON reference agrees with the TCCON-KA-HR

measurements (see Alberti et al. (2022), Figure 20 and Herkommer (2023), Chapter 3). Therefore, it is justified (and the best strategy) to compare with the COCCON-reference spectrometer.

- To make this clearer in the manuscript we added the following to Section 3 of the manuscript:
  "The reason why we are comparing to the COCCON reference and not directly to the TCCON-KA site is the following: As mentioned earlier, for short-term comparison different resolutions can induce variable biases in the final XGas products. To avoid these, it would still be possible to compare LR data measured with the TCCON-KA spectrometer with the TS. However, the focus of the TCCON-KA measurement is to collect standard TCCON and mid-infrared measurements with high resolution, hence, we only collect a LR spectrum every 20 minute. Therefore, there are significantly less TCCON-KA LR measurements available than measurement with the COCCON reference unit which collects about one measurement per minute. The airmass independent calibration factors used internally in the PROFFAST2 software are carefully chosen such, that the COCCON reference is tied to the official TCCON-KA HR data."

5. Is a seasonal bias as mentioned by Sha et al. (2020) considered?

- This effect described by Sha et al. (2020) is an effect of the different spectral resolutions of the instruments (low-resolution portable versus high-resolution TCCON observations).
- To avoid this disturbance, our study design incorporates the TCCON-LR data for the site evaluation. This does not imply a loss of information, as the low-resolution TS does not provide any handle for the verification of the high-resolution part of the TCCON measurement. This aspect is covered by TCCON by using gas cell measurements instead.
- We also report the official TCCON-HR vs TS differences, because these are undoubtedly of interest. But this comparison is inherently "noisy" due to the variable smoothing error contributions resulting from the different vertical sensitivities of low and high-resolution measurements. We agree, that this fact was not carried by us properly in the manuscript so far. Therefore, we added the following:
- In Section 2.2.2:
  "These effects are also observed by Sha et al. (2020)."
  and
  "As a consequence of the different resolutions it is important to note that the comparison of the TCCON-HR data with the TS data are affected by variable smoothing error contributions resulting from the different vertical sensitivities of low and high-resolution measurements. The judgement of the level of agreement of the TS measurements with the TCCON site measurements needs to be based on the TCCON-LR data. This does not imply a loss of information, as the low-resolution TS measurement does not provide any handle for verifying the high-resolution part of the TCCON measurement. This latter aspect needs to be checked by the use of low-pressure gas cells. Once the TS has visited a larger number of sites, a larger dataset of TCCON-HR vs TS comparison is available. This can probably be used to see systematic effects of over-, or underestimation of different gases by the different resolutions."
- In Section 7.3:
  "For the following discussion it is important to keep in mind that the comparison of the HR data are affected by variable smoothing error contributions resulting from the different vertical sensitivities of low and high-resolution measurements. This introduces an uncertainty when comparing XGas results."

Technical corrections

1. **L43: has been evaluated**
    - Done.
2. **L51: omit "profile observations by"**
    - "collocated airborne profile observations" --> "collocated airborne measurements"
3. **L208 even -> event**
    - Changed this paragraph, therefore removed.
4. **L273: remove first limits**
    - Done.
5. **L295: and Fig 2 caption Red crosses should be blue triangles.**
    - Done.
6. **Figure 4. Delta XCH4 is presented, relative to what? (Ref instrument is assumed)**
    - Yes, to the COCCON reference instrument. This is added to the manuscript:

      "Investigating the dependency of ΔXCH_4 ΔXCH_4^{S5P} of the reference EM27/SUN and the TS device as a function of the solar zenith angle (SZA)."
7. **Figure 6. Although not necessary in this case it is generally more pleasing to have the same y axis scale on adjacent plots.**
    - Done.
8. **L407: Extra the**
    - Done.
9. **Figure 10 caption. Repeated use of "normed" throughout. It is more normal to use normalized.**
    - Corrected.
10. **Fig 16 caption. Last sentence redundant, every figure should be discussed in the man text.**
    - Removed.
11. **L662: l-minute or one-minute?**
    - l-minute. Set "l" in math mode to make it clearer.
12. **Equations B7-B9 check the subscripts for consistency**
    - Done.

References:

Alberti, C. et al: "Intercomparison of low- and high-resolution infrared spectrometers for ground-based solar remote sensing measurements of total column concentrations of CO2, CH4, and CO", Atmospheric Measurement Techniques, 13, 2022, DOI: 10.5194/amt-13-4791-2020

Herkommer, B. 2023: "Improving the consistency of greenhouse gas measurements from ground-based remote sensing instruments using a portable FTIR spectrometer", Dissertation, Karlsruher Institut für Technologie (KIT), DOI: 10.5445/IR/1000168723