

Authors' answer to the interactive comments of Jacob Hedelius on "Building the COllaborative Carbon Column Observing Network (COCCON): Long term stability and ensemble performance of the EM27/SUN Fourier transform spectrometer" by Frey et al., Atmos. Meas. Tech. Discuss., amt-2018-146

First of all, we would like to thank Jacob Hedelius for the help in further improving the current presentment by a thorough assessment with regards of content and the careful technical proofreading resulting in the identification of several imprecisions and typos.

**J. Hedelius:** *"The authors may want to consider these comments in preparation for their final submission of this paper."*

*Abstract: It may be helpful to emphasize that the instrument is solar-viewing."*

**Authors:** Ok, done

**J. Hedelius:** *"P1L3 – The word "stable" is used throughout. The authors use the term to both refer to 1) mechanical stability of the instrument, and 2) comparability of the retrievals to another product. Because this is a subject term (e.g., one person may say 0.5% accuracy is stable, and another may say 0.05%) it would be useful if the author's metric of stability was defined numerically. In the future, requirements for "stability" may change as well."*

**Authors:** We agree and have added specific numbers (which also was requested by referee #1).

**J. Hedelius:** *"P1L5 – It may be useful to list the QA measures here, as the authors use several."*

**Authors:** The QA measures are explained in detail in the paper, we think that it would be too specific to provide these details in the abstract.

**J. Hedelius:** *"P2L2 – "Very uniform" is also subjective. It would be helpful to mention indicators of uniformness here in case readers only see the abstract."*

**Authors:** We have added further information (see reply to referee #1).

**J. Hedelius:** *"P2L13 – Numerically, what is the reference precision of the TCCON?"*

**Authors:** The performance of TCCON has been demonstrated and discussed in many papers, e.g. the cited paper by Wunch et al., 2011. We will provide the information in the manuscript for the readers.

**J. Hedelius:** *"P2L14 – Not only do 125HR instruments require more frequent maintenance than EM27/SUN instruments, it also needs to be done on site."*

**Authors:** True, we have added this information.

**J. Hedelius:** *“P2L20 – Ye et al. (ACPD, 2017) <https://doi.org/10.5194/acp-2017-1022> recently estimated city/urban emissions using satellite observations. Data from other current and future satellites may be used to estimate emissions from more localized sources, but that remains to be seen.”*

**Authors:** Thanks, we added the reference.

**J. Hedelius:** *“P2L25 – “Low-cost” is subjective, but I would actually say the EM27/SUN spectrometer is quite expensive, and cost-prohibitive for many institutions to own. The authors may consider stating the 2018 price range for these instruments.”*

**Authors:** “Low-cost” here is meant in comparison with operating a TCCON spectrometer, which requires not only a more expensive spectrometer, but also the provision of a controlled environment, e.g., by operation in a laboratory or special container. We will add the current price range, around 100000 Euro, in the manuscript.

**J. Hedelius:** *“P2L29 & throughout – The authors often use the word “calibrated” when “compared” or “scaled to” would be a better choice in this context. Calibrated is usually reserved for values more directly measured and compared to a standard.”*

**Authors:** Thanks, we revised the text accordingly.

**J. Hedelius:** *“P3L15 – Define IMECC”*

**Authors:** Ok, done

**J. Hedelius:** *“P3L24 – Define/describe the NCEP data”*

**Authors:** Ok, done

**J. Hedelius:** *“P4L4 – What does “nominal” mean here and throughout?”*

**Authors:** “Nominal” is matching the theoretical expectation.

**J. Hedelius:** *“Sect. 3.1 – The ME at MOPD is consistently around 0.985, so what should users running PROFFIT use for the ILS? Should the input ME at MOPD be 1.0? What was used in this study (e.g., what does “real ILS” mean on P12L17)?”*

**Authors:** Our current choice is to accept the bias in the method and to use the ME as it results from the LINEFIT analysis. Renormalization to 1.0 would slightly change the calibration values for XCO<sub>2</sub> and XCH<sub>4</sub> (in a systematic way, the instrument-to-instrument relation will not be affected).

**J. Hedelius:** *“P8L23 – Given that Dragos Ene is a coauthor of this study it seems strange to use “they” instead of “we.” The authors may consider removing the private communications citation and instead put in an author contribution section at the end: see Manuscript composition -> 14. Author contribution under [https://publications.copernicus.org/for\\_authors/manuscript\\_preparation.html](https://publications.copernicus.org/for_authors/manuscript_preparation.html)”*

**Authors:** We added an author contribution section and revised the text accordingly.

**J. Hedelius:** *“P9L7 – I agree with Reviewer #2 that the focus on comparing with a LR rather than an HR dataset from the 125 HR instruments is dissatisfying. I would expect the additional information in HR data should at least make it possible to construct a dataset with smaller absolute errors and biases. If 2 Xgas measurements have large, but equal errors or biases they will agree well.”*

**Authors:** In our reply to referee #2 we tried to make clearer why the use of LR data is the most sensitive way to quantify the small instrument-to-instrument biases which we need to detect. The generation of an LR dataset from the high-resolution spectrometer allows to generate comparable observation systems. The smoothing error which occurs due to use of an imperfect a-priori trace gas profile during a side-by-side observation period is essentially a systematic error (as clarified by the annual variations seen between TCCON and COCCON), it can only be removed from the intercomparison by matching sensitivities (this, in turn, by matching spectral resolution).

**J. Hedelius:** *“P13L19 – I would disagree that no maintenance is ever required. In my experience at least 6 of 9 EM27/SUN instruments I have been on campaigns with required some form of maintenance within their first two years. Even the reference spectrometer in this study needed maintenance in 2016. However, an advantage is they do not need to be maintained on-site, but rather can be shipped back to Bruker or KIT.”*

**Authors:** Correct, we have updated the text accordingly.

**J. Hedelius:** *“P13L21 – From here and the TCCON meeting the COCCON PROCEEDS sounds like a very exciting upcoming development. I think this project deserves a more complete description earlier on in the paper. I also agree that a more concrete description of COCCON will be useful.”*

**Authors:** We have added some more information on COCCON in the introduction.

**J. Hedelius:** *“P13L29 – Perhaps the authors may want to check with the editor, but there may be some conflicts of interest that should be declared ([https://www.atmospheric-measurement-techniques.net/about/competing\\_interests\\_policy.html](https://www.atmospheric-measurement-techniques.net/about/competing_interests_policy.html)). For example, receiving research funding from, or working for a commercial company could be considered a conflict of interest per the Copernicus policy.”*

**Authors:** Thanks for pointing this out, we discussed the point with the Editor.

**J. Hedelius:** *“Figure 4 – The authors may consider changing the y-axis scale. Scales of 15 ppm, and 5% ( $\pm 20$  ppm) are, in my opinion, quite large and make it difficult to judge comparability of the retrievals on shorter timescales. Especially as the satellite community is pushing towards accuracy of 1 ppm ( $\pm 0.25\%$ ) or better for XCO<sub>2</sub>.”*

**Authors:** We have revised figures 4 and 6, as was also suggested by referee #1.

**J. Hedelius:** *“Metrics of stability in the Xgas retrievals in addition to the linear fit over the full time series may be useful in the text. For example, on different timescales such as months or seasons – especially since differences on these timescales are quite noticeable. This will help if the COCCON is used in satellite validation to know if comparisons should only be done over multi-annual scales to get an overall bias as high and low values will cancel out, or if shorter time-scales are plausible. Seasonal or month-to-month biases would also lead to artificial cycles in global assimilation models.”*

**Authors:** The linear fit is performed for quantifying instrumental drifts. The discussion of seasonal changes is work in progress in the FRM4GHG consortium. These variations are mainly driven by variations of differing smoothing error contributions between TCCON and EM27/SUN. It is not related to the questions of concern in the publication under consideration: investigation of long-term instrumental stability and ensemble performance.

**J. Hedelius:** *“Table 1 – It would be helpful to have a caption as to why some uncertainties always propagate to negative on ME.”*

**Authors:** Thanks, we corrected this inconsistency.

**J. Hedelius:** *“Table 5 - Would all the authors advise that regular ILS monitoring is unnecessary and other EM27/SUN operators just use the values in this Table?”*

**Authors:** If regular atmospheric measurements are performed with a spectrometer, a drift or step change in XAIR will be a sensitive early indicator of any instrumental instability (assuming the availability of a reliable pressure record). If a change in the XAIR timeseries is detected, we would strongly recommend ILS measurements as a measure of diagnosis.

**J. Hedelius:** *“Table 6 - Would the authors recommend instrument operators not make their own side-by-side comparison at the beginnings and ends of instrument campaigns, and instead use these scaling factors?”*

**Authors:** We definitely would recommend as a measure of precaution to perform side-by-side comparisons before and after campaigns, if the campaign schedule allows. If e.g. one of the participating spectrometers received a mechanical shock during overseas transport due to mishandling, it could after recalibration still contribute (then with a slightly changed calibration factor) to the campaign dataset. Ideally, this spectrometer should be resend to the central calibration facility afterwards for recalibration (a change in instrumental characteristics might in addition indicate an instrumental damage).

## **Reference:**

Ye, X., Lauvaux, T., Kort, E. A., Oda, T., Feng, S., Lin, J. C., Yang, E., and Wu, D. (2017): Constraining fossil fuel CO<sub>2</sub> emissions from urban area using OCO-2 observations of total column CO<sub>2</sub>, *Atmospheric Chemistry and Physics Discussions*, 2017, 1–30, <https://doi.org/10.5194/acp-2017-1022>