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Atmospheric Measurement Techniques Discussions

Interactive comment on "Intercomparison of low and high resolution infrared spectrometers for ground-based solar remote sensing measurements of total column concentrations of CO_2, CH_4 and CO" *by* Mahesh Kumar Sha et al.

Anonymous Referee #2

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Review of Sha 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

This paper details the results from an intensive campaign wherein 4 portable spectrometers (Bruker EM27/SUN, Bruker IRcube, Bruker Vertex40, RAL LHR) were hosted near the Sodankylä TCCON station from March-September 2017. AirCore profiles were also flown throughout the campaign. The campaign resulted in some interesting data collected that helped reduce uncertainties in the Vertex40, pointed out where the

LHR needs improvement, and identified a problem unique to the Sodankylä TCCON station that was resolved.

This paper may be suitable for publication after the following concerns are satisfactorily addressed.

Major Comments

1. The nonlinearity problem at Sodankylä is unique to Sodanklyä, and this is not made clear in the paper. In general, TCCON stations have limited the light incident on the detectors by a combination of reducing the input field stop (on the aperture wheel) and placing an aperture stop after the input CaF2 window. From what I can glean from Section 5.8 (specifically, "The TCCONmod data set is a better representation of the true atmospheric signal. As TCCON is our primary data reference for the intercomparison study for this campaign, the non-linearity correction has been applied to the TCCON data."), this nonlinearity correction has been applied to all comparisons/figures/tables throughout the paper (except where the nonlinearity is discussed directly). If I have interpreted this correctly, I believe it is the correct approach, since it is more representative of the data a TCCON station would produce. That said, it should be stated up front (i.e., in section 2.2.1) that this correction has been applied, with a clear statement that this does not generally affect all TCCON data; just Sodankylä's. The details included in section 5.8 (and 5.9) ought to be relegated to Appendix A.

2. Your comparisons of Xair between the various instruments is misleading because it is not an apples-to-apples comparison. It is not only instrument effects that impact Xair: it is also spectroscopy. PROFFAST and GGG2014 do not include the same spectroscopy, line shapes, etc., and thus would be expected that they have different Xair values. It would be helpful to have a short (1-paragraph) discussion about the differences between the two retrieval software algorithms, as relevant to this issue. It is unclear to me why you would choose to use PROFFAST to analyse the EM27/SUN data and not also use the EGI wrapper for GGG2014 to maintain consistency with

the other retrievals. I suggest you add the EGI retrievals of the EM27/SUNs to your analysis. (https://bitbucket.org/em27gi/egi/wiki/Home)

3. It is unclear to me why you include the time period before the hardware upgrades of the Vertex and IRcube in your subsequent analysis. It makes more sense to me to show the significant improvement in their data after fixing the hardware in the time series plot, and then do not show the pre-improvement data in subsequent analyses, focusing only on the "good" data.

Minor comments

1. I found the authors' motivation for the need for the COCCON (or another complement to TCCON) misleading. I believe it is true that the TCCON could be usefully supplemented by LR portable spectrometers, but the atmospheric and surface conditions you list are generally already covered by TCCON stations. For example:

a. "A denser distribution of ground-based solar absorption measurements is needed to cover various atmospheric conditions (humid, dry, polluted, presence of aerosol), various surface conditions (high and low albedo) and a larger latitudinal distribution."

i. Humid –> Darwin

ii. Dry –> Armstrong, Eureka, Sodankylä, Pasadena

iii. Polluted –> Pasadena, Tsukuba, Wollongong (sometimes)

iv. Aerosol –> Pasadena, Tsukuba, sometimes Ascension

v. High albedo –> Armstrong

vi. Low albedo –> Park Falls, etc.

b. Where I do agree, is that if we want to cover geographic gaps in the locations of these stations, we need more stations, and the low-resolution instruments may be well suited to that.

2. It is unclear to me whether you use identical surface pressure values in your retrievals for each instrument. If they are different, this would also cause biases in Xair. For a fair comparison, they should be identical and calibrated to a meteorological standard. Please discuss and resolve if necessary.

3. It is unclear to me why the HR125LR has its own section. Why not include it in the comparisons with the other LR instruments wrt TCCON?

4. The water vapour dependence section is not conclusive, since Sodankylä is generally dry (XH2O <4500 ppm). This is therefore not an exhaustive test of XH2O dependence. I suggest moving this section to an appendix, noting in the main text that little XH2O dependence was found over the (relatively dry) conditions at Sodankylä.

Technical comments

1. P1L1: . . . the baseline *ground-based* network of instruments. . .

2. P1L5: Northern America –> North America and again in L72.

3. P2L25-26: This seems to imply that the nonlinearity is a problem throughout TCCON, which it is not. Please revise.

4. P2L41: increasing in ** recent years (no "the")

5. P2L43: You may want to mention the (important) role of VOCs in the production of CO.

6. P2L48: positive radiative forcing*, therefore it is* considered as an indirect. . .

7. P3 first paragraph: Generally unnecessary paragraph. It's unclear what you mean by "To ensure equal dependency on the input spectral data, . . ."

8. P3L74: Again, there are TCCON stations that span all those conditions. Rephrase.

9. P3L80. "However, there has been little characterization, intercomparison and harmonization of these new instruments in comparison to the standard instrument used in

TCCON." There is some literature on just this topic. Please cite:

a. Hedelius, J. K., C. Viatte, D. Wunch, C. M. Roehl, G. C. Toon, J. Chen, T. Jones, S. C. Wofsy, J. E. Franklin, H. Parker, M. K. Dubey, and P. O. Wennberg (2016), Assessment of errors and biases in retrievals of XCO2, XCH4, XCO, and XN2O from a 0.5 cm-1 resolution solar-viewing spectrometer, Atmos. Meas. Tech., 9(8), 3527–3546, doi:10.5194/amt-9-3527-2016.

b. Hedelius, J. K., H. Parker, D. Wunch, C. M. Roehl, C. Viatte, S. Newman, G. C. Toon, J. R. Podolske, P. W. Hillyard, L. T. Iraci, M. K. Dubey, and P. O. Wennberg (2017), Intercomparability of XCO2 and XCH4 from the United States TCCON sites, Atmos. Meas. Tech., 10(4), 1481–1493, doi:10.5194/amt-10-1481-2017.

10. While I understand that Sodankylä was chosen for (important) practical considerations, it is a challenging place for a ground-based campaign for a number of reasons, and these challenges ought to be clearly stated near the beginning of the paper with your thoughts on how those challenges may manifest:

a. High latitude means higher SZA

b. Lack of full seasonal cycle

c. Proximity to the polar vortex means increased likelihood of poor a priori profiles as GGG2014 does not handle vortex air

d. Dry atmosphere does not provide full range of XH2O seen in other locations

11. P3L85-85: Awkward sentence. Please clarify.

12. P4L88: Please cite the Karion paper when AirCore is introduced.

13. P5L124: What does "The number of usable detector positions differs for the three instruments." mean in practical terms for this work?

14. P4L136: Please cite: Keppel-Aleks, G., G. C. Toon, P. O. Wennberg, and

N. M. Deutscher (2007), Reducing the impact of source brightness fluctuations on spectra obtained by Fourier-transform spectrometry., Appl. Opt., 46(21), 4774–4779, doi:10.1364/AO.46.004774.

15. P4L138: Please state that this is the GGG2014 software that you are using.

16. P4L141: Are you recording just on the InGaAs detector alone? Are ghost corrections performed?

17. P7L187: build –> built

18. P8L232: atmospheric ** and local oscillator *beams* are mixed

19. P8L244: 13.4 mbar for ** ambient pressure*s between the surface and* 232 mbar, and 3.9 mbar for ** ambient pressure*s* lower than 232 mbar.

20. P9L260: Why are you listing this CO value in ppb?

21. P9L275: The sentence beginning with "The continuous operation" is awkward. Please revise.

22. P10L293: All teams performed *a* full functionality test. . .

23. P10: Change "highest OPD" to "maximum OPD".

24. P11L312: documentation (no 's')

25. P11L322: Is the surface pressure identical between instruments?

26. P11L328: What scaled ratio are you referring to? You refer to scaling several times throughout the paper and it is not clear what you are referring to. Please clarify.

27. P11L335: These two lines are repetitive with information stated earlier in the text.

28. P12L350: State your reasoning for the SZA cutoff earlier.

29. In general, I do not think that uncommon phrases, and/or phrases that are used only a few times in a manuscript should be given acronyms. I find these acronyms

detract from the readability of the paper. For example, I would appreciate it if you would type out the acronyms for:

a. LO

b. FO

c. NA

d. ME (though admittedly common in our field, but used only a few times)

e. PE (again, common in our field)

30. P13: consider reporting XCH4 differences in ppb instead of ppm.

31. In general, in these Xgas-specific subsections: I do not think the seasonal cycle needs to be described in words.

32. P14L430: "Any difference relative to the ideal case is an indicator for the instrument and retrieval code performance." And the spectroscopy, which can be distinct from the code itself. Please add.

33. P14L440: Again, the EM27/SUN data are processed using *an entirely different retrieval code with different spectroscopy* so it is not surprising (or an indication of instrument performance) that the EM27/SUN Xair shows the smallest airmass dependence. Please clarify.

34. P15L451: "However, no such instrument specific calibration factors were applied for the other instruments. . .". Why not? You know the biases wrt TCCON now.

35. P15L457: Why not just truncate the HR interferograms instead of recording special HR125LR interferograms?

36. P16L499: Again, without the LR AKs to compare with, we cannot assess the impact of errors in the prior on the total column comparisons.

37. P17S5.4.4: Is there a figure this section refers to?

38. P18L553: This paragraph is a non sequitur wrt the previous paragraph regarding XCO.

39. P19L576: "From the plots it can be seen that the SZA dependency. . . is related to the spectral resolution and the AK of the instruments." While I agree that it's probably true, it cannot be seen from the plots, since you have not shown the LR AKs.

40. P20L606: Any idea why this is occurring? This is a potentially interesting result.

41. P20L617: Again, these have different retrieval code and different spectroscopy. Please make that clear.

42. Section 5.7.1: Suggest moving to an appendix for the reasons stated above.

43. Section 5.8: Suggest putting brief sentence earlier in manuscript, and moving this section to Appendix A for the reasons stated above. Also, "These higher values could come from the spectral double passing of the signal within the interferometer." This sounds interesting but requires far more explanation. Where is the double-passing coming from? How can it be removed?

44. P22L687: "the annex 1" –> Appendix A.

45. P25L775-780: This discussion is confusing. Please clarify.

46. P26L817: This is not surprising, because the GGG2014 TCCON CO prior is a climatology. It will generally not capture pollution events.

47. Section 5.9.2: Move to Appendix.

48. P29L891: The airmass dependence of the retrievals is an effect of the software *and spectroscopy*.

49. P29L892: What is this "airmass correction factor" you're speaking of? Please make this language clearer throughout the paper, and define your terms.

50. P29L904: showed → provided

51. Figures. In general, there are far too many figures, the font size on the figures is far too small, the point sizes are too small, the point styles are indistinguishable, and there are too many points on the figures. This will be even more problematic after typesetting when the sizes of the figures are shrunk to fit into the AMT two-column format. Consider relegating some figures to appendices, using shading instead of individual points, removing whitespace between multi-panel figures, simplifying the content, etc.

52. Figure 6. Does the "PF" at the end of the HR125LRPF indicate "PROFFAST"? If so, please state clearly in the caption.

53. Figure 17. When plotting vertical profiles in the context of a total column retrieval, it is more natural to plot the vertical axis in linear pressure. This is because it better approximates the mass-weighting that the total column represents. Please change these plots to display them in linear pressure. Also, you show column averaging kernels for TCCON up to 85 SZA, but do not use them above 75 SZA. Why plot the other two SZAs? Furthermore, you do not show the HR125LR, EM27/SUN, Vertex, IRcube AKs, which is important to understand how the differences between the a priori profile and the true profile would affect the total column. Please add the AKs of the LR instruments (if they are basically the same, you can just add one representative set).

54. Figure 18. What exactly is being plotted? 10 minute averages or all individual points? If averages, please make this clear in the caption, and describe the number of points being averaged in each averaging period for each instrument.

55. Figure 21. If you are comparing data to a reference (in this case, AirCore is the reference), I believe it is customary to put the reference on the x-axis. You have plotted TCCON on the x-axis here.

56. Tables: In general, some tables could be combined and descriptive text should be in the caption, not embedded in the table (e.g., Table 4).

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