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Atmospheric Measurement Techniques Discussions

Interactive comment on "Towards verifying CH_4 emissions from hard coal mines using mobile sun-viewing Fourier transform spectrometry" *by* Andreas Luther et al.

Anonymous Referee #1

Received and published: 5 July 2019

This study presents methane measurements from a mobile solar-viewing IR spectrometer downwind of coal mine vents emitting methane. It includes not only a calculation of plume enhancements, but also emission fluxes. The authors also describe a detailed error budget. Overall I think this is a nice contribution to existing literature, and though I have a lot of comments, they are minor.

Specific Comments

S1: p1l1 - It is unclear if this statement is globally or just for Europe, where it seems about one-third of anthropogenic methane is from coal production. If it's global, please provide a reference in the introduction. In either case, give an approximate percentage.

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S2: p1l18 - “2.5 higher” do you mean “2.5 times as high as” or “1.5 times higher”? If pre-industrial is 680 ppb, 2.5 times higher is around 2400 ppb...

S3: p2l16 - This sentence needs to be reworded, it currently sounds like each of the studies of Hase 2015, Frey 2015, and Chen 2016 quantified urban fluxes of CO2 and CH4. However, only Hase quantified CO2, and only Chen quantified CH4. Frey 2015 quantified instrument bias and characterized the ILS in support of Hase 2015.

S4: p2l23-26 - These last 2 sentences are a jump in topic and should be removed from this paragraph. If the authors wish to include this information I suggest it be moved to a paragraph in Sect. 2.1 discussing measurement uncertainties. If the authors also wish to keep the Frey 2015 citation, it could be moved there as well.

S5: p3l2-10 - Please split into 2 paragraphs, one with measurements you use in this study (mobile FTS, wind lidar), one with other ancillary measurements not used here (stationary FTS, aircraft in situ, and aircraft remote sensing). You could also mention anticipating use of all data in a future study.

S6: p4l1 - Quantify “fast”

S7: p4l12 - Please be consistent with wavenumbers or wavelength. Generally I’ve seen IR measurements reported as wavenumbers, and wavelength for UV-Vis. I’m getting wavelength resolution as around 1.4 nm (but you should check if you go with those units).

S8: p4l14-16: I’m confused by “dwell times” and “observation time.” Did you only collect one ten scan average measurement per stop? I thought the 15 “x” symbols on Fig 4a indicated you made 15 stops, and at each stop you made multiple 10-scan averages (grey points), please clarify. Is “dwell time” the total time spent at one stop?

S9: p5l5: Is CalPy used here as well for the FFT?

S10: p5l6: Quantify the accuracy of the retrievals here. Precision is already included elsewhere.

S11: p5l8: More detail is needed on how you define your quality filters here. Is there some cutoff threshold? Maybe a histogram in the supplement of the DC interferogram signal would be helpful?

S12: p5l11 - “other gases” what other gases can be detected? Also I think “quantified” would be a better word that “detected” here - detection by itself is usually not particularly useful.

S13: p5l15 - Is this the first study to scale only the lower part of the a priori profile for EM27/SUN retrievals? Also, some examples of a priori and a posteriori profiles in e.g., the supplement would be helpful.

S14: p5l23 - I understand how you determined background within a single transect, but what are the other background variations you are describing here and how did you observe them?

S15: p5l27 - Please move all information on how measurements were collected to one location (e.g., the paragraph on p4). Does this mean you were at each stop for 20 minutes typically? (If each spectrum takes 120 s).

S16: p5l30 - You have the distance between stops on p10, but it would be helpful to list the approximate distance here as well.

S17: p5l32 - I agree that the $\sim$4 ppb is probably too large for a measure of instrument precision, and most likely is including real variations of XCH4. However, it seems like it would be difficult to model these shorter term variations in XCH4, even with the 3 wind lidars...

S18: p5l34 - “which is not possible [with measurements from] the EM27/SUN”. This is not entirely true. See the abstract for “B3.5 A real-time retrieval of greenhouse gases from portable, ground-based Fourier-Transform Spectrometers” here https://iwggms14.physics.utoronto.ca/documents/28/Abstract_Booklet_IWGGMS-14.pdf

S19: p7l8 - Given that dyi is not infinitesimally small, it seems like it would make more sense to represent it as Delta yi

S20: p7l11 - Here you convert back from an average dry-air VMR to a column, so why do you even have Eq. 1 in the first place? It seems like it would make sense to just stick with [CH4].

S21: p8l25 - "we selected all cases" - is this a subset of the 5 measurement tracks, or is this why you think the 5 tracks are good, or were there even more tracks and the 5 included here are a subset?

S22: p9Fig4 - I suggest you draw vertical lines separating the plume from the background. If you wanted to make the figures more information rich, you could include wind speed errors on a secondary axis.

S23: p10l3 - It looks like 2 peaks (though if just point 6 were gone, it would look like 1 peak). Do you think you found a "missing" vent by chance?

S24: p11l11 - I noticed there is no discussion about averaging kernels. This is a critical omission. For total column retrievals this could lead to a $\sim$20% bias in the results. It is unclear what the effect would be here on the lower atmosphere only scaling.

S25: p11l9 - Page 10 promised a more detailed analysis here of the 6 vs. 10 discrepancy for 2 transects of a plume from the same source. However, I find this section lacking in such an analysis. Please include a greater discussion on this. Is this due to real temporal variability in emissions? This seems less likely to me. Or is this due to measurement uncertainty? This second possibility seems more likely. Maybe the uncertainty is not any of the measurements themselves, but rather from the difficulty of accounting for variability on shorter (e.g., 1 minute) timescales, and from modeling eddies, etc. I think reporting both of these numbers is very useful to the community as it shows how good reproducibility is.

S26: p12l1 - 0.4 ppb? Compare with page 2...

S27: p13l22 - It seems unlikely for the vented methane to immediately be mixed uniformly throughout the full PBL. So I would like the authors to try another sensitivity test trying mixing to half of the PBL height (this is also somewhat arbitrary, but has been used by others (e.g., Wu et al., 2018 doi: 10.5194/gmd-11-4843-2018)). Start by recalculating the winds for this smaller mixing depth, as well as the effect of averaging kernels (if layers are fine enough).

S28: p14l11 - This is the first time I'm learning about how you distributed emissions. This information should come in an earlier section.

S29: p14l12 - How variable is the methane ventilation (e.g., 5%, by a factor of 2 or more)? Why is it variable?

S30: p14l13 - The personal communication reference should be omitted here since J. Swolkien is a coauthor and their contributions are listed in the "Author contributions" section.

S31: p14l21 - A 40% difference between transects still seems large. I would like to know the mechanism for variable emissions. See also S29.

S32: p15l10/p4l15 - While increasing the scan time decreased the time needed for ten scans, you should also mention that it also decreased your SNR (likely decreased by about a factor of 2).

S33: p15l14-15 - Of course even wind measurements onboard the truck would not provide the full picture as you are interested in the time varying winds from the source all the way to the truck. I agree though that it could be useful (e.g., these authors put a lidar in a truck: Clements et al., 2018 doi:10.1175/BAMS-D-17-0230.1)

S34: p15l16 - Quantify the confidence here.

S35: p15l18 - Quantify fast (1-2 hours per shaft?) and accuracy of method here.

S36: Title and p13l31 - The "towards verifying" in the title makes it sound like this is

the first of several steps in regular estimates of methane fluxes. If so, what are the next steps? Providing information to policy makers or to mining companies? Adapting the method to require fewer personnel hours? Decreasing the uncertainties? Repeating measurements over a longer time? If the first part of the title were changed “Towards verifying CH4 emissions from hard coal mines” -> “Quantifying methane emissions from hard coal mines in Poland” these questions become irrelevant.

Technical comments

As the editor mentioned, a proofreading may help improve the clarity. This is a long, and not necessarily exhaustive, list of technical corrections.

T1: p1l7 - “distance to” -> “from”

T2: p1l7 - Move “using a mass balance approach” to the end of sentence

T3: p1l13 - “itself” -> “themselves”

T4: p2l1 - omit “however”

T5: p2l5 - “with” -> “as”

T6: p2l6 - “With emissions of 466 . . .”

T7: p2l12 - “a” -> “a single” (this emphasis lets the reader know to not look for measurements from other instruments)

T8: p2l14 - “deliver” -> “are used to measure”

T9: p2l15 - omit “wavelength” it is implicit

T10: p2l23 - “four EM27/SUN” -> “four EM27/SUN instruments”

T11: p2l27 - omit “here”

T12: p2l33 - “used method” -> “method used”

T13: p3Fig1 - “performed by” -> “measured using”

T14: p2Fig1 - “EM27/SUN FTS” -> “EM27/SUN FTS locations”

T15: p3l2 - “Fig. 1” -> “Figure 1”

T16: p4l5 - omit “in”; “distance to” -> “of”; “source” -> “sources”

T17: p4l6 - “Depending on the wind direction we chose the transects” -> “We chose the transects depending on the wind direction”

T18: p4l15 - “our deployment, we tentatively increased” -> “our deployment on June 6 we increased”

T19: p4l16 - omit “This only concerns data collected on June 6.” (See also previous comment)

T20: p4l20 - “the two” -> “the standard two”

T21: p4l20 - “proposed by” -> “developed by”

T22: p5l3 - “tracking was” -> “tracking is”

T23: p5l5 - change to “For the retrieval of XCH4 from the FTS measurements we use the”

T24: p5l16 - “EMAC simulation results from a simulation similar to the simulation described” -> “EMAC results from a simulation similar to the one described”

T25: p5l22 - omit “and”

T26: p5l27 - I’m not sure what you are trying to say with this first sentence that is not already known. It could be safely omitted.

T27: p5l30 - “in 2 km distance” -> “within 2 km of the source.”

T28: p6l4 - “Three Doppler wind lidars of the type Leosphere Windcube 200S” -> “Three Leosphere Windcube 200S Dopplar wind lidars” Also, please include a reference describing these wind lidars.

T29: p6l8 - “in a” -> “towards the”

T30: p6l15 - “The 75o” -> “The 75o scans”

T31: p6l18 - “can” -> “is”

T32: p7Fig3 - “EDR smaller than” -> “EDR greater than” ?

T33: p7l2 - “tool for” -> “tool typically used for”

T34: p8l6 - “dyi” -> “yi” and “Equ.” -> “Eq.”

T35: p8l18 - “Fig.” -> “Figure”

T36: p8l24 - “a linear” -> “a linear least squares”

T37: p10l2 - “closest other” -> “next closest”

T38: p10l4 - “amounted” -> “were”

T39: p10l6 - “could finish” -> “finished”

T40: p10l9 - “North” - I believe convention is that north and south should not be capitalized here.

T41: p10l15 - “with” -> “as”

T42: p11Table2 - “1 June” -> “1 June, hence no E-PRTR estimate is reported”

T43: p11l5 - “was from” -> “was also from”

T44: p11l6 - Omit “compared to the morning transects”

T45: p11l5,7 - Directions here should be lower-case. Please fix capitalization throughout.

T46: p11l8 - “which calculates to” -> “from which we calculate”

T47: p11l10 - “error bars” -> “errors”

T48: p11l10 - “of the several” -> “of several”

T49: p11l10 - “along” -> “from terms in”

T50: p12l12 - “once” -> “once we”

T51: p12l17 - “large” -> “larger”

T52: p13l4 - “CH4” -> “XCH4”

T53: p13l16 - “averaging to” -> “averaging as”

T54: p13l29 - “1 June. The latter-day” -> “1 June, which”

T55: p14l7 - “error bars” -> “errors”

T56: p14l17 - “amount to” -> “are”

T57: p15l3 - “Mobile FTS emission estimates are best estimated with” -> “Our best estimate using the mobile FTS dataset is”

T58: p15l5 - “can be” -> “are”

T59: p15l5 - omit “listed with”

T60: p15l5 - “Best estimated emissions amount to” -> “Our best estimate using the mobile FTS data is”

T61: p15l6 - “in about” -> “within about”

T62: p15l7 - “distance to” -> “of”

T63: p15l17 - “a mobile” -> “a modified mobile”

Optional

These are additional comments the authors may completely ignore as they may be beyond the scope of this work.

O1: p4Fig. 2 - I am curious how the instrument is attached to the pad. Is it bolted down?

O2: p10l6 - I'm curious about what the issues were.

O3: p13l30 - If you are interested in extending this paper to make it more relevant to studies without wind lidars, you could try including some other estimates of wind and comparing with fluxes derived using the more accurate lidars. E.g., using surface winds (similar to Chen et al., 2016) or STILT (similar to Wu et al., 2018).

O4: p15l21 - This section shows the amount of effort needed to make these measurements, which has implications for scaling this analysis to e.g., other coal mines and shorter revisit times. Satellite data, while supported by teams, do not require them in the field for intensive campaigns such as this one and can often cover much larger areas across the entire globe even. It would thus be interesting to know if TROPOMI could be used to calculate similar enhancements, though perhaps the footprint size is too large (∼7x7 km2) and likely could only be used to get some aggregate USCB flux estimate. I agree CH4 imaging instruments would be useful including possibly GHGSat, and might even be able to be used in lieu of any ground-based mobile FTS measurements for much better scalability.

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