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Comment on acp-2021-808

Anonymous Referee #1

Referee comment on "Assessing vehicle fuel efficiency using a dense network of CO_2 observations" by Helen L. Fitzmaurice et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-808-RC1, 2021

Review of "Assessing vehicle fuel efficiency using a dense network of CO2 observations" by Fitzmaurice et al.

This manuscript describes a case study for which an inversion based on atmospheric measurements from a dense CO2 network was able to distinguish emissions characteristics over a strech of highway in the SF Bay area. Overall, the analysis is sound and promising. I had a few large-picture comments followed by specific comments, mostly pointing out some disorganization esp. on the SI.

A few bigger-picture comments:

Overall, this is a very interesting outcome and example case of how atmospheric monitoring networks can achieve high-resolution understanding of emissions variability. I also appreciate the honesty in showing when the inversion matches the Pems analysis and when it does not, as well as the prior. Clearly, this work benefited from a good prior estimate of emissions that were adjusted using atmospheric data. I wondered what figure 3, right panel, would look like for the prior emissions estimates. In this context, did the inversion improve the prior estimate?

Another larger comment: Could another reason for the early morning mis-match be larger meteorological model error early in the a.m. relative to the afternoon? Has this been investigated at all as a source of uncertainty in the inversion? Perhaps the authors could point to earlier work for this?

Overall, I wonder if some caveats are required on the conclusions here, while not detracting from the very positive outcome overall. Here very good agreement is shown between methods, claiming that 5% emissions changes could be detected. Over what time

frame could they be detected, and what does this level of capability depend on? i.e. a "good" transport/dispersion model, a dense network (this is already called out in line 239), a "good" prior - with "good" in quotations because likely how good a model or prior is needed is probably unclear. I think the paper could be improved by addressing some of these elements, or referring to past work that has shown the impact of things like the transport model or choice of prior, with a few sentences in the conclusion/discussion.

Specific Comments:

L83 might better reference https://doi.org/10.1029/2018JD029231, Nathan, B. J., Lauvaux, T., Turnbull, J. C.,
Richardson, S. J., Miles, N. L., & Gurney, K. R. (2018). Source sector attribution of CO2 emissions using an urban
CO/CO2 Bayesian inversion system. Journal of Geophysical Research: Atmospheres

Fig. 1 Left, can the authors add the meaning of the red dots to the caption?

L104 Fig 1 does not seem to show the time series of the number of sites.? Reword, or add to the figure? It would be interesting to explain the impact of sites coming in and out during the inversion period, and how that might affect the inversion results in addition the average daily cycle of concentrations. I.e. if one site was particularly closer to a source than another, when the mix of sites changes, the average co2 would change as well.

L119 over what area are non-highway sources 12% of total?

L138 Figure 2 left doesn't actually show the extent of the PeMS network compared to the BEACON footprint. (the BEACON footprint I assume is much larger than this set of pixels). Clarify here what is shown. Or maybe this should refer to Fig S1, left?

Fig S1 caption - I do not see a panel with CO2 emissions, only LDV and HDV?

L146 missing a period.

L149 kph should probably be expressed as km h-1 (where -1 is a superscript)

L156, should this read "for the emissions rates for each vehicle GROUP"?, i.e. at this point

the er from equation 1 is being used, which is the er for either LDV or HDV at this speed? Earlier these were defined as "groups", as they are a weighted average of er's from different classes within the group, right?

L156 regarding the spline fit, can the authors indicate why this was chosen? Earlier it was stated that the er's were calculated at 8 kph intervals, why is a piece-wise linear fit not sufficient for speeds between the intervals? (splines make me wary of over-fitting, what does this graph look like?).

L157, how long are these segments and stretches, approximately

Eq. 3 some parentheses would be useful indicating whether both terms in the sum are being summed over all segments.

Fig 2, not being familiar with this roadway, it is not clear on the left which is East and which is West, as the highway seems to travel mainly North-South in this section? This could be clarified in the text around L167, (e.g. Interstate 80 is an East-West highway whose orientation in this stretch is actually mainly North-South, with the eastbound lanes traveling North etc etc). Or something clarifying as such.

Fig 2 caption. Colon is missing after Right (bottom)

L174-180 this is interesting and makes the reader wish there were a figure showing the speed-dependent emissions profiles for LDV and HDV (also would answer L156 comment) - emission rates must increase substantially below some specific speed. Also, in Fig 2 it would be great to have a panel of the % LDV and HDV with time East vs. West to see what is driving the patterns in emissions shown here. This would address L171, where the authors note that the emission rates give insight into whether congestion or HDV percentage is the factor leading to variation - this is not shown in the figure at all, so there is no insight to the reader here. Otherwise, perhaps the authors could comment in the text on why the er of the East is so high at those low speeds in the evening, when the West is not that much faster but has very low er. (I do see the HDV and LDV time plots in Fig S1, but they don't show the difference between east and west nor showing just the fraction of HDV which sould be easier to show the effect here).

Fig2 should the y-axes in the right lower panels be g CO_2 / km or vkm? I'm not sure really or maybe they are the same thing here.

Fig 3, left, what are the red points? So the slope from the left figure is calculated and plotted in the right figure as one of the squares, and are the bars the error from the slope

fit? What kind of fit was used on the left figure slope (this is quite noisy, so could be sensitive to the fit - was it forced through zero, was it ODR or not?). [now having looked at the SI I see there is text addressing this, this should be referred to here, noting what the red points are].

L195 why were those hours chosen?

L200, mention this is for weekdays only (this is in the caption, but would be nice in the text as well).

L217 - One more sentence spelling this out would be useful, rather than letting the reader make a leap. The Pems method only uses hourly averages, so would have a lower emission rate than reality if reality were more like the second case? And here the authors are saying that it could be that morning rush hour exhibits this kind of large variability in speeds within an hour, leading to an incorrect estimate by the Pems method?

Figure 4, lower panels don't seem to be addressed in the text anywhere.

Figure S2 is not mentioned in the text either as far as I can tell.

Fig. S3 also is not mentioned but supports some of the text after L217 so should definitely be mentioned there! It also addresses an earlier comment I made asking for the plot of speed vs. emission rate.

Text S3: Seems to describe a different figure? Fig. S3 does not show the dependence on HDV percentage - the caption says it is showing the results at 8% HDV. This figure would address some of my earlier comments.

The SI is a bit of a mish-mash, in that there is some text at the top that is not labeled with a header (S1 or whatever), and later there is a Text S3. Also Table S1 I do not think was cited in main text.