

Atmos. Meas. Tech. Discuss., author comment AC1  
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## Reply on RC1

Trevor W. Coates et al.

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Author comment on "Field testing two flux footprint models" by Trevor W. Coates et al.,  
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## Change in Analysis

While addressing the reviewer's comments, we also made a change to the methodology of our study. The metric to evaluate the footprint models is the ratio of the model-calculated emission rate to the actual emission rate of the synthetic source ( $Q_{KM}/Q$  or  $Q_{LS}/Q$ ). In the original manuscript we calculated the arithmetic mean, the standard error of mean, and statistical significance assuming a normal distribution of the ratio data (i.e., traditional statistical inferences). It came to our attention that ratio (or normalized) data are more correctly evaluated using the geometric mean, with inferences based on log-transformed data (Fleming and Wallace, 1986; Limpert et al., 2001).

In the revised manuscript we re-evaluated our data using the geometric mean as the measure of central tendency, and calculated the 95% confidence intervals for the means using log-transformed data. Details are included in a new section "2.3. Statistical Analysis". This change did not alter the main conclusions or our study, nor did it alter the dataset included with this study. However, it did somewhat change some of the relationships between the two models, which is reflected in the modified discussion.

*Fleming, P.J., and Wallace, J.J.: How not to lie with statistics: the correct way to summarize benchmark results. Communications of the ACM. 29 (3): 218–221. doi:10.1145/5666.5673. S2CID 1047380, 1986.*

*Limpert, E., Stahel, W.A., and Abbt, M.: Log-normal distributions across the sciences: keys and clues. BioSci. 51, 341-352, 2001.*

## Response to Reviewer Comments

We very much appreciate the feedback, and thank Dr. Neftel for his careful reading of the paper. We respond to specific comments below.

**RC1:** 'Comment on amt-2021-106', Albrecht Neftel, 12 Jul 2021

RC1: This is a short paper and reports a comparison of two flux footprint models using an artificial CO<sub>2</sub> source of a limited areal extension as a known emission source. Technically I judge that everything is correctly made. The results show that both flux print models yield a recovery rates that is statistically not different from one.

I could sit back contentedly and rejoice that my simple Footprint Tool based on the KM algorithm still produces satisfactory results. Nevertheless, I think it is appropriate to address some warnings. The findings are based in total on 59 valid 10 minutes intervals. They were divided into three fetch-dependent groups. 10 minutes is a short time interval for EC analysis. Consequently, the variability in the recovery rate is large and the fact that the recovery rates are statistically not different from 1 cannot be a strong statement.

Author Response: There is little to disagree with in Dr. Neftel's statement.

Yes, 10 minutes (min) is a short interval compared to typical EC studies of surface fluxes, but it does fall within a broad 5 to 60 min averaging interval that has used in micrometeorological studies (e.g., footprint study of Kumari et al., 2020 used a 10 min interval). Given the short fetches in this study, and our experience of insensitivity in LS model accuracy with averaging intervals from 5 to 60 min, we think the conclusions of this paper are also valid for longer averaging periods. We did consider a 20 min averaging time, and found the longer interval resulted in a slight decline in the accuracy of our LS model calculations. But more importantly, the choice of a 20 min interval left fewer than half the number of good observation periods in our data, and accordingly larger statistical uncertainties.

We also agree that with our relatively small dataset, and large period-to-period variability in the accuracy of the footprint calculations, the finding that the KM and LS calculations are not different from each other is not a strong statement. We think this is noted in section 3 (e.g., "*This suggests that any systematic differences between the models in our study were obscured by the substantial period-to-period variability in the  $Q / Q$  calculations, and that the detection of model differences would require a much larger observational sample size than we were able to acquire.*"). However, the conclusions are still of value. Prior to our experiment, we expected large differences between the KM and LS models, and the demonstrable value of the LS model predictions. It was a surprise not to see large differences, suggesting that experimentalists may not see the advantages of a more complex LS model given the period-to-period variability of real world data. This is useful information.

Our results suggest that much larger datasets would be needed to discriminate between footprint models for a configuration like ours. But we note the difficulty of generating large field datasets for this type of comparison. This study does not provide the final word on this subject, but hopefully our dataset (provided as a supplement to the paper) will provide a useful piece of that effort.

*Kumari, S., Kambhammettu, B. V. N. P., & Niyogi, D. (2020). Sensitivity of analytical flux footprint models in diverse source-receptor configurations: A field experimental study. Journal of Geophysical Research: Biogeosciences, 125, e2020JG005694. <https://doi.org/10.1029/2020JG005694>*

RC1: I had a look at the data given in the supplement. It is striking that three consecutive data points or one 30-minute value of the KM based recovery data for the 30m fetch group are clearly  $< 1$  whereas the other four values are above 1, of course on average around 1. The bls based recovery rates for this group is clearly higher but does not reflect the distinction in two groups. I guess this is the typical behavior of real turbulence. This reminds me the flux simulation with a large eddy simulation approach that demonstrated the possibility of persistent structures lasting longer time that are inexistent in the KM or bls world. This information was presented during a workshop on ammonia measurements (Hensen et al, 2015). I recall the sentence: "*From the LES simulations we can assume that for time averaging below 15 minutes integration the effect of streaky structures might be detectable on the plot scale. For multi hour averaging on the other hand, the effect might cancel out.*"

Author Response: As Dr. Neftel notes, the period-to-period variability of our footprint calculations is large and difficult to relate to environmental variables. We agree with his simple explanation: "this is the behaviour of real turbulence". To be more specific, the KM and LS models are built on a representation of the atmosphere that is true (at best) in an ensemble average sense. They will not reflect the period-to-period fluctuations in our dataset. We have made this point in the final sentences of the manuscript, adding:

*"However, period-to-period variability is the nature of footprint calculations based on simplified models of atmospheric transport like the KM and LS formulations. These model calculations, which at best approximate an ensemble average realization of the atmosphere, will not reflect the period-to-period fluctuations of actual measurement periods."*

RC1: Footprint corrections are always necessary in case a measured flux over areas with different emissions must be interpreted. The new generation of researchers are generally well trained in computing languages such as R I recommend the use of a bls model because it tends to force the user to think about the micrometeorological boundary conditions. A special package made by Christoph Häni is available

Author Response: We share Dr. Neftel's preference for the more sound LS modelling approach, and endorse the LS analysis package by Häni. However, our experience shows that increased processing time is a significant penalty with the LS calculations. In a field study associated with this project, we used an LS footprint model to calculate the EC flux contribution from a field surrounding the EC system. Analyzing two years of EC measurements took several weeks of processing. Some researchers may have difficulty justifying the processing time of LS models relative to the KM calculations given the model agreement seen in our data.