Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., author comment AC2
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# Reply on RC2

Trevor W. Coates et al.

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Author comment on "Field testing two flux footprint models" by Trevor W. Coates et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-106-AC2, 2021

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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.*

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

**RC2: 'Comment on amt-2021-106', Thomas Foken, 01 Aug 2021**

RC2: Footprint models are widely used, but there has been little validation of the models (Leclerc and Foken, 2014). Such publications are very rare, as experimental validation is very costly. This publication is the description of such an experiment. It compares an analytical model (Kormann and Meixner, 2001) and a Lagrangian model (Flesch, 1996;Flesch et al., 2004) – both well-known model concepts – with a tracer experiment. Although the paper is brief, no methodological shortcomings could be identified. It should be published in the present version, unless the following comments make it possible to add to it.

Author Response: We thank Dr. Foken for his encouragement.  Yes, this type of experiment is difficult, and a great deal of effort and expense was required to get good (testable) observations (e.g., multiple source realignments in response to changing winds, cold weather freezing gas regulators, equipment issues).  Regardless of these difficulties, in retrospect the weakness of the study is the limited number of observations.  The most valuable aspect of this work is likely to be our dataset, which could be built upon by others and provide for a more robust examination of footprint models.

RC2: Thankfully, the measurement data were published in the supplement. A first look at the data showed me that with stable stratification the analytical model agrees particularly badly with the validation data, while the Lagrangian model delivers significantly better results. A similar result was found by Göckede et al. (2005) when comparing the models of Schmid (2002) and Rannik et al. (2004), also mentioned in the paper. Perhaps one could make an addition to the stability dependence analogous to Fig. 2 in Göckede et al. (2005) and thus enhance the contribution somewhat.

Author Response: We added Figure 3 to the manuscript showing the model comparisons versus stability.  Dr. Foken is correct that the KM results are inaccurate in stable conditions (the mean $Q_{KM}/Q$ = 0.36).  However, the LS results are similarly inaccurate ( $Q_{LS}/Q$= 0.44) in these conditions.  It is interesting that these results disagree with the calculations made by Göckede et al. (2005), who found large differences in calculations from the two models in stable conditions.  The similarity is also surprising given the substantial differences in the stable KM and LS footprint functions calculated by Wilson (2015).

We have added a reference to the Göckede et al. paper, indicating the surprising result that our measurements could not discriminate between the two models (end of the results section):

"*There are no clear patterns in terms of explaining the differences between the two footprint models based on environmental factors.  Whether we separate the data by fetch or by stability, the results from the two models are not statistically different from each other.  Windspeed, roughness length, and wind direction were also considered as factors to explain the model differences, but again, no pattern was observed.  This lack of model differences was unexpected given the studies of Göckede et al. (2005) and Wilson (2015) showing large differences in the calculations between analytical and LS models.  This suggests that in our study, any systematic differences between the models 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*."

RC2: At least in the further discussion of the data, attention should be paid to the positions of the maximum of the footprint. A possible explanation for the different agreement depending on fetch could be that the maxima of the footprint fit better with short fetch. This would be an investigation similar to that of Markkanen et al. (2009) for other model types and altitude ranges.

Author Response: The suggestion to look in detail at the footprint function (vs. fetch) is good, although we see this as of secondary importance given our simple objective of determining if the accuracy of the LS model was better than the KM model for our dataset (and to provide a short description of our dataset for others to use).  Further analyses of the footprint functions would require substantially more analysis, and would duplicate the analysis of Wilson (2015).  For example, Wilson's Figure 3 shows the difference between the KM and LS footprint functions for stable conditions in a configuration that has some similarity to ours ($z_0$ = 0.01 m, $z_{sonic}$ = 2 m, $L$ = 25 m). The peak of the LS footprint function is near $x$ = 20 m, while the KM peak is near $x$ = 26 m. Here the peak position is similar between the models, and midway between the short and medium fetches, however, it is unclear if this difference in peak position affected the $Q/Q$ ratios.

*Wilson, J.D.: Computing the Flux Footprint, Boundary-Layer Meteorol., 156, 1-14, https://doi.org/10.1007/s10546-015-0017-9, 2015.*

For the quality test of the eddy covariance data, no programme documentation should be cited, but either the original paper (Foken and Wichura, 1996) or the identical book publication (Foken et al., 2012).

We have made the suggested change regarding the citation for quality testing of the eddy covariance data.