Author response to interactive comment RC1 submitted by Gil Bohrer on Apr 02, 2019

In the document below, the comments by Gil Bohrer have been copied from the original review and are shown in black font, while the author comments have been added in blue.

The manuscript studies a very relevant and much discussed problem - the challenge to methane flux measurements, given the high importance of "hot moments" and strong flux bursts. The analysis methods they use are robust and innovative, and the conclusions, particularly with regard to uncertainty and evaluation of different empirical approaches methane flux modeling (gap-filling) are very relevant and interesting.

I have a few minor comments: Introduction- P2. L5-15 You discuss ebullition as the major (and only one discussed) source of flux peaks. This may be the case, but I argue (with much support from observations by my group and others) that the spatial heterogeneity of methane fluxes can be interpreted as bursts and peaks when observed by the tower. For example, if there is a small patch that for whatever reason emits 2X or 5X more flux than the surrounding area, a small movement of the footprint to overlap more with that patch will read as a strong peak in emissions. I think most of what you define later as cluster events are driven by this spatial heterogeneity and not bubbling. That is very typical in wetlands, even within what would otherwise be considered a homogeneous land-cover type. Please discuss spatial heterogeneity as a source of flux spikes, not only temporal bursts.
The authors agree that also spatial variability in CH_4 emission sources within the footprint of the flux sensor may lead to spikes in the flux time series. In the revised version of the manuscript, we will therefore include a new paragraph into the introduction section that acknowledges this influence of the spatial context.

In the companion paper by Schaller et al. (2019), the correlation of detected CH_4 outburst events with changes in environmental conditions was studied in detail. Here, no specific numbers are presented on the percentage of cases where the wind direction shifted substantially before and/or after an event. Still, several potential 'event triggers' are discussed that include a shift in wind direction, for example weather fronts. For most of these triggers, the dominating mechanism for a resulting change in flux rates is rather the change in atmospheric transport and turbulence conditions, as opposed to an associated shift in the field of view of the flux sensors.

Within the detailed analyses of 'peak' and 'up-down/down-up' events, we did not observe cases that could be attributed to an isolated shift in the footprint area, i.e. a shift in wind direction without changes in the turbulent flow field. The main reason to rule out the footprint effect is that all of these cases were observed simultaneously at the 2 towers that are located ~600m apart, and which clearly feature different microscale patterns in CH_4 emission sources within the footprint area. For the category 'cluster events', none such detailed attribution studies were possible, so for these cases, a potential role of footprint shifts as an event trigger is possible. These cluster events should be studied in more detail in future, including extensions in the observational setup (see also Schaller et al., 2019). Summarizing, our site does not seem to be susceptible for footprint triggers because of the gradients between high and low CH_4 emission areas and their spatial structure. At other sites, however, the role of wind direction may be more pronounced.

P2.L30-35 Xu, Metzger and Desai 2017 AFM used wavelet flux calculation as the foundation for their "Upscaling tower-observed turbulent exchange at fine spatio-temporal resolution". Please check out what they did. It will make sense to reference that study here, but there are many parallel between their study and yours that should be acknowledged, some would fit later in the discussion.
The methodology applied by Xu et al. (2017) indeed shows overlaps with our own, but the objectives of both studies are quite different. Using the eddy flux processing package based on wavelets originally presented by Metzger et al. (2013), Xu et al. (2017) compute turbulent exchange fluxes at 1-minute resolution, which is very similar to employing the wavelet method presented by Schaller et al. (2017; 2019) as done for this study. Accordingly, we agree with Gil Bohrer that the paper by Xu et al. (2017) should be referenced herein, and we will include it in introduction and discussion.
However, Xu et al. (2017) used the higher temporal resolution in the flux time series to decipher the role of a varying field of view of the eddy tower on variability in the flux time series, this way avoiding aggregation errors linked to wind direction variability within the regular 30-minute flux processing timesteps. In our study, on the other hand, the primary objective was to use an alternative, wavelet-based processing approach to circumvent the need for stationary signals in flux processing, while as a secondary target we wanted to constrain highly intermittent CH_4 'flux outbursts', and quantify potential biases linked to incorrect EC fluxes derived through regular flux processing.

Table 1 - the code in the table are meaningless outside the software package you used for flux processing. Can you provide equivalent physical ranges of something (standard deviation, thresholds to exceedance, % different before-after for stationarity ...) that will define these code and will make the table more meaningful? These codes define the analysis. Will be very important to define them using real-world (physical or statistical) conditions.
We agree that the overall quality flag rating in the form of numeric flags is of no importance in this context. We will therefore remove this column from Table 1, and will also delete all references to numeric overall quality flags from the main text. For the stationarity flags, we will add the numeric values of allowed percentage deviations that were defined by the quality control scheme devised by Foken et al. (2004; 2012) to Table 1.

Cited references

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Xu, K., Metzger, S., and Desai, A. R.: Upscaling tower-observed turbulent exchange at fine spatio-temporal resolution using environmental response functions, Agr. Forest Meteorol., 232, 10-22, 2017.