bg-2015-31

Author response to comments of referee #1

(referee comments are printed in *italic*, author responses are printed in blue)

I wondered why the paper considers only CH4. Surely the same kind of analysis could be undertaken for CO2 and water vapor? The analytical problem would be the same, but the weights of "soil" (ecosystem) and animal contributions would be different. Because of the different weights for the different gas species, it might then be possible to arrive at conclusions how the weights affect achievable accuracy.

We fully agree with the reviewer, that a similar evaluation can be done for other trace gases. The CO_2 topic will be presented in another paper, which is under review in Agricultural and Forest Meteorology at the moment. Presenting both gas species in one paper would end in a very long paper. Additionally the calculation of the background is more complex for CO_2 than for CH_4. Water vapour respired or transpired by animals represents a very small contribution to the total pasture evapotranspiration (typical magnitude 4 mm/day = 5 litres/m2/day). For an instantaneous stocking density of 20 animals on a 0.6 ha paddock area (= 33 heads/ha) this corresponds to a flux of 1500 litres/head/day, thus about two orders of magnitude more than the possible animal water respiration/transpiration. Thus the animal contribution would not be detectable in the EC flux.

A question not addressed is: were there differences in the performance of the footprint model (and, hence, the animal vs soil partitioning of fluxes) between stable and unstable stratification? I would hope that it was not too hard to separate the data in Tables 1 and 2 into two classes according to stratification.

Emissions for stable situation were on average higher than under unstable conditions. However this effect is difficult to interpret because it strongly coincides with the observed diurnal cycle (Fig. 11). Given the general scatter of individual flux values, it was not possible to separate a potential stability-dependent bias in the footprint model from real diurnal variations of the animal emission rates. Therefore we consider it not meaningful (or potentially misleading) to list just stability separated values in Tables 1 and 2. However, we will include this issue in the discussion of the diurnal cycle.

A point for the Discussion: the footprint model assumes that the cows emit the CH4 at ground level. However, that is not strictly true in reality, with some fraction of the gas being emitted higher up. What would be, qualitatively, the effect of the idealized groundlevel assumption on the total emission estimate: an overestimate or an underestimate? The question is relevant because the authors select the "near cows" class (where any such height effect would matter most) as their "most reliable" data.

With the analytical FP function of KM01, the effect of elevated source could (unfortunately) not be evaluated. However it was recently reported by McGinn et al. (2015, J. Environ. Qual. 44:97–102) that for a bLS application (with concentration measurements) they found no significant difference between sources at the surface and at 0.5 m height. It needs to be investigated whether this result is also valid for the EC flux footprint weight.

We will add a short discussion of this issue in the text.

Specific Comments

Title: "eddy covariance" implies that a "flux" is measured, so one word can be dropped to avoid redundancy

It is true that for people familiar with EC measurement the term eddy covariance already implies that a flux is measured. To mention the technique but also to state that fluxes are measured for an audience not familiar with EC measurement, we'd like to use both words.

Abstract L 13 replace "guess of" by "estimate from"

Will be changed accordingly.

P 3423 The site, climate and management details are perhaps too comprehensive for a study that is mainly focused on the effects of position-time information, and not on the greenhouse gas budgets per se. For example, I do not see the relevance of the site's history (L 16) or of whether this was a climatically unusual year (L 11-14) when the final budgets presented are only for half a year anyway.

We shortened the section by removing dispensable information that is not needed for context of this paper from the section describing climatic and management details. The climatically unusual year is indicated because we expected that the cows would spend more time on the paddocks measured by the EC system.

P 3424 L 11 Are paddocks 2 and 5 those later labelled "near cows" and the other four "far cows"? It would help to clearly state that here already.

The following sentence was added: "In the following the term 'near cows' refers to grazing in PAD2 or PAD5, whereas the term 'far cows' refers to situations when one of the other four paddocks was under grazing."

P 3426 L 4: Should "bi-passed" be "bypassed"?

Yes, will be corrected.

P 3426 bottom: It would be interesting to compare the CH4 time series (Fig. 2a) to that of temperature or water vapor for the same period, to get an idea what part of the variability is due to the passing of turbulent eddies and what part to the emissions from moving point sources.

We forgot to indicate that the examples in panels (a) and (b) represent midday intervals that are only separated by 1 hour and mainly differ by the presence of cow in the footprint. We will clarify this in the figure caption and illustrate the effect of the cows by using the same y-axis-scale for both panels (with a close-up plot as insert). In this way it gets very obvious that the much higher variability range in panel (a) is caused by the presence of the cows.

We can state, that no big difference was observed for other scalars for these intervals. However plotting them would add little information to the manuscript and would unnecessarily increase its length.

P 3428 bottom: Why is the "plausible range" for tilt angle not symmetric around zero?

We rephrased this sentence to: "small vertical vector rotation angle (tilt angle) within ±6° to exclude cases with distorted wind field". The original non-symmetric range may be misleading. It was indicated, because there were practically no cases between -6 and -2°.

P 3429 bottom and Table 1. It is not clear to me why the GPS and PAD method end up with different numbers of runs. That introduces the possibility of bias because the datasets are not matched. If outliers were removed for one method, the same periods should be removed for the other method also. However, why were "outliers" removed at this stage anyway? Is it not the nature of the beast (pun intended) that a single emitter in a location with high footprint contribution could cause high fluxes, and would the explicit point-source modeling not capture this?

The two methods represent two levels of information to discern fluxes with and without cow contribution. Therefore the selection criteria are different, because we aimed to show the difference/uncertainty of calculated emissions, which are induced by different levels of information.

P 3438 L 5 Why is Fig 11 only for the "near cows" class? Did the "far cows" follow the same pattern? If not, that might give clues why the mean emissions differed between these two classes.

The quantitative analysis of the diel cycle of the *far cows* case is difficult. Only 63 emission values were available for this analysis which results in very few data per hourly bin. However qualitatively the pattern over the day was similar as for the *near cows* case.

P 3439 L 16 "Obviously... possible only due to the GPS" does not seem correct. Surely, knowledge of the paddock being grazed and wind direction would suffice to identify the majority of runs with "uncontaminated" soil fluxes.

We agree that this sentence is not fully adequate in the context. It can therefore be omitted without affecting the statement in this paragraph.

P 3440-3441 In Section 4.2, it is not easy to follow the argument. The first paragraph seems mainly concerned with random errors, first of flux and footprint model, then of roughness length (which is a separate issue). The second and third paragraphs deal with the observed discrepancy between "near cows" and "far cows" (which requires a bias for explanation, not random error). It would help to subdivide the first paragraph further, and to state early in each paragraph what its subject will be.

We agree that the arguments in Section 4.2 are not fully consistent. Overall this Section was intended to discuss systematic errors (for z_0 and FP modelling mainly systematic errors are of interest), but some statements about random errors were included without clear separation (or declaration).

We will remove the random-error related parts from this Section.

P 3440 bottom: "Additionally [insert comma] variations of the wind direction... amplify the effect of moving." I do not understand this sentence.

We will remove this sentence from the text.

P 3441 L 22 "Hence the over-/underestimation tended to be balanced for the near cows cases". Was that actually tested, by picking example runs for different footprint-maximum locations and analyzing the cow position data for these? Or is the statement just qualitative arm-waving? Since the authors argue later that the near-cows GPS method was the "most reliable" one, it is important to show that bias was indeed small.

This statement cannot be tested by the use of actual cow positions. The assumed over- or underestimation of the FP weight at varying distance from the EC tower is purely a FP model problem. We will rephrase the text to clarify that our argumentation is based on the findings of Kljun et al. (2003) using the bLS FP model as a reference.

P 3441 bottom. Could it be that emissions at elevated level (from standing cows) contribute to a bias of the "near-cows" results, but less so for the "far-cows" class? With a measurement height of 2 m only, it may matter whether the sources are at ground level or at up to 1.5 m height. A good tool to assess this would be a Lagrangian model.
See our response to the third general comment above.

P 3444 L 13 Can the observed overall inhomogeneity of the cow density distribution be related to the locations of drinking-water supplies?
Indeed there was a water supply on the field (open drinking trough), but the location did not correlate to the cow density distribution. The trough was usually placed in a corner of the paddock.

P 3444 bottom: The animals in Laubach et al. were not "grazing", they were fed silage, and the locations of the silage and water supplies go a long way to explain why the animal distribution was uneven. This should be clarified.
This will be clarified in the text.

Table 2 It would seem fair to include columns of "near cows" and "far cows" combined, to show how much the authors' preference for "near cows" affects the result.
This is in our view not necessary (and could even be misleading). The 'combination' effect directly follows from the difference between the 'near cows' and 'far cows' means and the corresponding number of data (n) in each class also given in the table. We intentionally did not include the 'combination' result, because we argue that the 'far cows' result suffers from a systematic underestimation, and thus a combination makes not meaningful.

Table 2, caption. The passage "for different distances… (near, far)" should be placed before "and without cow position information", because it applies only to the first two methods
Will be changed as suggested.

Table 2: On first reading, I was confused by the two entries in the top row under "FIELD", each with its own footnote and no connection stated between the two. Perhaps it would be better to have only one footnote stating "The first number is... The second number is...".
We don't consider this as a better solution, because the footnote "b" is also used for other entries, and it clearly indicates which entries are related to each other. We will keep the present footnote structure but add a reference to the parallel footnote.

Table 3: Include the numbers from the present study for comparison (so the reader does not need to search for them in the text).
The mean result of the present study will be added to the table.