

Interactive comment on “Towards a more harmonized processing of eddy covariance CO₂ fluxes: algorithms and uncertainty estimation” by D. Papale et al.

Anonymous Referee #2

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The authors present results on the effect of three integral flux correction methods (u^* threshold, storage correction, spike filtering) on the net ecosystem exchange of CO₂ (NEE) derived from eddy covariance measurements. Twelve annual flux datasets of eight European flux stations in different types of forests are used for this purpose. An uncertainty estimation of the correction effects is made by: a) for u^* threshold: a bootstrapping technique and subsequent use of the 5% and 95% percentiles, b) for storage correction: difference between single point (discrete) and profile derived correction, c) for spike filtering: range of correction effects using different detection levels. The analysis is very useful for the FLUXNET community and therefore clearly deserves publication. It also matches the scope of the Biogeosciences journal. However, the

manuscript should be improved for various aspects detailed in the following.

GENERAL COMMENTS

1) The very interesting results presented in the manuscript are often only poorly discussed. A more detailed discussion is necessary, in particular for:

- Fig. 2 (p969 line 7ff): How may the mentioned variability in the u^* thresholds be explained by characteristics of the 8 measurement sites? Give concrete information/examples.

- Fig. 3 (section 3.2): The results in Fig. 3 are described but not discussed in the text! For example, explain or give possible reasons why the u^* correction makes the NEE for FR01-2002 more negative! Also discuss possible reasons for the observed differences in the double-counting effect!

- Fig. 5 (p971 line 3ff): Give possible reasons for the different storage correction effects of the three sites.

- Fig. 6 (p971 line 8ff): Is there a relation between the spike effect and the magnitude (diurnal variation) of the fluxes?

In addition, more practical conclusions and recommendation should be presented. In particular:

- Is a bootstrapping necessary and/or recommended to determine the u^* threshold?

- How should the storage correction be harmonized including the datasets for which no profile measurements are available?

- What is concluded concerning the application of the u^* filtering either to all data or only night-time data?

- Which spike detection level is finally recommended for application?

2) Considering the aim of the paper to contribute to a "harmonized" or "standardized

processing" of CO₂ fluxes, the entire methodology has to be described in such detail, that it can be fully reproduced by the interested reader. This is not always the case in the present manuscript due to lacking detail information or imprecise formulations (see specific comments below).

3) The diversity of the available measurement stations concerning their representativeness for other ecosystems should be addressed. Especially for the u^* filtering, it should be discussed whether the present methodology and findings for forest stations can be generalised to flux measurements over low vegetation.

4) The text suffers from a considerable number of typos, language problems and imprecise/misleading formulations (see comments below). Throughout the text, the expressions eddy covariance "data" or "measurements" are ambiguous since they can also denote the high-resolution (e.g. 10 Hz) time series. In order to make a clear distinction against data processing and correction done on the high-resolution data, I suggest to use in the present paper the more specific terms "flux measurements" or "flux data" and for the correction applied on this data the expression "integral flux correction(s)". Also the very unspecific expression "annual sum(s)" should be replaced by "annual NEE".

SPECIFIC COMMENTS

p963 line 3: What does "random measurement errors due to the technique" mean? Does it mean "instrumental errors"?

p967 line 10: Explain why a 99% threshold criterion was used in the present study and not a 95% criterion like in the cited references.

p967 line 16f: The formulation "...the u^* -class where the night-time flux reaches more than ..." is not entirely clear. I suppose that the arithmetic averages or medians of the classes are compared. Please specify!

p967 line 20ff: According to the method description, the u^* threshold is determined

as maximum of the four median values of 3-month-subsets. Was there a (systematic) difference observed between the u^* values of the different seasons. If the vegetation structure really has a significant influence (as supposed in the text) the proposed procedure might be not appropriate for agricultural vegetation that changes more rapidly!

p967 line 24f: Does "in cases where no u^* threshold could be found" mean that no result was obtained for all four seasons or for at least one season? How often did the failure cases occur?

p968 line 1f: Considering the aim for a harmonized processing of EC fluxes, the chosen minimum thresholds of 0.1 m/s and 0.01 m/s should be discussed and supported by literature references.

p968 line 6ff: Considering the importance of the bootstrapping technique for the uncertainty estimation, and for a complete documentation of the proposed harmonized processing, the bootstrapping algorithm should be briefly explained here. Could the uncertainty of the threshold determination technique be overestimated by the bootstrapping method (due to the strong reduction/weighing of data points in each bootstrapping run)?

p969 line 9f: The meaning of the last sentence of the paragraph is not clear to me. What does "the value and the amplitude of the uncertainty" mean? Which section later in the text does the sentence refer to?

p969 line 13: The statement "According to the eddy covariance data processing method, the CO₂ fluxes are corrected by storage fluxes and..." is unclear and should be rephrased. It should be documented how exactly the storage correction (profile or discrete) was calculated! This might be especially important in the light of the recent publication by Finnigan (2006).

p970 line 9: It is not mentioned here whether the common stationarity test (using sub-interval-fluxes), which is part of the standard EUROFLUX and CARBOEUROPE

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methodology, had been applied to filter the flux datasets before the integral corrections. Explain whether and why this common quality filter was not used here.

p970 line 12f: Since there is only one sentence about the exemplary Fig.4 in the text, it should either be moved to the Materials and Methods section (like Fig. 1) or it can be omitted.

p971 line 20ff: It is not mentioned (neither in the Fig. caption) which data were used for the analysis presented in Fig. 7. If the data of all stations were used, the results of FR01-2002 should lead to partially negative values in the Ust correction effect (according to Fig. 3)!?

p971 line 26ff: It is not clear from the text how the ANOVA was performed (with annual NEE data?) and what the results of Fig. 8 specifically mean in relation (or as complement) to Figs. 3, 7, and 9.

p974 line 9f: The statement "We showed that we can strongly reduce the margin of uncertainties through a standardized processing by avoiding inappropriate data treatment..." is somewhat trivial. An appropriate data treatment is generally supposed to give better results than an inappropriate one. The uncertainty is mainly reduced by positively identifying the appropriate treatment among all options (e.g. show that a u^* correction is necessary and gives better NEE results), but this was not the topic of the present paper. Here, the specific uncertainties of the correction procedures were quantified. One could possibly conclude from this study that the uncertainty of the correction is (much?) smaller than the correction effect itself.

p974 line 20ff: The conclusion that the uncertainty of annual NEE values remains generally ("except for exceptional sites") below 100 gC/m²/yr cannot be justified with the results of this paper alone. Here only the uncertainty introduced by tree corrections techniques have been quantified. An adequate discussion (based on literature results) on the quantitative influence of the other important error sources (e.g. various types of advection, potential underestimation of daytime fluxes due to mesoscale/topographic

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effects, gap-filling, footprint problems) would be necessary before presenting a general estimate of the annual NEE uncertainty.

Fig. 9a-d, lowest panel: It is not clear, how the NEE values (and their error-bars) were calculated. Are they the result of specific correction options (e.g. best available storage correction, median u^* threshold) or do they represent the average result of all correction options? The first case would be more meaningful in my opinion, but then, the error bars should show an asymmetric form (most prominently for F101-2002 that is dominated by the storage correction)!

Fig. 9 caption: Does spike detection level 0 signify "no spike detection"? In that case the detection level z is "indefinite" instead of zero! According to Eq. 2 (incl. corrigendum) $z=0$ would detect all data as spikes.

TECHNICAL AND LANGUAGE CORRECTIONS

p963 line 3: "... are sometimes difficult to assess."

p963 line 15: better "...low turbulence and thus limited air mixing."

p963 line 16f.: CO₂ is produced by the ecosystem during the whole day. Therefore replace "when CO₂ is produced" by "when there is a net emission of CO₂".

p964 line 11: Change to: "Although being currently the best and most widely used method to..."

p965 line 11ff.: The sentence "In this context it is important ..." should be moved further down and should be combined with the last sentence of the paragraph.

p965 line 23: Change to "...is based solely on half-hourly flux data to find the cases affected by"

p966 line 3: "For the present analyses ..."

p966 line 14: Formulate more clearly, e.g. "...before the half-hourly average flux is

calculated. However, spikes could also occur in the time series of the half-hourly flux values ..."

p967 line 14: More precisely: "For the determination of the u^* -threshold, ..."

p968 line 13: "...technique..."

p968 line 20: "...according to ..."

p969 line 3: "For the 12 annual datasets..."

p969 line 3: The formulation "...the 3 different u^* thresholds..." is somewhat misleading and should be changed since they are not three independent results but the median with the respective uncertainty limits.

p969 line 19: "Figure 3 shows ..."

p970 line 1: "...and lead to changes the site from sink to source." has to be rephrased.

p970 line 4: "...while for other sites it is not clear..."

p970 line 11: Replace "are relative to" by "contain" or "show"

p970 line 24: "...diurnal NEE trends of the day ..." should be rephrased

p971 line 5: "...between the two storage correction options..."

p972 line 2: "...indicates the relative role of the different correction in the uncertainty definition..." is unclear and should be rephrased.

p972 line 3: "For DE03 u^* has ..."

p972 line 25: In my understanding of the context, "since" should be replaced by "however".

p974 line 1: "Intercomparisons of eddy covariance data sets ..."

p974 line 2: "We consider the present systematic ..."

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Table 2: For a better readability, additional spacing should be added between the different site-year rows (mainly in the columns with daytime and night-time results).

Fig. 1 caption: "Example of the variability in the u^* threshold found ..."

Fig. 2 caption: better: "Median and selected percentiles of the u^* threshold distribution determined by the bootstrapping..."

Fig. 3 caption: "annual NEE" instead of "annual sums"

Figs. 5/6: the unit on the y-axes appear in my copy as "mmol...." instead of "umol...." (probably because of Latin instead of Greek/Symbol character)

Fig. 5 caption line 3: "...the other three..."

Fig. 5 caption line 4: "...and no storage..."

Fig. 6 caption line 2f: "In the upper panel, monthly mean diurnal cycles of NEE calculated from data before spike detection are shown." I suggest to generally replace the term "diurnal trend" by "diurnal cycle"

Fig. 7 caption line 2: replace "montly sums" by "montly NEE"

Fig. 7 caption line 6: replace "50% percentiles" by "inter-quartile range"; replace "black line" by "dashed line"

Fig. 7 caption last sentence: "...outlier values are displayed as numbers at the top and bottom of the plot."

REFERENCE: Finnigan J. (2006) The storage term in eddy flux calculations, *Agricultural and Forest Meteorology*, 136, 108-113.

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