Biogeosciences Discuss., 9, C1753–C1764, 2012
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Biogeosciences Discussions

Interactive comment on "Improved determination of daytime net ecosystem exchange of carbon dioxide at croplands" *by* P. Zhao and J. Lüers

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Received and published: 6 June 2012

We are grateful to the referees for their helpful comments. As the comments from both of the referees are similar to each other, with the references being to work from the same research group, we present our answers to both as follows.

We fully agree that the data-processing strategies by Foken and Wichura (1996) and Reichstein et al. (2005) are well-known and understood in the community. We are sorry that some ideas of ours are inadequately expressed, which possibly makes it difficult for the referees to fully appreciate the specific points in our paper. Nevertheless, we think that our study has specific advantages which are both appropriate and new.

General answers to both Referee #1 and Referee #2

The quality control (QC) tool for eddy-covariance (EC) data by Foken and Wichura (1996) (FW1996) is now a standard method, which has been used during recent years in most of the available EC data processing software (Foken et al., 2004, 2012). The FW1996 approach can only be applied if raw high frequency data or 5-minute covariance and standard deviation data are available. Since neither of these are available for the FLUXNET 'La Thuile' database, and because this database is used in the referees' references and comments, it could be assumed that the FW1996 approach is not applied for this database, especially in those data from before 2005. The use of the FW1996 approach in gap-filling techniques (e.g. Ruppet et al., 2006) is not new, but it is almost never applied in the community, not even in the last overview article (Papale, 2012).

Referee #1 criticizes that we do not use the ustar filtering. The scientific background of ustar filtering (Goulden et al., 1996) is to exclude all those data which do not indicate turbulence and where EC assumptions are not fulfilled, thus the EC method cannot be used (Foken et al., 2012). The FW1996 approach we use in our study is the same kind of test as the ustar filtering. We feel that it makes no sense to use two similar tests for the same database. But many authors use only the steady-state test without the integral turbulence characteristics (ITC) test of the FW1996 approach, therefore the ustar filtering must be applied as well. Specifically, ustar is a test which tries to guarantee that non-turbulent data is not considered. Nevertheless, turbulence still exists even for low ustar (probably up to 0.1 m s^{-1}) under steady-state conditions and no intermittent turbulence. These cases are excluded by the ustar filtering. Ruppert et al. (2006) shows that more data can be used to parameterize the Lloyd-Taylor function by applying the FW1996 approach than by applying the ustar filtering. On the other hand, more data could be selected for the Michealis-Menten light response function. More details can be found in Ruppert et al. (2006). In our specific case, ustar filtering will exclude too large a fraction of data because the fast-growing periods of rice and potatoes are very short. Therefore, the FW1996 approach has a significant benefit.

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The referees recommend rejection of the paper because they feel that it presents limited new aspects and would overlap with the available literature. Therefore, we have checked most relevant references again and have included their results in Table S1 (see supplement). We find that most references, some of which are cited by the referees, are related to forests and not to fast-growing crops (Page 2885 Line 24 to 25). Therefore, they use ustar filtering within time windows as long as weeks or months. On the other hand, the data-sets used in these references are from much longer periods than the growing seasons of crops (in our study only 4 months). Therefore, they have, in general, enough quality data for the statistics and parameterization available, which is not the case in our study. Thus we have to optimize the data quality check e.g. using the FW1996 approach.

It is true that some papers use a time window of 1 week or 4 days, but the selection of the time windows by the authors is more empirical than theoretical. The lack of experience for the extremely fast growing rice and potato plants, especially in a subtropical Asian region (Page 2886 Line 14 to 18), requires us to look for the best criteria for applying the binning methods for the ***first*** time with a statistical based, theoretical approach. Therefore, we suggest these additional approaches with a LAI factor. This new approach has not been made before, possibly because the LAI of forests is too large and the LAI change in time of forests is too small to detect with remote sensing techniques. Most of the available papers do not mention the LAI or PAI at all, and only a few papers treat LAI as a constant in time (e.g. Desai et al., 2005). Now our paper deals with very fast-growing crops for the ***first*** time in a subtropical Asian region under irrigated and non-irrigated agriculture management with only a short (4 months) and limited (typically with many gaps e.g. due to the monsoon influence) data-set. Therefore we need an improved (or better adapted) gap-filling method. Our statistical-based analysis shows very clearly that the inclusion of the non-linear LAI-factor into the Michealis-Menten light response function as described in our paper improves the ability to fill the gaps.

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It is likely that the referees' comments are based on the Taylor diagram (Fig.2 on Page 2913), in which the new LAI-factor scheme is not actually indicated. Nevertheless, this comparison is well analyzed in our study (Section 3.2 and 3.3 of the paper). But the major misunderstanding we unfortunately have produced arises because the time window scheme does indeed work well, with an index of agreement between 0.95 and 0.97, but only if a 16-day or smaller time window is used (Page 2897, Line 5 to 7 and see supplement Table S2) and the LAI-factor scheme (independent from time binning) is close to this value (0.93 for the potato field, see Page 2897, Line 24 to 26, and see supplement Table S2). Thus it may seem that the LAI-factor scheme does not have an advantage. But when the existing gaps are too long in relation to the plants' rapid development (e.g. a change of the potatoes' LAI from zero to 5 in one single month (Fig. 1 of the paper) and a gap of maybe 15 to 20 days) we show that the increase of the width of the appropriate time window will reduce the performance down to an index of agreement of only 0.66. In this case, the inclusion of the non-linear LAI-factor into the parameterization confers a big advantage (index of agreement is still 0.93) because the LAI-factor scheme uses the whole data-set, independent from the size of the gaps. In order to avoid creating this misunderstanding and to clarify this issue, we have produced a new Taylor diagram (Fig. S1) and a table (Table S2) including the performance of the LAI-factor scheme. Fig. S1 and/or Table S2 will be included in the revised manuscript and we will rewrite the relevant text if the editor and referees agree.

Answers to the comments from Referee #1

In GENERAL COMMENTS 1, Referee #1 mentioned that in most of the methods proposed in Moffat et al. (2007) the parameterization is done for short time windows (i.e. one week), which we were, however, unable to find in that paper. The time windows in Moffat et al. (2007) are 1 or 2 months long or even a whole year. Their data-set is taken from six forested European sites where it can possibly be assumed that the vegetation status does not change substantially, thus it is totally different from our case. Even over a period of one week the LAI in our case changed substantially (Fig. 1 on Page 2912).

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The LUT approach mentioned is normally based on monthly or even seasonal time binning. However, to consider a rapid LAI change, the width of the binning must be reduced to single days. But that could mean that the minimum number of data needed in each class for application of the statistics is not reached. The ANN needs a large data-set for training which is not available in our – and possibly many other – cases.

For the answer to GENERAL COMMENTS 2 by Referee #1, see the general answers.

In GENERAL COMMENTS 3, Referee #1 suggested that the saturation of LAI should be checked. We found that the overlapping of green leaves results in photosynthesis occurring with a lesser efficiency during the mid seasons of the crops than during the early and late seasons (Fig. 3, Sect. 3.3). Other techniques for obtaining an efficient LAI measurement could be expected to improve the simulation (Sect. 4 on Page 2904 Line 21 to 27).

Referee #1, OTHER COMMENTS 1: The model evaluation should be done with gaps larger than 10% if the authors want to demonstrate that it is possible to "fill large data gaps" (page 2903 line 4) and the distribution of the gaps should be explained.

Answer: We performed a random walk along the Database-high-quality to mark 10% of them as artificial gaps (Database-artificial-gaps) and use the remaining 90% of Database-high-quality to parameterize the models. The gap-filling methods were evaluated by examining the comparison between the simulation (Database-simulation) and Database-artificial-gaps (Sect. 2.3.4 on Page 2895 Line 14 to 20).

Referee #1, OTHER COMMENTS 2: Page 2897 Line 10-11: are the difference found using 2, 4 or 8 days significant?

Answer: We found that if the width of the time window increases above a certain length (in our case more than 16 days) the performance will decrease (see Table S2). E.g. for the potatoes we found no visible difference between the 2-day and 4-day time windows but a slightly poorer correlation of the 8- and 16-day time windows (Sect. 3.2 on Page

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2897 line 7 to 17, Table S2).

Referee #1, OTHER COMMENTS 3: The comparison between the parameters estimated using the LAI factor scheme should be better evaluated and discussed to avoid circularities, since both alfa and alfa prime are calculated from the same GPP.

Answer: We are sorry for the misunderstanding, but α and α' are calculated from different GPP. α is calculated from the data binned into time intervals (Sect. 2.3.3 on Page 2893 Line 7 to 11), while α' is calculated from the whole data-set (Sect. 2.3.3 on Page 2895 Line 11 to 12, and Sect. 3.3 on Page 2898 Line 19 to 20).

Referee #1 OTHER COMMENTS 4: In the temperature bibbing scheme (3.4) which time window has been used?

Answer: The whole Database-high-quality was used (Page 2894 line 4 to 5), which is 3 months (Page 2887 line 16 to 21).

Referee #1 OTHER COMMENTS 5: The discussion about VPD in the potato field is not relevant since as the authors say (Page 2902 line 20-23) when VPD was high the vegetation was basically not present, so it is obvious that it is impossible to see a VPD effect on GPP.

Answer: Yes, but we did not know this in advance. We first have to investigate this to obtain the result, because it is important to know the reasons (effect of growing stages, agriculture management or specific weather conditions like monsoon) for why the VPD has relevance or not. We found that in our case the VPD effect plays a minor role for the irrigated rice paddy and for the fully developed potato field (monsoon time). Only at the beginning of the potatoes' growing season (dry weather pre-monsoon season) is the VPD relevant (see Sect. 3.5). But this should be investigated for different sites and regions.

Answers to the comments from Referee #2

In the General comments, Referee #2 mentioned that the time window approach is

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much more common than temperature binning. We agree. Temperature binning is insufficient for the regression of the light response function. Nevertheless, the reason has not been explained in the literature. As far as we know, our research is the ***first*** to mention the reason, which is that the temperature binning contains some, but not all, relevant information of seasonal response for NEE gap-filling for croplands. The long-time seasonal and short time diurnal temperature response of the crops plays a minor role compared to the fast-changing development stages of the crop plant (Sect 3.4 on Page 2900 Line 26 to Page 2901 Line 26).

For the answer to the general comment Referee #2 on VPD effect, please see the answer to Referee #1 OTHER COMMENTS 5.

For the answer to the other general comments from Referee #2, see the general answers.

Referee #2 specific comment 1: p. 2886 l 13,14: " and we found that the use of the same routine as that employed for forest sites forced unexpected errors", please add a reference or if this is a result of this study please move to the results section.

Answer: Yes, we will rewrite this sentence and move it to the results section as the referee suggests.

Referee #2 specific comment 2: p. 2886 l. 22: what do you mean by biophysical factors?

Answer: These are factors such as the growing stage of the plants and the development of leaf area. A better word would be physiological factors.

Referee #2 specific comment 3: p.2893 l.26: the time window schemes fill gaps that are larger then the time window by interpolating the parameters, or fluxes computed with the parameter before and after the gap.

Answer: Yes, we agree with the use of simple interpolation from values before and after the gap, e.g. using obtained temperature and radiation information independently

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of the flux measurement. But this is only possible if the plants develop linearly, or no significant change of LAI occurs during the time of the gap. Unfortunately, the truth is that the LAI does not develop linearly with time (Fig. 1c on Page 2912). For instance, if a gap takes place during the period at the maximum of LAI when the potential photosynthesis ability reaches the maximal efficiency, this simple interpolation will definitely underestimate GPP. This non-linear interpolation problem could be solved by introducing our LAI-factor to the light response function (Eqs. 6 to 9 on Page 2895) based on the assumption that green leaves per unit area have identical photosynthesis ability during different growing stages. This is exactly the new idea in this study (see general answers).

Acknowledgment

We thank Prof. Dr. Thomas Foken very much for the discussion.

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/9/C1753/2012/bgd-9-C1753-2012-supplement.zip

Interactive comment on Biogeosciences Discuss., 9, 2883, 2012.

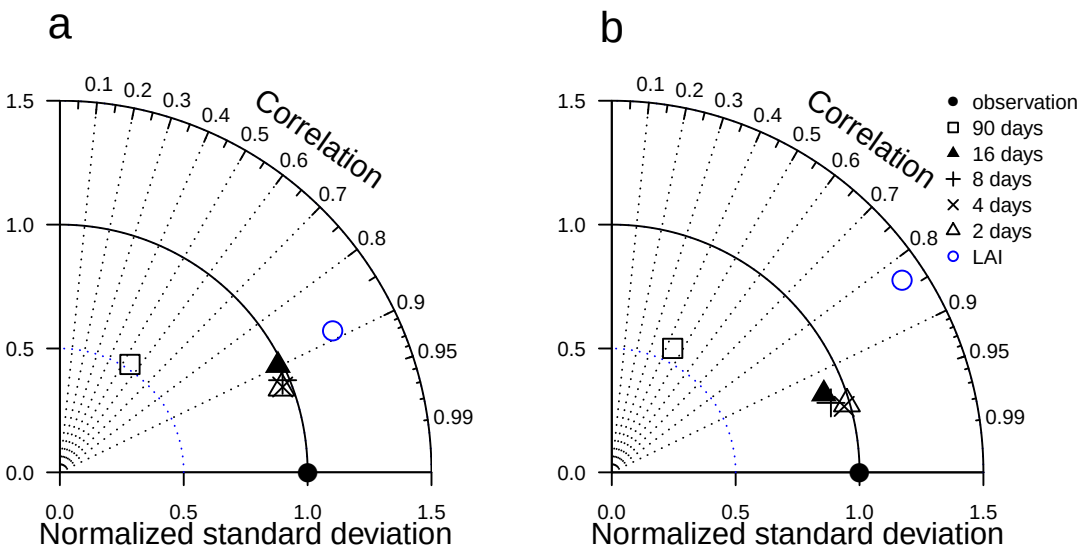

Fig. 1. Fig. S1. Taylor diagrams for the performances at the potato field (a) and the rice field (b). The blue circle denotes the LAI-factor scheme.

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