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Interactive comment

# *Interactive comment on* "Area-averaged evapotranspiration over a heterogeneous land surface: Aggregation of multi-point EC flux measurements with high-resolution land-cover map and footprint analysis" *by* F. Xu et al.

**F. Xu et al.**

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Dear Prof. Dr. Thomas Foken:

We appreciate very much for your valuable comments and suggestions on our manuscript. According to your comments, and those from other three referees, we have carefully revised all sections of the paper (revisions and corrections are marked in red). Detailed response to your worthwhile comments and suggestions are as follows:

Major comments:



Printer-friendly version

Discussion paper

1. Reading the manuscript, I found that the concept of the experimental design and the data analysis is very similar to the experiment LITFASS-2003, which was published in BAMS (Mengelkamp et al., 2006) and in a special issue of Boundary-Layer Meteorology (2006, vol. 121, issue 1). Some of these papers are quoted, but papers published later are missing (Foken et al., 2006; Foken et al., 2010; Charuchittipan et al., 2014).

Response:

Thanks. We have added the important references you specified.

2. Several parts in the paper are unclear, or information is missing that would enable the paper to be followed accurately:

(1) The area of investigation was very much dominated by maize fields. Only three stations had another dominant land cover (stations 1, 4, and 17). This is a significant limitation for the stated aim of the paper to determine area-averaged fluxes over a heterogeneous area. For the LITFASS-2003 experiment (and other experiments given as references), different land cover types were much better distributed. This deficit should be discussed.

Response:

As described in Section 2.1, even the dominant land-use type in the intensive observation area was maize field, the surface status of this oasis were actually very heterogeneous. The small square maize fields were all staggered with windbreak trees, roads, irrigation ditches, etc. We have classified four dominant types of the land-cover in the study area. The proportions of each land cover classes were 72 % (maize), 15% (non-vegetation), 8 % (woods) and 5 % (vegetable), respectively. According to the crop planting structure and land cover, 13 sites were spatially distributed under the dominated maize cropland; while only three stations, namely site 1 (vegetable field) and site 4 (residential area) as well as site 17 (orchard), were separately installed in respectively rather small area of land-use. This has been discussed in more detail in the revised manuscript.

(2) The function of the LAS in the aggregation schema was not clear. I could not find a reason for the use of such data. In LITFASS-2003, LAS systems were also used with a specific function: It was assumed that LAS can also measure the fluxes of larger turbulence or circulation structures and that this is not affected by the non-closure of the energy balance (Foken, 2008). This information was used to discuss the unclosed energy balance of the flux measurements and to correct this. The problem of the unclosed energy balance is not mentioned in the whole paper, but it is a standard for the analysis of surface flux measurements (Foken et al., 2012).

Response:

The LAS measurements for this paper are an intermediate point in checking the established flux aggregation algorithm. The procedure is as follows: the sensible heat fluxes representative for LAS source area were firstly integrated from multiple EC flux measurements, and then compared with the sensible heat fluxes from the 4 paths of LAS systems, to test the reliability of the developed flux integration method. Finally, the latent heat fluxes (daily evapotranspiration) of EC systems were extended to the study area using the aggregation scheme.

The energy balance closure (EBC) is a significant problem we are concerning from the very beginning of HiWATER. Moreover, relevant research has just published in JAMC (Xu et al., 2017). Generally, the energy balance closure ratio (EBR) during the 3 and half months was good. For the 17 EC stations in the intensive observation area, the average EBR was about 0.92. Except the lowest (0.78) in orchard site (#17), values in other sites were scattered without clear relation to the surface status. Site #15 (Super-station) had 2 heights, 4.5 m and 34 m. The relevant EBR were 0.89 & 1.03 respectively. This is quite reasonable.

We have added the detailed description on the EBR for the EC data of the HiWATER flux matrix in Section 2.2.1 and inserted a referenced here. We have discussed the effect of the unclosed energy balance in EC flux measurements on the results of the flux aggregation method in the revised manuscript.

(3) Any information is missing as to why the footprint model by Kormann and Meixner (2001) was used in your study. Perhaps the textbook by Leclerc and Foken (2014) would give you the relevant information. Questionable is the exact location of the small non-maize-covered areas in the footprint of the EC and LAS measurements. A discussion of the accuracy of the footprint analysis combined with the accuracy of the EC and LAS measurements is urgently necessary.

Response:

The advantage of the analytical footprint model by Kormann and Meixner (2001) was referenced in the textbook by Leclerc and Foken (2014). Related descriptions have been added into our revised manuscript. Besides, as we have checked, the footprint estimates of the Kormann and Meixner (2001) were in good agreement with the results of sophisticated backward Lagrangian footprint models, such as the Kljun scheme (Kljun et al., 2002;Kljun et al., 2015). The results from the newest version of Kljun's scheme (October 2016) was used to compare with what from that of Kormann and Meixner (2001). The differences were really minor. We have added some statements and relevant references in the revised paper.

The land-cover map used in the study was initially derived from the aircraft remote sensing images with 1-m spatial resolution, and was then carefully post-processed. Thus, overlapping the accurate 1-m land-cover map with the footprint of EC and LAS with same resolution can determine the location of the small non-vegetation areas in the footprint.

Quality-control and uncertainty-estimation for the EC and LAS data of the HiWATER flux matrix were carefully done. For the EC systems used in the data analysis, we have tried to reduce the systematic errors to a minimum with a pre-observation intercomparison and careful maintenances during the observation period (Xu et al., 2013).

The random errors were also analyzed by a separate research, which can be minimized in an ensemble average (Wang et al., 2015). As for the eddy-covariance systems, flux data from the 4 paths of LAS were also quality controlled. The systematic errors from data processing, e.g. the larger effects of Bowen-ratio correction in this oasis area, were carefully minimized. We checked the sensible heat fluxes (H) from the 4 paths of LAS with that from the nearer ECs. Except LAS 3, under its path there are clearly some village buildings so the H_las is higher, others agreed very well with that of ECs. Relevant statements on this have been added into Section 2.1.1.

(4) The applied multiple-linear regression analysis needs more information. Did you aggregate the fluxes according to the land-cover type in different effect levels of the footprint? Compare your method with the methods presented by Leclerc and Foken (2014).

Response:

Yes, we aggregate the fluxes according to the land-cover type in different effect levels of the footprint. We have supplemented some statements on the applied multiple-linear regression method in the study into Section 3.1.

As mentioned above, we have compared carefully the footprint results from Korman and Meixner (2001) with those from Kljun's scheme (Kljun et al. 2002, 2015) to insure the quality of our footprint analysis.

(5) What is meant by "Remotely sensed ET products"? If I understood the paper correctly, only the land-cover type was determined by satellite measurements, but, as seems probable, did these also include the net radiation for use in the Penman-Monteith equation? But this would then be difficult for the heterogeneous land cover. It is impossible to discuss the underestimation of the fluxes by the Penman-Monteith equation without knowing the parameterizations used in this equation. E.g., the atmospheric resistance and the stomata resistance are extremely variable and should be included in any discussion.

Response:

We benefit a lot from your valuable comments. We have removed the parts on comparison with remotely sensed ET products derived by Penman-Monteith equation, according to the comments from you and other referees.

(6) Please also show in Fig. 2 the daily cycle of the evapotranspiration and not only the daily sum. This is necessary to indicate the energy exchange of the different sites, possible oasis effects, and the Bowen ratio. The latter may be a good indicator which to classify the sites.

Response:

Accepted. We have changed the Fig. 2(b) (Fig. 3(b) in revised paper) from bar-graph with mm/d to line graph with W m-2, and also have re-stated the descriptions on the energy exchange of the different sites.

(7) Undoubtedly the authors have an interesting data set with a significant scientific potential. Such a data set should be published with a good scientific concept. Besides some deficits in the experimental design, the concept of area-averaged fluxes may be such a concept. But the paper needs significant improvements according to the points given above. Therefore I recommend major revisions.

Response:

Thanks for your constructive comments.

Minor remarks:

The numbering of the figures is confusing. Figure 3 should be renamed as Fig. 1.

Response:

Accepted.

Table 1: The instrumentation (sonic anemometer, gas analyzer) is missing.

Response:

Accepted.

Table 2: Do not mix LAS type and LAS producer, please give both for all sites.

Response:

Accepted.

p. 6, line 21: What do the flags mean?

Response:

The flag 0, 1 and 2 represent high-quality, intermediate-quality and poor-quality flux data (Mauder and Foken, 2015), respectively. We have added this reference in the revised manuscript.

p. 6, line 23: Why did you use 2D-rotation and not planar fit? Was the terrain absolutely even?

Response:

Our study area, the oasis in the middle reaches of Heihe River basin, is relatively very flat. To use the common 2-D rotation method is not only simpler but also enough in this situation. We have compared the results of 2-D rotation and Planar fit during previous data-processing works. The differences were very small.

p. 7, line 13: L can be easily misinterpreted as the Obukhov length in a micrometeorological paper.

Response:

We have changed the symbol L to R.

Fig. 4 and 5: Why did you use different names or land cover types in both figures?

Response:

We are sorry for our mistake. We have unified the use of land cover types in both figures.

Fig. 6: Probably y has a lower accuracy than given in the figure!

Response:

The different statistics (e.g. the root mean square error, RMSE) between x and y listed in Table 3 were calculated with data shown in the Fig. 7 of the revised manuscript.

p. 16, line 11: The reference should probably be Fig. 3!

Response:

Accepted.

p. 17, line 12: This is trivial; when maize dominates the land cover it is normal that maize also dominates the ET.

Response:

Removed.

Table 6: Give the units in the columns.

Response:

The relevant information on the comparison with P-M estimated ET throughout the paper has already been removed, including Table 6.

p. 19, line 16-25: Such a paper needs a well-written conclusion chapter and not only ten not very significant lines.

Response:

The conclusions have been re-written.

p. 22, line 13: Many authors are missing

Response:

Accepted.

p. 22, line 18: Print CO2.

Response:

Accepted.

References:

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of Applied Meteorology and Climatology, 56, 127-140, 2017.

Thank you very much again for your valuable comments and suggestions on our manuscript. A newer version of the revised manuscript is attached as supplement.

Sincerely yours,

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Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-602/hess-2016-602-AC4-supplement.pdf

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