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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Energy fluxes and surface characteristics over a cultivated area in Benin: daily and seasonal dynamics" *by* O. Mamadou et al.

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Reply to the review of the anonymous referee # 2

Firstly we warmly thank the referee for his deep work in this review and for the helpful comments and suggestions. In the following, we provide an item-by-item response to the comments.

Major points (1)

The manuscript is overall very detailed and descriptive, however, clear objectives or hypotheses seem missing, see e.g. page 10607, line 22ff – documentation seems to

be the first & only aim of this paper?. Accordingly, the results contain large amounts of detailed descriptions (for 16 Figures and 3 Tables) of various variables without making it clear to the reader to what extend this contributes to the main objectives. Potentially new insights and the main results are thus diluted and limit the applicability of this study for other colleagues.

Response: We reformulated the objectives.

Initial version

In this context, the first aim of this paper is to document the seasonal variation of latent (LE) and sensible heat (H) fluxes in Sudanian region where surface-atmosphere exchanges are expected to affect monsoon dynamics.

Text modification

In this context, the specific objectives of this paper are threefold: (1) to describe the seasonal and daily variations of latent (LE) and sensible heat (H) fluxes in Sudanian region where surface-atmosphere exchanges are expected to affect monsoon dynamics; (2) to quantify the energy partitioning related to surface characteristics and (3) to evaluate the ability of standard models to reproduce the daily and seasonal dynamic of LE observations in this specific tropical site.

Major points (2)

The structure of the manuscript is not coherent, i.e. the content of the main sections are mixed-up to such a large extend that makes it hard to follow a clear line of argumentation and understanding. The methods section is relatively short and does not contain all methods, corrections, assumptions or definitions used throughout the analysis. For instance, (a) the footprint method selection and assessment appears first in the results section (3.2), or (b) the modelling approaches used in the discussions section (4.2 ff) are not listed in the methods and the reader gets informed about these there for the first time. The results and discussions section appear not clearly distinguished between each other at all, i.e. the results contain substantial amounts of interpretations and referencing to other results already, while the discussion section continues to derive and list results, instead of clearly discussing the results from the prior section. According to the journal guidelines, the authors need to comprehensibly decide for a either a separated Results & Discussion section, or clearly merge both sections. The unusual long conclusions section does not conclude from the results and discussions before but is rather a summary of everything, by repeating large parts of the introduction and results, and still referencing to other published research. It would certainly help the manuscript if the authors would streamline their overall structure.

In summary, I would suggest the authors to rethink the objectives of their study and align their manuscript structure and content accordingly to convey a clear message to reader.

Response: OK. The structure of the manuscript has been modified according to the journal guidelines. We have included in the methods section, about the description of the footprint analysis and modeling approaches.

New outline of the paper:

1. Introduction

2. Material and Methods

2.1. Study area

2.2. Instrumentation and data processing

2.3. Diagnostic tools for data quality control (added)

2.3.1. Footprint analysis (added)

2.3.2. Energy balance

2.4. Diagnostic tools to characterize surface processes (modified)

2.4.1. Derivation of surface parameters

2.4.2. Surface conductance models (added)

3. Results and Discussion (modified)

3.1. A contrasted seasonal cycle

3.1.1. Dry season and period 1

3.1.2. Dry to wet season and period 2

3.1.3. Wet season and period 3

3.1.4. Wet to dry season and period 4

3.2. Data quality control

3.2.1. Spatial representativity of the eddy covariance measurements (modified)

3.2.2. Energy balance closure

3.3. Seasonal and daily dynamics of energy budget terms

3.4. Characterization of surface processes (modified)

3.4.1. Energy partitioning and surface characteristics

3.4.2. Daily cycle of evaporative fraction (EF)

3.5. Evaluation of surface conductance models (added)

4. Conclusions (corrected)

Method section:

Text insertion in the

“2.3.1. Footprint analysis”

Quantifying the area that contributed to each flux measurement the so-called footprint area was an important step for characterizing the representativeness of the measured fluxes. The flux footprint may be defined as the contribution per unit emission of each element of a surface area source to the vertical scalar flux measured at a given height (Horst and Weil, 1992). Among numerous footprint approaches developed in the past decades (Horst and Weil, 1992 ; Hsieh et al., 1997; Hsieh et al., 2000; Schmid, 2002; Kljun et al., 2004), the simple analytical Hsieh 1-D model (Hsieh et al., 2000) with a 2-D extension (Detto et al., 2006) was chosen because of its explicit formulation for a 2-D diffusive footprint calculation. The footprint model was applied to the half-hourly flux data to get a succession of 2-D distribution functions of the sensible heat flux contributions. In this study, we calculated, average footprints weighted by the corresponding sensible heat fluxes to take into account the strength of the source of each 30 min contribution. This average footprint area is then more representative of day time when footprint extension was limited by convective atmospheric conditions. This approach gives a good extension of the average footprint area for water flux sources, but is not representative for CO2 fluxes for which night contributions are as important as day contributions. The roughness length (z0) and the displacement height (d) used to compute the footprint extension have been derived from vegetation height using the Brutsaert formulation (d=0.67 hveg). The roughness length linear relationship has been inferred from local eddy covariance data (z0 = 0.17+0.097*hveg). The high residual roughness (0.17) results from the remaining roughness during the dry season (yam bumps and sparse bushes).

Text insertion in the

"2.4.2. Surface conductance models"

Observed conductance is the combination of aerodynamic, soil, stomata and roots conductances. To analyze these respective contributions to the observed evapotranspiration dynamic in this specific tropical site, different models were considered for evaporation and transpiration. During the dry season when the soil is entirely bare, the bare soil resistance modeling laws proposed by Sellers et al. (1992), Lee and Pielke

(1992), and Sakaguchi and Zeng (2009) are used to evaluate the ability of these bare soil models to capture the behavior of bare soil conductance in tropical conditions. During the wet season, transpiration processes have been modeled with the Ball – Berry stomata conductance model as described by Collatz et al. (1992) for C4 vegetation. More details about this model can be found in chapter 8 of CLM4 technical note (Thornton, 2010). A C4 grass was chosen for stomata characteristics (PFT). The required atmospheric (air temperature, precipitation, humidity) and surface (LAI, soil moisture) forcing conditions are those presented further in Fig. 2. The Photosynthetically Active Radiation (PAR) was calculated as a fraction (0.5) of the observed incoming shortwave radiation for both sun-lighted and shaded leaves. Leaf temperature was assessed from outgoing longwave radiation measurements using Stefan-Boltzmann law and a 0.97 emissivity for leaves.

The conclusion also has been corrected (see the corrected paper).

Specific comments

The term 'cultivated area' seems rather confusing to me, would agricultural land not be more appropriate if considering the dominant land use within the footprint of the flux tower?

Response: Ok. For us, a cultivated area is an area of land that is used for farming, meaning it has been or is being prepared or used for farming/growing crops. It includes crops and fallows. We inserted this precision in the text.

I would consider it essential to reference and refer to the content of the companion paper on surface radiation budgets that was published by the authors for the same site in early 2013: Kounouhéwa et al. 2013, Atmospheric and Climate Sciences, 2013,3,121-131,DOI:10.4236/acs.2013.31014,http://file.scirp.org/Html/14 4700125_27583.htm.

Response: Done.

P10608, line 3: do you mean 'energy fluxes' here instead of the 'climate'? Response:

It is “climate” but we reformulated completely this sentence according to the comment of A. Guyot.

Text insertion

The Sahelian climate fluxes have been documented for periods of a few weeks (Kabat et al., 1997; Schüttemeyer et al., 2006) and annual periods (Bagayoko et al., 2007; Brümmer et al., 2008), but to the author’s knowledge, Sudanian climate has been studied only for few weeks in the dry to wet transition period in Nigeria (Mauder et al., 2007) and Ghana (Schüttemeyer et al., 2006).

P10612, line 6ff: The 4 specific periods of 15 days were not yet introduced in the methods section at the point of first usage (Page 10612, line 6ff) and should be before instead of refereeing to later.

Response: Ok. We inserted a text to introduce the four specific periods of 15 days.

Text insertion

Data were analyzed at seasonal and daily time scales. Daily averages were computed to characterize the seasonal cycle. For meteorological variables simple 24-hour averages have been computed whereas surface characteristics have been averaged over a 10:00 - 14:00 period (UTC). The daily cycles were analyzed for specific period for which composite daily cycle have been computed. It concerned four specific periods of 15-day which have been selected (from P1 to P4) for their quasi steady state thermodynamic conditions, and the quasi absence of rain (except during the wet season) to ensure a good quality of the eddy covariance data. These periods have the same number of days, which make their statistical characteristics as comparable as possible. During the selected periods, the tests described previously eliminated: 4% of H and 5% of LE in P1, 20 % of H and 37% of LE in P2, 35% of H and 55% of LE in P3, 25 % of H and 30% of LE in P4.

The usage of soil water content in term of units appear confusing and requires further

explanation or adjustment: while the authors measure with CS616 sensors in cm3/cm3 (Tab. 1), they report the results in mm (page 10625, line 2; Fig. 2g) without giving details on how they derived these. Instead, Fig. 2g seems to indicate that volumetric SWC might be actually displayed in percent. In contrast to earlier use and the figure, the authors than use the term ‘soil water storage’ with the unit in mm later on (Page 20624, line 16f).

Response: Ok. We corrected this.

Page 10615, line 16f: The term ‘monsoon flux intrusions’ is not clear to me. Could you try to elaborate this? Response: Monsoon flux intrusions correspond to the presence of both southwesterly (SW) winds which are observed during the night whereas northeasterly (NE) conditions prevail during the day. It a special feature of the West African monsoon due to the diurnal back-and-forth movement of the inter-tropical discontinuity. The later is related to the large-scale forcing (horizontal temperature gradient across the continent) and vertical development of the boundary layer (Lothon et al., 2010).

The figure below illustrates the feature.

The sentence was also corrected. The “moistening transition season” (from dry to wet season) is characterized by monsoon flux intrusions (southwesterly winds bringing moist air from the ocean at night, whereas northeasterly conditions prevail during the day).

Page 10617, line 27ff: (1): It would be helpful to get some distance values for the maximum footprint extension reported here. (2) Why is the footprint only relevant for the sensible heat flux & what about the latent heat flux then?

Response: (1) OK. We have specified in the text maximum extension of the footprint functions during night and day.

Text insertion

One has to keep in mind our averaging procedure favor day time footprints and give less importance to night time footprints which can extend up to 750 m in the upwind direction. During period P1 (Fig. 4a), the measurements were likely affected by some shrubs in the upwind direction. The riparian forest located to the north of the site (which appears at the top of the image) was far enough not to contribute to the measurements for day conditions when footprint extension is limited to 70 m.

(2) We did not mention that the footprint is only relevant for the sensible heat flux. Indeed, according to the footprint definition, footprint areas are relevant for any scalar transported by turbulent eddies. Shear and convection are the only processes responsible for advection of fluctuations (T', q' etc...) from the ground to the sensor. In the text, we described how footprint areas have been averaged to obtain a composite footprint area for each period (from P1 to P4). This gives an overview of the sources area for each period. We have reformulated this sentence in the new method section.

Page 10622, line 25ff: Was the latent heat flux statistically different from zero, particularly if considering all measurement & method uncertainties?

Response: During the dry season, positive latent heat fluxes are systematically observed, and then the average value is robust as it was shown by the standard deviation calculation (see Table 2). On the other hand, we have specified that the direct covariance (w'q') observations are non zero and always positive during day time. This means that positive water fluxes are observed. The remaining uncertainty concerns only the strength of these positive fluxes. For the eddy covariance method, uncertainties for the latent heat flux were about 20-30 % and lower than 200 W/m2 in the literature (Foken et al., 2004; Richardson et al., 2006). For the maximum observed value during period 2 (41 W/m^2) the uncertainty is about 12 W/m^2.

Page 10624, line 2ff: If P4 cannot be used or generalization with the 15-day sample, why did you choose this period and still use it for analyses?

Response: We agree with this comment. We chose this period because it is particularly different from the others in term of atmospheric and surface conditions (vegetation

cover state etc...). We think that highlight energy fluxes behavior as well as surface characteristics during this period of the year can be useful for both parameterization and evaluation of land surface models. We specified this in the text.

Text insertion

Although it cannot be generalized to the entire wet to dry season, the P4 period characterize a long surface drying episode with vegetation in senescent phase which can be useful for both parameterization and evaluation of land surface models. In addition, we still use it for analyses because even if it cannot be used to generalize findings, it stays a part of the seasonal cycle. Such contrasted atmospheric and surface conditions remain one of the features of the sudanian climate.

- The authors should evaluate if the modelling part at the end of the paper is really needed and contributing to the story and for this manuscript.

Response: We still think that this part is useful because it helps to interpret data time series with insights on physiological and aerodynamic processes. We have reformulated the objectives in the text to justify the relevance of this modelling part.

- Most figures contain a lot of content and are scaled rather small (thus captions etc. tiny) to read the content properly, in particular the Figures 2+3+5+6+8+9+10+13 and Table 2 Figure 5 is for instance largely redundant with the information listed in Table 3 already.

Response: Ok. We have removed table 3 from the text.

In addition to that, the authors should evaluate if all figures are needed for the story of the paper.

Response: We think that figures all together give a complete overview of the data set and are necessary to interpret seasonal and daily cycles of surface characteristics. If some are described briefly, we think the systematic plot of results for the 4 periods keep the coherence and give more reliability to the study.

- Table 1: (1) The last column appear to be not needed (as same entry everywhere) and this info could be added e.g. in the caption. (2) What is ‘Eurosep’ for the LI-7500, which is produced by Licor?

Response: Ok, (1) we have removed the last column of table 1 and added the averaging interval in the caption. (2) Eurosep has also removed from table 1.

- Table 3: The dates should be given here for each specific period (P1 to P4) and it might be good to mention in the caption, that each period is 15 days so to avoid confusion about the small versus large number of n compared to the full year.

Response: Ok, done.

Figure 4: The periods should be named & defined here in the caption linked to the panels a-d. Similar considerations should be taken for the captions of Figures 8+9+13+16, to clearly define and name which periods are dry/wet/transition for the reader without flipping back-and-forth in the manuscript all the time.

Response: Ok, done.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 10605, 2013.

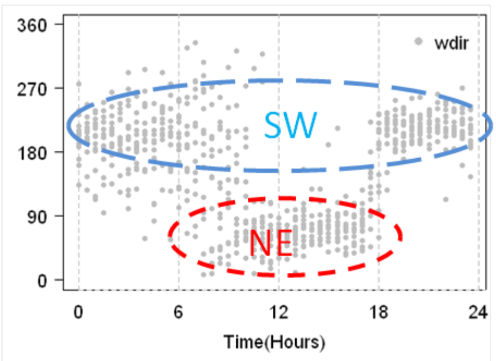

Fig. 1. Diurnal cycle of the wind direction at Nalohou site during transitional phases (2008).