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Interactive comment on "Understanding model biases in the diurnal cycle of evapotranspiration: a case study in Luxembourg" *by* Maik Renner et al.

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We thank reviewer 1 for his careful review. In our reply we will respond to all comments step by step. We repeat each reviewer comment in bold font, followed by our reply. Changes in the text of the main manuscript are highlighted in blue color.

Reviewer 1: "The study attempts to assess the model biases in the diurnal cycles of evapotranspiration and to analyze the influence of observed input variables under dry and wet conditions. Much effort has been undertaken to analyze a wealth of observed and modeled data. The approach applied in this study is relatively logical. The findings in the paper may be rational. Therefore, I appreciate

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the authors' effort to handle such much work. However, I have one concern on the presentation. The paper would be publishable in HESS after minor revisions if the author satisfactorily address my concerns."

Reply: We thank the reviewer for his assessment.

Reviewer 1: "Lines 22-30 in page 1, This part should be simplified and keep concise for good read- ability."

Reply: The reviewer refers to the 2nd paragraph of the abstract which includes most findings of the study in a very condensed way. To improve the readability we simplified and focussed on our main findings and rewrote the paragraph as follows.

We found remarkable, almost linear relationships of the turbulent heat fluxes with Rsd, which, however, exhibit significant phase lags during wet periods. The diurnal signature of a phase lag to solar radiation provides a mechanistic insight into the diurnal heat exchange processes of the surface with the atmosphere. While the surface energy balance fluxes show rather small phase lags, the temperatures of the surface, the air and the related vapor pressure deficit of the air show very large phase lags. Including these variables as forcing for models (such as vapor pressure deficit in Penman-Monteith based formulations) may cause that the predicted fluxes yield a phase lag that is larger than what is observed. In contrast the surface to air temperature gradient used in well-established remote sensing based approaches corresponds well in its diurnal phase shift with the observed sensible heat flux and therefore yields a better agreement of the phase lag of λE with observations under both, wet and dry conditions. We conclude that the phase lag of surface variables to solar radiation represents a simple, but valuable metric to evaluate and improve the representation of land-atmosphere coupling in land-surface schemes.

Reviewer 1: "Lines 20-23 in page 2, This study focus on revealing the model

biases of evapotranspi- ration by multivariate metrics, therefore recent literatures should be summarized such as Zhou et al., (2018, published in ACP, doi: 10.5194/acp-18-8113-2018) and Zhou et al., (2017, published in JC, doi: 10.1175/JCLI-D-16-0903.1) that investigated the model biases of regional warming in current reanalysis products and attributed those to the modeled land-atmosphere energy budgets and precipitation frequency."

Reply: We thank the reviewer for his suggestions on recent literature. The mentioned papers are well suited as references since these use statistical relationships of different model variables, such as temperature and incoming solar radiation (Zhou et al., 2018, 2017). Differences in these relationships between models and observations highlight different sensitivities and helps to evaluate models in a systematic way. Therefore we will include these references in the introduction.

Reviewer 1: "Section Introduction in pages 2-4, some recent relevant literatures should be sum- marized in the paper, such as van Heerwaarden et al., (2010, published in JC, doi: 10.1175/2010JHM1272.1)"

Reply: We thank the reviewer for pointing us to the paper by van Heerwaarden et al. (2010). We will update the introduction and include this valueable reference paper.

Reviewer 1: "Lines 11-21 in page 5, There are other approaches to regress this type of the response. Some reasons of the selection of the Camuffo-Bernardi equation should be provided for good readability."

Reply: We agree with the reviewer that the choice for the Camuffo-Bernardi model should be better motivated, since we have good reasons to use it. We added the following paragraph to the introduction:

Here, we choose the Camuffo and Bernardi (1982) model because it provides an objective mea-

sure of the magnitude of hysteresis loops and it allows for an assessment of statistical significance. We extend the Camuffo and Bernardi (1982) model in two ways. First, we use incoming solar radiation (Rsd) as reference variable instead of net radiation to estimate the phase lag of surface heat flux observations and models. And secondly, we use a harmonic transformation of the Camuffo and Bernardi (1982) regression model to compare the phase lag of variables with different magnitudes and units. This extension allows to compare the diurnal phase lag signatures of the different model inputs and how these influence the resulting diurnal course of the latent heat flux estimate.

Reviewer 1: "Lines 25-end in page 8, The average gap is up to 67 Wm-2 and then the diurnal cycle may has a larger gap. How to quantify the influence of energy balance closure gap (before and after correction) on the magnitude and phase lag in the paper?"

Reply: To assess the potential impact of the closure method we also computed the phase lag statistics for the non-corrected latent heat flux (see Figure 7, Tables 3 and 4). Results show that the phase lag estimates are very similar showing that the correction does not influence magnitude of the observed phase lags.

To improve the communication of this result we adapted P15L11 in the manuscript as follows:
The uncorrected observations showed a slightly lower wet-dry difference , highlighting that the method to close the energy balance closure gap does not significantly influence the estimated phase lag.

Reviewer 1: "Line 21 in page 22, how to justify the sentence ('These interactions are also affected by soil water availability, as reflected in the phase lags.') in the paper? whether adding related literatures or not?"

Reply: We replace this sentence with: *We also found that the phase lag of the turbulent heat fluxes is affected by soil water availability.*

Reviewer 1: "Section Conclusions in pages 25-26, The author should rewrite this part to make its logic smooth. If necessary, some discussion should be added to help the readers understand the importance and advantages of this study."

Reply: in order to improve the readility of the conclusions we improved the summary of our research setup in the beginning of the conclusions.

We analyzed the relationship of surface heat fluxes and states to incoming solar radiation at the sub-daily timescale for a temperate grass site which experienced a summer drought. Most variables show significant hysteresis loops which we objectively quantified by a linear component and a non-linear phase lag component using multiple linear regression and harmonic analysis. We then compared these diurnal signatures obtained from observations of an Eddy-Covariance site with commonly used but structurally different approaches to model actual and potential evapotranspiration. The models have been forced by the observational data such that the differences to observations can be attributed to model formulation and signals contained in the input data. In terms of actual evapotranspiration, our results ...

References

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