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Hydrology and Earth System Sciences Discussions

Interactive comment on "Adapting the thermal-based two-source energy balance model to estimate energy fluxes in a complex tree-grass ecosystem" *by* Vicente Burchard-Levine et al.

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The authors would like to thank the anonymous reviewer#2 for the comments and suggestions. Below are reviewer′s comments followed by our response to each comment. Attached is a revised version of the manuscript, as some responses make reference to changes to the manuscript by specifying line numbers.

Reviewer#2 comments

"This paper applies various combinations of parameterizations of the TSEB model over

a tree-grass ecosystem in Spain for 3 sites and 3 years: 2 wind profiles, 2 end-member representations of the system (trees and grass). It also performs a sensitivity analysis of the initial model. It shows that the most sensitive parameters are the vegetation height and the green and total vegetation fractions, that both profiles have similar performances, and that only the model made of a succession of endmembers is able to provide satisfying (o(50 W/m2)) H and LE RMSD values. This is an important contribution in the field of retrieving ET, E and T from RS data in orchard-like eco- and agro-systems (isolated trees with herbaceous understorey)"

Main comments:

The introduction and discussion sections should position this work with respect with similar work by Andreu et al., (2018) using TSEB on the same dataset, ref. P 32 L 671."

Authors' Response

- Response: Yes, we referenced Andreu et al. (2018) and contextualize their work with ours in the introduction (L75-76). In addition, we more directly compare our results and methods with Andreu et al. (2018) in the discussion (L582-590), where we mention that similar error bounds are achieved with different approaches for the same ecosystem and that the different findings complement each other.

-Reviewer#2 comments-

"I don't understand what is meant exactly by "default model configuration" (P13 L293-300): why is fc constant (and not varying according to LAI) ?"

Authors' Response

- Response: By the default model configuration, we refer to the standard TSEB model where we attempt to parameterize the vegetation source as a mix between tree and grass (as seen in the tower footprints). We decided to assume that the trees have highest contribution to resistance (i.e. as discussed in El-Madany et al., 2018) and parameters related to this were assumed with tree characteristics (i.e. hc). While, since the surface cover is dominated by grass, we assume grass characteristics for vegetation cover characteristics (i.e. fc and fg).

The fractional cover (fc) stays constant because the surface is always covered with vegetation throughout the year even though grass understory dries during the summer. Meaning that while LAI varies throughout the year, the vegetation fractional cover (fc) is actually constant as the surface is constantly vegetated even if the grass layer is not/less photosynthetically active during the summer. In TSEB-2S, the fc changes during the summer to 0.2 because the assumption changes to the surface being a tree cover (which represents 20% of the surface cover) and the understory was assumed (and modeled) as a rough bare soil. The fraction of vegetation observed by the sensor in eq.2 is, by contrast, a function of LAI.

-Reviewer#2 comments-

"Is the “effective” roughness (following Raupach 1994) used in all model configurations? It seems later that this only applies to when hc=8 m. This needs to be clarified."

Authors’ Response

- Response: Yes, the roughness estimation for the tree layer (i.e. TSEB_tree) and default model (i.e. TSEB_DF) follows the procedure described in Schaudt and Dickinson (2000), which stems from the work of Raupach 1994. But when considering the grass layer (TSEB_grass), the fixed ratio to canopy height method is used (Campbell and

Norman, 1998). As such, in TSEB-2S, the summer period uses Raupach 1994 but during growing season, when the model assumes a grass surface layer, the fixed ratio method was used. This was briefly mentioned in section 2.2.2 however more details were added in section 2.4.1 and 2.4.3 to more directly state the roughness estimation method used for the different modeling cases (L317-318;398-397).

-Reviewer#2 comments-

"It is not clear why the default model do not work properly, and only the endmembers do. An explanation/analysis should be more thoroughly presented in the paper."

Authors’ Response

- Response: TSEB assumes only one vegetated layer, being more or less photosynthetically active, over a non-photosynthetically active layer (i.e. bare soil or similar). The problem with surfaces with multiple vegetation layers, such as tree-grass ecosystems, is the difficulty in parameterizing the single vegetated layer assumed in the modeling structure to properly characterize the surface observed (mix between tree and grass) in these ecosystems. Additionally, the influence of the grass understory changes throughout the year due to its phenology, where the grass understory largely becomes non-photosynthetically active (i.e. not transpiring) during the summer. As such, two major situations occur in this ecosystem: 1. Tree grass and soil all contribute to latent heat and 2. Grass is senesced and only the tree and soil nearly entirely contribute to total latent heat. TSEB-2S allows the separation of the modeling period between these two situations and, therefore, different parameterizations can be applied according to the assumed ‘dominant’ vegetation structure and cover. As such, without any changes or adding complexities to the model structure, we can more or less accurately simulate latent heat by changing the parameterization according to the seasonal period. While the default model was attempted to be parameterized as a mixed layer between tree and grass vegetation, it was not able to accurately reproduce latent (and sensible) heat largely because it was unable to consider the drastic change occurring during the summer, where 80% of surface cover (i.e. grass understory) becomes non-physiologically active. This way in TSEB-2S, when we consider the senesced grass as bare (but rough) soil during the summer, we are able to improve the accuracy of model results. On the base of these assumptions, we can apply a two-source model for what is essentially a three-source system. This is added and better explained in the discussion section (L557-566).

-Reviewer#2 comments-

"The abstract is not clear enough (esp., assertion Line 25 is too vague) about the various versions of the models that are evaluated."

Authors' Response

- Response: The abstract has been edited to be clearer and now it makes better reference to the various model configurations used in this study (L24-27).

-Reviewer#2 comments-

"The Goudriaan and Massman equations for the aerodynamic resistances should be mentioned in Appendix, so that one understand for example the impact of Hmax, Xi,soil and Cd on the turbulent transfers."

Authors' Response

- Response: The authors agree, however, due to comments about clarity of the manuscript from Reviewer 1, we have decided to eliminate the analysis regarding the two different wind profile schemes in the revised manuscript. It was discarded since the different wind profile schemes resulted in little change to model performance and this analysis likely distracted from the overall objectives of the paper. See response to reviewer 1 for more details.

-Reviewer#2 comments-

"One could easily shorten the model presentation (Eq. 1 unnecessary) in order to provide more insight on the measurement protocol (number of soil heat flux plates, representativity of the CNR4 FOV etc)."

Authors' Response

- Response: Eq. 1, the heat transport equation, is used to introduce and clarify the problem regarding estimating sensible heat flux with radiometric land surface temperature even though it is the aerodynamic temperature that satisfies this equation (central problem that TSEB attempts to solve). Therefore, we believe this equation is important to introduce TSEB model, especially for readers less familiar with this model. Following suggestions of the reviewer, we added more details on measurement protocol in section 2.3.1 (L246-249)

-Reviewer#2 comments-

"Also, the way the tree and grass LAI and the resulting fg and fc contributions are partitioned in the various model versions is not clear enough from 2.3.2: one does not understand when one refer to an effective (total) fg for the TGE? The grass fraction, or the tree fraction."

Authors' Response

- Response: We included additional figures (Fig. 3 and 4) to better explain tree, grass and ecosystem LAI. The vegetation data that were used for the different model configurations was more clearly stated (section 2.4.3)

-Reviewer#2 comments-

"I don't understand why the endmembers in TSEB_2S are not weighted by a scaling factor depending on the development of the grass layer (instead of changing the model version abruptly from one season to the other)."

Authors' Response

- Response: Indeed, this type of methodology could be used to allow for a 'smoother' transition between model configurations. This would especially affect the transitional periods of the dry-down and re-greening. Since the phenology changes very rapidly in this ecosystem, we see that even this abrupt change can produce reliable and robust results for different years (with different seasonal transitions). However, the idea of this manuscript was to test if the simple assumption of parameterizing the model differently between just two seasons based on the dominant vegetation cover was able to provide reliable estimates of LE and H in a complex 3-layered site. Many models for global applications assign specific parameter sets depending on the assumed vegetation cover (i.e. based on a land cover map) therefore we wanted to apply something similar by specifying 'typical' land cover parameter sets (i.e. grassland or scattered broadleaved forest) at different phenological periods to investigate if, this way, we are able to ob-

tain relatively accurate results for a complex ecosystem. As shown, model performance is quite high using this relatively simple strategy and considerably improves upon maintaining a single parameter set throughout the year, even when attempting to characterize the mixed vegetation present, (TSEB-DF). Of course, more sophisticated methods can be applied (especially for sites with longer transitional periods) but the basic methodology will be the same. Adding a scaling or weighing factor may further 'tune' the model and may be an added complexity in the modeling procedure that may increase uncertainty.

-Reviewer#2 comments-

"Why didn't you look at the partitioning with the default model configuration ?"

Authors' Response

- Response: We didn′t look at the partitioning of the default model since the total/bulk fluxes were not well estimated, therefore we presume that the partitioning would also have large errors and bias.

-Reviewer#2 comments-

"It would be interesting also (since the maximum PT parameter is not very sensitive) to show the time evolution of the reduced PT coefficient as simulated by the various model versions."

Authors' Response

- Response: Below a figure showing the average daily alpha_PT parameter for 2015 at the CT for TSEB-2S. The largest difference occurs during the summer period in TSEB-2S, when the model is simulated as a scattered broadleaved forest, compared to TSEB-DF with alpha_PT maintaining values closer to the initial value (1.26). Discussion of the alpha_PT parameter doesn′t lie directly within the objectives of the paper so we believe it may be better not to include this discussion (or perhaps only to keep it in the supplementary material) to make the manuscript more concise with less added complications (as was recommended and suggested by reviewer 1).

-Reviewer#2 comments-

"Minor comment:

P3 Line 63: missing verb"

Authors' Response

- Response: Sentence was changed and edited.

-Reviewer#2 comments-

"P3 L67 to 68: the topic changes abruptly, one needs a transition"

Authors' Response

- Response: Yes, introduction section was edited and adapted to be more clear and better articulate the objectives of the paper (also following reviewer 1 comments) (see L38-97)

-Reviewer#2 comments-

"P4 L74: a model is overparameterized only if there is not enough constraint on its outputs, it is not an effect of its sole complexity (in Beven's paper this refers to Discharge as the sole constraint on parameter calibration)"

Authors' Response

- Response: The line was deleted as overparameterized models are not the focus or discussed in this manuscript.

-Reviewer#2 comments-

"P4 L75 and 76: it is not clear what is meant by "main effect" end what is "total parameter contribution"

Authors' Response

- Response: The 'main effect' or 1st order response refers to the influence a change in values of a single parameter (while keeping other parameters static) has on the output of the model, but does not quantify nor take into account the interactions it may have with other parameters. As such, part of the influence or sensitivity may not be accounted for when only considering the 1st order. The total order contribution, in addition to the first order effects, also takes into account the interaction the parameter may have with other parameters (2nd order effects). This was clarified better in the introduction (L60-65).

-Reviewer#2 comments-

"P8 L175: permits > allows?"

Authors' Response

- Response: The line was edited to change 'permits' to 'allows' (L183)

-Reviewer#2 comments-

"P9 L 209: "local LAI": do you mean "clump LAI" ?"

Authors' Response

- Response: Yes, local LAI, as referred to in Kustas & Norman (1999), is referring to clumped LAI

-Reviewer#2 comments-

P10 L249 / P11 L250: this is a bit radical, usually this correction is only used when there is a closure of less than 80%, is that the case (provide numbers)

Authors' Response

- Response: We decided applying this correction following the existing literature. For example, it was applied in Guzinski et al. (2014), Kustas et al. (2012), Cammalleri et al. (2010) and Kustas et al. (2019). Folken et al. (2011) suggest errors in LE are larger than H due to instrumental issues and some studies (i.e. Prueger et al., 2005) suggest that allocating the residuals to LE may be a better method for energy balance closure.

-Reviewer#2 comments-

"P11 L260: CNR4 is not a fully hemispherical measurement; what about the FOV of each instrument and its representativity for the Tree-Grass mix ? How many heat flux plates were used ?"

Authors' Response

- Response: 8 heat flux plates were used as stated in L243. The CNR4 has two pyrgeometers measuring longwave radiation, where one faces upward and another faces downward. The FOV of the upward-facing pyrgeometer is about 180 degrees while the downward radiomneter has a FOV of 150 degrees. This results in a view footprint consisting approximately between 19 to 25% tree cover for the three towers (i.e. CT, NT and NPT) used in the study, which is very similar to the EC footprint characteristics of the same towers reported in El-Madany et al. 2018 (L246-249)

-Reviewer#2 comments-

"Eq. 13: 0.94 is a very low figure for bare soil emissivity, and is somehow a model parameter itself; did you perform a sensitivity of this as well ?"

Authors' Response

- Response: The value of 0.94 has been used for broadband bare soil emissivity in other studies (e.g. Nieto et al., 2019; Sobrino et al. 2005). Additionally, computing broadband emissivity of soil spectra in the TIR region (i.e. 4-14um) from the ECOSTRESS spectral library (https://speclib.jpl.nasa.gov/) obtains values ranging between about 0.925 and 0.95 (quick estimation from 4 inceptisols). We did not include the emissivity constants within the sensitivity analysis because normally emissivity is retrieved or assumed in the estimation of the remote sensing LST product, so uncertainty in emissivity is embedded within the uncertainty of LST (where we included a local input SA analysis for LST)

-Reviewer#2 comments-

"Table 2: the range of values for the parameters that are measured in the field (e.g. fg, fc and hmax) seems unrealistically large, I understand that through this range one addresses the uncertainty of the tree+grass mix "effective" parameters linked with transpiration and turbulent transfer, but maybe this should be explained before presenting this Table."

Authors' Response

- Response: With the proposed range we aimed to cover different types of tree-grass ecosystems. The tree fc in the study site is about 20% but, in other more scattered tree-grass ecosystems or savannas, the fc may reach 10%. The grass fg will also be quite close to 0 during the dry summer period. The sensitivity analysis was done to account for a wide range of situations that may not only necessarily occur in the study site in question. We added a line to directly state this (L366-367).

-Reviewer#2 comments-

"Table 3: when hc=0.5, I guess that roughness is no longer computed from Raupach 1994. This should be clarified."

Authors' Response

- Response: Yes, the fixed ratio method is used when the model is configured as grasslands. This was briefly mentioned in section 2.2.2. A line was added (L397-398) to clarify this.

-Reviewer#2 comments-

"Table 4: it is identical to Table 3, except for *, is this Table useful ? One understands that TSEB-2S is TSEBgrass for one season and TSEBTree for the other, is that correct?"

Authors' Response

- Response: Yes, that is correct. We agree with the reviewer and the tables were adapted and this was better specified (L420-423). See table 4 in revised manuscript.

-Reviewer#2 comments-

"P26 L515: this is ofetn the case in TSEB, since a moderatly stressed vegetation with a soil that is still moist is interpreted in the model as a fully transpiring vegetation and a completely dry soil."

Authors' Response

- Response: We added this observation in the discussion (L615-616)

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-354/hess-2019-354-AC2-

supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-354, 2019.

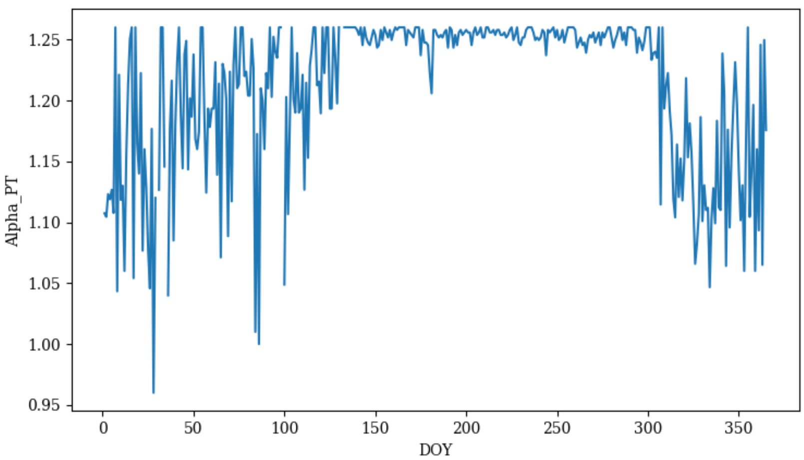

Fig. 1. Alpha_PT_timeseries