Interactive comment on "The SPARSE model for the prediction of water stress and evapotranspiration components from thermal

infra-red data and its evaluation over irrigated and rainfed wheat" by G. Boulet et al.

Anonymous Referee #1

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Comment: The paper presents and evaluates a land-surface energy flux model (SPARSE) based on the Two-Source Energy Balance (TSEB) modelling scheme. The differences between the original TSEB model and SPARSE (and their justifications) are generally well presented. However, the paper contains gaps in the description of the proposed SPARSE model (i.e. it is not clear how some of the terms were derived) and there is some confusion between the "patch" SPARSE and "parallel" TSEB implementations. Additionally, the comparison of the performance of SPARSE and original TSEB models (and therefore the evaluation of the improvements introduced by SPARSE) needs to be more robust. For example, there is no discussion of TSEB model in section 3 even though the testing of the first guess assumptions of canopy transpiring at the potential in the TSEB model (as well as in SPARSE) is listed among the main objectives of this paper in the end of section 1.

Reply: The main objective of the paper is to describe the SPARSE model and assess its limits with respect to theoretical limitations, measurements as well as simulations by a selection of published versions of TSEB. We might underline this in our objectives and rephrase the sentence in order to focus the paper on SPARSE rather than TSEB and to avoid any misunderstanding in the intended level of intercomparison with TSEB.

As stated P 7145 L3-5, there are two associated grounding elements (hypotheses) in both SPARSE and TSEB models: 1- that the first guess assumption is a potential transpiration rate and 2- that if the vegetation is experiencing water stress the evaporation is at a minimum rate (null flux in general). Section 3 is mostly illustrating the limit of such assumptions in a fully synthetic and consistent framework, i.e. by using the same model in forward ("prescribed") and inverse ("retrieval") modes. The parameterization used by SPARSE is different from that used by TSEB, but a "prescribed" mode is clearly defined in SPARSE, contrarily to TSEB.

It is not possible to use a combination of SPARSE and TSEB in Section 3, as suggested below, because it would not be possible to interpret the results, i.e. to warranty that inconsistencies are due to the limit of the underlying assumptions and not the parameterization differences between SPARSE and TSEB. A prescribed mode could be built on the basis of TSEB, but it is beyond the scope of the study.

In Section 3, we mostly explain why the retrieval using the two core/grounding hypotheses is sometimes deficient, illustrate it with a synthetic case, and find out that for this particular case the retrieval with the parallel version is less robust. This is consistent with findings by Li et al. 2005 and Morillas et al. 2008 (see below) but brings a new light on the source of the lack of robustness for the parallel model.

We don't claim that the differences between series and parallel retrieval capacities also fully apply to TSEB but since they share the same strong underlying assumptions and differ mostly by the parameterization of the fluxes, we're convinced that similar differences would be found with TSEB if

TSEB could be run in a prescribed mode. We will discuss accordingly the limit of section 3 with respect with TSEB and discuss the potential extension of these findings to all TSEB versions based on those core assumptions in the discussion section.

Comment: Additionally, in section 4.2 only one statistical parameter (root mean square error) is used in the evaluation, the implementation details and parameterization of the TSEB model are not presented and the discussion is brief and does not always reflect the results presented in figures and tables.

Reply: We will add the bias and review the discussion in order to address the specific comments on the presentation of the results given below.

Again, the TSEB model implementation is not the core of the paper but is rather an additional estimate of the energy balance components from a related model, to compare SPARSE's outputs to. Parameterization of TSEB is that of the publications referred to, with default values of the parameters, otherwise the same inputs are used for both TSEB and SPARSE. This will be clarified in the text (see below). Since both models are uncalibrated, raw performances and subsequent comparisons should be treated with care, we draw main tendencies rather than absolute rankings of both models. The fact that both model applications are done with "default" (uncalibrated) parameters will be emphasized in a revised manuscript.

Comment: Therefore, I would recommend a resolution of a number of issues listed below before the manuscript is reconsidered for publication HESS.

Specific comments:

Comment: P7129 L27: Series model is more robust in case of SPARES but not in case of TSEB so this statement should be more precise.

Reply: Agreed, we'll specify we refer only to SPARSE in that statement.

Comment: P7130 L2: Should "globally" be "generally"?

Reply: Yes

Comment: P7131 L11-12: Dual source energy balance models allow deriving of both composite and component (vegetation and soil) water stress, not just the latter.

Reply: Indeed, though we hardly speak of "water stress" for the soil. Moreover, practical applications focus in general on the vegetation water stress evaluation.

Comment: P7131 L15-16: Even though there is currently no operational satellite with dual-view land surface temperature (LST) observations, the soon to be launched Sentinel-3 mission will have such capability (Donlon et al., 2012). This might be worth mentioning.

Reply: Yes, this will be mentioned, although the resolution won't be compatible with most agricultural plots.

Comment: P7132 L18-19: Provide reference for the study which introduced incremental decrease of transpiration efficiency. Also what does bulk retrieval mean in this context?

Reply: The iterative procedure is mentioned along the net radiation improvement in Kustas et al. 1999 and is initially a way to solve for the unknowns Ts an Tc iteratively (Page 27: "Therefore an iteration procedure will compute LEC values below estimates given by Eq. (A.19) until values of TC and TS used in Eq. (A.1) agree with the measured TR(¢)"). The respective sentence will be modified to link both improvements. However, most papers refer to Kustas et al., 2004 for that aspect (Kustas, W. P., Norman, J. M., Shmugge, T. J., and Anderson, M.C.: Mapping surface energy fluxes with radiometric tempera- ture, (Chapter 7), in: Thermal remote sensing in land surface processes, edited by: Quattrocchi, D. A. and Luvall, J. C., 205–253, Boca Raton, Florida: CRC Press, 2004).

The following sentence in brackets ("bulk retrieval") is unnecessary and will be suppressed.

Comment: P7133 L2-3: It should be made more clear "classical resistance scheme" refers to Penman-Monteith formulation and that this formulation (as well as Priestley-Taylor equation) are used just to obtain the first guess of plant transpiration.

Reply: OK

Comment: P7134 L1-3: I am not sure how T can be above the potential level since it is initially assumed to be at potential level and later can be reduced if the model doesn't obtain plausible results (i.e. E < 0) but is never increased.

Reply: It can be above the potential level when there is a strong "micro-oasis" effect, i.e. a strong coupling between the soil and the vegetation through conditions at aerodynamic level (stability correction notably): maximum transpiration for a plant surrounded by very dry bare soil is increased above the potential transpiration rate as computed in a fully wet environment. This coupling might be excessive and a potential transpiration of a wet environment is an interesting baseline to assess excess in this coupling. We agree that this aspect is important and a paragraph discussing the reason for the existence of T above potential levels as well as the reasons to use (or not) the potential boundaries will be added in a revised version.

Comment: P7134 L15-16: The first guess assumptions of the TSEB model are not tested in this study since section 3 deals only with SPARSE model. It would be interesting to evaluate the performance of the original TSEB formulations in retrieving the transpiration and evaporation efficiencies. Possibly it could be done by running SPARSE in prescribed mode, then using the resulting temperature as input to TSEB model and estimating the efficiencies by dividing LE_s and LE_v by their respective potential values.

Reply: This could be interesting, but then it would not be possible to evaluate whether retrieved efficiencies (simulated using a combination of SPARSE and TSEB) are different to the prescribed ones (simulated by SPARSE) because of the differences between SPARSE and TSEB, or only due to the TSEB algorithm.

Comment: P7134 L21 – P7135 L2: It would be more clear if the order of the equations presented here corresponded to the order in which those equations are introduced in sections 2.1.1 and 2.1.2 and mentioned on P7144 L5-6 (i.e. latent heat flux equations, followed by energy budget of soil and vegetation and finally relating radiative surface temperature to the temperatures of soil and vegetation).

Reply: Agreed, this will be changed accordingly.

Comment: P7137 L15-16: More details of the iterative procedure should be given. This is its only mention in the whole manuscript.

Reply: This is an alternative version only, its mention will be suppressed for the sake of clarity.

Comment: P7139 L17: How is R_atm obtained in this study? Was it measured (there is no mention of that in section 4.1), estimated from T_a or obtained in another way?

Reply: R_atm was estimated from T_a (Brutsaert clear sky R_atm equation will be provided).

Comment: P7140 L4: T_rad is often observed from angles other than nadir and becomes T_rad(theta) where theta is the view zenith angle. How is the view zenith angle ac- counted for in eq. 17? In appendix A2 there is a vegetation cover fraction (f_c) parameter but there is no explanation of how it is derived and I couldn't see any parameter taking theta into account.

Reply: Yes, although here all directional quantities (fc and T_rad) are obtained at nadir, we'll refer to classical equations to extend the model's application to different angles and provide the relationship between cover fraction and LAI.

Comment: P7141 L5-L9: Why are the stability correction factors not estimated separately if T_0s and T_0v are known?

Reply: This is explained P7131 L28-P7132 L12: vegetation and soil patches are linked, liked in TSEB, only though their common stability conditions with a common Surface Boundary Layer.

Comment: In appendix A1 z_om,s is already estimated and d could also be estimated thus r_a and Richardson number could also be estimated separately for soil and vegetation. What would be the expected effect of estimating r_a,s and r_a,v separately?

Reply: Again, cf. P7131 L28-P7132 L12: this would mean that there are two SBLs above the soil and the vegetation, which, given the size of the respective areas, is not realistic.

Comment: P7141 L12: Again, how is f_c estimated.

Reply: The corresponding equation will be included (classical Beer Lambert law).

Comment: P7141 L15-18: The "patch" representation of SPARSE model consists of two independent flux networks (one for vegetation and one for soil) which are combined using the fraction of sub-pixel the source of each flux occupies. In this approach the fluxes represent current densities if the resistance networks are considered in electrical terms (Sanchez et al. 2008). In the "parallel" TSEB implementation the interaction between the canopy and soil fluxes is still minimal but the two component fluxes are added up to obtain the total flux. This implies that the fluxes are treated as currents in electronic networks since currents are additive when two parallel branches meet. Therefore, even though both approaches ("patch" and "parallel") are correct based on the assumption they make, they are not directly comparable and the interchangeable use of "patch" and "parallel" terms when describing SPARSE might be confusing when the "parallel" TSEB term is also used in the manuscript. Therefore the difference between the two approaches should be clearly described and taken into account when analysing TSEB and SPARSE model results.

Reply: We're not sure to fully understand this comment. "patch" and "layer" approaches (i.e. the way the soil-plant-atmosphere interactions are described schematically) are fully redefined in Lhomme et al. 2012, while "series" and "parallel" refer to terminologies well known to most readers and correspond to the electric analog used to describe the turbulent fluxes in the respective approaches: "patch" and "layer" refer to the level of interaction between the soil and the vegetation, while "series" and "parallel" refer to its translation in an algorithm. In the Introduction section, we start with the "patch" and "layer" approaches (and its schematic) to introduce the "series" and "parallel" versions that are based on those approaches. Later on in the manuscript, we refer only to "series" and "parallel" versions and do not use the terms "patch" or "layer" interchangeably to describe them since by then they are fully described. In particular, the way individual fluxes are summed to obtain the totals is given in eqs 5, 6, 12, 25, 26 and 29.

Comment: P7147 L28: In the figure the indicated efficiency is 0.6

Reply: Yes, to be corrected.

P7148 – Section 3: What would be the effect of incrementally reducing B_v and re- running the model in case of negative evaporation instead of setting B_s immediately to 0? You mention this technique as an improvement to original TSEB on P7132 P18-19 so why not implement it in SPARSE. Also, the performance of TSEB should also be assessed in this section (see comment related to P7134 L15-16).

Reply: In SPARSE, all variables are solved simultaneously, including Ts and Tv, therefore the iterative procedure to reduce B_v to reach convergence is not useful.

Comment: P7149 L3: Was LST acquired from nadir? If it was acquired at a different view zenith angle then how was this taken into account?

Reply: It was acquired at nadir, we'll specify it P7149 L4.

Comment: P7149 L8: Does residual method mean that residual energy was assigned to LE or H? Also maybe consider the approach from the study of Ingwersen et al. (2015).

Reply: In this experiment, there was clearly a problem with the fast response psychrometer, but we'll keep your suggestion in mind for closure analysis in the future evaluations of SPARSE.

Comment: P7149 L18-19: In Section 4.2 it is often not clear which models are being discussed. The original TSEB model implementations should be listed here and not only in the caption of Table 1. Why are different references used for the parallel and series versions of TSEB? Cammalleri et al. (2010) were looking at different representations of wind profile in the canopy but did not present any modifications to the actual TSEB formulations. So is one of the wind profile models presented in Cammalleri et al. (2010) used in the series version of TSEB but not in the parallel? What would be the justification for that and which wind profile model was used? Also implementation and parameterization details of the TSEB model should be clearly stated. For example, what default value of alpha_PT was used, was clumping factor used, was fraction of vegetation that is green (f_g) set to 1 or varied during senescence. In particular it would be interesting to look at the effects of varying or not varying f_g estimate in the TSEB model as it has a large effect on the estimated fluxes and is available in this study since hemispherical photography and destructive sampling were used to estimate LAI.

Reply: We've used the TSEB series and parallel versions of Kustas et al., (1999), i.e. the Goudriaan (1977) wind profile. We mentioned Cammalleri et al. (2010) because it is a more recent and complete description of the series model including choices of parameter default values for the resistance ras. it is therefore not necessary to refer to it if parameter values are specified and we'll keep the Kustas et al. 1999 reference for the model and refer to Cammalleri et al. (2010) for some of the parameters. For instance, Alpha_PT was set to its classical value 1.26, f_g was calculated according to green and total LAI but we kept the value of one which provided the best performances with TSEB. All this will be explicit in the model application over both sites.

Comment: P7150 L1: If the model is designed to be routinely applied with remote sensing data then it should be explained how the view zenith angle of the LST observations is taken into account.

Reply: Yes, cf supra.

Comment: P7150 L5-6: More thorough statistical analysis should be performed and presented in Table 1 (and Table 2).

Reply: Yes, cf. supra.

Comment: The effect of bounding LE estimates should be explored by looking not only at RMSE but also other statistical parameters, for example (but not necessarily limited to) bias, correlation or coefficient of variation. During what conditions do the outputs have to be bound? Is it mainly during plant growth stage or senescence?

Reply: It is mostly important in selected dates throughout the growing stage mostly, we'll provide more details about when E and T are above the potential rates and the relative position of both total rates with the observations in the results and the discussion.

Comment: P7150 L6-13: The description in this paragraph does not reflect the results presented in Table 1. For example, the RMSE of parallel and series versions of SPARSE are not "almost similar" as stated on L7 (see difference between non-bounded models in irrigated wheat),

Reply: We agree, but since the model is uncalibrated differences must be described with special care. We can change "almost similar" to "of similar order of magnitudes".

Comment: The reduction in RMSE stated on L9 is only true for SPARSE model and the statements on L9-13 are only true for bounded versions of the models. I would suggest rewriting this paragraph (after further statistical measures have been included in Table 1) and being more clear about which version of the model (SPARSE/TSEB, parallel/series, bounded/unbounded) is being discussed.

Reply: Agreed.

Comment: P7150 L14-15: Are any fluxes recalculated after LE_s and LE_v are bounded? If not, then wouldn't the estimates for H, G and Rn be the same for bounded and unbounded case?

Reply: Yes, for consistency, all fluxes are set to the corresponding bounding energy balance components if LEs or LEv is bounded. This will be mentioned.

Comment: P7150 L18: Be more clear in what exactly is consistent with Li et al. (2005) and Morillas et al. (2013). What did those studies show?

Reply: Those studies indicate that the series model tend to provide more robust and slightly better results, but that the parallel model does not always show significantly worse statistical criteria. This will be made explicit.

Comment: P7151 L20-23: On L20, should it be "little to no stress" instead of "little to no evaporation"? Furthermore in top-right Figure 3 (low evaporation efficiency) the most accurate retrieval of evapotranspiration efficiency for parallel SPARSE model is for high transpiration efficiencies (small vegetation stress values) which is contradictory with the statement on L22-23.

Reply: We're referring to evaporation only.

Comment: P7152 L14: How is theta_sat estimated and what is its value?

Reply: It is obtained in-situ (values will be given).

Comment: P7153 L5-9: Can the temporal pattern of agreement be explained by the patch/layer representations present in parallel/series SPARSE model versions being more appropriate at different stages of vegetation development?

Reply: It was not possible to relate those patterns for sure to specificities of both model representations.

Comment: P7154 L3-5: Was this finding presented in the results section? P7154 L5-6: I do not understand this sentence.

Reply: This refers to section 3 findings only (it will be specified).

Comment: P7154 L17: It should be 0.2 not 0.1.

Reply: Agreed

Comment: P7154 L27-28: In the rainfed field senescence began around DOY 80 and vegetation was fully brown by around DOY 120 (Fig 3). Looking at Fig 10 the agreement between the soil evaporation efficiencies modelled with SPARSE and soil moisture data agree very well between DOY 120 and DOY 160. Therefore, at least at this site SPARSE models seems to be performing well over "low or senescent vegetation" (although be- tween DOY 80 and DOY 120 the agreement is not so good). This is not fully consistent with statement on L27-28.

Reply: As pointed out, there is a mismatch between observed and simulated soil efficiencies before DOY120 and after DOY160, on the basis of which this general comment is drawn. However, the good performance between DOY 120 and DOY160 is mentioned P7153 L7. On that basis the previous statement is softened in P7154 L28-29.

Comment: P7156 L4-5: How are d and z_om estimated?

Reply: Equations will be provided (rule of the thumb).

Comment: Table 1: Add more statistical measures as mentioned in comment P7150 L5-6.

Reply: OK

Comment: Table 2: Add more statistical measures to be consistent with Table 1. Also, why was the series TSEB model not included in this table?

Reply: Bias and TSEB series performances will be added

Comment: Table A1: There are some mistakes present in this table. For example r_a, r_as, r_av and r_w have the same definition. Double check the other parameters as well.

Reply: Yes thanks

Comment: Figure 2: This figure is too complicated. I would remove the input data for synthetic test and also the synthetic test branch (broken line) to improve clarity.

Reply: This line is useful for section 3, but could be dropped.

Comment: Figure 5: The shown plots appear to be for green LAI. It would be good to also show total LAI and possibly f_g, especially if the effect of varying f_g in the TSEB model during senescence is investigated as suggested in comment P7149 L18-19.

Reply: OK

Comment: Figures 7 and 9: The legend captions should be fixed.

Reply: You mean extended and not referring to 6 and 8 ?