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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.

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Comment:

Page 12 Eq. (7) & (8): How are Ts and Tv determined and is the view angle of the radiometer accommodated? I can't find an expression in the text that describes this.

Reply:

Ts and Tv are solutions of the inversion of the 5 model equations including the two com-

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ponent energy budgets. This is mentioned in only two places in the model's presentation and should probably indeed be made more explicit (P7134 L19-21: "The SPARSE model computes the equilibrium surface temperatures of the soil and the vegetation at the meteorological time step as a signature of the energy budget equations of each source. Five main equations are solved simultaneously.", and P7143 L5-7: "The system of five equations to be solved simultaneously consists in Eqs. (5), (6),(13), (14) and (17) for the series model, and Eqs. (25), (26), (30), (31) and (33) for the parallel model." Then in prescribed mode L12-13 "In that case the system is solved for the following unknowns: Trad,Ts,Tv,e0 and T0" as well as in retrieval mode P7144 L9-10 "the system is solved for unknown Les [or Lev], Ts, Tv, e0 and T0").

In order to improve the clarity of the model's description, we'll add explicitly the symbols Ts and Tv in the model's introduction (beginning of section 2.1), and stress at the beginning of Section 2.2 that by solving this system of 5 equations 5 unknowns are solved, including T0, Ts and Tv for all model runs.

We agree that we should also include information about the radiometer view-angle (nadir) and an equation to use Trad from a different view angle (this is also suggested by Reviewer 1) following the view angle dependent vegetation fraction cover.

Comment:

Page 15 Eq. (24): What is the physical basis for simply weighting the aerodynamic temperature estimated for the soil and vegetation? In addition, have two aerodynamic temperatures for the soil-canopy system is not physically plausible at the canopy/micrometeorological scale-this needs some explanation/discussion.

Reply:

The parallel version is built on the same theoretical framework than TSEB (same total aerodynamic resistance, electrical analogy and way of weighting the component fluxes) while the surface to aerodynamic level aerodynamic resistances are different.

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The conditions at the aerodynamic level are usually not looked at in the TSEB parallel version, since it is not required in the algorithm. Here, in order to provide a comprehensive comparison with the series model, we've made explicit the temperatures of the nodes at the aerodynamic level between both resistances of each electrical branch. Although there is a physical basis for the weighting of the temperatures of each branch (described below and in the Supplement material), it is not necessary to the model's description and will be removed in the revised manuscript.

The existence of two aerodynamic temperatures reveals a slight departure of the main temperature profile from the classical profile in the parallel model. It is discussed in P7135 L7-21: "In TSEB, both soil and vegetation patches share a common surface boundary layer (and therefore the same aerodynamic resistance from the aerodynamic level to the reference level) but the patch representation allows defining different aerodynamic temperatures at the aerodynamic level over the soil and the vegetation. As pointed out by Lhomme et al. (2012), the patch representation should in theory only apply to patches large enough to develop different surface boundary layers, e.g. fallow fields amongst wetter and taller vegetated areas rather than bare soil patches even few meters large. Here, we keep the TSEB assumption for our parallel version and assume that the wind profile in the canopy and above the soil surface are identical in both versions. The main difference lies therefore in the lateral gradient in aerodynamic temperature: in the series version, a single aerodynamic temperature is computed, while in the parallel version two different aerodynamic temperatures are computed above the soil and the canopy, allowing a small departure of the temperature profiles above the soil and the canopy level from the standard mean profile."

In TSEB, the stability correction uses total H (a weighted fraction of individual fluxes from the soil and the vegetation). In SPARSE, we use the Richardson number which requires an aerodynamic temperature T0 computed also from the total sensible heat H=rocp*(T0-Ta)/ra.

We can demonstrate that T0 retrieved using total H is the same as a weighted average

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of the temperatures at the nodes of each branch at aerodynamic level (demonstration is provided in the Supplement material of this reply).

We agree with Reviewer 2 that this is somewhat confusing. Since computing T0s and T0v is not compulsory, we will suppress those notations throughout the paper and simplify the parallel model presentation by relating T0 of the parallel approach to total H (eq 26) though T0=Ta+raH/rocp. Figure 1 will be modified accordingly (cf. Supplement).

Comment:

Page 17 Lines 5-9. It's unclear to me how the iterative procedure works more clarification is needed.

Reply:

This alternative way of solving the system of equations is not necessary and will be removed.

Comment:

Page 18 Lines 21-24. The discussion of realistic bounds for LEx based on Su (2002) seems to be a critical part of the modeling approach, but is not explained in any detail. Some further discussion is needed.

Bounding is indeed an important final processing step, and its implementation as well as its justification will be expanded at the end of Section 2.2 and discussed in more details in Section 5. It uses the potential rates computed by the prescribed mode:

P7143 L20-22: "[the prescribed mode] is also implemented as a final step in the retrieval mode to provide theoretical limits corresponding to maximum reachable levels of sensible heat (fully stressed conditions) or latent heat (potential conditions) for each component (the soil and the vegetation)"

and

P7144 L20-22: "Finally, in order to ensure that LEx outputs are within realistic bounds, LEx values are limited by the evapotranspiration components in potential conditions LEx(betas=1, betav=1).

We'll precise there that those latter LEx estimates are provided using the prescribed mode.

The reference to Su (2002) is not meant to provide a bounding estimate but a reference to an energy balance model which also bounds a posteriori its output LE flux. Indeed, the single source model SEBS derives LE through the one-source energy balance equation and bounds LE by a maximum potential rate LEwet. It will be clarified in Section 2.2 that SPARSE does not use Su's (2002) LEwet but bounds LEs and LEv by their respective potential rates computes by SPARSE in prescribed conditions. Lines 21-24 might be confusing and will be rephrased in order to clear any misunderstanding. A reference to the SPARSE schematic (Figure 2) will also be inserted here to visualize the algorithm.

The justification and rationale of this a posteriori bounding will be also expanded and discussed in the discussion section as recommended by reviewer 1 (see reply to Reviewer 1 comments).

Comment:

Page 19 Section 3.1/3.2. It's not clear to me if this simulation experiment/synthetic test is truly independent of the model structure. Why didn't the authors use a more complex SVAT that generates Trad, Ts and Tv and component fluxes to compare with SPARSE? Justification for this synthetic test needs to be made.

Reply:

The synthetic test illustrates the theoretical limit of the 2 underlying assumptions of SPARSE, which are also the underlying assumptions of most TSEB versions. It builds on the existence of both modes (prescribed and retrieval) of SPARSE to test the capacity of the model to retrieve correctly the water status of both sources (represented in SPARSE by their respective efficiencies) when they are known. It is important to keep the same model and the same parameters for this test, because otherwise it would be impossible to know whether inconsistencies between the prescribed and the retrieved efficiencies are due to the model structure or represent the theoretical limit of the retrieval (absence of bijective relationships) due to its assumptions. This will be underlined in a revised manuscript.

As recommended also by Reviewer 1, the findings of this test and their application to TSEB will be discussed in the discussion Section 5.

Comment:

Page 23 Line 5. What was the closure values achieved by the eddy covariance system and what was done with the missing energy flux?

For the rainfed wheat site, there was clearly a problem with the fast response psychrometer with a closure of 60 %. Thus for that site the closure was forced to LEcorrected=Rn-H-G. For the irrigated site, the half hourly closure was of the order of 80%: H+LE= 0.78 * (Rn-G) with a correlation coefficient of 0.8. For this site closure was achieved with the conservation of the bowen ratio H/LE: LEcorrected=(Rn-G)/(1+bowen).

Those elements will be specified in the revised manuscript.

Page 23 Lines 26-27. The minimum stomatal resistance was set to 100 s/m, so what would happen if 50 m/s was chosen? This is certainly plausible for cereal crops.

There is indeed a wide array of Rsmin values published for wheat crops in the literature, with values ranging roughly from 50 to 150 s/m. The value of 100 s/m, although somewhat arbitrary, lies in the middle of this range and is consistent wih values found for wheat crops growing in mildly water stressed climates. It corresponds to the value obtained for the same Moroccan region for a study on the previous agricultural season

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when calibrating a SVAT model (Gentine et al., 2007, page 26). This reference will be added to make the choice less arbitrary.

Also, in case of using Rsmin=50 s/m, RMSE on latent heat flux increases by 4 W/m2 in bounded conditions for the rainfed wheat site (62 W/m2) and 13 W/m2 for the irrigated wheat site (66 W/m2) for the series version. For the parallel model it increases by 12 W/m2 (82 W/m2) and 8 W/m2 (74 W/m2), respectively. This short sensitivity analysis will be included in the discussion section.

Comment:

Page 24 Lines 5-19. There is little explanation again on how the bounded versus unbounded model results were determined.

Reply:

The corresponding paragraph will be expanded. The unbounded model results are obtained by running the SPARSE model in retrieval conditions only, i.e. by producing output fluxes from known radiative surface temperature observations without checking whether the resulting rates are above or below the corresponding potential latent heat fluxes, and the bounded model results are obtained after limiting the latent heat flux produced by the unbounded model runs by the corresponding potential latent heat flux rates obtained with the prescribed potential conditions model run.

Comment:

Also Tables 1 and 2 should include more statistics, such as mean of observed and modeled, also the mean absolute error statistic and a percentage difference.

Reply:

The various biases will be added, as requested by both Reviewer 1 and 2. Mean of observed and modeled fluxes are useful in the case of applications to individual surface temperature images, but represent a wide range of situations over the whole season,

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it would be difficult to extract additional information from these values if biases are mentioned.

Comment:

Moreover, I'm confused that the series TSEB model is based on a citation from Cammalleri et al (2010) while the authors use the citation for TSEB parallel version of Kustas and Norman (1999), even though I believe a series version is also developed in that paper. There needs to be an explanation as to what the differences are in TSEB formulations used in the 2 papers.

Cammalleri et al (2010) specify a single value for the Priestly and Taylor (PT) coefficient, contrarily to Kustas et al., 1999, this is why we've selected the latter reference. However, we agree with Reviewer 2 that both serie and parallel TSEB versions appear in Kustas et al. 1999. We'll mention the fact that in Table 1 TSEB is run with a nominal (1.26) value for the PT coefficient (see also the Reply toReveiwer 1 comments) and use the single reference Kustas et al., 1999 for both model versions.

Comment:

Page 28 Lines 5-8. So is the SPARSE model considered more reliable than the TSEB based on Table 1 and 2 results?

TSEB and SPARSE are run with default values corresponding to typical vegetation classes, as it is the case for routine applications of remote sensing energy balance models to lead to spatially distributed evapotranspiration products. They were not calibrated against in-situ data. It is thus difficult to conclude on their absolute respective reliability. We compare their relative performance with default values on 2 datasets only. We do not claim that SPARSE is more reliable than TSEB, but find that SPARSE with default values of the parameters performs better TSEB for those 2 datasets and might be more reliable in semi-arid conditions since it takes into account the characteristics of semi-arid environments as advised by Colaizzi et al., (2012). This will be further commented in the discussion section.

Comment:

In larger scale applications, should the authors consider a lack of having reliable vapor pressure data and what impact this may have on models such as SPARSE which require this input?

Reply:

This a very valid point which will be mentioned in the discussion. It is true that TSEB does not require vapor pressure data, and can avoid the need of air temperature data through the ALEXI/disALEXI system. However, TSEB requires wind speed data which is hard to distribute accurately in space and time, and is usually obtained from reanalysis datasets.

At large scale, reanalysis data includes vapor pressure, air temperature and wind speed, which can be used to run SPARSE. At local scale, such as irrigated perimeters, there is an increasing availability of agrometeorological data.

Impact of uncertainty on available meteorological data (reanalysis or RS products vs local met station network) on SPARSE model performance will be assessed in the future. This discussion will enrich the last section and we thank Reviewer 2 for bringing it up.

Reference:

Gentine, P., Entekhabi, D., Chehbouni, A., Boulet, G., Duchemin, B., 2007. Analysis of evaporative fraction diurnal behaviour. Agricultural and Forest Meteorology, 143(1-2): 13-29.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C3967/2015/hessd-12-C3967-2015-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 7127, 2015.

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