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Avignon, 20 April 2015,

Dear Editor,

We would like to thank you and the two anonymous referees for the review of our revised paper. We have addressed the reviewer comments and made the requested modifications to the manuscript. By building on the remarks of referee-1, we simplified and clarified the structure of the results. Besides, we conducted the requested sensitivity analysis by running additional simulations. This led to relevant results that help to understand how the investigated soil parameters influence the simulation of evapotranspiration and its soil/vegetation component over the crop succession.
Below, we provide detailed answers to each of the referee's comment. Changes in the manuscript are highlighted in gren.

A/ Response to referee-1

0/« The structure is still unclear and redundant. Focusing on soil key parameters (θs ***,*** θ_{fc}***,*** θ_{wp} ***), the results should be thoroughly re-organized in a simple and clear structure. I suggest to implement only 3 simulation cases. First two with constant parameters in time (***θs ***,*** θ_{fc}***,*** θ_{wp} ***) retrieved either by PTF or LAB methods. The third case exploits the FIELD measurements in order to obtain time-variable soil parameters (*** θ_{fc}***,*** θ_{wp}).

We agree. We re-organized the analysis and re-stated the objectives of in Introduction. We reduced the number of simulation cases. We provided clear rationale for each simulation case in Section 4.1 and 4.2. We re-organized the results and the discussion in a more simple and clearer structure. We also improve the naming of simulations by using the explicit terms (PTF, FIELD and LAB) given by referee-1.

This work addresses now the following aspects:

- The impact of crop rotation on the dynamics of ET and root-zone soil moisture.
- The overall performances of the ISBA-A-gs simulations achieved with the standard soil and vegetation parameters over a 12-yr Mediterranean crop succession.
- The relative influence of each soil parameter on the simulation of ET and its soil/vegetation components, over a crop succession through a sensitivity analysis.
- The impact of the method used to retrieve the soil parameters on simulated ET. We test pedotransfer function, laboratory measurement and field monitoring methods. While

constant values in time of the soil parameters are generally used in LSM, we assess whether the representation of the variations in time of the wilting point and the maximum rooting depth over the crop succession improves the simulation of ET.

- The propagation of uncertainties in the soil parameters on ET predictions. We quantified it through a Monte-Carlo analysis and we compared it with the uncertainties triggered by the mesophyll conductance which is a key above-ground vegetation parameter involved in the stomatal conductance.

In discussion, we explain how the investigated soil parameters influence the simulation of ET, we discuss the sources of uncertainties related to each soil parameter retrieval method and we put into perspective the model performances by quantifying the uncertainties in measured ET.

While the new analysis mainly focuses on the soil moisture at saturation (θ_s), the soil moisture at field capacity (θ_{fc}) and the soil moisture at wilting point (θ_{wp}), as suggested by referee-1, we also address the impact of using crop-dependent rooting depth ($Z_{root\text{-}zone}$). Indeed, both the wilting point and the rooting depth are crop-dependent parameters (Wetzel et al., 1987; Verhoef and Egea, (2014)) which can lead to variations in time of the root-zone water reservoir over the crop succession (see Table 3 in the revised manuscript). Table 3 shows that the variations in time of θ_{fc} are much lower than for θ_{wp} and $Z_{root\text{-}zone}$. We thus decided to investigate the impact of using time-variable θ_{wp} and $Z_{root\text{-}zone}$ parameters over the crop succession on ET simulations and we assume constant in time θ_{fc}.

We implemented the following simulation cases:

- *PTF*: This is the standard simulation achieved with θ_s, θ_{wp} and θ_{fc} derived from the ISBA pedotransfer functions and $Z_{root\text{-}zone}$ derived from the ECOCLIMAP-II surface parameter.
- *LAB*: θ_{fc} and θ_{wp} are derived from laboratory methods.We removed the case achieved with θ_{fc} derived from a matric potential h=-3.3m . We kept θ_{fc} retrieved from an hydraulic conductivity of K=0.1 mm d^{-1} to be consistent with the pedotransfer function used in the standard implementation of the model, as requested by referee-1.
- *FIELD*: θ_{fc}, θ_{wp} are derived from the monitoring of field soil moisture measurements. We distinguish between
  - *FIELD$_{cst}$* uses constant in time values of θ_{fc}, θ_{wp} and $Z_{root\text{-}zone}$. It uses their average values computed over the 12-yr crop succession.
  - *FIELD$_{var}$* also uses the average value of θ_{fc}. But it uses time-variable values of θ_{wp} and $Z_{root\text{-}zone}$ which have been estimated for each crop cycle (see Table 3).

1) “constant parameters *(*θs , θ_{fc}*,* θ_{wp} *)* in time: run a sensitivity analysis to see the effect (and uncertainty) on ET for realistic ranges. Which soil parameter influences ET significantly? Why? Then run two case- scenarios with constant parameters: PTF and LAB. For the LAB scenario I would consider FC as deriving from K=0.1 mm/d (as in the standard-PTF method) and delete FC as deriving from h=-3.3 m.”

We agree and we incorporated a sensitivity analysis to provide a quantitative understanding of the relative impact of θ_s, θ_{fc}, θ_{wp} and $Z_{root\text{-}zone}$ on ET and ET soil/vegetation partitioning over the crop succession. The analysis is conducted with the *PTF* simulation case. The parameters are tested one by one. We explore similar variations in θ_s, θ_{fc}, θ_{wp} around their standard values used in *PTF* (+/-0.015, +/-0.03). We aslo test the sensitivity of errors in these parameters by testing their in situ values used in the *FIELD$_{cst}$* experiment. We do not consider variations in $Z_{root\text{-}zone}$. If the latter lead to similar variations in MaxAWC (Eq. (1)) than those triggered by θ_{wp}, the impact on ET will be similar than the impact of θ_{wp}. In this work a 0.25 m variation in $Z_{root-zone}$ leads to similar increase in MaxAWC and transpiration than a 0.015 m^3 m^{-3} decrease in θ_{wp}.

The analysis shows that evapotranspiration mainly results from the soil evaporation when it is simulated over a succession of crop cycles and inter-crop periods for Mediterranean croplands. This results in a high sensitivity of simulated evapotranspiration to the soil moisture at field capacity and the soil moisture at saturation which both influence the simulation of soil evaporation. Field capacity was proved to be the most influencing parameter on the simulation of evapotranspiration over the crop succession due to its impact on both transpiration and soil evaporation.

We do not explore the interactions between parameters. A simple analysis is sufficient to provide key insights on which soil parameter influences ET significantly and why. Besides, conducting a comprehensive sensitivity analysis representing the interactions between parameters and implementing a proper numerical experiment plan would have required too important numerical effort (see the remark at the end of this document). The interactions between the investigated soil parameters are qualitatively investigated by comparing the distinct simulation cases (PTF versus FIELD and LAB versus FIELD).
Answer to the rest of the comment is given above.

2) "the model can be then improved by using FIELD parameters and test associated uncertainty."

Both $FIELD_{cst}$ and $FIELD_{var}$ simulations are needed for the analysis. $FIELD_{cst}$ is used to explore the impact of using field estimates of θ_{fc} and θ_{wp} compared to LAB and PTF retrievals. By comparing $FIELD_{cst}$ and $FIELD_{var}$, we investigate whether the use of time-variable values of θ_{wp} and $Z_{root-zone}$ over the crop succession improves the simulation of ET compared to the use of temporal average values.

The uncertainty analysis using Monte-Carlo analysis has been implemented on the $FIELD_{cst}$ case and incorporated in the previous revision. We did not modify this part.

3) **"the impact of the vegetation parameter (mesophyll conductance) is still not clear. Root depth is a vegetation parameter as well!"**

We agree with referee-1 that $Z_{root-zone}$ is a below-ground vegetation parameter. But it has similar role as θ_{fc} and θ_{wp} in the definition of the root-zone water stock (MaxAWC, Eq. (1))which drives the simulation of transpiration. For sake of simplicity, the term "soil parameters" used in the text also comprises $Z_{root-zone}$.
We performed a Monte-Carlo analysis to quantify the propagation of uncertainties in the soil parameters on simulated ET. To assess the relative importance of the impact of uncertainties in the soil parameters, we chose to compare it with the propagation of uncertainties in the mesophyll conductance which is a key above-ground vegetation parameter involved in the simulation of the plant transpiration (Calvet et al., 2012). This was a request of referee-2 in the previous review. We better justifies this choice in the text (Section 4.3).

4)"Please, delete all qualitative discussions on structural model errors (Section 6.2) that require deeper analysis"

We agree and we deleted this Section. We used some ideas of this Section to give perspective to this work in Conclusion.

5)”**Section 2.2 ("Field measurements") is still unclear. A new figure showing map, transect, positions, legend etc. would be optimal in order to better understand the methodology. It is still unclear how many soil profiles? What's their inter-distance? How large is the experimental field? How about the measurements on the plants? The crop characteristics were regularly measured on a single crop or on different crops? Which techniques have been used for LAI, height, biomass etc? Where is the weather station?”**

We improved Section 2.2 by giving the requested additional information on the measurements. We incorporated a new Figure 2 which shows a map of the site with the location of the micrometeorological, soil and vegetation measurements.

Neutron probe was used to retrieve volumetric soil moisture over 3 (0–1.90 m) soil profiles with a vertical resolution of 10 cm. To implement the measurements, 3 neutron probe access tubes, spaced 40 m apart, were installed along a north-south transect located at the centre of the field.

The field size is 1.9 ha.

Plant characteristics have been monitored over all the crop cycles since 2001. Canopy height is measured every 2 weeks using a meter tape. Leaf Area Index and plant biomass were measured at the key crop phenological stages (5 to 6 measurements per crop cycle) using destructive methods. LAI was retrieved using planimeter technique and biomass was measured from precision scale device. Plant characteristics were measured at 4 locations of the field (Fig. 2) to sample the within field variability. Average values were recorded. Vegetation height was linearly interpolated on a daily basis. Daily interpolation of LAI was achieved using a functional relationship between LAI and the sum of degree-days (Duveiller et al., 2011).

A micro-meteorological station is located at the centre of the field and provides measurement of the needed climate variables: air temperature and humidity, pressure, wind speed. A standard meteorological station is located over the same site (200m apart from the centre of the field) and provides cumulative rainfall and backup for the climate variables. Net radiation (RN) was computed from shortwave and longwave upwelling and downwelling radiations measured from a net radiometer device located at the centre of the field.

We provide these information in the text. All the detailed protocols (particularly for plant measurempents) will be given in the site website which is being updated. We plan to apply for a DOI for this dataset and if we obtain it prior to the publication of this paper, we will add it.

Minor comments

- **“The title should be changed as " Evaluation of land surface model simulations of evapotranspiration over a 12 year crop succession: impact of the soil hydraulic and vegetation properties "**

  We agree and we modified the title

- **“Table 1 is not a Table but Nomenclature or Appendix 1”**

  We moved Table 1 to Appendices

- **“The Table and Figure captions are too long. Please reduce words and descriptions that are already in the te**xt”

We reduced the captions to avoid redundancies with the text. This particularly concerns Fig. 4,5, 6

- **"Please add the dashed lines in the legend in Fig. 3 and Fig. 4. Add vertical bars too to split crop and intercrop seasons"**

  We tried to add the dashed lines which represent the transpiration, but with the new longer simulation names it leads to heavy legend. We prefer keeping the meaning of dashed line in the text. Vertical gray/white bars are already included in the Fig. 3 (old Fig. 2) and Fig. 8 .

B Response to referee-2

1/ « **The authors have made a lot improvement in the revised manuscript. But there are still some concerns. There is a confliction in the Line 44-49 description in the abstract, namely, if spatiotemporal variability of soil parameters causes substantial uncertainties in ET, why the temporal crop-varying soil parameters has little impact? «**

The investigated uncertainties in the soil parameters are more related to the use of effective field value for the soil parameters. We chose to represent the uncertainties in each parameter by the available information we have on their possible spatial and/or temporal variations at the field scale. Given our knowledge of field, we think that the tested variations are realistic enough.

Based on this estimate of the uncertainties in the soil parameters, we showed that the impact on ET can be large over a 12-year period. We think that the originality of the result lies in the propagation of the uncertainties over a long period of time.

We have corrected this confliction in the abstract and in the text. Based on these comments, we also discussed our estimate of uncertainties in the soil parameters (Section??)

2/ « **Secondly, in the manuscript no spatial variability of soil parameters is quantified by some mathematical methods. So this conclusion seems to be unreliable.**

We agree that the characterization of the field spatial variability requires the use of geostatistical methods (Garrigues et al., 2006[1]). This would require additional measurements and adapted protocols that are not currently available for this site. Given our knowledge of field, we think that the selected ranges of variations in the soil parameters are representative of the spatial variations in soil depth and soil structure

3/I doubt about the conclusion that stomatal conductance is less sensitive to ET than soil parameters. »

Based on the estimate of the variability of the mesophyll conductance found in literature (Calvet et al., 2000&2008), we found that uncertainties in the mesophyll conductance has a lower impact than uncertainties in the soil parameters over the 12-yr crop succession. This finding is consistent with

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1Garrigues, S., Allard, D., Baret, F., Weiss, M., 2006b. Influence of landscape spatial heterogeneity on the non linear estimation of leaf area index from moderate spatial resolution remote sensing data. *Remote Sensing of Environment, 105* (4), 286-298. DOI : 10.1016/j.rse.2006.07.013

Calvet et al., 2012 who showed that the root-zone water stock (Eq (1)) has a much larger influence on the ISBA simulation than the mesophyll conductance.

We added the following text in Section 6.2.3 to discuss these aspects raised by referee-2 :

"Our results depend on the assumptions made on the variability of the tested parameters. The selected ranges of variations in the soil parameters are representative of the spatial variations in soil depth and soil structure according to our knowledge of the field. However, the spatial variability of these parameters should be properly quantified using adequate spatial sampling protocols and geostatistic methods (Garrigues et al., 2006). Besides, the variations in the soil hydrodynamic parameters may be larger when the model is integrated at regional scale (Braud et al., 1995). Finally, other vegetation parameters (e.g. water stress parameters, Verhoef and Egea., (2014)) may be source of uncertainties and should be investigated in further works."

C/ Additional remarks

We performed consequent simulation efforts for the revision of the paper. The uncertainty analysis conducted for the first revision required 20 days of simulations. For the sensitivity analysis, we performed 15 additional runs. We hope that these substantial simulation efforts have improved the quality of the paper.