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Hydrology and Earth System Sciences Discussions

Interactive comment on "Integrating MODIS images in a water budget model for dynamic functioning and drought simulation of a Mediterranean forest in Tunisia" *by* H. Chakroun et al.

H. Chakroun et al.

hedia.chakroun@enit.rnu.tn

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Reponses to Referee#1 The authors thank the anonymous Referee#1 for his/her review of the manuscript and for his/her constructive comments that will help in the final version of the paper. We have provided answers to each point raised by the reviewer (designated as "C"); our response is designed as "R".

C1 : This paper discusses the use of LAI values derived from MODIS imagery for

improving a water budget model. Unfortunately, the paper only presents a very brief description of the model. A more elaborate discussion is necessary in order to understand its functioning.

R 1 : We will present a more elaborated explanation of model functioning in the revised version.

C2:Also the validation of the model at the study site is not demonstrated.

R2 : see R5

C3: I have problems with the 'framework for integrating remotely sensed LAI in a model'. Basically, what is done is that the original module in the model which calculates LAI from leaf biomass is replaced by the remotely sensed observation. I wouldn't call this a framework! A better (?) way may have been to assimilate the MODIS-LAI into the model? In this way, uncertainties in the RS-LAI could be accounted for when updating the model.

R3:What we mean by "Framework" is the stages for integrating dynamic vegetation driven by LAI-MODIS into the model. It is not related to any complex assimilation methods into the model, it rather encompasses steps of satellite images processing, including validation and calibration (see R4 for details about LAI-MODIS calibration).

C4 : The LAI derived from MODIS is hardly validated: this definitely forms a problem for interpreting the results of the study. Problems are reported, and some references are made to literature. However, a more in depth analysis is needed: how are the ground truth LAI values measured? Can one compare these with those of MODIS (due to spatial resolution).

R4: Ground measurements of LAI were based on homogeneous plots of vegetation (details of measurements method and statistics will be added to the revised version). Besides, we will add a comparison of these in situ measurements to a SPOT image taken at the same period (May-June 2006). This will allow to make a "ground truth" LAI

HESSD

9, C3639–C3646, 2012

map based jointly on measurements and a 20 m spatial resolution satellite image.

The issue of MODIS coarse resolution and validation to ground truth has been raised in the paper. Despite the 1km resolution of LAI-MODIS product, we showed that comparison of LAI ground measurements to LAI-MODIS for NDVI < 0.7 is quite acceptable (p6260, Line 27-28, P 6261, Line 1-5). However, the problem of validation of LAI-MODIS arises from highly overestimated values for high biomass pixels (NDVI > 0.7) limiting the use of this product. To overcome this, and as suggested in the discussion (P 6266, Line 21), we will perform in the revised version a correction of LAI-MODIS as follows : (1) Production of a "ground truth LAI map" from analysis of the relation between NDVI (from SPOT taken in June 2006) and measured LAI. This map is called LAI-SPOT. (2) Aggregation of LAI-SPOT from 20 m to the 1 km resolution (we call this image LAI-SPOT-AG) (3) Comparison pixel by pixel LAI_SPOT-AG to LAI_MODIS. (4) Calibration of LAI-MODIS images by LAI-SPOT-AG.

C5: How well do the model LAI values (calculated with the original model based on the leaf biomass) compare to the ground-based observations and to the MODIS LAI? Can you perform a statistical analysis to compare results? Where does the maximum value of LAI=2.5 come from? With respect to the model results (section 4), results are hardly validated.

R5: We have not considered to compare water budget results from the original SIERRA model (based on self-equilibrated leaf biomass) to results from our method (replacing this module by integrated remote sensing data of LAI) in order to avoid any interpretation of results variation that could be attributed to deviation between LAI model estimation and satellite LAI. For example in Brut et al. (2009) a whole study was dedicated to this issue discussing both uncertainties in the models and in satellite products. This is beyond the scope of our study since our objective was to detect the effect of inter-annual variability of LAI on water budget and on drought monitoring just by the use of satellite products; this was achieved by comparing water budget simulation results in two cases : LAI constant (e.g. mean of LAI-MODIS during the simulation year) and

HESSD

9, C3639–C3646, 2012

weekly LAI-MODIS.

Validation issue : we agree that validation issue is crucial for any modelisation. As mentioned in P6267-Line 22, the site begins to be equipped by a ground station of transpiration based on sap flow densities measurements during a complete vegetative season. In the revised version we will include a comparison of simulated results to measured actual evapotranspiration for 2009 season; this will allow to estimate deviation between simulations and ground measurements. That said, regarding our study objectives (2) (P 6255, Line 15 : Despite the coarse spatial resolution of LAI-MODIS (1 km), what kind of improvements of water budget modelisation and drought monitoring), our work focuses on relative comparisons of dynamic-LAI scenario to constant-LAI one, and not absolute comparison of model outputs to measured ones. Even if the model SIERRA had not yet been calibrated in the study site, we considered that using it in this perspective can be fairly justified.

Brut, A., RÂÍudiger, C., Lafont, S., Roujean, J.-L., Calvet, J.-C., Jarlan, L., Gibelin, A.-L., Albergel, C., Le Moigne, P., Soussana, J.-F., Klumpp, K., Guyon, D., Wigneron, J.-P., and Ceschia, E.: Modelling LAI at a regional scale with ISBA-A-gs: comparison with satellite derived LAI over southwestern France, Biogeosciences, 6, 1389–1404, doi:10.5194/bg-6- 1389-2009, 2009.

C6: Also a comparison between the original model (where LAI is calculated) and the 'new' model (where MODIS LAI is used) is lacking: how much do both runs deviate? Can these deviations be explained?

R6: As mentioned in R5, since we do not compare LAI-MODIS to simulated ones based on self-equilibrated leaf biomass according to carbon budget, we did not consider to compare water budget outputs from two inputs of vegetation (simulated and MODIS). In the revised version, we propose to correct LAI-MODIS (see R4) and we will undertake analysis of model outputs by considering constant LAI along the year to dynamic ones (brought by corrected weekly LAI-MODIS). These comparisons will be made in order

HESSD

9, C3639–C3646, 2012

to evaluate whether or not vegetation dynamic has a perceptible effect on water budget outputs (evapotranspiration, soil water content) and consequently water stress index and drought monitoring.

C7: The sensitivity analysis discussed in section 4.2 should be improved. Now, only two different simulations are run and a comparison between both runs is made. I don't believe one can call this a sensitivity analysis! It is also not clear what the authors want to learn from this sensitivity analysis.

R7: On the light of what have been stated earlier, in particular the objective (2) (P6255, Line 15), the sensitivity analysis in basically a comparative analysis between model outputs from two scenarios, one considering vegetation as dynamic during the year (LAI-MODIS), the other considering a constant value of LAI along the year. This was done to reveal if the temporal component driven by MODIS sensor in measuring LAI have a perceptible effect on a global indicator of drought (STR) calculated at annual scale. This is the essential question we want to answer from this analysis. Besides, this investigation was motivated by previous works in Mediterranean ecosystems (P 6265, Line 4 to 7) conducted at local scale and showing that increase of LAI is accompanied by a increase of drought stress. Then, we attempt to verify the validity of this result at regional scale. We agree that traditionally, sensitivity is supposed to make analysis of outputs variations regarding input variations of different parameters, this is not the case in our work because the principal effect we are investigating here is the effect of dynamic vegetation on simulation results. We can replace sensitivity by another term (e.g. comparison) to avoid ambiguity.

C8: In section 4.3. a spatial analysis is made on drought conditions. Again, this section is very weak with respect to its analysis and conclusions are very flew. The objective of this analysis is not clear: what is the merit of MODIS LAI for this analysis? What should we learn?

R8: From these spatial analysis, drought vulnerability expressed in terms of simulated

HESSD

9, C3639–C3646, 2012

stress index STR, is different depending on the vegetation species in place (P 6265, Line 15-18). Moreover, we show that soil is an explanation factor of stress index (P 6265, lines 25-27). Previously, in section 3.2 dedicated to time- series MODIS data analysis, we have already showed that there is a clear discrimination of LAI-MODIS between evergreen and coniferous vegetation (P6262, line 20) and there is also a good discrimination between LAI of dense deciduous within different soil states of water storage and holding capacities (P 6262, Line 6-8). Thus, vulnerability to drought, which is not climate or topography dependant but vegetation-soil dependant (as we have concluded from this analysis), can be more appropriately evaluated by assimilating data such as LAI-MODIS since they discriminate different vegetation-soil areas. The merit of using MODIS LAI can be justified from these results : in case of lack of updated data on vegetation and soil in a similar study ecosystem, one can use validated LAI-MODIS data since they discriminate different states of vegetation-soil. Considering MODIS-LAI coarse spatial resolution, this use should obviously be reserved to regional scale studies.

C9: In the conclusions, some statements are made, which I believe, were not properly addressed in the paper: Integration of LAI of MODIS 'could' improve results of the simulation: this was not validated as the model without MODIS info (i.e. the original model) was not run and compared with. Only through comparing both runs, one could argument whether or not improvements are made.

R9: See R5 .

C10: The conclusion states that an alternative solution is to calibrate LAI-MODIS with other sources of satellite data or with in situ LAI: this was not performed.

R10: see R4

C11: The conclusion furthermore states that, based on LAI from MODIS, one could demonstrate that increase in LAI is accompanied by increase in drought conditions: Was this based on LAI from MODIS, or is this merely due to the model? One cannot

HESSD

9, C3639–C3646, 2012

make such statement if the results are not compared to a model run where MODIS data is not used!

R11: Results present in section 4.2 (p 6265, line 1-2 : We have showed that dynamic LAI-MODIS integration into water budget model revealed that LAI increase is accompanied by STR increase) were based on constant LAI scenario (equivalent to LAI-MODIS not used) versus dynamic LAI scenario. This latter is characterized by an increase of LAI during the year brought by a weekly integration of LAI-MODIS into the model. Thus any variation of outputs simulations is a consequence of the dynamic effect of vegetation.

C12 : Unfortunately, I find that the paper lacks sufficient validation to prove the statements that are made. I hope that the authors may perform some additional research that could lead to more validated conclusions.

R12: In the revised version, the main researches that will be added are : (1) Validation of simulations by comparing transpiration based on sap flow densities measurements during a complete vegetative season (one ground station) to model simulated results of actual evapotranspiration.

(2)Correction and calibration of LAI-MODIS overestimation: we propose a method to make calibration of LAI MODIS by integrating in-situ measurements and NDVI-SPOT image.

(3)Integration of corrected LAI-MODIS into SIERRA model (instead of LAI-MODIS not corrected) and analysis of two scenarios runs (weekly corrected LAI-MODIS versus constant LAI computed as mean of LAI-MODIS during the year).

(4) Remake “sensitivity” or comparative analysis based on simulations integrating corrected LAI-MODIS and constant LAI. From this analysis, one could evaluate the variation extent of model outputs with LAI dynamic forcing variable in the context of a natural ecosystem of south Mediterranean.

HESSD

9, C3639–C3646, 2012

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HESSD

9, C3639–C3646, 2012

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