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Reply on RC1

Sinan Li et al.

Author comment on "Simulating carbon and water fluxes using a coupled process-based terrestrial biosphere model and joint assimilation of leaf area index and surface soil moisture" by Sinan Li et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-131-AC1, 2022

Referee 1:

The paper by Li et al. proposes using a four-dimensional variational assimilation method (PODEn4DVar) with soil moisture (SM) and leaf area index (LAI) observations for calculating the evapotranspiration (ET) and gross primary production (GPP). The paper is rich in content but there are a lot of confusions. Therefore, major revisions are required before proceeding with your paper.

As you said, the spatial scale mismatch between the ground observed footprint size and satellite-derived footprint size were the vital factors affecting assimilation performance. The spatial resolution of assimilated GLASS LAI data is 5 km, and thus the resolution of ET and GPP estimates is 5 km. The spatial footprint of EC measurement of ET and GPP is at most about 100-500 m. Hence, there is a mismatch between the footprint of model estimates (5 km) and field EC measurements (100 m). Larger spatial representation mismatches can lead to completely wrong conclusions, especially on heterogeneous surfaces. Perhaps you discussed it in the manuscript, but such uncertainty will strongly change the result.

Response*:* Yes, the scale mismatch between the field EC measurements and satellite-derived footprint or model estimates exists and cannot be avoided. However, many studies have shown that GLASS LAI products (Xiao et al.,2014; Xu et al.,2018; Liu et al.,2018), SMOS and SMAP products (Burgin et al.,2017; Colliander et al.,2017) are consistent with the in situ measurements in terms of temporal variations, that is, the consistency of tendency, and that overall bias is controlled within reasonable limits. In addition, we also extracted site-scale LAI and SSM for comparative analysis, and the results are shown in the attached figure S8 and S9 of Supplement Material. As shown, GLASS LAI products, SMOS and SMAP products can accurately capture the daily variation of the observations, and the absolute errors can be partially eliminated when they are considered as observation errors during assimilation. In summary, the assimilation results of this manuscript can be compared with the measured values at the site level for accuracy evaluation.

Also, we did discuss this uncertainty in the manuscript (Page 57 Line 728-740).

Lines 47: Maybe it should be "GLASS LAI"?

Response: The “GLASS” has been modified to” GLASS LAI”.

Lines 73: "ENKF" or "EnKF", please unify.

Response: ENKF in this manuscript has been unified as ENKF.

Lines 74: There have been many applications of four-dimensional variational method (4DVar).

Response: Yes, there have been indeed many applications. More references about the application of four-dimensional variational method (4DVar) have been added in Line 82.

Lines 165: What does this equation mean? What are the constraints of SM on ET?

Response: This equation is an implicit soil moisture constraint. Although soil moisture data did not directly constraint ET, both RH and VPD in this equation are related to soil moisture. Thus, it can reflect the condition of the soil moisture where the vegetation is located to a certain extent.

Lines 170, 179, 180: Confusing expression! Do you assimilate ET in the manuscript?

Response: We did not assimilate ET. the SSM was assimilated to LPJ-PM. The sentence was revised to clarify this issue (Lines 192-193).

Lines 187: The flow chart of the LPJ-VSJA assimilation program is complicated and needs to be simplified. What are "section 3.1.1" and " section 3.2" in the Figure 1?

Response: The flow chart of the LPJ-VSJA assimilation program has been simplified. The section 3.1.1 and section 3.2 was deleted.

Lines 196: RMSD and ubRMSD have similar meanings, maybe you only need to keep one.

Response: The ubRMSD was retained and the associated charts and analysis have been adjusted accordingly.

Lines 216: Observation errors should be defined based on the errors of instruments measuring LAI. Why did you choose arbitrary values for LAI observation errors?

Response: In this study, we set the model and observation errors at a given time as 20% and 10% (optimal scale factors for assimilation performance) of the LAI value and the observed LAI value, respectively (L235-240). They are not the arbitrary values.

According to some previous studies, the observation error of LAI is usually a fixed value determined by the errors of instruments measuring LAI. However, in fact, errors have a strong correlation with the vegetation and environmental conditions (e.g. vegetation types, season, geospatial distribution), (Fang et al.,2013). For example, GLASS LAI products have been confirmed that it has high accuracy in the growing season and for tropical forest vegetation types, as well as in tropical and northern high latitude regions (Xiao et al.,2013(a); Xiao et al.,2013(b)). The analysis increments depend not only on perturbation sizes and defined errors, but also on the plant physiological activity. As perturbation sizes have been defined as proportional to the amount of active biomass, the background error definition may require a similar adaptation. Sabater et al. (2008)

defined the observation and background errors as a constant 1 m^2/m^2, while Jarlan et al. [2008] introduced a variable model error of 20% of the forecast LAI state. For LAI, perturbations are set to a fraction (0.001) of the modelled LAI following Rüdiger et al. (2010). LAI background error SD is set to 20% of the LAI value for modelled values above 2.0m^2 m^{-2} and to a constant 0.4m^2 $m^{-2}$for modelled values below 2.0m^2 m^{-2}. This SEKF configuration is the same as the one detailed in Albergel et al. (2017). Thus, the scale factor method was adopted to confirm the optimal LAI error.

Lines 217: "(R, RMSD, BIAS,)" remove the comma.

Response: The comma has been removed.

Lines 229: What is the time step and spatial resolution of the model running?

Response: The time step is daily and the spatial resolution is 0.25°□Line 222□□

Lines 301: I can't find ubRMSD in the Taylor diagram of Figure 10.

Response: We modified the description of ubRMSE in the Taylor's diagram.

Lines 318: Please add the reference about Liu et al. (2018). You should add the download URL about Heihe data.

Liu, S., et al., 2018. The Heihe Integrated Observatory Network: A Basin-Scale Land Surface Processes Observatory in China. Vadose Zone Journal 17, 180072. https://doi.org/10.2136/vzj2018.04.0072

Response: The reference and the URL about Heihe data were added in L343.

Lines 337: You should add download URLs for LAI, SM, and other remote sensing data.

Response: The URLs were added in L365, 369.

Lines 367: The spatial resolution of MODIS ET is 1km, and the spatial resolution of GLASS ET is 5km. To be consistent, have you resampled?

Response: Yes□in the manuscript, in order to maintain consistency with the SMAP Enhanced 3 Level product (Entekhabi et al. 2010), model-forcing data were resampled to a 9 km spatial resolution based on EASE-2 projection grid for site simulation. In the global spatial simulation, the model-forcing data were resampled to 0.25° using bilinear interpolation to ensure consistent temporal and spatial resolution of the driving data required for this study. According to Yang et al. (2020), the spatial resolution is determined by considering the model's output efficiency of carbon and water flux simulation. The corresponding modification have been added to L383-385.

Lines 387: You should mention Figure 3 in the description.

Response: The Figure 3 has been mentioned in L414.

Lines 395: The unit format is not uniform, you need to double check. "g C/m^2/mon" or " g C m^{-2} mon^{-1} ", please unify. The x-axis in Figure 3 and 6 is confusing, or you can express it in years.

Response: The unit format in the manuscript was unified and the x-axis in Figure 3 and 6 was modified to the “year”.

Lines 408: Over cropland, the data assimilation scheme tends to generally underestimate GPP. What is the reason for the underestimation?

Response: In cropland, human interference, especially seasonal irrigation and fertilization, is an essential factor for cropland production. In the LPJ-DGVM model, the artificial management module and the nitrogen cycle were missing, which led to the underestimation of GPP simulations. Although the leaf area index and soil moisture assimilation could improve GPP simulation, the leaf area index and soil moisture products were also underestimated compared with the field footprint observations (Xiao et al.,2013; Zhang et al.,2019; Liao et al.,2015). Therefore, the GPP for croplands is generally underestimated.

Lines 411: “Fig.4”, Full name or abbreviation? please check carefully!

Response: Modified.

Lines 413: There are a lot of up-scaled ET and GPP products (Jung et al., 2009, 2020) that can be used for regional validation.

Jung, M., et al., 2009. Towards global empirical upscaling of FLUXNET eddy covariance observations: validation of a model tree ensemble approach using a biosphere model. Biogeosciences 6 (10), 2001–2013.

Jung, M., et al., 2020. Scaling carbon fluxes from eddy covariance sites to globe: synthesis and evaluation of the FLUXCOM approach. Biogeosciences 17, 1343–1365. https://doi.org/10.5194/bg-17-1343-2020

Response: FLUXCOM GPP products (2010-2015) were used to compare with all other products, including LPJ-VSJA products studied in this manuscript (Table S6). FLUXCOM GPP products included the above referred literature.

Lines 504: The X-axis label is the same as the y-axis label in the Taylor chart.

Response: The X-axis label in Figure 9 has been modified to avoid confusion with the code in the Taylor diagram.

Lines 516: The full name should be used the first time you use it (NSD).

Response: The full name of NSD has been added in L541.

Lines 548: In column A, GPP is low in the tropics and high in arid regions?

Response: The legend of Column A has been reversed, and so now GPP is high in the tropics and low in arid regions.

Figure 13: The TC method has been used to quantify uncertainties of gridded datasets. The TC method can only calculate uncertainty based on three (ET/GPP) products. How did you calculate the five (ET/GPP) products?

Response: In this study, the five products were divided into three product categories, including satellite product (MODIS, GOSIF GPP), reanalysis product (GLASS, GLDAS) and data assimilation product (GLEAM ET, LPJ-VSJA). The LPJ-VSJA product was set as the reference.

For GPP products, choose GOSIF, GLASS, and LPJ-VSJA were treated as a group, and MODIS, GLASS and LPJ-VSJA were treated as another group to calculate the errors; the final errors were determined by the average of these two.

Similarly, to calculate the errors for ET, GLEAM, GLASS, and MODIS were chosen as a group; LPJ-VSJA, GLDAS, and MODIS were treated as a group; LPJ-VSJA, GLASS and MODIS were considered as a group. In order to reduce the influence of orthogonality hypothesis of error, this basis for grouping was selected for indirect and effective comparison between LPJ-VSJA product and GLEAM product.

The above explanation was added in section 2.4 (L340-348)

Lines 579: "Except for MODIS, GLASS, and LPJ-DGVM (0–60 mm month-1), the σ of other products was generally between 0-20 mm month-1.". This is hard to see in Figure 14.

Response: In the figure 14, it is clear to see the range and distribution of σ for each product. The starting and ending values on the x-coordinate reflect the approximate range in the histograms of error standard deviation (σ) of Figure 14. Thus, the figure has not been revised.

Reference:

Rüdiger, C., Albergel, C., Mahfouf, J.-F., Calvet, J.-C., and Walker, J. P. (2010), Evaluation of the observation operator Jacobian for leaf area index data assimilation with an extended Kalman filter, J. Geophys. Res., 115, D09111, doi:10.1029/2009JD012912.

Jarlan, L., G. Balsamo, S. Lafont, A. Beljaars, J.-C. Calvet, and E. Mougin (2008), Analysis of leaf area index in the ECMWF land surface model and impact on latent heat and carbon fluxes: Application to West Africa, J. Geophys. Res., 113, D24117, doi:10.1029/2007JD009370.

Bonan, B., Albergel, C., Zheng, Y., Barbu, A.L., Fairbairn, D., Munier, S., & Calvet, J.-C. (2020). An ensemble square root filter for the joint assimilation of surface soil moisture and leaf area index within the Land Data Assimilation System LDAS-Monde: application over the Euro-Mediterranean region. Hydrology and Earth System Sciences, 24, 325-347

LIAO Yanran,GAI Yingying,YAO Yanjuan,FAN Wenjie,XU Xiru,YAN Binyan.Validation methods of LAI products on the basis of scaling effect[J]. National Remote Sensing Bulletin,2015,19(01):134-142.