Review of "Modeling the impacts of diffuse light fraction on photosynthesis in ORCHIDEE (v5453) land surface model" by Zhang et al.

Summary

There is a plethora of observational evidences supporting that diffused light favors higher plant productivity thanks to radiation being more evenly distributed and accessible across the shaded part of the canopy. Yet, few Land Surface Models (LSMs) have a representation of light transmission within the canopy that explicitly accounts for the quality of light (direct vs diffuse) and its effect of primary productivity. Zhang et al. implemented such a capability in the ORCHIDEE LSM (ORCHIDEE_DF) and this paper provides the details of their modelling framework as well as a solid evaluation of ORCHIDEE_DF performance against a large set of ground site measurements (FLUXNET).

This paper reads very easily as it is well written and well structured.

The first part of the paper describes the model framework and the parameterisations. It is generally well written, although some symbols / equations could be improved, and a couple of sections swapped together (see general comments).

The second part of the paper presents a very good evaluation of ORCHIDEE_DF. The added value of introducing a representation of diffuse light fraction is convincingly exposed and rigorous efforts were made to disentangle this from other cofounding effects (e.g .VDP, Temperature). Despite the calibration of model parameter being sub-optimal for this new configuration of ORCHIDEE, the analysis and supporting plots are very useful and effectively achieve to highlight where the model performs well, and which future development efforts should be prioritized. This is a useful evaluation effort which will also benefit the wider LSM community beyond the ORCHIDEE user base. The effort that the authors went through in evaluating ORCHIDEE_DF against a large ensemble of observations goes much further than previous attempts published in the literature and is greatly appreciated.

Adding a representation of diffuse light fraction in the canopy can only be useful if the boundary conditions – that is the fraction of diffuse radiation hitting the top of the canopy – is known. This information is usually lacking from the dataset that are used to drive LSMs. Technically, this is a problem that is external to land surface modelling, but it is great to see that Zhang et al. provide a practical framework to retrieve that missing information and could offer some insight to the terrestrial carbon cycle community for a developing a harmonized framework in future LSMs inter-comparisons.

The topic covered in this paper is absolutely relevant to GMD and I therefore strongly support its publication after addressing those minor very few points.

General Comments

1. I believe it will be improved at production stage, but some equations are not easy to read in current form. Use of upperscript and lowerscript could help bringing better separation between the terms in the equations (e.g. Km_C instead of KmC, C_c instead of Cc, etc).

2. Would it make more sense to introduce section 2.1.3 (Light transmission in ORCHIDEE_DF) before section 2.1.2 (Light partitioning in ORCHIDEE_DF) so it follows naturally section 2.1.1 (Light transmission in ORCHIDEE_trunk), especially given that the calculation of the fraction of diffuse light hitting the canopy top could eventually be treated by the radiative transfer of the driving

atmospheric model as it is done in an Earth System Framework (e.g. Yue et al., 2017; Malavelle et al. 2019) making a specific parameterization for this not necessary in ORCHIDEE?

3. For the evaluation framework described at P11 L324 to 326 – Getting the same level of PPFD that way may involves comparing GPPs at different time during the day which might not capture vegetation in similar physiological states. Wouldn't it be easier to simply normalize the cloudy and sunny GPPs by their respective PPFDs rather than removing a part of the dataset (likely the mid-day data for the sunny GPP when insolation is maximal and light saturation of the sunlit leaves possible)?

4. P13-L387-389 – It is interesting to note that both ORCHIDEE trunk and DF underestimate the dGPP and the dLUE around mid-day. Could it be related to the relative high proportion of sunlit leaves which is primarily a function of the solar zenith angle in the DF configuration? Segregating the dataset into latitudes may help to appreciate if this behaviour occurs more in the tropic or the mid-latitude sites.

Specific Comments

P02-L050 - VPD acronym has not been defined yet.
SC2: P02-L55 - "large-scale aerosol changes". [optional] You could add "and long-term changes in cloudiness".
P03-L075 - How come? Is it because of the large reduction in radiation under cloudy sky that tends to outweigh beneficial the effect of increased diffuse light?
P03-L076 - My bad, explanations for my comment above are provided in the following sentences. I would remove the word "Finally" which creates confusion during the transition between the two sentences.
P03-L077 - Williams et al. 2016 (year not matching the reference at the end, i.e. 2014).
P03-L087 - Le Quere et al. 2018 missing from the reference list.
P05-L143 - You can maybe point the reader towards Fig 3 as well. This schematic is useful for visualizing what eq. 4 calculates. I initially misunderstood what the cumulative LAI represente. It only represents the cumulative LAI above the current layer but does not include the current layer (if I got it right).
P05-L152 - Shouldn't it be $dI_i/dLAI\_c_i$ instead of $dI/dLAI\_c$ in eq. 6? What does the vertical bar symbol $|$ represents? Is it a derivative at fixed LAI_c_i?
P06-L170 - Either explicitly provide the relationships or give a reference where those are documented.
P06-L175 - "forcing datasets": Do you mean dataset used to drive LSMs?
P06-L179 – Fdf_{PAR}. Should it be rewritten $fPAR_{df}$ to be consistent with the notation in other equations?
P07-L216 – Same as above, fPPFDdf instead of $FdfPPFD$?
P08-09 – eq. 26, 28, 30. Should it be LAI_ci instead of LAI_ai in the exponentials?
P08-L253 – Ref to Hikosaka et al. (2016) missing from the reference list.
P09-L268-270 – Same as eq. 6. The notation for the derivative is not clear to me. Could you explain?
P09-L289 – Change to "from 252 sites in total".
P10-L292 – Good job getting the references for all the sites!
P10-L292 – "annual climate" sounds weird. Could be rephrased by saying, "(climatological) annual mean temperature span the range xx to yy while (climatological) annual mean precipitation … span the range". Same for Fig S2 legend.
P13-L411 – This (fig 9 & 10) is an extremely useful way of presenting the sensitivity of the two models.
P14-L422 – Could that result be related to similarities in parameter traits and optimum points (e.g. Vcmax) between PFTs used to represent temperate and tropical biomes?

Figure 2 – The subtle light gradient makes it hard to appreciate the density of points. Could you maybe add a Probability Density Function along the x (respectively y) axis to represent the distribution of modelled (respectively observed) fraction of PPFD?

Figure 6 – “is controlled the same” feels a bit clunky. Could be rephrased by just saying that the sunny and cloudy days are sampled at equal light levels.

Mentioned References

Malavelle, F. F., Haywood, J. M., Mercado, L. M., Folberth, G. A., Bellouin, N., Sitch, S., and Artaxo, P.: Studying the impact of biomass burning aerosol radiative and climate effects on the Amazon rainforest productivity with an Earth system model, Atmos. Chem. Phys., 19, 1301–1326, https://doi.org/10.5194/acp-19-1301-2019, 2019.

Yue, X. and Unger, N.: Aerosol optical depth thresholds as a tool to assess diffuse radiation fertilization of the land carbon uptake in China, Atmos. Chem. Phys., 17, 1329–1342, https://doi.org/10.5194/acp-17-1329-2017, 2017.