Response to Reviewer #2

General comment:

"This manuscript led by Zhang presented a study on improving the ORCHIDEE land surface model with specific consideration of the impacts of diffuse light fraction on vegetation photosynthesis, a well recognized phenomenon but poorly represented in the existing version of ORCHIDEE model. The new model, named after ORCHIDEE_DF, has included a scheme for partitioning light into direct and diffuse components, and separated the existing multi-layer canopy into sunlit and shaded leaves with a two-stream radiative transfer model folowing Spitters 1986. Then the authors used global fluxnet observations to evaluate the new model and found that the new model better simulates GPP under different illumination conditions. Examinations on the effects of diffuse light on GPP and light use efficiency and the interactions between diffuse light and other environmental factors such as temperature and vapor pressure deficit were conducted. The new model is suggested to have great potential in investigating aerosol effect on global biogeochemical cycles.

Overall the manuscript is very well organized and written, and easy to read. The description of the model development is clear, and the evaluation strategy is comprehensive and convincing. The analyses sections provide insightful understanding of the interactions of diffuse light and environmental factors. I don't really have much to add, but here I provide some minor suggestions and hope they can help further improve the quality of the manuscript."

[Response] We thank the reviewer for the review and helpful comments and suggestions, which helped us to further improve our manuscript. We have addressed all the suggestions and comments in our revision. Please find below the reviewer's comments, followed by our responses and relevant changes in the manuscript. We hope that the revised version addresses all the issues and satisfies the reviewer.

Comments:

1. Line 42-43: "However, this effect remains poorly represented in current land

surface models". This is not accurate, at least CLM (Oleson et al., 2013), JULES (Mercado et al., 2009), CoLM (Dai et al 2004), iTem (Chen et al., 2014), and YIBs (Strada et al., 2016) have included processes that account for the diffuse light effect.

Oleson, K., Lawrence, D. M., Bonan, G. B., Drewniak, B., Huang, M., Koven, C. D., ... Yang, Z. -L. (2013). Technical description of version 4.5 of the Community Land Model (CLM) (No. NCAR/TN-503+STR). doi:10.5065/D6RR1W7M Mercado LM, Bellouin N, Sitch S, et al. Impact of changes in diffuse radiation on the global land carbon sink. Nature. 2009;458(7241):1014-1017. doi:10.1038/nature07949 Dai, Y., R. E. Dickinson, and Y. Wang, 2004: A Two-Big-Leaf Model for Canopy Temperature, Photosynthesis, and Stomatal Conductance. J. Climate, 17, 2281–2299 Min Chen & Qianlai Zhuang (2014) Evaluating aerosol direct radiative effects on global terrestrial ecosystem carbon dynamics from 2003 to 2010, Tellus B: Chemical and Physical Meteorology, 66:1, DOI: 10.3402/tellusb.v66.21808 Strada, S. and Unger, N.: Potential sensitivity of photosynthesis and isoprene emission to direct radiative effects of atmospheric aerosol pollution, Atmos. Chem. Phys., 16, 4213–4234, https://doi.org/10.5194/acp-16-4213-2016, 2016.

The first three have been introduced in the paragraph of Line 88-100, but latter two were directly applied for examining aerosol impacts and should be discussed as well.
[Response] Thanks for the suggestion. We have added these studies to our updated manuscript: Line 42-43: “this effect remains poorly represented or evaluated in current land surface models.” Line 92: “This two-big-leaf scheme was further used in iTem LSM (Chen and Zhuang, 2014) and got partly inherited in later CLM models (Oleson et al., 2013).” Line 100: “Apart from JULES, the Yale Interactive terrestrial Biosphere model (YIBs) also included a two-stream multilayer canopy light transmission scheme, but few efforts have been made to evaluate the ability of YIBs model to capture the observed diffuse light fertilization effect, especially at sub-daily time scales (Yue and Unger, 2015).”

2. I would suggest the authors provide a table of acronyms in Section 2.1.2 and 2.1.3 as an appendix so that the readers are easier to follow the equations.

[Response] An appendix section of acronym list has been added to the manuscript.

After Line 524:

"**Appendix A**

List of acronyms:

Fdf: Fraction of diffuse radiation

GPP: Gross Primary Production

LAI: Leaf Area Index

LSM: Land Surface Model

LUE: Light Use Efficiency

NIR: Near-Infrared Radiation

PAR: Photosynthetically Active Radiation

PFT: Plant Functional Type

PPFD: Photosynthetic Photon Flux Density

SW: downward Shortwave Radiation at the top of canopy

TOA: Top of Atmosphere

TOC: Top of Canopy

VPD: Vapor Pressure Deficit

* The variable names in Section 2 are listed in Table 1"

3. Section 4.2 discussed factors affecting response of GPP to diffuse light and the authors suggested that the lower temperature and VPD may be the main cause of the higher midday GPP under cloudier conditions. Does ORCHIDEE simulate leaf temperature at different canopy layers? If not, it is not very convincing to me, as the short-term air temperature and VPD variations are mainly determined by the meteorological system, rather than the radiation regime.

[Response] Thanks for raising this concern. In current ORCHIDEE trunk and DF model, the air temperature is taken directly as leaf temperature and does not vary

within the canopy. We agree that the short-term air temperature and VPD variations are mainly determined by the meteorological system. The explanation of leaf temperature is added to the manuscript: (Line 171) “Because in current ORCHIDEE, there is only one energy budget per grid cell, from which we cannot determine the leaf temperature, the air temperature is used to represent the leaf temperature in current model.”

We compared the observed Tair and VPD under cloudy and sunny conditions at midday time and found that the cloudy midday Tair and VPD is lower than the sunny ones (Fig. R4). Therefore, the lower midday temperature and VPD could be the main cause of the detected midday ΔGPP in the manuscript. This lower cloudy midday Tair and VPD at site level might be because the time scales of weather systems which cause overcast conditions are often long enough to affect Tair. As a result, dynamics in canopy leaf temperature are not necessary to explain the simulated effect shown in the manuscript in line with the FLUXNET observations.

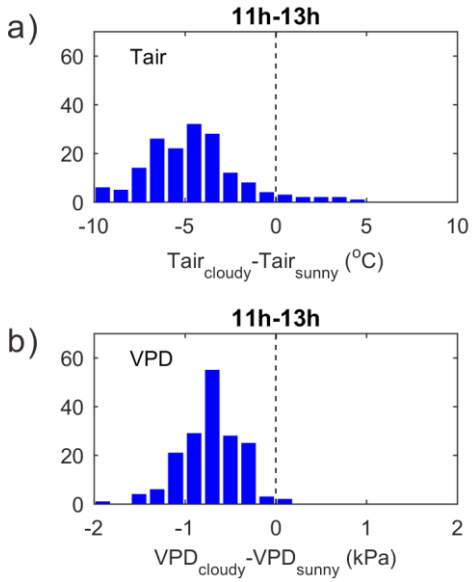

Figure R4. Site distribution of (a) the Tair difference (b) the VPD difference between cloudy (diffuse light fraction >0.8) and sunny (diffuse light fraction<0.4) conditions between 11:00 and 13:00.

4. Section 4.3. I think another important limitation of the developed ORCHIDEE_DF model for examining aerosol impacts is that it does not consider the impacts of the changing radiation regime on leaf temperature. This might be a second-order effect, but could be potentially important as shown in Chen and Zhuang, 2014 Tellus B.

[Response] Thanks for pointing out this limitation. Indeed, there remains no representation of the impacts of the changing radiation regime on leaf temperature in the current model, which may be potentially important. We have added some discussion of this point in Line 503 "Besides the possible bias in parameters, both ORCHIDEE trunk and ORCHIDEE_DF lack a representation of the response of leaf temperature to radiation. Instead, the air temperature is used directly to represent the leaf temperature throughout the canopy for simulating gas exchange processes in current model. As shown by Chen and Zhuang (2014), the changes of radiation regime due to aerosols can significantly affect leaf temperature, which could potentially affect GPP. For now, ORCHIDEE_DF remains not capable of dealing with this response of leaf temperature. Further developments are needed for disentangling the role of leaf temperature and diffuse light on GPP". This will be a future direction of our model development work.