Response to Reviewer #2

General comment:

"This manuscript presents a study on how the errors in the reconstructed fraction of diffuse radiaiton (Fdf) would affect global GPP estimation using the ORCHIDEE_DF land surface model. The authors have investigated a few methods to reconstruct Fdf under pre-industrial aerosol emission conditions and shown that different reconstruction method may result in diverse Fdf and large biases in global GPP estimation. The study may be useful for the land surface modeling and global carbon cycling research community and thus worth publishing, however I have a few concerns that I feel have to be addressed."

[Response] We thank the Reviewer for the review, comments and suggestions, which helped us to improve our manuscript significantly. We have addressed all the suggestions and comments in our revision. Please find below the Reviewer's comments (italics), followed by our responses (roman font), with red color indicating relevant changes in the manuscript. We hope that the revised version addresses all the issues raised by the Reviewer.

Comments:

First, the title is not accurate. Since clouds can be a major contributor to diffuse radiation, the paper is actually about aerosol-induced diffuse radiation scenario.

[Response] Thanks for this suggestion, we have changed the title to "How to reconstruct aerosol-induced diffuse radiation scenario for simulating GPP in land surface models? An evaluation of reconstruction methods with ORCHIDEE_DFv1.0_DFforc"

"Second, the presentation quality of this paper needs to be improved. A lot of important details are missing. For example, L49: what are the time spans of 'historical' and 'preindustrial'? L106-112 is an extremely long sentence. Consider breaking it into shorter ones. The calculation of Fdf is confusing. How did you make the 'atmospheric

radiative transfer calculations'? How do you make sure Fdf is consistent with the CRUJRA data, while using aerosol data from other sources? For which years the reconstructing methods were applied? Which years were used for ORCHIDEE_DF runs? These all need to be stated in the methods section."

[Response] Thanks for the suggestions. We have rephrased these sentences and added more information in the manuscript (Line 49): "e.g., the scenario with actual anthropogenic aerosol emissions and the one with aerosol emissions at pre-industrial level (before or in early 20th century)". (Lines 106-112): "For the sake of investigating the effect of diffuse radiation with a framework consistent with the TRENDY simulation protocol (http://sites.exeter.ac.uk/trendy/), a new Fdf field during 1900-2017 was calculated along with the above-mentioned climate variables at the same spatial and temporal resolutions. The radiative transfer calculations to obtain the Fdf field are based on monthly-averaged distributions of tropospheric and stratospheric aerosol optical depth, and 6-hourly distributions of cloud fraction. The tropospheric aerosol optical depth of each aerosol type is from the HadGEM2-ES historical and RCP8.5 simulations (Bellouin et al. 2011). To correct the biases in HadGEM2-ES, tropospheric aerosol optical depths are scaled over the entire period to match the global and monthly averages obtained by the CAMS Reanalysis of atmospheric composition for the period 2003-2017 (Inness et al. 2019), which assimilates satellite retrievals of aerosol optical depth. The stratospheric aerosol optical depth is from the climatology by Sato et al. (1993), which has been updated to 2012. Years after 2012 are assumed to be background years without significant influence of volcanoes and the stratospheric aerosol optical depth is assumed to be the same as a recent background year 2010. This assumption is supported by the Global Space-based Stratospheric Aerosol Climatology time series (1979-2016; Thomason et al. 2018). The time series of cloud fraction is obtained by scaling the 6-hourly cloud distributions simulated by the Japanese Reanalysis (JRA; Kobayashi et al. 2015) to match the monthly-averaged cloud cover in the CRU TS v4.03 dataset (Harris et al. 2014). Surface radiative fluxes calculation accounts for aerosol-radiation interactions from both tropospheric and stratospheric aerosols, and for aerosol-cloud interactions from tropospheric aerosols, except mineral dust. The radiative effects of aerosol-cloud interactions are assumed to scale with the radiative effects of aerosol-radiation interactions, and regional scaling factors derived from HadGEM2-ES are used in the calculation. Atmospheric constituent other than aerosols and clouds are set to a constant standard mid-latitude summer atmosphere, but their variations do not affect the diffuse fraction of surface shortwave fluxes." (Line 115): "Based on the assumption that this sample is representative of the pre-industrial aerosol conditions, four methods are used to reconstruct 0.5 ° x 0.5 ° 6-hourly pre-industrial Fdf field and corresponding simulations are set up for the period 1901-2017."

Third, which I think the most problematic, the reconstructing methods don't remove the huge cloud impacts on Fdf, thus implicitly apply the cloud conditions in the base years in 1901-1920 to other years. Therefore, if I understand it correctly, the work doesn't actually study the aerosol-induce changes of Fdf. In addition, as stated in L137, 'Except the Fdf field, all these simulations use the same climate and land use maps which vary throughout the simulations'. Usually the downward shortwave radiation covary with Fdf; in other words, if Fdf is changed ('reconstructed'), the total downward radiation should also be changed accordingly â˘A˘T this is why a lot of empirical method can successfully estimate diffuse radiation from the total downward radiation with promising accuracy (e.g., see Berrizbeitia, S.E.; Jadraque Gago, E.; Muneer, T. Empirical Models for the Estimation of Solar Sky-Diffuse Radiation. A Review and Experimental Analysis. Â˘aEnergiesÂ˘a2020,Â˘a13, 701.). Actually these empirical methods are efficient options for estimate (or reconstruct) Fdf with historical climate fields, although they are not able to distinguish the contribution of anthropogenic aerosols.

[Response] Thanks very much for this comment.

First, the full impacts of aerosol and clouds should include the impacts from changes in both light quantity (SWdown) and light quality (Fdf). In this study, we focus on the impacts of light quality only, which is similar to the study of Mercado et al. (2009).

That is why we kept the SWdown unchanged in all the simulations. To understand the full impacts of aerosol-induced radiation changes, SWdown changes need to also get considered. However, it is out of the scope of this study. We have added a statement of this point in the manuscript (Lines 135) "It should be noted that all the simulations in this study use the same SWdown field because the target of this study is to understand the impact from aerosol-induced radiation quality, i.e. Fdf, changes only. In reality, the aerosols and clouds also cause a coincident change in radiation quantity, i.e. SWdown, which is important to consider when investigating the full impacts for aerosols. But it is out of the scope of this study."

Second, we totally agree with the reviewer that clouds can strongly affect Fdf and should be considered when doing the reconstruction. However, current statistical reconstruction methods are not able to decompose the impacts of aerosols from clouds, therefore, the impacts of clouds on Fdf are omitted in the DF-PI-6H-CLIM, DF-PI-MON-CLIM and DF-PI-ENS reconstructions. In contrast to the statistical method-based reconstructions, the variation of cloud is considered the DF-PI-AERO reconstruction because it used varying clouds in the Fdf calculation.

Although the impacts of clouds are not included in the statistical reconstructions, we still can compare the GPP among the simulations in the early 1900s to evaluate the reconstruction methods because the cloud fractions are at the same level for the scenarios with and without anthropogenic aerosol emissions. It is clear that the disagreement among simulations start from 1901 (Fig. 2b). Furthermore, the DF-PI-ENS and DF-PI-AERO reconstructions have different cloud impacts after the 1920s but show similar global GPP (Fig 2b). Therefore, the difference in the consideration of clouds should not be the reason of the GPP bias detected. The conclusion that the smooth of Fdf in the reconstruction caused the GPP bias remains valid. Nevertheless, considering the changes of cloudiness is still important for an accurate investigation of the impact of Fdf changes. The impact of clouds is discussed in Lines 260-264: "Despite that both reconstructions are acceptable in detecting diffuse radiation impacts, the impacts detected by the DF-PIAERO and DF-PI-ENS reconstructions are not exactly the same. This is because that the DF-PI-ENS reconstruction implicitly eliminated Fdf changes caused by all factors including aerosols and clouds, while the DF-PI-AERO here has varying cloud information. In this study, the impacts of cloud difference on GPP are much smaller than the bias caused by the problematic Fdf reconstructions (Fig. 2). However, we still cannot conclude with negligible cloud impacts because current cloud data remains very inaccurate."