Response to Referee #1

We are grateful to the reviewer for their time and energy in providing helpful comments and guidance that have improved the manuscript. In this document, we describe how we have addressed the reviewer's comments. Referee comments are shown in black italics and author responses are shown in blue regular text.

Yue and Unger studied the effect of aerosol pollution on land carbon uptake. Although this is a timely topic, the manuscript has no clear objectives. It is not clear whether the study aimed at developing better methods and demonstrates the achievement with an application over China or whether the study aimed at enhancing our knowledge about the interplay between aerosol pollution and carbon uptake. Although the title suggests the latter, parts of the result and discussion suggest a methodological study. The lack of explicit objectives makes it difficult to assess the value of the study. Depending on its objectives some of its shortcomings might be acceptable whereas for other objectives it is not.

→ We explicitly clarified the focus and methods of the study in the revised manuscript, so as to emphasize that the study is objective-orientated rather than method-orientated:

"The main objective is to explore the responses of NPP to current aerosol pollution with and without the appearance of clouds. First, we perform multiple sensitivity experiments to derive the NPP sensitivity to aerosol optical depth (AOD) at 550 nm and compare it with available observations (Table 1). Second, we calculate the aerosol-induced DFE 'tolerance' of China's land biosphere by defining and computing two thresholds of AOD: (i) AOD_{t1}, resulting in the maximum NPP, and (ii) AOD_{t2}, such that if local AOD < AOD_{t2}, the aerosol DFE always promotes local NPP compared with aerosol-free conditions. Third, we estimate changes in NPP between simulations with and without aerosol DFE, and relate these changes to the derived AOD thresholds so as to understand the causes of NPP responses to aerosol radiative effects." (Lines 97-107)

Furthermore, following Reviewer #2 we have changed the title to "Aerosol optical depth thresholds as a tool to assess diffuse radiation fertilization of the land carbon uptake in China". The new title immediately captures that the study is objective-orientated and emphasizes the two main novel contributions of this study (AOD thresholds and aerosol radiative effects on NPP in China), and their connection.

Some definitions of the carbon fluxes at the ecosystem level (both in the introduction and the discussion) are not correct. In the manuscript, NPP, for example, is called the net carbon uptake. NPP is the net primary production. Rh needs to be subtracted to derive the net carbon uptake. In is not clear whether the reference for ''uptake" is the land-atmosphere interface (then the common term is NEP or NEE) or the ecosystem (then the correct term should be NECB or NBP). Have a look at Chapin et al 2005 to get the terminology straight.

→ We have different opinions on the terminology.
First,
In the manuscript, we defined NPP as "Net Primary Productivity", following the traditional terminology. The term "net carbon uptake" appears once to describe the differences between GPP and NPP, but is not used as a definition:

"Now, we consider NPP responses, instead of GPP, because the former represents the net carbon uptake by land ecosystems." (Original)

To avoid possible misunderstanding, we have changed the "land ecosystems" to "plants", so that we use NPP only for vegetation (not including soil part). Our manuscript never refers to "storage".

"Now, we consider NPP responses, instead of GPP, because the former represents the net carbon uptake by plants after subtracting autotrophic respiration for maintenance and growth." (Revised) (Lines 366-368)

Second,
We think the word "uptake" is not necessarily connected to NEE or NBP, which are more precisely connected to the words "sink" or "exchange". Many carbon-climate studies used "land carbon uptake" to represent GPP or NPP. For example:

(1) "The large range of GPP results by process-oriented biosphere models indicates the need for further constraining CO2 uptake processes in these models." in Beer et al. (2010) also refers "CO2 uptake" to GPP.

(2) "… anthropogenic aerosols have enhanced land carbon uptake …" in Mercado et al. (2009) refers "land carbon uptake" to GPP.

References:

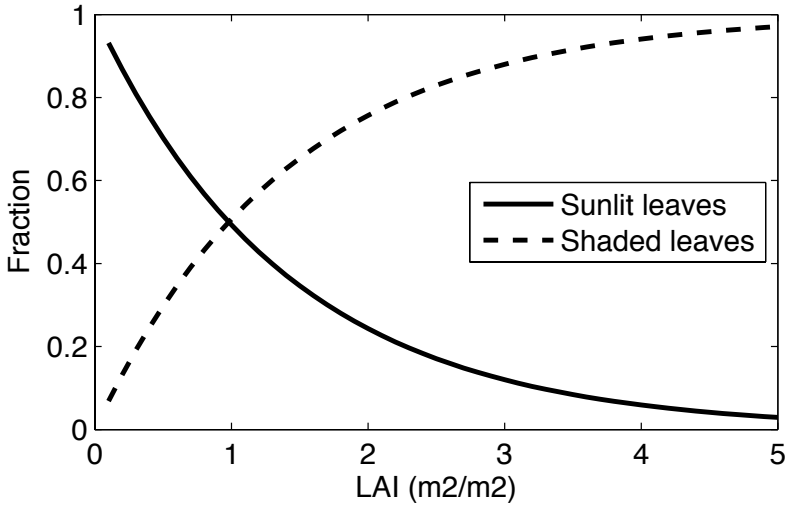
(1) Beer, C., Reichstein, M., Tomelleri, E., Ciais, P., Jung, M., Carvalhais, N., Rodenbeck, C., Arain, M. A., Baldocchi, D., Bonan, G. B., Bondeau, A., Cescatti, A., Lasslop, G., Lindroth, A., Lomas, M., Luyssaert, S., Margolis, H., Oleson, K. W., Roupsard, O., Veenendaal, E., Viovy, N., Williams, C., Woodward, F. I., and Papale, D.: Terrestrial Gross Carbon Dioxide Uptake: Global Distribution and Covariation with Climate, Science, 329, 834-838, doi:10.1126/Science.1184984, 2010.
(2) Mercado, L. M., Bellouin, N., Sitch, S., Boucher, O., Huntingford, C., Wild, M., and Cox, P. M.: Impact of changes in diffuse radiation on the global land carbon sink, Nature, 458, 1014-1017, doi:10.1038/Nature07949, 2009.

The use of a big leaf model assumes that the leaf mass is homogeneously distributed in space (reflected in the equations). This is not the case and may become important when one of the key processes is that diffuse light can penetrate deeper into the canopy than

direct light. Whether this is true or not will depend as much on the canopy structure as on the LAI itself (noted in the discussion). Along the same lines: different PFTs may have a very different canopy structure. When differential effects between PFTs are targeted, this should be accounted for in the parametrization of the big leaf model. The authors address several of these issue in the discussion but the study makes no effort towards solving these issues. Therefore, the modelling work does not represent an advancement. Existing approaches have been implemented in YIB. I'm not saying these issue necessarily invalidate the results of the study but they should be clearly addressed both in the text and these considerations should be reflected in a sensitivity study. Again, whether these assumptions are acceptable depends on the objectives of the study.

→ It is not a goal of this study to develop a new canopy radiation scheme. This study focuses on assessment of particle pollution impacts on large regional-scale carbon uptake. Our approach is to use a well-established and scientifically validated existing algorithm (Spitters, 1986). We concede that the current canopy radiation scheme includes several approximations, such as the homogeneous distribution of leaves, which may introduce biases in the modeling. However, as a widely cited and applied scheme, the Spitters et al. (1986) framework can capture the basic radiative transfer process within the canopy suitable for large-scale earth system modeling applications up to 1000s of km. More importantly, the validation shows that it is appropriate for the current study.

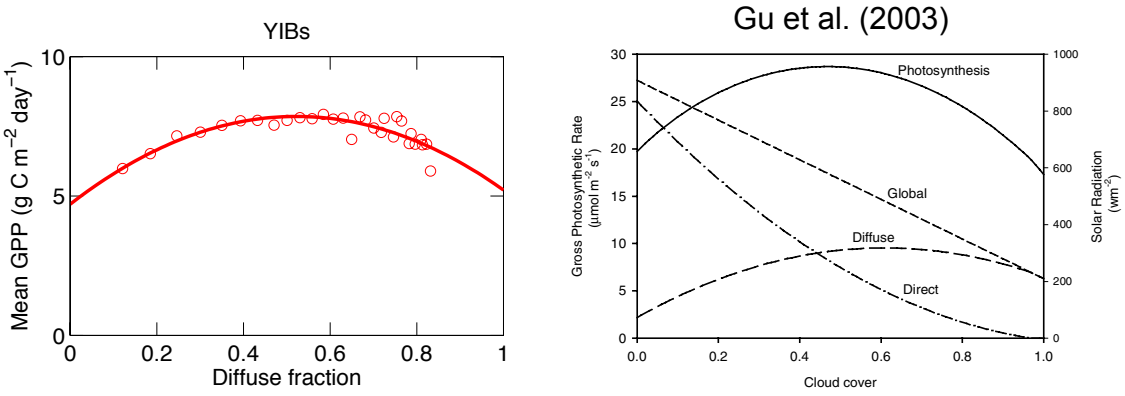
First, the term of "big leaf" refers to the models considering only total solar radiation without separating diffuse and direct light for sunlit and shaded leaves (Schaefer et al., 2012). In the YIBs model, diffuse and direct radiation are separated in the multiple layers and are projected onto sunlit and shaded leaves with theoretical calculations (though with approximations). In this sense, the YIBs model is a typical 2-leaf model.



Second, the key process that "diffuse light can penetrate deeper into the canopy than direct light" has been implemented in YIBs canopy radiation scheme. (1) Both diffuse

and direct light intensity decreases exponentially with LAI when penetrating in the canopy (see Equations 5-7). Part of direct light is converted into diffuse light in this process (see Equation 8). (2) The area of sunlit leaves receiving both direct and diffuse light is decreasing with canopy depth (see Equations 10-11). In contrast, the area of shaded leaves receiving diffuse light is increasing with canopy depth, indicating that diffuse light penetrating deeper than direct light. The figure above shows the changes of fractions of sunlit leaves (solid) and shaded leaves (dashed) with canopy LAI (Based on Equations 10-11):

Third, simulated GPP responses to diffuse light with Spitters' scheme are reasonable compared with other studies. In Figure 4, we show the absolute changes of GPP and diffuse fraction. Here, we compare Figure 4a with results from Gu et al. (2003), which shows impact of cloud instead of aerosols. We can see that GPP in both studies reaches maximum when diffuse fraction is around 0.55-0.6 (please notice the cross point between diffuse and direct radiation in Gu et al. (2003), which means DF=0.5). The enhanced percentages in GPP are similar between two studies. We have also compared our estimates (Figure 3-4) with other studies in Table 1 in section 3.2.



References:

(1) Spitters, C. J. T.: Separating the Diffuse and Direct Component of Global Radiation and Its Implications for Modeling Canopy Photosynthesis .2. Calculation of Canopy Photosynthesis, Agricultural and Forest Meteorology, 38, 231-242, doi:10.1016/0168-1923(86)90061-4, 1986.
(2) Gu, L. H., Baldocchi, D. D., Wofsy, S. C., Munger, J. W., Michalsky, J. J., Urbanski, S. P., and Boden, T. A.: Response of a deciduous forest to the Mount Pinatubo eruption: Enhanced photosynthesis, Science, 299, 2035-2038, doi:10.1126/science.1078366, 2003.
(3) Schaefer, K., and coauthors: A model-data comparison of gross primary productivity: Results from the North American Carbon Program site synthesis, J. Geophys. Res., 117, G03010, doi:10.1029/2012jg001960, 2012.

MODIS NPP is classified as an observation (L224-226). This is overly optimistic: MODIS NPP is a model. Where NPP is calculated from a light-use based GPP and a modelled Ra. At present there is no means to detect Ra from space. So MODIS should not be considered an observation. Until present validating NPP, therefore, has to rely on scattered site observations.

→ We agree that MODIS NPP cannot be considered as an observational data and may have some biases compared with site-level data. However, it is constrained with satellite data and is a valuable resource against which to assess the simulated spatial pattern of NPP. In the text, we have changed the word "observation" to "data product" for MODIS NPP. We also added following statement to support the utilization of MODIS NPP in our model evaluations:
"The MODIS dataset provides indirect estimates of global NPP using an empirical light-use function between GPP and meteorology, as well as the modeled plant respiration. The actual values of MODIS NPP may exhibit certain biases at the regional scale compared with site-level observations (Pan et al., 2006). However, the spatial pattern of the product is in general reasonable and has been widely used for model evaluations (e.g., Collins et al., 2011; Pavlick et al., 2013)." (Lines 242-247)

We also change the title and caption of Figure 1 to make sure that the word "observation" is replaced by "data product".

On several occasions Table 1 is used to demonstrate that the sensitivity of the simulated GPP and NPP to diffuse light is acceptable. However, the majority of observational evidence in Table 1 is for NEP. If the observations for NEP are not used in the study they should be removed from table 1. Alternatively the simulated NEP response to diffuse light should be validated.

→ Table 1 provides not only a data source of model evaluations, but also a summary of "very good state-of-the-art observational studies of cloud and aerosol DFE" (comments by Reviewer 2). We consider it useful to retain all results with NEP to inform readers of the progresses and current understandings about aerosol/cloud DFE. For the evaluations of simulated DFE (Figures 4 and 5), we use GPP instead of NEP because GPP is the direct carbon metric affected by DFE. Changes in NEP are also related to plant and soil respiration, and as a result may introduce more uncertainties to the evaluations. We added following statement to clarify the reason for GPP evaluation: "Most results listed in Table 1 are based on NEP, however, we evaluate the sensitivity of GPP because it is the direct carbon metric affected by DFE." (Lines 357-359)