Reviewer #2:

General Comments:

Comment #1

Overall, this manuscript is a straightforward evaluation of a PFT parameterization in a well-established global biogeochemical model. The authors are adding parameterization of specific plants that are used in lignocellulosic biomass for biofuels. The study is motivated by need to connect a global land biogeochemical model, which typically do not have specific parameterization of biofuel crops, to Integrative Assessment Models that include extensive uses of biofuels in many scenarios for energy development.

I appreciate the authors documenting this model developing through a relatively short publication and that the parameters presented are commonly used across other global biogeochemical models. This will allow the manuscript serve as a resource for other modeling groups that add these bioenergy crops to their simulations.

Response #1

We thank the reviewer for the comments and suggestions. Please see the detailed point-by-point responses below.

Comment #2

My main critique of the manuscript is that it needs more analysis and discussion of causes of the model-data mismatch, specifically the role of management in the parameterization and the observation datasets.

The authors mention that there is considerable variation many of the parameters (e.g., Page 5, line 24). Is that variation related to management? Could there be a parameterization for high intensity management (nutrient additions, irrigation, advanced genetics) and a parameterization for lower intensity management? In general, it would be useful to provide more information about the drivers of variation in the parameters for each species.

Response #2

As suggested, we will add sentences to discuss the variations of parameters related to managements on P14L26: “We adjusted some key parameters (e.g. $V_{\text{cmax}}$, $J_{\text{max}}$ and SLA) related to productivity of bioenergy crops based on a collection of field measurements. We only took the medians and the ranges to validate the parameter values in the model but didn’t explicitly consider the impacts of management (e.g. fertilization, species) on these parameters, neither in the model nor in the measurements. Here, we summarized some management effects on these parameters for different bioenergy crops based on measurements as follows.

1) Miscanthus: Wang et al. (2012) found that biomass yield of Miscanthus increased under nitrogen addition through elevated SLA, but fertilization didn’t affect $V_{\text{cmax}}$, stomatal conductance ($g_s$) or the extinction coefficient ($k$). Yan et al. (2015) measured photosynthesis variables of three Miscanthus species in two experimental fields and found significantly higher $g_s$, $J_{\text{max}}$ and $V_{\text{cmax}}$ of Miscanthus lutarioparius than M. sacchariflorus and M. sinensis.

2) Switchgrass: SLA differed significantly among nine cultivars of switchgrass but didn’t respond significantly to water stress or nitrogen application for individual cultivar (Byrd and May II, 2000). Trócsányi et al. (2009) reported a lower SLA of switchgrass from the early harvest than from the late harvest. Hui et al. (2018) investigated leaf physiology of switchgrass under five precipitation treatments and found significantly higher photosynthesis rate and $g_s$ under elevated precipitation but no significant difference under reduced precipitation compared to control plots.

3) Eucalypt: Lin et al. (2013) measured photosynthesis response of six Eucalyptus species to temperature and found significantly different $J_{\text{max}25}$ and $V_{\text{cmax}25}$ among species but non-significant differences in their ratios ($J_{\text{max}25} / V_{\text{cmax}25}$) and in the temperature response of $J_{\text{max}}$ and $V_{\text{cmax}}$. With extra nitrogen supply, $J_{\text{max}}$ and $V_{\text{cmax}}$ of Eucalyptus grandis increased significantly, mainly associated with elevated leaf nitrogen content (Grassi et al., 2002). Sharwood et al. (2017) also found that $J_{\text{max}}$ and $V_{\text{cmax}}$ of Eucalyptus globulus were correlated with leaf nitrogen content and the ratio of $J_{\text{max}}/V_{\text{cmax}}$ was constant under elevated CO$_2$ or elevated temperature, but SLA is influenced by different CO$_2$ and temperature treatments.
4) Poplar and willow: In experimental trials of three Populus deltoides clones and two P. deltoides × P. nigra clones, $J_{\text{max}}$ and $V_{\text{cmax}}$ of the former species were significantly higher than the latter hybrid despite some clonal variations (Dowell et al., 2009). Wullschleger (1993) summarized the species-specific estimates of $J_{\text{max}}$ and $V_{\text{cmax}}$, and the five Populus species displayed large variations. In a poplar free-air CO$_2$ enrichment (PopFACE) experiment, $P$. alba, $P$. nigra and $P$. × euramerica showed significant difference of $g_s$ but non-significant difference of $J_{\text{max}}$ and $V_{\text{cmax}}$ among species, while the elevated CO$_2$ significantly decreased $J_{\text{max}}$ and $V_{\text{cmax}}$ but had no influence on $g_s$ species (Bernacchi et al., 2013). SLA was also found to differ significantly between $P$. deltoides × $P$. nigra family and $P$. deltoides × P. trichocarpa family (Marron et al., 2007). For willows, SLA increased significantly under fertilization and irrigation, but the magnitude of response varied among six varieties of Salix species (Weih and Ronnberg-Wastljung, 2007). Similarly, the response of SLA and $g_s$ to nitrogen fertilization differed among three willow clones, but no significant difference of $V_{\text{cmax}}$ was found between fertilization and control plots for all clones (Merilo et al. 2006).

In general, the values of parameters like $V_{\text{cmax}}$, $J_{\text{max}}$ and SLA differ among different species or genotypes within each bioenergy crop type. The parameter responses to management like fertilization and irrigation also show large variations depending on the specific species. Although the effects of management on these parameters seem evident in some cases, a set of quantitative relationships that can be applied in relation to simple management operations in a global vegetation model for large scale and generalized PFT is still lacking. Expanding PFT level to species level in global vegetation models requires substantial computational resource, and more importantly, there may be not enough measured parameters of each species for all the processes implemented in the models. At this stage, therefore, using the medians and ranges across a great number of observations is a more justified and practical way to tune the parameters in the models. But more field measurements and quantitative reviews of relationships between individual parameter and individual management as well as interactions between different parameters and managements are highly needed in future research.”

Reference


Different managements (i.e. fertilization, irrigation, and use of specific genotypes within a grid-cell) should be taken into account in addition to the fertilization rates but unfortunately, there are large variations in the observations within a grid-cell. I assume that much of this variation can be attributed to differences in management of the bioenergy crop. For example, there are likely different levels of nutrient fertilization, irrigation, and use of specific genotypes within a grid-cell. I recommend exploring this variation more. Do the simulations compare better to yields from specific types of management? Addressing this question will help set a path for future model development that includes management practices. For example, if the simulations compare better to the nutrient fertilization treatment trials, then including nutrient limitation will potentially help improve the simulations of the biofuel. I realize that the paragraph on page 11, line 9 address this issue but I found paragraph to be weak. Can the studies not be roughly categorized by management intensity? Furthermore, the final sentence "implying the model is able to capture at least some of the observations in these grid cells" does not give much confidence that the new parameterization is actually an improvement.

Response #3
As suggested, we further categorized the observations with different managements (i.e. fertilization, irrigation and species) and added three figures and two tables (reproduced below) to show the model-observation comparison. We also fully discussed the management effects on biomass yields for each bioenergy crop based on evidence from reviews or meta-analyses (Heaton et al., 2004; Cadoux et al., 2012; Kauter et al., 2003; De Moraes Gonçalves et al., 2004; Wang et al., 2010; Fabio et al., 2018. See details below). We will also add sentences in the revised manuscript to incorporate these aspects:

"Management like fertilization, irrigation and species plays an important role in the biomass yields. In ORCHIDEE-MICT-BIOENERGY, nutrient limitations and management by irrigation and fertilization are not explicitly implemented. Instead, we used parameter values in the range that favors a higher productivity (Section 2.3, Fig. 1) and compared the simulated yields with the median values of all observations regardless the management (Fig. 3). We further categorized the observations into three groups (fertilization, non-fertilization or non-reported) and compared with simulated yields (Fig. S5). There is no systematic bias between simulated yields and yields at fertilized sites for all PFTs (orange dots in Fig. S5). The model seems to overestimate the yields of eucalypt at sites with non-reported information of fertilization (most gray dots above 1:1 line in Fig. S5a, Table S4) and overestimate yields of poplar and willow at sites without fertilization (green dots in Fig. S5b, Table S4). Yields at sites with non-reported fertilization information are underestimated by the model for Miscanthus (gray dots in Fig. S5c, Table S4) but overestimated for switchgrass (gray dots in Fig. S5d, Table S4). We didn’t group the observations based on different fertilization rates because there are large variations in the biomass response to fertilization rates. For example, in a quantitative review by Heaton et al. (2004), the relationship between yields of Miscanthus and nitrogen application rates were not significant. Cadoux et al. (2012) reviewed 11 studies that measured Miscanthus yields under fertilization, and the biomass response to nitrogen fertilization was positive in 6 of the studies but no response in the others. Similarly, some studies showed positive biomass response of poplar to nitrogen fertilization, but others didn’t (Kauter et al., 2003). Eucalypt also showed variable response to fertilization while the general response was positive (De Moraes Gonçalves et al., 2004). In quantitative reviews of fertilization effects on yields of switchgrass (Wang et al., 2010) and willow (Fabio et al., 2018), the relationship between biomass yields and nitrogen fertilization rates was significantly positive but the coefficient of determination (r²) was very low. In summary, biomass response to fertilization varied largely, and evidence from field measurements is not conclusive. More importantly, the basic soil characteristics should be taken into account in addition to the fertilization rates but unfortunately,
we didn’t have information of soil nutrient contents nor types, nutrient stoichiometry, rates and timing of applied fertilizers for each site from observations.

We also separated the observations based on irrigation information (irrigation, non-irrigation and non-reported) in comparison with modeled yields (Fig. S6). Both underestimation and overestimation were found for sites with different irrigation management for different PFTs. The yields of eucalypt were underestimated at sites with irrigation (blue dots in Fig. S6a, Table S4) but overestimated at sites with non-reported irrigation information (gray dots in Fig. S6a, Table S4). Compared to fertilization, not many sites reported irrigation information and the quantification of irrigation rates is more difficult. For example, some studies reported irrigation amount per year while some others only reported descriptive information like “soil moisture maintained to field capacity” or “irregular irrigation when necessary”.

Comparison between simulated yields and observations for the main species of bioenergy crops is shown in Fig. S7. The model overestimated yields of *Eucalyptus urophylla × E. grandis, E. globulus* and *E. nitens* (Fig. S7a, Table S5). For poplar and willow, the model generally overestimated yields of *Populus deltoides × P. nigra, P. deltoides* but underestimated yields of *P. trichocarpa* and *Salix schwerinii × S. viminalis* (Fig. S7b, Table S5). There is underestimation of yields for *Miscanthus × giganteus* but overestimation for *Miscanthus sinensis*. In fact, the observed yields of the former are significantly higher than yields of the latter (t-test, p<0.01). Only four sites reported yields for *Panicum pretense*, and they were overestimated by the model (Fig. S7d, Table S5).

"We also revised the final sentence as: “In addition, the error bars for most sites (67%, 73%, 74% and 64% for PFT14 to PFT17 respectively) reach the 1:1 line (Fig. 3 left panel), implying that at least some observations in these grid cells can be represented by the model.”. Here we only stated that although the medians are not on the 1:1 line, some observations can be captured by the model. We didn’t imply the improvement after new parameterizations here, because the improvement from the previous model version be clearly seen from Fig. 11 and discussed in Section 4.2.

Fig. S5 Comparison of biomass yields simulated by ORCHIDEE-MICT-BIOENERGY and observations with or without fertilization. Orange, green and gray colors represent the median values of observations with fertilization, without fertilization or non-reported information, respectively in each grid cell. The red line indicates the 1:1 ratio line.
Fig. S6 Comparison of biomass yields simulated by ORCHIDEE-MICT-BIOENERGY and observations with or without irrigation. Blue, green and gray colors represent the median values of observations with irrigation, without irrigation or non-reported information, respectively in each grid cell. The red line indicates the 1:1 ratio line.

Fig. S7 Comparison of biomass yields simulated by ORCHIDEE-MICT-BIOENERGY and observations for the main species of bioenergy crops. Different colors represent the median values of observations for different species in each grid cell. The red line indicates the 1:1 ratio line.
Table S4 Median and 1st and 3rd quartiles of biomass yields under different management practices from observations and the model simulation. N is number of half-degree grid cells with observations.

<table>
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<tr>
<th>PFT</th>
<th>14, eucalypt</th>
<th>15, poplar &amp; willow</th>
<th>16, Miscanthus</th>
<th>17, switchgrass</th>
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<tr>
<td></td>
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Table S5 Median and interquartiles of biomass yields for the main species from observations and the model simulation. N is number of half-degree grid cells with observations.

<table>
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<tr>
<th>Species</th>
<th>N</th>
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<th>observation 1st quartile</th>
<th>observation 3rd quartile</th>
<th>model median</th>
<th>model 1st quartile</th>
<th>model 3rd quartile</th>
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<td>17.7</td>
<td>14.9</td>
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</tr>
<tr>
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<td>18.9</td>
<td>18.5</td>
<td>19.3</td>
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<td>6.8</td>
<td>4.9</td>
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</table>
Reference

Comment #4
Also, these is an issue for the editors to provide input on, but the paper leans heavily on a data paper that is submitted to another unnamed journal. Therefore, a reviewer of this paper is unable to comment on the quality and applicability of the observational dataset. Should this paper be allowed to be published before that data paper is available?

Response #4
As shown on P9L15-24, we briefly reported information on the dataset related to this study. We already submitted the revised version of the dataset after peer-review in a data journal. If the dataset paper is accepted before this GMD manuscript, we will provide the detail reference information. The dataset will be eventually available to public and free to access (hopefully soon).

Comment #5
The spatial mapping of the model-bias is useful but it opened the question whether there are spatial differences in management that could explain the spatial variation in the mismatch.

Response #5
We agree that management would contribute to the spatial mismatch between model and observation. However, it is difficult to isolate individual management factor (e.g., species, irrigation and fertilization) or systematically evaluate the role of all these factors in driving model-observation mismatch. In addition, if we separate the spatial maps of sites with a specific management, the number of sites is limited in most cases and consequently, no spatial patterns can be observed. We thus discussed the management effects on the biases between model and observation globally as suggested by the reviewer (see Response #3) but didn’t analyze further the regional management contributions to the spatial patterns of mismatch here.

Specific Comments:
Comment #6
The model evaluation and discussion sections blur together a bit at the edges (section 4.1 seems like a continuation of section 3). I recommend making the separation more clear.

Response #6
We will move section 4.1 from Discussion to Model evaluation section.

Comment #7
Section 3.3 says that the model-observations results generally lie around the 1:1 ratio line but doesn’t provide any statistics on the fit. What is the slope and intercept from the 1:1 fit?

Response #7
We will add sentences here to report some statistics: “Although the regression between modeled and observed medians is not significant with a low $r^2$ value because of the overestimation and underestimation at some sites (Fig. 3 left panel), the difference between the two samples of modelled and observed yields is not significant (t-test, p>0.17) and the percent bias (PBIAS, defined as sum of biases divided by sum of observed values, Moriasi et al., 2007) ranges from 2% to 8% for all PFTs,
implying that the global distributions of modeled and observed yields are consistent (Fig. 3 right panel). In addition, the error bars for most sites (67%, 73%, 74% and 64% for PFT14 to PFT17 respectively) reach the 1:1 line (Fig. 3 left panel), implying that at least some observations in these grid cells can be represented by the model.”

Reference

Comment #8
Figure 6. It is hard to see the gridcells in the subboxes. For example, box 2 in Figure 6 has lower points that are impossible to see. Can the subboxes be bigger. I also recommend adding a histogram inset that summarizing the data across grid-cells for all the similar figures (Figure 6-9)
Response #8
We will enlarge box 2 in Figure 6 and add a histogram inset in Figure 6-9 as suggested.

Comment #9
Figure 10 stated that there is a 1:1 line that is not present in the figure
Response #9
We will delete this sentence in Figure 10 caption.

Comment #10
Page 3 Line 25:Change "ORHCIDEE" to "ORCHIDEE"
Response #10
We will revise it accordingly.

Comment #11
Page 8, line 22: change 'through leaf falling off' to 'though leaf senescence'
Response #11
We will revise it accordingly.

Comment #12
Page 9 Line 8: Change "corresponding" to "corresponds".
Response #12
We will revise it accordingly.

Comment #13
Page 11 Line 27:Change "after plantation" to "after planting"
Response #13
We will revise it accordingly.

Comment #14
Page 12 Line 13:It is unclear what is meant by "because of the large spacing of plantation the trial experiment which results in . . .". Perhaps what was intended was something like: "because of the large spacing of the planting in the trial at that experimental site, which results in . . .".
Response #14
We will revise it accordingly.

Comment #15
Page 13 Line 9: Change "US" to "the US
Response #15
We will revise it accordingly.