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Discussions

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Interactive comment on "An improved parameterization of leaf area index (LAI) seasonality in the Canadian Land Surface Scheme (CLASS) and Canadian Terrestrial Ecosystem Model (CTEM) modelling framework" *by* Ali Asaadi et al.

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We thank the reviewer for taking the time to review our manuscript and her/his constructive comments. Our point-by-point responses are included below. The reviewer's comments are indicated in italic font and our responses in regular font.

Reviewer:
These are my comments of the work entitled: An improved parameterization of leaf

area index (LAI) seasonality in the Canadian Land Surface Scheme (CLASS) and Canadian Terrestrial Ecosystem Model (CTEM) modelling framework. Firstly, I want to thank the authors for the work done. I felt the manuscript quite interesting. This paper describes the addition of the Non Structural Carbohydrates (NSC) module, to the CLASS-CTEM model. NSC module allows to better represent Leaf Area seasonality, as well as to provide a mobile carbohydrate pool to the trees to increase its resilience to disturbances in absence of photosynthesis. It is tested in three Fluxnet sites, where GPP, LAI, and heat fluxes (Incident radiation, latent heat and sensible heat) model projections are contrasted against real data. In my opinion, this is an interesting, thoroughfull work, where the authors clearly demonstrate that the addition of the NSC module clearly improves model performance. My major concerns about the present paper are about its novelty. Currently most of process-based forest simulation models does include the NSC module (Fontes et al., 2010), in a similar way than the new module for the CLASS-CTEM model. So, in my opinion, your current manuscript doesn't clarify the novelty of your work. Furthermore, throughout your manuscript there is little reference to other models that include this key compartment, and I think it would be a nice element to include in the discussion, as there is plenty of other works in which the addition of NSC in a given model clearly improves its performance.

Authors:
We will modify our manuscript to include references to existing work on inclusion of NSC pools in ecosystem models. Although NSC have been included in other process-based models, the CLASS-CTEM model lacked this part and the present study is the first effort to address this problem. While we do not claim novelty for the present study, we will clarify and stress the importance of NSC pools even more when revising our manuscript.

Reviewer:
Specific considerations:
I felt a little lacking how the Maintenance respiration was calculated in CLASS-CTEM.

I've seen other reviewers asking for the same point, and I feel like an addition of the maintenance respiration formula as well as the assumptions of the model about this process would improve significantly the paper. Besides, I have a couple of questions about maintenance respiration: it is dependent on temperature? It is assumed the same respiration rate for the structural and non-structural carbohydrates?

In lines 175-177, you state that respiratory carbon loses are assumed to occur from the non-structural part. Does it mean that structural carbon is not accounted in maintenance respiration? I guess you did not mean that, but as it is stated, it may lead to misinterpretations.

Authors:

The text was modified and some clarifications were added in response to the editor's review (lines 160-162 and 187-189) in the context of maintenance respiration. Although the model's maintenance respiration along with other processes have already been discussed in previous publications (e.g., section A3.1 in Melton and Arora, 2016), we will add more complementary text and equations to show how the model calculates maintenance respiration . Yes, indeed maintenance respiration is temperature dependent. In the modified (i.e., NSC-added) version of the model presented in this study, maintenance respiration occurs only from the non-structural pools consistent with observational and modelling studies (e.g., Hoch et al., 2003; Sperling et al., 2015; and Li et al., 2016) which show that plants' NSC stores become depleted during dormant season and cold and drought stresses due to excess respiration.

Reviewer:

It is a minor issue, but, in general, I think your explanations about Leaf Area (LA) importance upon photosynthesis. However, I think you are wrong when referring to them as LAI (for example, lines 1, 63). LAI doesn't perform photosynthesis, it is the Leaf Area, that does it. LAI is just an explanatory index about the surface of leaf area per unit of surface.

Authors:

We feel this is a terminology issue. While it is true that photosynthesis is a function of the total "leaf area", several of the model's parameterizations use leaf area index. For example, CLASS-CTEM model uses the Beer-Lambert law ($1 - e^{-k(LAI)}$, where k is a vegetation-dependent light extinction coefficient) to scale photosynthesis from the leaf to the canopy level. Nevertheless, we will try to clarify this terminology issue.

Reviewer:

In point 2.1.1 (Reallocation of non-structural carbon during leaf out period), you do state that "after reaching a threshold LAI, NPP is allocated to stem and roots in addition to leaves". I could not find in your work how these compartments are developed. Do your model follow any predefined rule (e.g. the Pipe model rule, Shinozaky, 1974)? Or they are equally allocated throughout the tree compartments according to a predefined rate?

Line 451. Again, following which rule, besides the "after reaching a LAI threshold", are the carbohydrates allocated through the three compartments? A fixed rate? A mechanistic rule?

Authors:

While the model's several processes have been described before in Melton and Arora (2016), we will add additional details to clarify these allocation-related questions raised by the reviewer. In brief, the model uses dynamically calculated allocation fractions for leaves, stems and roots based on light, water and leaf phenological status of vegetation. The preferential allocation of carbon to the different tissue pools is based on three assumptions: (i) if soil moisture is limiting, carbon should be preferentially allocated to roots for greater access to water, (ii) if LAI is low, carbon should be allocated to leaves for enhanced photosynthesis and finally (iii) carbon is allocated to the stem to increase vegetation height and lateral spread of vegetation when the increase in LAI results in a decrease in light penetration. The dynamically calculated allocation fractions are further modified to ensure that root to shoot ratio is realistic and that there is enough woody biomass to support green biomass.

Reviewer:

Line 372-373. I would remove the sentence "The figure legends, in addition to identifying the two mode versions and observations, also show the mean annual value of the quantity plotted", and I would include it in the figure footnote.

Authors:

Agreed.

Reviewer:

Lines 419-420. Your sentence assumes an equilibrium between the atmospheric CO_2 and the biosphere. Maybe is far beyond the discussion of your paper, but I think that this is not strictly true, as there has been previous works identifying the instability of the atmosphere-biosphere complex (e.g. Higgins et al., 2002). It is a minor change, but I would suggest to erase the "currently" in the sentence, thus indicating the responsive nature of biosphere to historical changes in atmospheric CO_2.

Authors:

Agreed.

Reviewer:

Point 3.3. Here, you find that you do overestimate latent heat when modelling your three forests. Are there any research papers about evapotranspiration experiments in those forests? If they are, maybe you should transform latent heat into evapotranspiration values, so you can compare them to your data, and you might then have a better explanation about why does your model overestimates so high the evapotranspiration (Latent heat). In addition, how do this relate to your overestimation of Leaf Area? I see a little discussion about it in lines 508-512, but I think you minimize the effect that you overestimate the LAI during the growing season by about 2 m^2/m^2 in each plot, and this affect both the evapotranspiration at canopy level, but also to the evaporative energy available at ground level.

Authors:

As the reviewer noted evapotranspiration and latent heat fluxes are the same quantity but in different units. Evapotranspiration is expressed in water units (mm) and latent heat flux is expressed in energy units (W/m^2). At the flux net sites latent heat flux is available but as mentioned in section 3.3 of the manuscript it suffers from energy balance closure. So it is difficult to conclusively determine how much of this overestimation is due to overestimation by the model and how much of it is due to bias in the observed data. Our experience with the CLASS-CTEM model in the past has been that in locations where soil moisture constraint is not very large, as is the case at these three sites, total evapotranspiration is controlled by available energy. Hence the expected seasonality in latent heat flux is characterized by higher values during summer and lower during winter at these sites. Since the latent heat flux at these three sites is primarily controlled by available energy the resulting implication is that if evaporative demand cannot be met by transpiration then it will be met by evaporation from the soil. As a result, changes in LAI do not significantly affect total evapotranspiration (or latent heat flux) but change the partitioning of evapotranspiration flux coming from transpiration, evaporation of intercepted water on canopy leaves, and evaporation from the soil. Therefore, had the model simulated lower LAI than it currently does, then the latent heat flux would not have been significantly different from its current values. We will include additional discussion along these lines when revising our manuscript.

Reviewer:

Lines 519 to 523. Please, revise the Vmax concept: as states the original paper from Kattge et al, (2009), Vmax is the maximum carboxilation capacity, not the maximum photosynthetic rate. In addition: you are justifying a tautology: This is the parameter that we want to apply to Vmax, so we adjust all other model parameters to fit the results according to this Vmax value. In addition, you finish the sentence with "it is possible that the average Vmax value derived by Kattge et al. (2009) is not representative of [...]". I agree that mean Vmax value not representing correctly your forest performance is a possible explanation, but I would rather discuss that Vmax is not the only constrain to photosynthesis, as Jmax is also limiting assimilation rate.

Authors:
Yes, indeed Vmax is the maximum carboxilation capacity. Thank you for catching this. The CLASS-CTEM model uses the Farquhar approach for modelling photosynthesis, and therefore photosynthesis is limited by carboxilation capacity but also light and transport capacity limited rates. However, Vmax remains a very strong parameter that controls photosynthesis in the model. We will clarify this aspect when revising our manuscript. We did not adjust other model parameters to accommodate Kattge et al. (2009) Vmax values. In fact, the very first version of the model used a value of Vmax of 65 $umolCO_2/m^2s$ for its broadleaf cold deciduous PFT which is close to the value of 57 $umolCO_2/m^2s$ suggested by Kattge et al. (2009).

It is probably worth mentioning that at the global scale the performance of CLASS-CTEM model when implemented in the Canadian Earth System Model (CanESM2) is fairly realistic. Figure 11 of Anav et al. (2013), who compared different Earth system models used in the phase 5 of the coupled model intercomparison project (CMIP5), shows that the CLASS-CTEM's simulated "annual global mean" LAI is among one of the best estimates compared to other models. Figure 9 of Anav et al. (2013) shows that the model also does a good job in simulating global annual GPP.

Reviewer:
Figures 4-6. I would expand a little the footnote, to include the information that results are represented as averaged daily values. In addition, I would consider to change the Leaf Area Index inner pannel to represent the median values during the vegetative period rather than average values, as I think they would be more indicative of the similarities-differences between Fluxnet measurements and model outputs.

Authors:
Thank you for pointing this out. We will change the annual mean LAI to mean LAI over the growing season. We will also modify figures' footnotes.

References:

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