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Interactive comment on "Coupled eco-hydrology and biogeochemistry algorithms enable simulation of water table depth effects on boreal peatland net CO_2 exchange" *by* Mohammad Mezbahuddin et al.

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Referee's comment: General Comments The manuscript addresses impacts on CO2 fluxes from changes in water table depth by using the ecosys model. The model is tested with eddy covariance and chamber CO2 fluxes from a boreal peatland field site. The manuscript is dense throughout and requires very careful attention on the part of the reader to follow along. While the ecosys model is complex, how this paper is written exacerbates the complexity of the model. Right now, this paper would be an incredibly useful guide to someone wanting to run the ecosys model themselves, but

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lacks a clear and story that is supported by the results of this work.

Authors' response: Significant effort will be made to edit the story of the manuscript to simplify it as much as possible. The linkage between the findings and the data will be made clearer following the suggestions of the reviewer wherever applicable.

Referee's comment: The major issue I have with this work is the relative complexity of the ecosys model next to the small amount of observed data that the model is compared with. Since ecosys has so many moving parts “under the hood”, I can't say that I'm surprised at all to see it match data as well as it does. A good fit to observed data is not a new finding itself, and in a broader sense, the research questions aren't new. In fact, there is a good amount of overlap with Mezbahuddin et al. (2016), as brought up by Referee 1. So, I'm stuck reading through a dense description of a complex model, and at the end, it's compared with limited amounts of data that itself is modeled. The main conclusions seem to be focused on internal modeled variables within the ecosys model that have zero comparison to data. The major conclusions are changes in modeled O2 diffusion, N mineralization rates, nutrient availability, microbial concentrations, plant functional type GPP. These results, as currently presented, are simply not supported by comparing to net CO2 fluxes. The authors state in the conclusions that “These modelling hypotheses were also corroborated by various field, laboratory and modelling studies over similar peatlands (Sect. 4.1)” but the reader is left to dig out bits of information through the entire discussion section. At a bare minimum, for me to trust the conclusions of this work, the authors must provide a clear and succinct comparison of their model parameters to literature values in a table/graph, including error analysis. Also, asking the reader to trust your conclusions because they match literature is fine, but there is a major issue when the story of the paper is that inter-site variation of peatland sites is high.

Authors' response: Northern peatlands are likely to be important in future carbon cycle-climate feedbacks due to their large carbon pools and vulnerability to hydrological change. Current predictive capacity of water table depth (WTD) effects on peat carbon (C) accumulation and degradation is limited by poor representation of peatland biogeochemistry in the peatland C models. So, the novelty of this research lies upon its effort to test whether a coupling of algorithms from independent published research that describe feedbacks among peat biogeochemistry, peatland hydrology and peat forming vegetation would be able to simulate and explain WTD effects on peatland CO2 exchange in a boreal peatland. This testing of algorithms representing interactions between peatland biogeochemistry and hydrology not only improves our predictive capacity of WTD effects on peatland CO2 exchange, but also help reconcile our current understanding based on inferences drawn numerically from relationships among EC-gap filled partitioned NEP, GPP, Re and WTD.

Section 1 describes how peatland WTD – C cycle feedbacks vary across peatlands depending upon climate, hydrology, peat substrate type, and peatland vegetation (lines 58-119). It does not stop at only portraying the inter-site variations of these feedbacks. It goes further to explore, by using existing literature, how these inter-site variations are mediated by the interactions among peat forming climate and vegetation, peatland hydrology, and peat type (lines 58-119). Following recommendations from previous model inter-comparison studies, it describes how representing interactions among peat biogeochemistry, hydrology and peat vegetation physiology could lead to improved predictive capacity of the effects of these inter-peatland variations of WTD–C process feedbacks without peatland-specific parameterization of model algorithms (lines 101-119). So, the objective of this study was to examine whether a coupling of site-independent model algorithms describing peatland carbon, nitrogen, oxygen, and water cycling which was fed by site-specific measurable inputs with physical meanings would simulate and explain WTD effects on peatland CO2 exchange for the boreal peatland. Physical and biological processes that mediate WTD effects on peatland CO2 exchange, if accurately modelled, should manifest themselves as increased CO2 effluxes from increased Rh with increasing WTD, offset by increased CO2 influxes with increased N uptake. At some point, further increases in WTD will manifest itself as decreased CO2 effluxes and influxes with greater water stress. These manifestations

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should then be corroborated by observations by EC and flux chambers and by other eco-physiological measurements such as N status as has been done in our manuscript.

In the current manuscript, the hourly modelled outputs of net ecosystem CO2 fluxes were first tested against hourly net CO2 fluxes measured (excluding the gap-filled values) by eddy covariance (EC) approach over a gradually drying weather period from 2004 to 2009 (first five rows of tables 1 and 2). Then the modelled trend of WTD drawdown effect on net CO2 exchange were examined closely for shorter periods (e.g. 10-day) of gradual WTD drawdown along with EC-measured hourly net ecosystem CO2 fluxes, and chamber measured hourly net understory vegetation and soil CO2 fluxes (Figs. 3-5). The examination of WTD effects on CO2 exchange was then extended to daily, growing season, and annual time-scales along with EC-gap filled NEP and partitioned GPP and Re aggregates (Figs. 2, 6-7). The internal peat biogeochemistry and peatland nutrient cycling modelled in "ecosys" were tested against leaf nitrogen concentrations, N mineralization, rooting depth, GPP, and Re measured at either our site or at sites that had similar peat substrates, hydrology and/or plant functional types (Secs. 3.4., 4.1). The above mentioned model validation ensured that the modelled outputs were tested against 6 years of hourly EC measurements under contrasting conditions e.g. wet vs. dry, cool vs. warm. These tests were further corroborated by observations by flux chambers and by other eco-physiological measurements such as N status. So, the testing of the modelled results were as robust as it could be within the best availability of measurements. However, there is always room for improvement and we will be making the following edits as suggested by the referee:

1) The "Objective and rationale" section (Sec. 1.1) will be edited to make the research question more vivid and to clearly depict the novelty of the research question. The potential of modelling peat biogeochemistry to explain and simulate the effects of site-variability on peatland WTD-C process feedbacks will be described more clearly to avoid any confusion.

2) The comparison among modelled parameters, site measurements, and other litera-

ture values of peat biogeochemistry and nutrient cycling will be presented in a separate table instead of the way they are now presented in the texts in Secs. 3.4. and 4.1.

3) The overlaps with Mezbahuddin et al. (2016) has been identified in lines 481-501. Mezbahuddin et al. (2016) talked about hydrological modelling of the same site some of which were relevant to the current manuscript. However, these overlaps will be removed as much as possible.

Referee's comment: Specific Comments to expand on the above general comment, the eddy covariance and chamber data is not explained well enough in this paper. Let me be clear, that doesn't mean that I have issues with the data itself, just how it is presented and used here. Referee 1 brought up the issue of comparing model output to gap filled data, which is comparing a model to another model. That is absolutely an issue in this work, and I second what Referee 1 highlights as a major issue, but I'll go further. There needs to be more discussion of the data, how it was gap-filled, possible sources of error and what that means when compared to the model results. I know this is a modeling work, but with very limited observational data to compare the model results with, simply saying in two sentences "To examine how well ecosys simulated net ecosystem CO2 exchange at the WPL, we tested hourly modelled net ecosystem CO2 fluxes against those measured by using eddy covariance (EC) micro-meteorological approach by Syed et al. (2006) and Flanagan and Syed (2011). Quality control, and gap-filling of EC measured net CO2 fluxes, and partitioning of EC-gap filled net CO2 fluxes into GPP and Re were done by Syed et al. (2006) and Flanagan and Syed (2011)" is not enough when the first line says "we used observational data" and the second says "please read those other papers for their methods". Now, when we get to the details of the chamber fluxes, there are slightly more details, but again, not nearly enough. Again, you partition net CO2 using a model, but don't explain anything beyond that.

Authors' response: Daily, growing season and annual aggregates of EC NEP includes number of gap-filled net CO2 fluxes. The sole reason of regressing modelled results against gap-filled CO_2 fluxes was to examine how much of the deviation between modelled and EC gap-filled estimates of growing season and annual NEP, and between modelled and EC-partitioned GPP and Re were contributed by the gap-filled fluxes (Tables 1 and 2; and lines 920-936). However, since it creates confusion, we could move those regression results for gap-filled vs. modelled net CO_2 fluxes to a separate table and could put the table in the appendices.

Methods for screening, gap-filling, and partitioning of EC datasets will be described in sufficient details in sec. 2.2.2.

Referee's comment: You average over 9 chambers, but don't say why or what that means? How much error is introduced here? What is the range of observed fluxes? The reader doesn't know, so again going back to my main issue, with very limited observational data, ecosys modeled results look good at the surface, but the work is limited in how much the reader can trust the results of an over-parameterized and under-tested model.

Authors' response: Those 9 chambers were in place to cover spatial variation due to peatland micro-topography while measuring the net CO_2 fluxes from understory vegetation and soil. We averaged those chambers to include overall hummock-hollow variations of those fluxes. The reasoning will be described in sufficient details in sec. 2.2.2. Also, figs. 4 and 5 will be redone to include standard error of means of spatially averaged chamber fluxes so as to represent flux variations among the chambers. Moreover, there will be a separate regression test between modelled understory and soil CO_2 fluxes, and the chamber CO_2 fluxes for 2005 and 2006 for which we had measurements available. This will further strengthen the robustness of the test of modelled outputs.

Referee's comment: Once we move past the issue of how the observational data is described, we move through a lot of model descriptions and results that are very, very dense. I'm very happy to see what looks like the full set of equations that go into ecosys in the appendixes, but the reader is left with only very dense blocks of text to try to figure out what parts of the model are important and why. I would suggest keeping the entire set of equations in the appendix, but moving the main equations used here into the text of the manuscript. Then, the reader doesn't have to dig out the equations for context and, more importantly, it would be easier to focus the story around those few equations.

Authors' response: The model development in sec. 2.1. in current manuscript only describes the key equations that are related to the hypotheses. The respective equations that are listed in the appendices are also cited within the text. The current model description is self-explanatory and a reader does not have to always go back to the appendices to understand the processes. However, the citation of the equation within the text makes sure that a reader can go back to the appendices at any time to see details of a particular equation. Few key equations from the appendices could be pasted into and described in sec. 2.1 as suggested. But we feel that it will either make the section even denser or the story could be incomplete if roamed around too few equations. Instead, our preference is to include a flow chart summarizing those key processes and linking the flow chart with the description as suggested by reviewer 3 (please see the figure attached with the authors' response to the comments of reviewer # 3 as example).

Referee's comment: As the reader is starting to get a handle of the main story presented, a major issue comes up again. There isn't enough data to support the conclusions. Even the highlighted results in the abstract are heavily focused on things like nitrogen dynamics, nutrient mineralization, GPP of plant functional types, all of which are 100 percent internal to the model without any space in the manuscript devoted to why the read should trust the internal model equations.

Authors' response: How the modelled outputs were tested against measurements and how the testing would be improved have been discussed in reply to the general comments above. The model equations were derived from independent research which

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were rigorously tested in other published studies. The sources of those equations have been listed in the supplementary material. However, a separate brief discussion about the sources and significance of the model equations will be added to section 2.1.

Referee's comment: Finally, the conclusions presented are simply changes in variables that are internal to the model, without anything to compare them with other than literature values from other studies. As mentioned in the general comment above, the literature values could be a valid check if done well, but as this manuscript is currently written, that needs to be done more formally and not in the discussion. With the suggestion of strengthening the comparison of the modeled conclusions to literature as well as the authors pinning a lot of the trust in their conclusions on said literature values, when the ending of the introduction/justification section is as follows: "Moreover, since hydrological feedbacks to key peatland C processes are highly non-linear and site-specific, testing of ecosys algorithms across contrasting peatlands would also facilitate formation of a modelling platform for scaling up simulations of those feedbacks across peatlands at larger spatial scales i.e., national, regional, continental or global as also recommended by Waddington et al. (2015)" the reader is going to be confused. On one hand, you compare your conclusions to literature and say "look, these results fit with other studies" but the entire paper was setup with the story of "there are lots of variations across peatland sites" throughout the introduction. So, I'm confused and this needs to be cleared up either by heavy editing of the story.

Authors' response: The conclusion section will be sufficiently edited to include general conclusions, and the implications of those conclusions. A formal comparison between the modelled outputs and measurements from the same site, and/or similar sites from earlier studies will be done in a separate table as mentioned earlier. The mentioned sentence within the quote will be rephrased to remove any confusion and contradiction with earlier description.

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