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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: This paper compares the results of the ecosystem biophysical model ecosys against field measurements of environmental variables (primarily water table depth – WTD) and carbon fluxes measured by eddy covariance (EC) at a treed peatland in western Canada over a 5 year time frame when WT was decreasing at the site. The model, ecosys, is a very sophisticated tool and has been widely applied in the past against many different ecosystem types, with success. It is fair to say that is among the top ranked platforms for simulating ecosystem functioning. With that said,

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the purpose of this particular paper is a bit foggy. The EC flux measurements from this site, including the time series over which the WTD had declined, have been clearly reported in previous literature, as has been cited in this study. Therefore, is the purpose of this study 1) to simply to test if ecosys can simulate the trend in measured EC fluxes over the study period, or 2) to use ecosys to explain the behaviour of the EC-fluxes, which cannot be obtained from most common EC and environmental measurements? The paper seems to do a bit of both, but the main objective is not clear. However, given the extensive testing of ecosys at other peatlands and other ecosystems, the former seems to be quite a weak objective. The latter is more scientifically interesting, but that is not the way the paper is set out.

Authors' response: The objective of this paper was 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 help reconcile our current understanding based on inferences drawn numerically from relationships among EC-gap filled partitioned NEP, GPP, Re and WTD. However, given the non-linearity and peatland-specific responses of WTD-C cycle feedbacks, testing these algorithms in peatlands with contrasting peat type, vegetation, hydrology, climate and weather conditions also have important scientific and practical implications. 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 testing ecosys algorithms against measurements in a boreal fen, which is very different from the earlier peatlands where ecosys was tested in terms of climate, hydrology, peat forming substrates and vegetation, should complement those in earlier papers in examining the adequacy and robustness of our predictive capacity of these feedbacks.

The objective and rationale section (lines 121-134) will be edited as much as possible

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to clearly lay out the objective, purpose and the implications of the study to remove any confusion.

Referee's comment: There are 4 operating hypotheses (not repeated here). These are not stated in terms of what is reflected in the EC-derived measurements, which seems to be the main thrust of the paper from the rest of the introduction, but rather in terms of biophysical processes that will take place in the model. Hence, it is a source of some of the confusion about the purpose of this paper. It would be nice to see an attempt to improve the introduction with a clearer purpose.

Authors' response: Perhaps the best way to present the model hypotheses is to state the physical and biological processes affected by WTD and how they are modelled, as we have done in the current manuscript. These processes, 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 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 the manuscript. The reflection of those hypotheses in EC-measurements has also been somewhat stated in lines 171-175. However, it will be weaved better as suggested. Overall, sections 1.1 and 1.2 in the introduction will be edited as much as possible to clearly lay out the objective, purpose and hypotheses so as to remove any confusion upfront as also mentioned above.

Referee's comment: Another concern about the present manuscript is that there is a lot of attention to how ecosys performs in simulating the WTD. It seems to me that this topic was adequately covered in the previous paper, Mezbahuddin et al. (2016), so why do we need the emphasis here.

Authors' response: The contents in lines 481-501 will be removed as much as possible to eliminate the overlap with Mezbahuddin et al. (2016).

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Referee's comment: I have a small worry about the comparison of ecosys modelled fluxes against gap-filled data (especially nighttime (Re) fluxes – section 3.3). Since the gap-filling is a model itself – now we are comparing one model against another. I realize there is a discussion of how this may have affected the comparison, but that does little to convince readers that the comparison of modelled and measured data is sound. Why not just compare half hours where measured data were available to test ecosys, if that is the point of the paper (see above).

Authors' response: The real test of modelled outputs of hourly net CO2 fluxes was against EC-measured hourly net CO2 fluxes (no gap-filled fluxes) (first five rows of both Table 1 and table 2). Since the model is hourly time-step, we averaged two half-hourly measured EC net CO2 fluxes (no gap-filled fluxes) to test the modelled fluxes against with (lines 417-423). If any or both of the two half-hourly fluxes was gap-filled, the average hourly net CO2 fluxes were termed as "gap-filled".

Daily, growing season and annual aggregates of EC NEPs include number of gap-filled net CO2 fluxes. The sole reason of regressing modelled results against gap-filled CO2 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 CO2 fluxes to a separate table and could put the table in the appendices.

Referee's comment: Section 4.2 Divergence between modeled and EC-derived fluxes makes some interesting points, but as it stands very little of this has been tested or analyzed in any detail, so we really don't know what the source of the discrepancy is. It would be nice to see some attempt or suggestions as to how to hone in on the most likely causes of the discrepancy. You seem to suggest the EC-derived measurements are wrong, which may well be, but I am not sure that the model is not without fault.

Authors' response: In ecosys model, productivity of the plant functional types (PFT) is governed by leaf nitrogen status which is constrained by root nitrogen availability and uptake. So, the uncertainty in modelled outputs for the productivity of the PFTs depends on the accuracy of model inputs of soil organic nitrogen, wet or dry deposition, fixation and any other sources of nutrient inputs into the ecosystem. The model inputs for organic nitrogen in each peat layers were measured from the site. The background wet and dry deposition rates for NH4+ and NO3- reported for the site area were used as model inputs. However, from field observations, it was evident that there was significant nutrient inflow with the lateral water influxes into this fen peatland from the surrounding upland forests which was not quantified. To mimic this, we doubled the background wet deposition of NH4+ and NO3- reported for the area and used these as a surrogate of lateral nutrient inflow into the modelled ecosystem (lines 371-377). We also included a nitrogen fixing mechanism by lichens which was reported for the boreal forests (lines 405-408). We tested the adequacy of these nitrogen inputs into the model by comparing modelled leaf nitrogen contents against those measured in the field. The modelled leaf nitrogen contents for black spruce, tamrack and dwarf birch PFTs corroborated well against site measured leaf nitrogen contents during the summer of 2004 (lines 659-666).

To further examine the contribution of model uncertainty towards the divergence between modelled vs. EC-derived seasonal and annual GPP and Re, we performed a sensitivity test where we had a parallel run without doubling the background nitrogen wet deposition rates in the model, hence simulating no lateral nitrogen influx. This parallel run gave GPP and Re outputs for the modelled ecosystem that matched better with the EC-derived GPP and Re compared to the current run. However, the regression of the modelled net CO2 fluxes from the parallel run on the EC-measured (excluding gap-filled fluxes) fluxes gave slopes of $\sim$0.8 indicating under-simulation of the EC-measured fluxes in the parallel run with no lateral nitrogen inflow despite better matching EC-derived GPP and Re aggregates.

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The above discussion of model uncertainties will now be added to section 4.2.

Referee's comment: The Conclusion section is not really a conclusion. First, much of it is simply a re-statement of the main findings. Second, it suffers the same problems as the objective of the study namely, not really being clear. The final statements about the value and application of the ecosys model, while possibly true, seem a little self-serving.

Authors' response: All of the re-statements will be removed. The conclusion will be edited to link better with the revised statements of objectives. The final statements will be rephrased to remove any confusion.

Referee's comment: Finally, the manuscript needs a good editing, although the writing is such that it is understandable, there are many awkward statements/phrases, issues with tense, or grammatical errors that could be addressed to improve the manuscripts readability. I have pointed out some of these in the minor points below, but there are several others. Overall, this could be quite a useful contribution, especially if cast in the role of using ecosys to help understand the pattern and responses of EC-derived fluxes over time, something that is hard to get from just EC and environmental measurements, rather than just another test of the ecosys algorithms at another peatland site.

Authors' response: The manuscript will be thoroughly revised and edited to remove any sentence structure related or grammatical errors. The objective and rationale section (Sec. 1.1) will be revised to clearly represent the focus of the study which was to simulate and examine the underlying processes affecting WTD – peatland C cycle feedbacks. This would also serve as a reconciliation of the inferences drawn on WTD-C feedbacks in this peatland by using EC-gap filled and partitioned aggregates.

Referee's comment: Minor Issues: 1. Line 81-82 & line 87, Lafleur et al. (2005) reference is inappropriate here, they discuss Re not GPP. Also relevant on lines 908-911. 2. Lines 95-97, as above this reference does not discuss a threshold for WTD and GPP, perhaps another reference by this author?

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Authors' response: The correct reference will be "Lafleur, P. M., Hember, R. A., Admiral, S. W., and Roulet, N. T.: Annual and seasonal variability in evapotranspiration and water table at a shrub-covered bog in southern Ontario, Canada, Hydrol. Process., 19, 3533-3550, 2005." It will be corrected in the revised manuscript.

Referee's comment: 3. Lines 98-107, the start of this paragraph is poorly worded. First one does not start a new paragraph with the word 'therefore". The sentence beginning "So, to adequately predict : : :" is awkward and doesn't quite read right. As with the next sentence – the phrase "do not have prognostic WTD dynamics that prevent simulation" is confusing and awkward.

Authors' response: All of the three sentences will be rephrased.

Referee's comment: 4. Lines 314-317, these two sentences that describe the simulated mosses are very difficult to understand, some revision for clarity is needed. Should be put in terms of what a real moss is and where it grows.

Authors' response: Those sentences will be edited to describe more clearly how moss is simulated in ecosys.

Referee's comment: 5. Line 447, the word diurnal here is incorrect; Table 1 compares instantaneous half hour fluxes. Diurnal suggests some course of measurements over the daytime.

Authors' response: It will be edited as suggested.

Referee's comment: 6. Line 457-58, the sentence here about 2009 is not needed here; simply add it as a foot note to the Table.

Authors' response: The line will be removed from the text and will be added as a footnote to the Table 1 as suggested.

Referee's comment: 7. Line 478-81, this sentence is somewhat heuristic; the Figure certainly does not show these components. I think it is adequate just to say the model

simulated measured WTD well.

Authors' response: The line will be edited as suggested.

Referee's comment: 8. Line 536, word 'also' is not needed.

Authors' response: It will be removed.

Referee's comment: 9. Line 537, what does 'It' refer to?

Authors' response: 'It' referred to 'similar day-time fluxes in 2005 and 2008 despite larger night-time fluxes in 2008 than in 2005' (will be revised).

Referee's comment: 10. Line 538-41, this long sentence is somewhat awkward and doesn't really say anything new.

Authors' response: It will be removed.

Referee's comment: 11. Lines 559-61, the sentence here seems to be missing a word or words, does not read well.

Authors' response: The sentence will be rephrased.

Referee's comment: 12. Lines 55-570, you seem to miss an opportunity here. You describe how warming does not stimulate Re when water table was high in 2005, and how it is stimulated by warming in low WT years (2006 and 2008), yet given the sophistication in ecosys there is not real explanation of why this works the way it does, what is the biogeochemical functioning that does or does not stimulate Re under low and high WTs respectively? Further down you describe the mechanisms associated with GPP, why not the same with Re?

Authors' response: The mechanisms describing how warming affected Re in shallow vs. deeper WT conditions have already been discussed in lines 764-769.

Referee's comment: 13. Line 632-33, this was mentioned above (#6), no need to repeat it here.

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Authors' response: This sentence will be deleted.

Referee's comment: 14. Lines 664-69 Section 3.5, You state this drainage experiment ": : : would 667 also serve as a climate change analog in providing us insight into how potential WTD drawdown 668 under future drier and warmer climates would affect boreal peatland GPP, Re and hence NEP." I don't see how, as the atmospheric changes of higher temperatures and perhaps higher VPD are not included. I think it is fair to say this simulation represents the effects of WT drawdown only.

Authors' response: We did not include rise in temperature and consequent VPD effects in our drainage simulation. Those sentences will be edited as suggested to remove the confusion.

Referee's comment: 15. Lines 673-74, I don't think you need this sentence, it is rather obvious that changes would occur and you have a lot of words following to describe them.

Authors' response: The sentence will be deleted.

Referee's comment: 16. Lines 683-696, is this enhanced evapotranspiration coming from the tree cover or ground vegetation or both?

Authors' response: The enhanced evapotranspiration was coming from the tree cover (will be added to the text).

Referee's comment: 17. Lines 848-51, should note here that his Dimitrov et al. 2010 study was on a temperate bog not a fen.

Authors' response: Yes that was a bog. The sentence will be omitted.

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