Reply to referee comments

Manuscript: ASSESSING THE PEATLAND HUMMOCK-HOLLOW CLASSIFICATION FRAMEWORK USING HIGH-RESOLUTION ELEVATION MODELS: IMPLICATIONS FOR APPROPRIATE COMPLEXITY ECOSYSTEM MODELLING

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Referee: L. Kutzbach

Note: Our response to referee comments are in red.

The manuscript of Moore et al. presents a very interesting and comprehensive analysis of the microtopographic structure of boreal non-patterned bogs. The paper scrutinizes the binary hummock-or-hollow classification approach, which is often followed in sampling design or modeling of biogeochemical and ecophysiological peatland processes.

The authors applied a well-designed combination of elaborate field data acquisition methods, targeted statistical analyses and appropriate process modeling. I am particularly pleased about the creative and thorough usage of various spatial statistical methods for analyzing the heterogeneity of peatland microtopography (e.g., Gaussian mixture models, Fourier transform power spectra of microtopographic variability along transects, slope and aspect analysis for microtopographic features, fractal dimension of plots). I also like the approach of simulating water content and net primary productivity in dependence of microtopography properties as an approach to demonstrate the relevance of thorough microtopography characterization for quantification of energy and matter fluxes. The authors show that non-consideration of the full continuum of microtopographical variability can lead to serious biases in spatial averages of net primary productivity due to negligence of microforms that are intermediate between hummocks and hollows. Even more pronounced bias would be expected for, e.g., methane emissions, which are controlled by water level depth below the moss surface in a highly nonlinear way.

Thus, the presented study is of high scientific relevance and originality. However, I think that the quality of the manuscript needs to be improved. In the following, I provide lists of (1.) general comments, (2.) specific comments, and (3.) technical comments. I recommend the manuscript for publication after major revisions.

General comments

(1) The experimental design of the study needs to be better explained. It is now too difficult for the reader to find out which method was applied where. That the many analyses were conducted at various peatland sites, needs to be more clearly stated already in the introduction. Furthermore, I think that a figure explaining the study design by including maps of different scale (e.g., northern hemisphere with location of all investigated peatlands, Nobel peatland with location of random plots in detail), would help. It would be also helpful if information on site and/or spatial scale would be added to all of the figure captions.

Response: In general, we used the terms 'site-level' and 'plot-level' to systematically orient the reader in methods/results. However, it is clear from the referee's comments that improved clarity is needed. As suggested, we have explicitly included 'site-level' or 'plot-level' to figure captions where appropriate for additional clarity. It is possible that this provides the necessary additional clarity, but we have also created a figure which provides visuals of the experimental design (see Figure 1 below). Given that the main manuscript already has nine figures and the size of the new figure, we feel that the new figure is best added to the supplemental material. However, we are happy to place it in the main text as is or in a modified form if there are any strong opinions on the matter

(2) The approach for modeling water content and potential NPP needs to be better described (L. 224-240). What is the basis for the parameterizations for water content for the different microforms? Please provide references. Is NPP considered as a CO2 flux or a carbon flux? Without specifying this, the modelled NPP values cannot be checked for plausibility. However, such a plausibility check would be necessary. Please compare your modelling results with empirical data on NPP of bog microforms.

Response: The purpose of the empirical modelling was not to represent what the actual net photosynthesis of a given plot at a given site would be, but rather to highlight the potential bias introduced by modelling microtopography as a binary system. However, we realised that it is not clear from the methods that the empirical models presented are from field-based studies of hummock-hollow plot-scale water content and capitula flux measurements. We have revised the methods for clarity and also included references to the relevant source material, some of which was previously only cited in the figure captions. Moreover, we have added additional content to the discussion to compare the modelled net photosynthesis with other relevant studies.

Specific comments

L. 50: I do not like this often used comparison because it is like comparing apples with oranges: The carbon pool of peatlands is estimated over their mean peat depth (can be more than 15 m), whereas carbon pools of soils are estimated for specific reference soil depths (e.g. 1 m , 3 m). Hence, do peatlands contain one third of the upper meter of global soils or of the upper 3 m or how many meters? Furthermore, soils store not only organic carbon but also inorganic carbon!

Response: Fair enough. We have removed the comparison from the introduction.

L. 69: I would think that the area covered by a hummock can be also quite larger than 1 m2.

Response: While we agree that hummocks can be quite larger than 1 m^2, we are trying to be somewhat general in the introduction and are referring to the order of magnitude (i.e. they are far more likely to be closer to 1 m^2 than 10 m^2). Nevertheless, we have softened the language to say that hummocks typically occupy and area of up to a few square meters.

L. 96: I suggest adding the reference: Cresto Aleina F., Runkle B. R. K., Kleinen T., Kutzbach L., Schneider J., Brovkin V. (2015): Modeling micro-topographic controls on boreal peatland hydrology and methane fluxes. Biogeosciences 12: 5689-5704.

Response: We appreciate the suggestion and have added the reference.

L. 112-113: Sentence not clear to me; please rewrite! I do not understand how you want to "explore DEM-derived properties" "using multi-site plot-scale sampling".

Response: We have revised the sentence which hopefully makes it clearer now.

L. 137: Write more specific: What kind of "individuals"? Have these been scientists, students, or farmers neighboring the peatland?

Response: We replaced "individuals" with "academic peatland researchers".

L. 157: Unit of resolution?

Response: We have updated to include the unit of resolution (i.e. pixels).

L. 234: According to SI system, do not mix units and quantities. Better "WC is the ratio of the mass of water and the mass of the non-water components of the soil (Unit: g g-1)."

Response: We have revised the sentence according to your suggestion.

L237: Specify the variable x. Probably, x equals WC, correct?

Response: Thanks for catching that. Yes, it is supposed to be WC and has been revised accordingly.

L 238: Better: ". . .represents percentage of maximum NPP"

Response: Revised accordingly.

L. 836: It is confusing to use the two terms "net photosynthesis" and "NPP" as y-axis titles of different diagrams in the same figure, respectively. Do you use the terms as synonyms? In my view, integration of net photosynthesis over time at the canopy scale leads to NPP; thus "net photosynthesis" and "NPP" would be closely related but not synonymous.

Response: We were admittedly a little sloppy with this abbreviation, where we used NPP to represent potential net photosynthesis. Understandably, this is easily confused with the widely used "net primary productivity", so we have replaced also cases of NPP in the manuscript by either spelling out "net photosynthesis" or abbreviating as NP.

Technical comments

Response: Where relevant for the technical comments, we have revised the manuscript according to the reviewer's comments/suggestions. Some suggestions were not adopted because the original text was removed as part of other revisions.

L. 29: Correct "examine" Done.

L. 31: Correct: "northern" Done.

L. 38: Correct: "positions" Done.

L. 50 Correct "one third"

Response: The text was removed as part of other revisions.

L. 107: Hyphenate: "plot-scale" Done.

L. 121: Hyphenate "transect-based" Done.

L. 145: I suggest writing: " 0.1 m x 0.1 m x 0.1 m (same for similar expressions throughout the manuscript) Done.

L. 179: Comma before "and" (beginning of independent sentence) Done.

L. 186: Number the equations. Done.

L. 208: better "selected" instead of "decided" Done.

L. 239: "mo" is not a standard abbreviation for a SI unit. Please define this somewhere before using it.

Response: We have opted to simply spell it out where used.

L. 296: I would move the F statistics in parentheses to the end of the sentence. Done.

L. 311: Infelicitous usage of statistical terminology: In my view, a result can be either significant or non-significant, give a specific error probability. It cannot be strongly of weakly significant.

Response: We agree that once a level of significance is chosen, that significance is determined by whether the p-value is equal to or less than the level of significance (i.e. reject null, results are significant) or greater than the level of significance (i.e. do no reject null, results are not significant). However, we also recognize that the choice of significance level is arbitrary to some degree, and that the p-value is an indicator of probability, so that the magnitude of the p-value could be interpreted as the null hypothesis being more/less probable on a continuous scale. The use of the terminology 'not strongly significant' was in part an attempt to recognize greater potential type II error given the sample size and p-value near the significance level. Nevertheless, we have opted to switch the statement to 'not significant'.

L. 374: Hyphenate: "under-samples" Done.

L. 380: Better a full stop instead of a comma after "conditions"

Response: Unfortunately, because "conditions" was used twice on line 380 of the submitted manuscript, I'm not sure which "conditions" you were referring to.
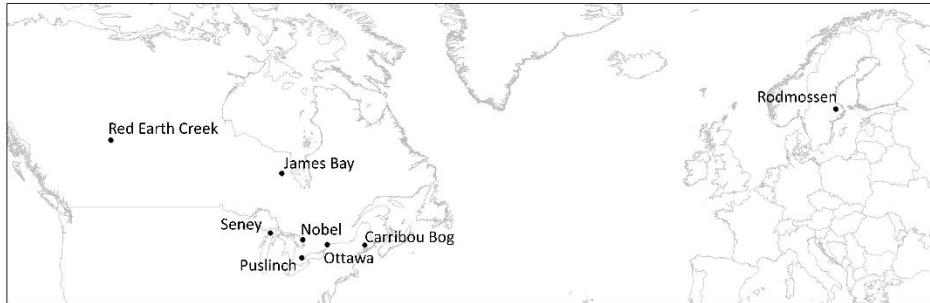
L. 465: Comma before "which" Done.

L. 507: Hyphenate "water table-dependent" Done.

L. 516: Comma before "where" Done.
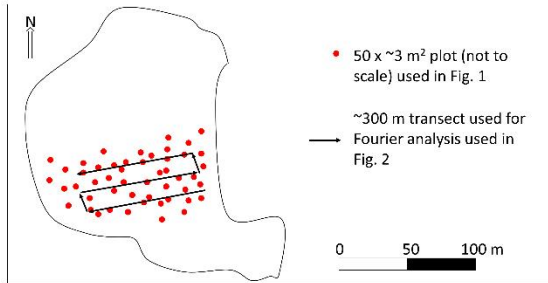
L. 532: Comma before "where" Done.

Figure 1: Overview of site locations, site-level measurement design, and plot-level hummock-hollow pairs (see Table 1 for additional details).

Site locations

Red Earth Creek – site-level analysis

DEMs of select plot-level hummock-hollow pairs