Reply to referee comment (#2) on HESS-2021-585

We would like to thank Anonymous Referee #2 for reviewing our paper and for the constructive comments. In the following I listed the referee comments in normal and our reply in italic text.

I apologize with the Authors for the time it took to provide my review. I enjoyed serving on this study and I do think it is of definite interest. My main concerns are related to the quantification of the uncertainties associated with model parameters and the way they can propagate to model results. I do think that a detailed discussion on this element can strengthen the quality of the results obtained. In the absence of such a quantification, I do think the quality of the model results is at best undetermined. It is with this spirit, and to provide the Authors with ample time to design their revisions, that I am recommending a set of revisions that can range from moderate to major (depending on the way the Authors decide to address these).

While the Authors state that the model they rely upon can lead to a reasonable match with available observations, they offer only limited insights about uncertainties associated with estimated model parameters. Additionally, I do think that the type of sensitivity analysis performed by the Authors does not provide too much quantitative insights about the relative importance of model parameters and I am not entirely sure if the Authors can rely on their results to rank importance of typically uncertain model parameters and the way this impacts model results. I do think at least some discussion on these elements should be included so that the readers can have a full picture at their disposal.

As an additional point of example, it is not clear how the uncertainty associated with parameters governing partially saturated flows (which can be marked while these can be spatially heterogeneous) can impact the quality of the results obtained by the Authors.

The lack (or partial lack) of a rigorous uncertainty quantification in this sense is an element that in my view hampers the way we can quantify the quality of model forecasts. The emphasis that is given to the model performance could be retuned in light of this element, which is critical, in my view.

The Authors find and discuss that NEE displays a linear relation with the water level at the site analyzed. Can they provide some physical meaning to such a linearity? Can in their view this result be transferred to other sites? Perhaps this discussion is already included in the study and I missed these details. In this case, I do apologize with the Authors.

Can the Authors include some details about measurement uncertainties and their view about these can impact model parameter estimation through model calibration?

Response: *We will add a section in the supplementary to quantify the parameter uncertainties for modeling continental bog systems and discuss how it would influence our findings on the water table and NEE regulation. However, given our current results are evaluated with 21 years of energy, hydrology, and C fluxes, and the fact that most of the parameters are obtained from many earlier investigations for this site (references for the parameters listed in Table S1 in Supplementary Information), we anticipate that the influence of parameter uncertainties on our key findings will be minor.*

CoupModel has been applied previously to several boreal peatlands thus parameter uncertainties associated with hydrology and C fluxes were already quantified, e.g., Metzger et al. (2015, 2016), He et al. (2016) and Kasimir et al. (2021). These studies provide prior information for calibration and uncertainty quantification. However, these earlier studies were conducted on fen peat or drained bogs. We expect the following parameters at Mer Bleue would differ from the peatlands evaluated before:

Saturated hydraulic conductivity (ksat); maximum stomata resistance of shrubs; the maximum rooting depth of the shrubs; phenology parameters that regulate the start of photosynthesis; the parameter regulating the decrease of photosynthesis when water table depth drops; the decomposition rate of labile and resistant C, (kl and kh); temperature response (i.e., Q10); and soil moisture response for decomposition rate.

These are known key parameters that cover the hydrological, photosynthesis, and respiration processes. We will add a calibration using the GLUE approach (He et al. 2016, He et al. 2021) to rank the parameter sensitivity in controlling the water table and NEE.

The peat water retention characteristics at Mer Bleue and other similar bog sites have been summarized by Letts et al. (2000). More recently, our peat water retention curves are also shown to be well constrained by a meta-analysis by Liu and Lennartz (2019) who reviewed the existing peat literature. Thus, we have left those coefficients out of the uncertainty analysis.

The unique long-term data at Mer Bleue revealed that NEE had a close to a linear relationship with the growing season water level at the annual scale. We have discussed this and expect this to be a general case for other bog sites, see our Discussion (Lines 370-380). This relationship reveals the self-regulation of the bogs that show strong coupling by water storage and growth- also see our Introduction (Lines 36-44).

For measurement uncertainty, we will also add a section in SI to describe the eddy covariance processing methodology and the uncertainty related to gap filling. The uncertainty associated with water table depth is documented in the Wilson thesis (2012). We will use those uncertainties to determine the thresholds of accepted model simulations when conducting our GLUE calibration.

Metzger, C., Jansson, P.-E., Lohila, A., Aurela, M., Eickenscheidt, T., Belelli-Marchesini, L., Dinsmore, K. J., Drewer, J., van Huissteden, J., and Drösler, M.: CO_2 fluxes and ecosystem dynamics at five European treeless peatlands – merging data and process oriented modeling, Biogeosciences, 12, 125–146, https://doi.org/10.5194/bg-12-125-2015, 2015.

Metzger, C., Nilsson, M. B., Peichl, M., and Jansson, P.-E.: Parameter interactions and sensitivity analysis for modelling carbon heat and water fluxes in a natural peatland, using CoupModel v5, Geosci. Model Dev., 9, 4313–4338, https://doi.org/10.5194/gmd-9-4313-2016, 2016.

Hongxing He, Per-Erik Jansson, Magnus Svensson, Astrid Meyer, Leif Klemedtsson, Åsa Kasimir, Factors controlling Nitrous Oxide emission from a spruce forest ecosystem on drained organic soil, derived using the CoupModel, Ecological Modelling, 321, 46-63, https://doi.org/10.1016/j.ecolmodel.2015.10.030, 2016, *Kasimir Å, He H, Jansson P-E, Lohila A and Minkkinen K (2021) Mosses are Important for Soil Carbon Sequestration in Forested Peatlands.* Front. Environ. Sci. *9:680430. doi: 10.3389/fenvs.2021.680430, 2021.*

Letts, G. M., Roulet, N. T., and Comer, N. T.: Parametrization of peatland hydraulic properties for the Canadian land surface scheme, Atmosphere Ocean, 38, 141-160, 2000.

Liu H., Lennartz, B. Hydraulic properties of peat soils along a bulk density gradient- a meta study, Hydrological Processes, 33 (1) 101-114, 2019.

Wilson, P.: The relationship among micro-topographical variation, water table depth and biogeochemistry in an ombrotrophic bog, Master of Science thesis, McGill University, 2012.

Hongxing He

On behalf of all authors