Interactive comment on “ORCHIDEE-PEAT (revision 4596), a model for northern peatland CO2, water and energy fluxes on daily to annual scales” by Chunjing Qiu et al.

We thank the two anonymous referees very much for their constructive comments. In the following, please find our response to the comments. Our responses are in bold, modifications done in the revised manuscript are in blue. All figure and table numbers, line numbers and pages refer to the initial manuscript version.

Referee #2

The authors present a new peatland model as part of the ORCHIDEE land-surface model. The manuscript is well written and does a nice job of describing recent advances in peatland modeling and identifying the need for the model developments reported here. Specifically, the model simulates water table by prescribing peat-specific hydraulic properties across the 11 soil-profile layers. Water table is then used to determine decomposition rates in in the near-surface acrotelm and deeper, saturated catotelm. The model is evaluated using eddy covariance measurements from 30 sites across northern hemisphere (bog, fen, and tundra). In general, I think the manuscript is in good shape, and I have a few relatively minor comments:

1. Would it be possible for the authors to evaluate model performance of heterotrophic respiration or ER vs. observed values?

We added comparisons of simulated vs. observed ER, please refer to our response to the first comment of Reviewer#1.

2. Line 132 – Should be permafrost “thaw”, not “melt

Corrected now in the text.

3. Lines 231-232 – While incorporating a peatland-specific PFT is a step in the right direction, I was surprised the authors did not develop a bryophyte or shrub PFT for application in this study, particularly given the range of peatlands used for model comparison. It seems like at the very least, the authors should acknowledge this as a cause of discrepancies between model output and observations.

Currently, ORCHIDEE (both the standard ORCHIDEE and ORCHIDEE-PEAT) lacks representation of mosses and shrubs. In the grid-based simulations, we do not know fractional coverage of the peatland vegetation at each site. Wania et al. (2009, Global Biogeochem. Cy.) parameterized flood-tolerant C3 graminoids and *Sphagnum* in LPJ-WHy to represent peatland-specific vegetations, with peatland extent defined from an organic soil map and the fractional cover of PFTs determined by bioclimatic conditions including temperature, water table depth, inundation stress etc. Stocker et al. (2014, Geosci. Model Dev.) applied a version of Wania et al’s model but removed the

upper temperature limitation of the peatland-specific PFTs and further included three additional PFTs — flood tolerance C4 grasses, tropical evergreen and tropical raingreen tree PFTs, with peatland extent diagnosed by TOPMODEL. Previous studies have shown that there was considerable overlap between the plant traits ranges among different plant functional types, while variations in plant traits within PFTs can be even greater than the difference in means among PFTs (Verheije et al., 2013, Biogeosciences; Wright et al., 2005, New Phytol; Laughlin et al., 2010, Funct. Ecol.). For simplicity, in this study, we applied only one PFT to represent an average of all vegetations growing in the peatland ecosystem. However, only one key photosynthetic parameter—V_{cmax} of the PFT has been tuned to match with observations at each studying sites, other processes and parameters of this PFT was inherited from a C3 grass, this simplification may cause discrepancies between model outputs and observations.

Druel et al. (2017, Geosci. Model Dev. Discuss.) added non-vascular plants (bryophytes and lichens), boreal grasses, and shrubs into ORC-HL-VEGv1.0, biogeochemical and biophysical processes of these new PFTs were defined and evaluated in their study. Their work is in parallel with our model, after both ORCHIDEE-PEAT and ORC-HL-VEGv1.0 are incorporated into the main branch of ORCHIDEE in the future, it will then be possible to verify how many plant functional types are needed by the model to reliably simulate the peatlands at site-level and larger scales, though the vegetations implemented by Druel et al. are not peatland-specific. To acknowledge these, we added these sentences on Page8, Line 230: "……and extensive root systems (Boutin and Keddy, 1993; Iversen et al., 2015). Previous peatland models have incorporated more than one PFT to represent peatland plants and dynamically simulate fractional vegetation cover. For example Wania et al. (2009b) separated flood-tolerant C3 graminoids and *Sphagnum* moss in LPJ-WHy to represent peatland-specific vegetation, with peatland extent defined from an organic soil map and the fractional cover of PFTs determined by bioclimatic conditions including temperature, water table depth, inundation stress etc. Stocker et al. (2014) applied a version of this model but removed the upper temperature limitation of the peatland-specific PFTs and further included three additional PFTs — flood tolerant C4 grasses, tropical evergreen and tropical raingreen tree PFTs, with peatland extent diagnosed by the TOPMODEL scheme. At present, however, ORCHIDEE-PEAT lacks representation of dynamic moss and shrub covers, and we do not know the fractional coverage of different vegetation types at each site in grid-based simulations. Previous studies have shown that there was considerable overlap between the plant traits ranges among different plant functional types, while variations in plant traits within PFTs can be even greater than the difference in means among PFTs (Verheijen et al., 2013; Wright et al., 2005; Laughlin et al., 2010). Therefore, for simplicity, we applied the PFT of C3-grass with a shallower rooting depth to represent the average of vegetation growing in northern peatlands.

Only one key photosynthetic parameter—V_{cmax} of this PFT has been tuned to match with observations at each site. This simplification may cause discrepancies between model output and observations. Druel et al. (2017) added non-vascular plants (bryophytes and lichens), boreal grasses, and shrubs into ORC-HL-VEGv1.0. Their work is in parallel with our model and will be incorporated into the model in the future. It will then be possible to verify how many plant functional types are needed by the model to reliably simulate the peatlands at site-level and larger scale.**”.**

4. Line 321-324 – Please clarify how the CENTURY-type model of the standard ORCHIDEE is incorporated in the new decomposition parameterizations for the peatland version. As is, it’s not clear how the three-pool set-up relates to these equations.

We clarified the structure of the carbon module in ORCHIDEE-PEAT in the text and modified Fig.S1 to show the scheme of the model clearer, please refer to our response to Reviewer#1 (Specific comments, Line 299-301 and Fig. S1) for details.

5. Line 566-567 – The model does incorporate hydraulic properties of peat soils. It seems like it would have been relatively straightforward to also incorporate thermal properties of peats to improve soil temperature performance and its effects on respiration.

ORCHIDEE-PEAT lacks parameterization of peat-specific thermal characteristics due to the original thermal scheme of the model. Within a gridcell, different soil columns are represented but only the charactericstic of the dominant are used to define the thermal properties (soil thermal conductivity and heat capacity) in the model. The model configuration doesn’t allow us to assign different properties for each soil column in the same one grid cell. An ideal solution would be to change the structure of the model so that peat soil can have peat-specific thermal properties while non-peat soil columns keep using the dominant mineral soil texture. This is the approach we used for soil hydraulics. We would like to mention that a study by Guimberteau et al. (2017, Geosci. Model Dev.) conducted in parallel to our study added the feedback effects of soil organic carbon concentration on soil thermics into ORCHIDEE, specifically, soil physical properties of one grid cell is a weighted average of mineral soil and organic soil, with carbon content for organic soil derived from the soil organic carbon map from NCSCD. This approach takes thermal properties of peat (pure organic soil) into account in a simplified way. Guimberteau et al.’s development can be used by ORCHIDEE-PEAT after the model is merged into the main branch of ORCHIDEE in the near future.

6. The authors point toward possible causes of the poor model performance with respect to water table in the Discussion. It would be helpful if they could lay out some practical future steps to improve model performance, particularly given the importance of WT on below-ground C cycling parameters.

We added following senteneces to the discussion, Page22, Line641: “……depend on the soil depth (Lafleur et al., 2005; D’Angelo et al., 2016). Correct representation of peatland hydrology is a challenging problem in large-scale land surface models (Wania et al., 2009a; Wu et al., 2016). The simulated water table by ORCHIDEE-PEAT depends on water inflows from the surrounding non-peatland areas, and a water routing analysis on sub-grid scales can be included to improve the model performance for water table in the future (Ringeval et al., 2012; Stocker et al., 2014). Other studies have shown that microtopography exerts important influences on hydrological dynamics of peatlands, however, to capture the influence of microtopography on water table, high-resolution micro-topographic feature and vegetation information are needed (Gong et al., 2013; Shi et al., 2015). **” .**