Answer to Referee #2

General comments

Although peatlands cover only a small part of the global land surface, they have the highest carbon density and their development during the Holocene has influenced the global carbon balance. A proper representation of peatlands in global carbon models is therefore important. The paper contributes an improved peatland module in a dynamic global vegetation model. I agree that including nitrogen cycling and dynamic acro-tocatotelm transfers are good changes. There is not much model description and I have sometimes difficulties understanding the simulation results as presented in the figures (see further below).

We thank Referee #2 for the constructive comments. It is indeed a comprehensive model and a lot of information has to be referenced. During the revisions we made changes that hopefully help better understanding the simulation results.

Not clear to me is the role of the plant functional types. How do they compete for nitrogen? Do they influence the carbon balance?

Plant functional types do not directly compete for nitrogen. Nevertheless, they can be N limited by N availability. All plant functional types are equally limited and no plant functional type has advantage to access mineral N. This limitation has then a feedback on the carbon balance of each plant functional type, in addition to the competition for water and light. We added this information to section 2.2.2.

Simulated peatland carbon density compares quite well to soil carbon density date in North-America, but it is not clear to me whether the prescribed peatland area influences this soil carbon density.

Yes, the prescribed peatland area is factored in for the grid cell average for both, high resolution data and low resolution model output. We also show total C density from peatland and mineral soils weighted by the respective area (Fig. 8). We modified the corresponding description:

"For this, the high-resolution soil C data were regridded to the LPX grid using the fractional peatland area; deviation in total soil C stocks between the regridded and original data set are small (Fig. 8)."

The manuscript could be written more concisely, although in some other places more explanation is needed. I find the sections 5.2 and 5.4.2 less interesting.

We have shortened section 5.2 accordingly. In section 5.4.2 we compare the simulated total peatland C to literature estimates, and thus think it is essential for beeing included. But we put less emphasis on scenario T09$_{LGM}$ (see response to D. J. Charman).

Specific comments

p.5636, l.26 LPX is new for me. What is the relation with LPJ models? It is a new name for the LPJ models?

LPX is a new model based on existing versions of LPJ and replaces the LPJ version *previously used in our group. It contains many more features tied to land surface processes and not just vegetation (e.g. CH_4 and N_2O emissions, peatland and permafrost simulation, new land use schemes, and not least a dynamic N cycle), which makes it clearly distinct from a standard LPJ version. In section 2.1 you can find a list of these new features now embedded in LPX. Clarification has been added to this section.*

p.5639 Does varying water table also influence GPP or NPP or competition between the PFTs?

Yes, there are two functional types for peatlands: graminoids and moss (section p. 5637, line 12ff). Both have different sensitivities to actual water table position as described in Wania et al., 2009b. If the water table is too high or too low then GPP is reduced separately for each plant functional type, which has consequences for plant competition.

p.5640, l.25 What is N availability in the model? Is it the sum of N inputs and N mineralisation from soil organic matter? Do the PFTs compete for the same N sources?

N availability is a function of soil water content and the size of the inorganic nitrogen pool, including NO_3^- and NH_4^+. N inputs and N mineralisation enter these two inorganic N pools (see Xu-Ri et al., 2008).

As explained above, plant functional types do not directly compete for nitrogen. Nevertheless, they can be N limited by N availability. All plant functional types are equally limited and no plant functional type has advantage to access mineral N. This limitation has then a feedback on the carbon balance of each plant functional type, in addition to the competition for water and light. We added these 3 sentences to the N cycle description .

P5642, l.1 It surprises me that Sphagnum has a lower C:N ratio (i.e. higher N concentration) for new production than the graminoids. Does this mean that growth of Sphagnum is more often N-limited than growth of graminoids? Generally it is assumed that Sphagnum growth is less nutrient-limited than vascular plant growth. N concentrations in Sphagnum are generally related to N inputs and can be quite high, as in the Netherlands with high atmospheric N deposition. Such N concentrations do not reflect N demand.

No, Sphagnum is not more often N limited (see previous answer). Yes, we assume Sphagnum does require more N per C for new production, but due to a lower Sphagnum-associated soil C:N ratio the model scheme implicitly simulates higher N influx into the system. This reflects biological N fixation in Sphagnum vegetation.

p.5655, l.9 ... shoals ...?

We replaced “shoals” by “rises”.

p.5658, l.7 So what is the conclusion of this comparison of alternative peatland development scenarios?

The scenarios T09 and Y10 give present day estimates for peatland soil C that scale nearly linear with the respective area. Sentence added at the end of this paragraph:

“One thus can conclude that differences in the geographical distribution of peatland area between scenarios T09 and Y10 are probably less important than the difference in total peatland area for simulated peatland soil C."

The $T09_{LGM}$ scenario is meant to be an illustrative example for the impact of peat initiation on C content at present. It highlights the imbalance of the WSL peatland ecosystems under present conditions as represented in the model. We modified Section 5.4.4. to give more emphasis on the illustrative character:

"From the $T09_{LGM}$ simulation it becomes clear that even though present day peatland NEP is not that different from T09, the peatland initiation and history are very relevant for total C storage in these ecosystems."

p.5661, l.23-24 How come that the temperature effect is so small? Is there also a difference in precipitation between the two RCPs that partly compensates for the temperature difference?

Temperature influences many processes in the model, which can cancel out each other. E.g. high temperatures have a negative effect on C storage by accelerating respiration. However, this also adds to N mineralisation, relieves N-limitation and ultimately enhances NPP and has a positive effect on C storage. Higher temperatures also increase growing season length and thus NPP.

There is indeed a precipitation difference that can have a compensation effect. On global average the precipitation is 52 mm higher in RCP 8.5 than RCP 2.6 averaged over all CMIP5 output for the period 2090-2100 AD. This average difference is a bit larger (86 mm) for the high northern latitudes (45°-90°) only. We add reasons for the small response of peatland C to future climate change compared to other types of soil C (e.g. permafrost soil C).

p.5662, l.3 Remove ... and the Holocene

Done.

Table 1 Is there a difference between moss and graminoid decomposition rate? Sphagnum is generally overrepresented in the peat due to their low decomposability.

No, both plant types have the same decomposition rates. We add a sentence in the introduction part to clarify this shortcoming:

"In the litter pools we do not further distinguish C by their original plant functional type. All plant type remnants have the same decomposition rate. "

Table 3 Please explain T09, T09LGM and Y10 scenarios in the legend. Is it correct that T09LGM ends with exactly the same peatland area as in T09?

Thanks for this remark. Explanation is added in Table 3. Yes, T09 and $T09_{LGM}$ have the same present day area.

Fig. 3 Why are thermokarst lakes in this figure?

All cumulative data sets shown in Fig. 3 were used in the publication by Jones and Yu, 2010. They give additional estimates when ecosystems started to form in the past. This serves as a comparison with peatland data sets.

Fig. 5 Why are simulated (and reconstructed) accumulation rates higher in Siberia than in North-America and Europe? Interesting that DyN increases accumulation rate in Scotland and decreases accumulation rate in Finland. Does this imply that NPP was not N-limited in Scotland and highly N-limited in Finland?

As stated in the text (P5650, l.15) the peat core near Tomsk has an exceptional high accumulation rate that can bias the regional average. Because there are only very few cores available, these averages are not necessarily representative for the whole region.

The purpose of Fig. 5 is to demonstrate the better agreement of reconstructed accumulation rates with the model simulation using DyN, compared to the model simulation without DyN. However, each simulation was tuned independently to the reconstructed peatland accumulation rates and give different model parameters ($k_{10,acro}$, $k_{10,cato}$; see section 4.3). The tuning was done in each case for all 33 sites and for all time periods together (see response to D. J. Charman). Thus there are considerably differences between reconstructed and simulated accumulation rates for single sites or regions. Points in Fig. 5 represent averages over regions, but also over time. The peatland accumulation rate thus rather represents the state of peatland equilibrium, than its productivity.

It is thus not straight forward to make an interpretation on N-limitation from this plot. We modify Fig. 5 to become simpler and clarify the description.

Fig. 6 These results I do not understand. How can GPP in many points be larger with DyN than without DyN? Why is NPP with DyN so much lower? Does autotrophic respiration depend on N availability?

In the model, GPP is not directly N-limited, while NPP is. Therefore, NPP will in general be lower, as N represents always a reduction. Exceptions (NPP dots above the 1:1 line) are likely due to the fact that in these cases, autotrophic respiration is much lower with DyN turned on. In this case, autotrophic respiration depends on a variable tissue C:N ratio which might end up being much higher than in the no-DyN case, where it is fixed.

Explaining GPP dots above the 1:1 line is not straight-forward. In general, GPP is not directly affected by N-availability/N-limitation. Indirect effects of N-limitation act on GPP via NPP -> allocation -> growth/competition -> fractional plant cover -> absorbed radiation -> GPP. In Fig. 6 we aimed at illustrating that GPP is not consistently shifted to lower values (yet, the blue line is below the 1:1 line), while NPP and RH are.

As described in section 5.1, Wania et al., 2009 discuss that NPP was significantly overestimated in the version without DyN. An important factor in the N-limitation is the temperature dependence of N-uptake, which limits growth in months with low soil temperature.

Fig. 7 This figure seems not necessary to me.

We would like to keep this figure as it results from the dynamic C-N-cycles during the simulations. Previous studies used a single fixed number for this transfer.

Fig. 9 I cannot read the axes labels, font is too small

Figure 9 has been improved, text enlarged.

Fig. A1 I accept that there can be large deviations for several reasons, but is there perhaps a pattern from which we can learn about model behaviour?

Generally we do see mostly linear increases at individual grid cells, which might be related directly to the simulated climate data we use as a LPX model input. But you can see that accumulation rates drop to zero, if conditions are not optimal for peat growth. Overall we are very reluctant to interpret too much into these site comparisons as we still compare large grid cell averages (from simulated climate) with real local sites.