Answer to D.J. Charman (Referee #1)

This paper reports the development of a new aspect of the LPJ/LPX DGVM to incorporate N dynamics in the peatland part of the model and develop an aspect related to the transfer of C from upper to lower layers in the peat. The model is used to simulate peat growth since the LGM and output is compared to temporal and spatial patterns from peat core and soil map data. The final part of the analysis is to simulate future changes in peat C accumulation to 2100. The model development is a further advance in the progress of LPX and the simulations suggest that this approach has much promise. This is a major contribution to the science and I have only minor suggestions for change and a few questions and comments.

We are pleased to hear that our study is of interest and thank D. J. Charman for his comments on the manuscript.

5638, L25. This implies that acrotelm thickness is varied and if so how is it defined – by water table position alone? Is this the average or maximum WT depth in the year? Later it is suggested that the acrotelm is fixed at 0.3m. Acrotelm definitions and variability are a bit unclear especially in relation to the discussion of water table variability in 2.2.1.

Yes, we agree that the term 'acrotelm thickness' is misleading here. The thickness is indeed fixed at 0.3 m, which is also the maximum water table depth. With carbon accumulation in the acrotelm layer the 'acrotelm C pool size' will increase and technically outgrow space in the acrotelm. We thus change the sentence on L25 to:

"Section 2.2.3 describes the process that acrotelm-to-catotelm C transfer rates dynamically depend on acrotelm C pool size."

Further, in 2.2.1 we change the description to:

"In LPX the depth to the water table (d_{wt}) can vary from the fixed depth of the acrotelm (d_{wt} = 0.3 m) up to 10 cm of standing water above the surface (d_{wt} = −0.1 m)."

5642, L15-25. It is always easy to criticise the simplifications necessary in modelling studies such as this but the use of interpolation between 1000 yr timeslices of the climate model data needs further comment. We know that there have been very significant (sub)millennial scale changes in hydrology (and temperature) through the Holocene in many northern peatland regions. It would be interesting to know what the potential impact of these short term events might be on peatland C cycling. I am not suggesting that these analyses are done here but it would be good to see some comment on this. P5649 mentions this variability, but how big is the estimated influence of these factors?

This is the first transient simulation of peatland C dynamics at high spatial resolution, and here we focus on long-term change in peatland C. However, we agree there may be large impact of millennial-scale or even shorter time scale climate variability on C accumulation. In a future work we plan to repeat this analysis for sub-millennial scale climate variability. We added a more thorough discussion of the possible impact of (sub-)millennial scale climate change on peatlands and enlarged the existing discussion section:

"For the simulations in this study we used average millennial climate output from simulations with the coupled ocean-atmosphere Hadley Centre climate model (HadCM3; Singarayer and Valdes, 2010) that does not fully reflect millennial-scale climatic features such as the Younger Dryas (YD) cold event or the Bølling-Allerød (BA) warming period (Severinghaus et al., 1998). It is expected that the BA warm period likely favoured peatland development, while the cold temperatures (decrease of ~10 C) during the YD most probably delayed and slowed down peat growth. While the BA and YD event stand out as northern hemispheric synchronous climate events there was probably also more disconnected regional millennial scale variability during the Holocene. Such variability probably did not affect the catotelm C pool directly as the effect on decomposition of deep peat is small. Significant C pool changes are possible through the mechanism of acrotelm-to-catotelm C transfer as discussed in section 2.2.3. However, there are also compensation effects on the impact of millennial scale variability on the acrotelm C balance, that is, an increase in NPP would partly be offset by an increased acrotelm decomposition in a warm climate."

P5645. Section 3.2.2. Does this mean that the model data are not being used to determine the timing of peat initiation at all, as they are set by basal peat age?

Yes, the peat initiation dates at site runs are prescribed. There are cases where simulated peat does not develop from the beginning of peat initiation. But in most cases peat would grow if not prohibited by prescribed initiation.

P5648. 4.2.2. Tuning using peat accumulation as the target. Does the use of the total C accumulation for each time step limit the tuning? It is clear from the plots of simulated C compared to observed C (Fig A1) that the patterns of change over time are very different even if the total C accumulated might be similar. Is the model right for the wrong reasons?

The calibration of the model using C accumulation data was to find the best parameters (such as N_{in}, $k_{10,acro}$, $k_{10,cato}$) that would produce the smallest RMSD for all 33 paleo sites. We have discussed this in detail in Section 4.3. As we can only use one set of parameters for the transient simulations in the study, we decided to optimize the parameters using all 33 records together. As a result, for some sites simulated C accumulation rates are very different from observed rates (Figure A1), not only in terms of long-term pattern but also the total C storage (kg C/m^2) at the sites (the integrated area under curves in Figure A1). However, we found the parameters with the smallest overall RMSD. It is surprising that even though we only tuned our model parameters using the overall goodness with the 33 sites the final simulated northern hemisphere C pool is reasonable compared with the recent independent estimate in the literature (as commented on page 5657). We added a sentence in this paragraph as well.

P5649. L15-20. The comparison between data and model for the Scottish sites is interesting because it shows that the data are more variable than the model. The Glen Torridon site shows an early Holocene peak – does this imply that perhaps local autogenic factors are at play – perhaps plant community influences? In general, the model underestimates the variability and often the temporal trends in peat accumulation shown by the data.

It is most plausible that the disagreement has to do with local scale effects, given the fact that Glen Tossidon and Glen Carron lie in the same grid cell (as stated on P5649). So, if we prescribe average climate on a grid cell of the size of Scotland one could easily think of a couple of reasons, why trends may cancel out compared to site data.
The reason for less variability in simulated results could also be due to the fact that we used 1000-yr average climate model output, so we didn't capture the shorter scale variability.

Fig 4 P5677. Are these the mean annual T and P or seasonal?

These are mean annual T and P. We clarified the figure caption.

Fig 5 and P5650, L12-13.: Is this correlation only for 5 points? It looks as if the Siberian site drives this almost completely. Without Siberia there looks to be no relationship because only a very small part of the gradient has data.

This is true, without Siberia the linear relationship has only an $R^2 = 0.24$. We change the caption of Fig. 5 and make a more general statement:

"Correlation of LPX simulated versus reconstructed apparent peat C accumulation rates averaged by region (Yu et al., 2009). The inclusion of dynamic N cycle in LPX (DyN; red) brings average rates closer to the 1:1-line."

P5653 L4. Why is there such a high frequency of near zero acrotelm-catotelm transfer rates? Perhaps I missed this but this needs some comment and explanation.

When acrotelm respiration is larger than C input to the acrotelm the F_{AC} gets slightly negative. The implemented mechanism (Eq. 5) then moves carbon from the catotelm to the acrotelm over the course of the following year. If climatic conditions are similar in the following year, one expects that acrotelm is balanced because of the acrotelm to catotelm transfer. As a consequence FAC = 0 after the second year and no carbon will be transferred for the third year. So, for balanced or decaying peatlands, F_{AC} oscillates around 0 gC/m^2 with a higher probability for negative rates. Thus there are lots of grid cells and time periods that fall within the same bin (-1 to 0 gC/m^2) by the way we implemented this mechanism. We modified the explanation on that page:

"The way we implemented F_{AC} (Eq. 5) very often leads to slightly negative values, whenever acrotelm respiration is larger than C input to acrotelm on an annual basis. So, for balanced or decaying peatlands, F_{AC} oscillates around 0 gC/m^2 with a higher probability for negative rates. Thus there are lots of grid cells and time periods that fall within the same bin (-1 to 0 gC/m^2) that shows up as a frequency peak in Fig. 7 (a total of 72,187 occurrences)."

P5656. Section 5.4.4. I am not clear why scenario T09 LGM was run. The data on peat initiation are pretty unequivocal so it is not surorising that in this section the modelling suggests that the WSL could not be older than the data – if the model had showed it was possible, I would have doubted the model, not the data!

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."

P5658. Section 5.5. Can you comment on the limitation posed by the different timescale for future response? All the model testing is over 1000 year timesteps and the model is good at multi-millennial totals but less good a temporal variability over shorter periods.

How good is the model likely to be at simulating 100 years in the future? I guess that because the climate changes are large by comparison with the past this may not matter too much but can you comment?

Thanks. It is indeed not clear how good the model performs on shorter time scales, as we have only compared large scale changes to site data over long time periods. But we think it is suited to give an estimate to whether the large changes of the next 100 years can actually impact on these long term trends. And it does, at least after halfway through the next century. For a prediction of decadal variability in peatland growth it probably needs further checking, especially the hydrology part of the model. So we agree that climate changes are large, and also the impact of increased N deposition in the future is significant, that will justify the use of the model on general trends. We added this point to Section 5.5:

“Although we only calibrated the model for multi-millennial time scales we argue that it is useful to provide an assessment for the trend in peatland C storage over the next 100 years. The large projected changes in climate and N deposition justify such an application of the model to study the impacts over the next 100 years, which would normally happen during millennia. “

The fonts on many of the figures are illegible or very difficult to read. Please check these are all OK in the final pdf file.

For the submission of the CPD paper, the figures have been compressed to match size limits. Figures will be updated and generally embedded text will be enlarged. If we can, we also provide vector images to CP.