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Interactive comment on "Modelling past, present and future peatland carbon accumulation across the pan-Arctic" *by* Nitin Chaudhary et al.

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We appreciate the time and effort spent by the editor and the reviewers in reviewing this manuscript. We have addressed all the issues indicated in the review reports. General comments:

Over large parts of the manuscript the reader is wondering what the authors want to tell him or her. This is especially severe in sections 3 and 4, where results are reported and discussed. The section 3.2, first paragraph is one example: Here the authors discuss results of climate change experiments. Reading the paragraph feels like a near endless list of carbon accumulation rates defined in slightly different ways and for different regions. It is not possible to list all occurrences of lacking clarity, therefore I suggest the authors carefully look at the manuscript and rewrite unclear sections. In addition the

conclusions section is extremely weak and vague in discussing the conclusions, while half of the section consists of an outlook that is out of place in the conclusions section. Finally, the authors only scratch at the surface of the capabilities of their model. LPJGUESS should be able to determine changes in vegetation composition – however these are not discussed in the manuscript. Similarly, the authors lay claim to unique capabilities of their model (Conclusions section) – however the results of these unique capabilities are not actually discussed

Response: We are thankful to the reviewer for these reflections. We deliberately limit the scope of the paper to the modelled peatland carbon accumulation, and believe that extending the scope to covering other aspects of the modelled dynamics, such as vegetation change, would make the analysis too broad and detract from the main C-cycle related findings, exacerbating rather than improving any issues with clarity. The logic of the paper structure is to first report the simulated mean pan-Arctic and regional carbon accumulation rates (CAR) also referring to modelled permafrost extent as a critical mediating factor. We then go on to attribute regional and overall patterns in carbon accumulation to temperature, precipitation, and CO2 concentrations as drivers, enabling a discussion of which driver(s) might play an important role in the future. Our intention was to highlight the role of different climate forcing on the fate of peatland carbon and CARs in different regions across the pan-Arctic. We argue this is a reasonable scope and logic for one paper.

While we have referred to changes in vegetation composition and productivity at various places in the manuscript (e.g. lines 309-315, 321-322, 328-329, 359-362, 385-392, 400-404, 411-420 etc.) we have not done so in detail as our main focus in this study was on the dynamics of peatland carbon accumulation. However, we accept the reviewer's point that changes in vegetation composition should receive more attention in the paper, especially in regard to how it influenced CARs. To this end, we will add a paragraph to the Discussion addressing this issue. We have renamed the final section "Conclusions and outlook" to more adequately reflect its content.

While we fully understand that every paper must stand on its own, we do note that this is the second of two companion papers in the same journal, the other, already published, - Chaudhary et al. (2017);doi: 10.5194/bg-14-2571-2017, describing the model and its evaluation in greater detail, also covering the coupling of carbon cycle to vegetation dynamics, and the unique capabilities of our model in comparison to other peatland models (Table S1 in the original paper).

In addition there are a number of minor issues:

The climate forcing used to drive the Holocene experiment is unclear, the reader needs to read Chaudhary et al. (2016) in order to understand how it was derived. A two sentences summary how it was derived, including the Miller et al reference, would help.

Response: We have now included a more detailed description of the Holocene climate input data.

Revised Text:

Each simulation was run for 10,100 years, and comprised three distinct climate-forcing periods. The first, Holocene phase, lasted from 10 kyr before present (BP) until 0 BP. During this period, the model was forced with daily climate fields (temperature, precipitation and cloudiness) constructed by interpolating between monthly values from the year 10,000 calendar years before present (cal. BP) until the year 1900. The monthly Holocene climate forcing data was prepared by the delta-change method by applying the relative monthly anomalies of temperature and precipitation the nearest GCM grid-cell to the site location to their average monthly values from the CRU TS 3.0 global gridded climate data set (Mitchell and Jones (2005) from the period 1901 to 1930. We then linearly interpolated the values between the millennium time slices to get values for each year of the simulation. This method conserves the interannual variability for temperature and precipitation throughout the simulation. Finally, the monthly Holocene temperature values were interpolated to daily values while total monthly precipitation

was distributed randomly among the number (minimum 10) of rainy days per month. For cloudiness, the monthly CRU values from the years 1901-1930 were repeated for the entire simulation period.

The second, historical phase ran from 1901 until 2000. During this period, we forced the model with the CRU TS 3.0 global gridded climate data set (Mitchell and Jones, 2005). Finally, the future scenario phase (see Section 2.3.2) ran from 2001 until 2100, and the climate fields were extracted from RCP8.5 scenario for each location.

Fig. A1 is a reproduction from MacDonald et al. 2006. It is therefore not needed, the authors can refer to the original figure.

Response: We have removed this figure from the Appendix and referred to the original paper.

Page 8 / line 289: The authors refer to regions with shallow active layers (ALD < 0.1m) and refer to their Fig. 6a. This is impossible to follow, since the Fig. only show ALD 50-100 cm, 100-200, 200-300 and > 300 – the range referred to in the text is not shown

Response: Thank you for pointing this out. We have corrected this in the text.

Revised text: active layers (ALD < 50-100 cm)

Page 9 / line 325: the authors refer to Fig. 5b. I assume they mean 6b?

Response: Thanks, we have corrected it in the text.

Revised text: Our simulations suggest that the significant temperature increase implied by the RCP8.5 future scenario will lead to disappearance or fragmentation of permafrost from the peat soil, and deeper active layers (Fig. 6b).

Page 9, lines 324-329: The paragraph deals with temperature effects. The authors then refer to their Fig. 8 III and IV – however panels III and IV show the precipitation and CO2 effects. Clearly there is some logical error in this paragraph.

Response: CO2 and precipitation effects in Fig. 8 III and IV are mentioned in the context of their role as drivers of plant (and litter) production, offsetting temperature-induced increase in decomposition. We make this link clearer in the revised text:

Our simulations suggest that the significant temperature increase implied by the RCP8.5 future scenario will lead to disappearance or fragmentation of permafrost from the peat soil, and deeper active layers (Fig. 6b). Additional soil water changes resulting from the effects of higher temperatures on evapotranspiration rates could then either suppress of accelerate the decomposition rate at many peatland locations (Fig. 8II). Effects of precipitation changes and rising CO2 concentrations on plant productivity can offset decomposition changes, in terms of effects on peat accumulation rate. In the Siberian (C, D and E) and Alaskan (F) zones, the projected higher decomposition rates are compensated by higher plant productivity due to increases in soil moisture and CO2 fertilization (Fig. 8III and IV); bars), leading to a net increase in CAR by 2100 in this scenario.

Page 11, line 375: The authors write that Loisel et al. (2014) is limited to north of 69°N. However, it is south of 69°N that is meant.

Response: We have changed to the south of 69°N:

Revised text: Furthermore, the dataset is limited to areas south of 69 °N.

Page 11, lines 381: unclear, when moist conditions played a role

Response: We have revised the sentence.

Revised text: Suitable climate and optimal local hydrological conditions influenced by favourable underlying topographical settings accelerated the CAR which led to the formation of large peatland complexes in the pan-Arctic region (Yu et al., 2009). CAR is the balance between biological inputs (litter accumulation) and outputs (decomposition and leaching) and these two important processes are quite sensitive to climate variability (Clymo, 1991).

Page 12, lines 415-418: Is this trend only reported in the literature, or does it also occur in the model?

Response: It is reported in the literature but we have also found this in some of our model evaluation sites in our companion paper (Chaudhary et al., 2017). We have referred to the companion paper and other studies in the manuscript.

Page 14, line 490: the authors refer to Fig. 8 b, c and d, but they mean II, III, and IV

Response: Thanks, we have corrected it.

Revised text: Hence, this region is projected to act as a C sink in the future (Fig. 8 I). It is notable in our simulations that temperature increases in the T8.5 experiment have a very limited overall effect on decomposition rate in Russia (Zones C, D and E) while precipitation and CO2 fertilization have a positive effect on C build up (Fig. 8 II, III and IV).

Fig. 4: What the authors call a “dotted” line in the Figure legend is usually referred to as a “dashed” line. In addition, the black line discussed in the legend is invisible in the Figure.

Response: We have changed that to a “dashed” line in the caption and the black line discussed in the legend is also the same dashed line. We have clarified this in the text.

Revised text: Fig. 4 Simulated Holocene peat accumulation rates across the 10 zones considered in this study (blue dots) and for the pan-Arctic region as a whole (dashed black line). The x axes show the number of sites partitioned into 10 zones. The black dashed line is the pan-Arctic average with standard deviation (black line outside the y-axes) and the red dashed line is the average among zones with standard deviation in light red patch. (I) simulated long-term (apparent) rate of C accumulation (LARCA); (II) simulated actual rate of C accumulation (ARCA) for the last 30 years. Blue bars show the difference between ARCA and LARCA mean values for the respective zone (II-I)

Fig. 6: Choice of colours is less than perfect. 1) Are no active layer depths of less than

50 cm shown? This is implied by Figures 6a and b. 2) the colour scale chosen in Fig. 6c usually implies a symmetric range from positive (green) to negative (red), with no change indicated by yellow. However in this Figure all values are negative.

Response: Thank you, we have improved the figure taking these points into account.

Fig. 7c: Colour scale not symmetric – zero value unclear (see also my comment to Fig. 6, part 2)

Response: Thank you, we have improved the figure taking these points into account.

Fig. 8: The same dashed / dotted issue as in Fig. 4

Response: We have changed it to a “dashed” line.

Fig. A2: Colour scales are not centered around zero and are different between plots, making comparisons very hard.

Response: Thank you for pointing this out. We have improved the figure.

Fig. A3: On an A4 printout, this Figure is still too small to see any details. In addition, there are no axis subdivisions between -0.5/0/0.5, making it extremely hard to read C3 BGD Interactive comment Printer-friendly version Discussion paper anything from the Figure

Response: Thank you for pointing this out. We have improved the figure.

Reference:

Chaudhary, N., Miller, P. A., and Smith, B.: Modelling Holocene peatland dynamics with an individual-based dynamic vegetation model, Biogeosciences, 14, 2571-2596,doi: 10.5194/bg-14-2571-2017, 2017. Loisel, J., Yu, Z. C., Beilman, D. W., Camill, P., Alm, J., Amesbury, M. J., Anderson, D., Andersson, S., Bochicchio, C., Barber, K., Belyea, L. R., Bunbury, J., Chambers, F. M., Charman, D. J., De Vleeschouwer, F., Fialkiewicz-Koziel, B., Finkelstein, S. A., Galka, M., Garneau, M., Hammarlund, D., Hinchcliffe,

W., Holmquist, J., Hughes, P., Jones, M. C., Klein, E. S., Kokfelt, U., Korhola, A., Kuhry, P., Lamarre, A., Lamentowicz, M., Large, D., Lavoie, M., MacDonald, G., Magnan, G., Makila, M., Mallon, G., Mathijssen, P., Mauquoy, D., McCarroll, J., Moore, T. R., Nichols, J., O’Reilly, B., Oksanen, P., Packalen, M., Peteet, D., Richard, P. J. H., Robinson, S., Ronkainen, T., Rundgren, M., Sannel, A. B. K., Tarnocai, C., Thom, T., Tuittila, E. S., Turetsky, M., Valiranta, M., van der Linden, M., van Geel, B., van Bellen, S., Vitt, D., Zhao, Y., and Zhou, W. J.: A database and synthesis of northern peatland soil properties and Holocene carbon and nitrogen accumulation, Holocene, 24, 1028-1042,doi: 10.1177/0959683614538073, 2014. Mitchell, T. D. and Jones, P. D.: An improved method of constructing a database of monthly climate observations and associated high-resolution grids, Int. J. Climatol., 25, 693-712,doi: 10.1002/joc.1181, 2005.

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