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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: 1. I'd suggest that the authors briefly describe how they generate Holocene climate input data to drive the model. I understand that has been described in detail in the previous model description/calibration paper, but it would be useful to provide a concise description in the paragraph (Lines 191-206 in the original manuscript (OM)) as well (such as model- simulated paleoclimate).

Response: We avoided a detailed description of the Holocene climate input data to make the paper more concise, referring instead to our companion Paper I (bg-2106-319) but based on the suggestions of the reviewers, we have now included a more

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detailed description of the Holocene climate input data in this paper.

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 gridcell 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 inter-annual 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.

2. I have some difficulties with those C accumulation terms as described in lines 217-221 in OM and in Figure 2. I am familiar with but personally don't really like those acronyms. I think some are more useful than other. I think that LARCA is useful as it also represents long-term (10 kyr in this case) actual/"true" average C accumulation rates – which is equivalent to the mean time-weighted C rate from individual cores or synthesis products as cited in the paper. LARCA also should be the same as overall net C balance as discussed in Yu (2011), due to the same peat mass (conservation)

through the last 10 kyr. So LARCA can be used to compare with present and future C accumulation (sequestration) rates. The difference in apparent and actual/"true" C accumulation rates was also discussed in Spahni et al. (2013) and Frolking et al. (2014).

However, I find ARCA is problematic, as it is actually a metric for apparent C accumulation rates – that is, dM/dT (T = 30-year period), despite its name "actual (net) rate of C accumulation". The true C balance rate should consider the decomposition C loss of the entire peat profile during that 30-year period. Am I missing something? A "true" C accumulation rate considering decomposition of previous accumulated peat is needed to compare with past 10 kyr (LARCA) and future C rates. I find that the difference between FLARCA and LARCA is a useful metric to quantify the average true C accumulation rates in the future, so that should be the metric showing in Table 1 and discussed. Both NFRCA and RERCA are apparent C accumulation rates and may not be as useful. I don't think RERCA has been discussed much in the manuscript. I suggest they can be removed from discussion.

Response: We agree that the LARCA is a more useful metric than the other carbon accumulation terms but all of them give different information about the peatland carbon accumulation rates. We have not included RERCA in Table 1 because we think it adds little to the existing information. For ARCA calculation, we do take into account the previous decomposition loss of the entire peat profile. So, it is not an apparent rate, but the actual one. The same is true of NFRCA, which allows a comparison of how different regions might behave in the future (Table 1, Figure 8). It is also a useful metric for readers wishing to compare our findings with those of other studies so we would prefer to keep this in the manuscript. The difference between FLARCA and LARCA is already present in Figure 7 and discussed in the text as well (see lines 485-490 and 545 to 550 in the OM).

3. In general, the manuscript is well written and clearly organized. However, I find some text in subsection 3.2 belong to Discussion, rather than Results section. For example,

lines 315-322 and lines 336-339. Perhaps these can be moved to Discussion section.

Response: We feel that the text in lines 315-322 and lines 336-339 are more suitable for the Results section because we describe results shown in Figure 8. We return to these results in the Discussion section (see lines 564-570 and 394-420 in the OM).

Specific comments:

Title: I suggest to change to ". . .across the pan-Arctic region", as stated in some places of the text. It should change throughout the text.

Response: We have changed "the pan-Arctic" throughout out the text to " the pan-Arctic region".

L22: change to "central and eastern Canada" (lower case)

Response: We agree with this and changed it to a lower case.

L28: change to "higher CO2"?

Response: We agree with this and changed it to higher CO2.

L47: either "organic-rich" or "C-rich", but both together a bit awakward

Response: We have changed it to "C-rich".

Paragraph 1 L57-74: A nice paragraph to summarize peatland models. I'd suggest to concisely mention the following models as well: Spahni et al. (2013), Stocker et al. (2014) and Wang et al. (2016). The first two used an LPJ model version to simulate peatland C dynamics, while Wang et al. (2016) used a different ecosystem model (TEM).

Response: There are many models which included Peatland dynamics in their modelling framework, and we have included a description of those models from which we took the inspiration to develop our model. The functionalities and scope of a representative set of current peatland models (mentioned by the reviewer) are presented in

Table A1 in Paper I (bg-2016-319). We have now summarized these three models in the same paragraph.

L165: add "," after "depth"

Response: We have added a comma "," after depth.

L193: change to "from 45 to 75. . ."

Response: We have changed it to 45 to 75 °N.

L196: defining 0 BP as 1900 is unnecessary and potentially confusing, as conventionally present = 1950 AD. I suggest just to call it 10,000 years before 1900 AD.

Response: We agree with this and we have changed it to 10,000 years before 1900 AD.

L198: describe concisely how Holocene climate input data were generated and prepared. See my general comments above.

Response: We have added a detailed paragraph about the Holocene climate input in the main text. See our response to the general comment 1 above.

L202: are the CO2 concentration simulated or measured from ice cores? If they are ice-core based measurements, then you could just interpolate ice-core data for your purpose, rather than from the data used in UM model, which likely used the ice-core data in the first place. Clarify. Response: We took the same CO2 values used by the UM model in their time slice experiments and linearly interpolated them to yearly values to force our model. We have clarified it in the text below.

Annual CO2 concentration values to force our model from 10 kyr BP to 1850 AD were interpolated from the millennial values used as a boundary condition in the Hadley Centre Unified Model (UM) (Miller et al., 2008) time slice experiments that were run for each millennium from 10 kyr BP to 1850 AD. From the year 1850 to 2000, we used CO2 values from atmospheric or ice core measurements.

L217: see my general comments about these acronyms.

Response: See our response to the general comment 1 above.

L299-300: I don't think the difference between 20.78 and 20.8 should be discussed. Are they robust enough for discussion? It would be useful to present these differences for different zones in Table 1, instead NFRCA. Apparently some zones accumulate more C in the future than other zones, and differences cancel out.

Response: The results show that climate change and CO2 increases can result in many pan-Arctic regions becoming carbon sources while other regions may enhance their sink capacity. Overall, however, the pan-Arctic sink capacity will remain largely unchanged (similar to 2000) by the end of the century (2100), under the high-end scenario (RCP8.5).

We have changed these lines from:

In the FTPC8.5 experiment, where all the drivers were combined„ a marginal decrease in global mean FLARCA (20.78 g C m-2 yr-1) compared with the mean LARCA (20.8 g C m-2 yr-1) (see Fig. 2) was noticed

To

In the FTPC8.5 experiment, where all the drivers were combined, the global mean FLARCA (20.78 g C m-2 yr-1) was largely unchanged from the mean LARCA (20.8 g C m-2 yr-1) (see Fig. 2).

We think that NFRCA is quite informative and it determines how peatlands have been behaving in response to climate change. The difference between FLARCA and LARCA is important and already presented in Figures 7 and 8 (see blue bars).

L306: the value of 53.2+/-37.0 is different from the one (error term) in Table 1. Check this and other values.

Response: Thank you, we have corrected it in the text.

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L315-322: move to Discussion?

Response: We have addressed this point above.

L336-339: move to Discussion section?

Response: We have addressed this point above.

L348: ARCA is an apparent C accumulation rate, so comparing it to LARCA is not very meaningful. But if overall decomposition is considered, it would become “true” C rate. See general comment above.

Response: ARCA is not the apparent C accumulation rate, See our response to the general comment 2 above.

L384: change to “litter addition”?

Response: Done.

L546: change to “permafrost, for example in western Siberia. . .”

Response: Done.

L552 and l585: change to “in the future”

Response: Done.

L600: Table 1: -suggest to modify ARCA by considering decomposition loss from all previous peat. That way, it becomes an actual/“true” C accumulation rate. As now, it is a metric for apparent C rate that does not reflect the C sequestration rate and may not be appropriate to compare with LARCA and future C rates. See my general comments.

-Replace NFRCA by (FLARCA minus LARCA)? (FLARCA minus LARCA) represents mean “true” C sequestration rate from 2001 to 2100. See my comments above. -Note for the Zone J, NFRCA is 52.3 +/-19.2, but it was indicated as 52.3+/-37.0 in the text on line 306 (different error terms). Check this and other values.

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Response: ARCA takes into account the decomposition loss from all the previous peat layers and it is an actual/true carbon accumulation rate. We clarified this in the text above.

NFRCA is also a good metric to see how peatlands have been behaving in each region. We have already presented FLARCA – LARCA (see Fig. 7 and 8 (see blue bars)).

Thanks, we have corrected the NFRCA values for Zone J.

Figure 2: -suggest to redefine ARCA by considering decomposition C loss of all previous peat, and delete RERCA and NFRCA. See general comments above. -For FLARCA: change to (Mt/(t+f))? (add an extra pairs of brackets)

Response: We have redefined the ARCA and removed the RERCA from the text (but we kept it in Figure 2) but we prefer to keep NFRCA as explained above. We have added an extra pair of brackets in Fig. 2.

Figure 3: change X-axis label to “Age (ka BP)”

Response: There are different ways to abbreviate the term past thousand years. We use kyear (cal. BP) throughout the paper, and prefer to keep the same notation in this figure.

Figure 4: redefine ARCA?

Response: We have redefined ARCA in the text.

Figure 5: I find these results are exciting. -I wonder if it is useful to add a panel to show (and discuss) the observed permafrost distribution (with various categories of continuous, discontinuous, etc.). -if so, three panels should be on one row from left to right, panels a, b, c (the same for Fig. 6) -perhaps Figures 5 and 6 can be merged as one figure with 5 or 6 panels in two rows, as they are relevant results and easier to compare.

Response: We have improved the figure taking these points into account.

Figure 7: Again, these results are exciting. -What does the “simulated mean C accumulation rate” mean? Is it apparent C rate or actual/“true” C rate (net C balance) that considers decomposition of all previous peat? -maybe better to put 3 panels in one row and move them closer.

Response: The simulated mean carbon accumulation rate is the long-term carbon accumulation rate (actual/“true” carbon rate). In this figure, we presented the mean of LARCA values from the year 1990 to 2000. We have improved the figure taking these points into account.

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