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

**Anonymous Referee #1**

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In this manuscript, Chaudhary et al. present and discuss results from a simulation study of past and future carbon accumulation dynamics of pan-Arctic peatlands using a process-based model LPJ-GUESS. An earlier paper (available online as Biogeosciences Discussions paper) by the same authors presents details about revising this LPJ model version to simulate peatland C dynamics. In particular, I find that the inclusion of microtopographic features (patches of uneven height) and subsequent treatments of within-gridcell hydrology is novel and represents a major progress in simulating peatland carbon dynamics at large scale.

This manuscript uses this model to simulate peatland C dynamics at 180 grid cells across the pan-Arctic region, representing the major northern peatland regions. This is an interesting strategy to capture differences and similarities in spatial patters of C dynamics across the pan-Arctic region. This approach would not allow to quantify any



changes in total peat C stocks over time, as it does not explicitly prescribe or simulate peatland extent and its change over time. But still it is effective to evaluate the C accumulation rates at different sites/regions.

The simulated peat accumulation rates over the last 10 kyr are used to provide baseline information in evaluating future change in peat C accumulation rates. The simulation results show that peatlands in southern regions will become C sources due to moisture limitations in a warm climate, while peatlands further north will likely continue to be a C sink due to warming-induced increase in production. These results appear to be robust and will make an important contribution to our understanding of peatland C dynamics in a changing climate.

I think that this manuscript presents an important study and should be published after considering and addressing the following comments.

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) as well (such as model-simulated paleoclimate).

2. I have some difficulties with those C accumulation terms as described in lines 217-221 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.

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.

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.

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

L28: change to "higher CO2"?

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

Paragraph l 57-74: 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).

L165: add "," after "depth"



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

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.

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

L217: see my general comments about these acronyms.

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.

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

L315-322: move to Discussion?

L336-339: move to Discussion section?

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.

L384: change to "litter addition"?

L425: subsections 4.1 – 4.3 provide nice summaries of empirical data and their comparison with simulated results.

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

L552 and l585: change to “in the future”

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.

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

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

Figure 4: redefine ARCA?

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.

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.



Suggested references: Frolking S, Tlabot J and Subin ZM (2014) Exploring the relationship between peatland net carbon balance and apparent carbon accumulation rate at century to millennial time scales. The Holocene 24: 1167-1173. Spahni, R., F. Joos, B. D. Stocker, M. Steinacher, and Z. C. Yu (2013), Transient simulations of the carbon and nitrogen dynamics in northern peatlands: From the Last Glacial Maximum to the 21st century, Clim. Past, 9(3), 1287–1308.âĂĺ Stocker, B. D., Spahni, R., and Joos, F.: DYPTOP: a cost- efficient TOPMODEL implementation to simulate sub-grid spatio-temporal dynamics of global wetlands and peatlands, Geosci. Model Dev., 7, 3089–3110, doi:10.5194/gmd-7-3089- 2014, 2014. Wang, S., Q. Zhuang, Z. Yu, S. Bridgham, and J. K. Keller (2016), Quantifying peat carbon accumulation in Alaska using a process-based biogeochemistry model, J. Geophys. Res. Biogeosci., 121, 2172–2185 âĂĺ Yu, Z. C.: Holocene carbon flux histories of the world’s peatlands: Global carbon-cycle implications, Holocene, 21, 761–774, 2011.

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