General Comments:

What is the time-step of the PTEM model? If it is hourly to daily, I think the water table depth extrapolations are probably meaningful. However, PTEM is run at an annual time step. The extrapolation of mean water table depth to constant states throughout an annual cycle is inappropriate. The dynamics of winter snowfall accumulation and melt, precipitation variation and temperature, and seasonal changes in evapotranspiration drive a dynamic water table depth in peatlands that needs to be captured in models. With decomposition, methanogenisis and methanotrophy being dependent on oxygenation associate with dynamic water table position.

Author's response: The time step of PTEM is monthly. When simulating water table dynamics on monthly scale, we consider the snow melt, precipitation and evapotranspiration which all influence peatland water table position.

Due to the extensive use of abbreviations, I found the manuscript hard to read and follow. Please limit their use.

Author's response: We deleted the abbreviations for the uncommonly used terms in the paper (e.g., CRU, ALD, FAO), and add Table 1 at the beginning of the Method section for abbreviations and their full names.

While certain science disciplines may be well acquainted with the IPCC forcing and climate projections, I believe the paper would be more approachable by the average reader if Table S2 and a similar Table for forcing details were included in the published paper.

Author's response: SI Table 1 was added to compare IPSL-CM5A-LR and bcc-csm1-1 forcing.

Arctic regions in the posted polar maps seem to extend into Boreal regions. What land cover is the basis the global calculations of change impact? Perhaps a supporting table defining the lands for the model spatial extrapolations would be helpful. How much peatland/wetland area? How much upland area? How much permafrost vs. discontinuous permafrost vs. temperate area?

Author's response: In this study, we only consider wetlands/peatlands. When considering the climate change, we are talking about grid cells with peatlands. When considering ecosystem dynamics, we are only talking about the peatlands. There are some peatland coverage in boreal regions, but with relatively low abundance (Figure S2, left panel). The dynamic peatland/wetland area and permafrost area is given in Table S2, and in the main text Section 2.2.3:

'…the pan-Arctic wetlands area for the reference dataset is 2.93 Mkm^2, the calibrated wetlands area with IPSL-CM5A-LR forcing input is 2.81 million km^2, and with bcc-csm1-1 forcing input is 2.86 million km^2.'

The abundance of wetland is presented by Figure S3-4. We do not include information on upland coverage since it's not our research objective. The permafrost extent is in Figure S6-7. PTEM only simulates one active layer depth for one grid cell. Therefore, PTEM can only classify grid cells into with permafrost or without permafrost. If a grid cell is in the discontinuous permafrost region, i.e., part of the grid cell has permafrost and the other part has no permafrost, it's still classified into these two categories depending on the forcing data. The area of the non-permafrost area is simply the difference between 'northern peatlands permafrost area' and 'total peatland area' in Table S2. We've added rows to Table S2 for this information.

I don't understand the authors' use of the phrase "run-on". Is this suggestive of a transitional fen state between raised bogs and open aquatic systems?

Author's response: It refers to the water input from nearby water body or ground water to the peatlands. We've added this explanation to where run-on shows up the first time (Introduction section, line 61).

Does PTEM include depth layers? Are the bins mentioned on Line 254 peat layers?

Author's response: PTEM simulates peat thickness for 1cm depth layers. But the bins in line 254 are the bins classified by the TWI values in one grid cell. These bins are essentially dividing the 0.5 degree grid cells into finer grid cells of 0.05 degree resolution (1 into 100). However, these 100 grid cells are derived by clumping a bunch of even smaller grid cells with similar TWI values. We've clarified this by saying '…among the 100 bins classified by TWI…'. To make the technical routine easier to understand, we've added a figure to Supporting Information to explain how to derive water table from 100 TWI bins.

Specific Suggestions:

Line 7: Adjust text to: "have been a large C sink…."

Author's response: Change has been made.

Line 10: Adjust text to: "Peatland area expansion, shrinkage and C accumulation and decomposition are modeled."

Author's response: Text was adjusted.

Line 14: I don't understand "the peatland being C sources".

Author's response: Text was adjusted as 'C sources are attributed to'.

Line 24: Adjust text to "plant litter from being fully decomposed"

Author's response: Text was adjusted.

Line 31: A possible additional phenology reference:

Richardson AD, Hufkens K, Milliman T, Aubrecht DM, Furze ME, Seyednasrollah B, Krassovski MB, Latimer JM, Nettles WR, Heiderman RR, Warren JM, **Hanson PJ** (2018)

Ecosystem warming extends vegetation activity but heightens cold temperature vulnerability. *Nature* 560:368-371, doi:10.1038/s41586-018-0399-1.

Author's response: The reference was added.

Line 32: You might change "will" to would.

Author's response: The word was replaced.

Line 35: Change to: "To date, multiple modeling studies" to distinguish this work from observational or experimental data.

Author's response: 'modeling' was added.

Line 41: Change "considering" to including.

Author's response: Word was replaced.

Line 54: Change "However, the" to ", but future ….".

Author's response: Text was adjusted.

Lines 93 & 100: What is CRU?

Author's response: CRU is Climate Research Unit, we've removed the abbreviation for CRU and replace it with full name throughout the text.

Line 205: Please add the specifics of the CO2 concentrations simulated to the treatment tables mentioned above.

Author's response: CO_2 concentration was added to Table S2.

Lines 243 to 246: Some explanation for the inclusion of and need for pH specificity would help the reader.

Author's response: We've added 'pH values are influential to CH_4 production process…' to explain why we simulate pH values.

Line 290: Expand "the threshold temperature" to "the threshold temperature needed to transition the peatland from a C sink to a C source". If you state it this way, lines 291 and 292. Might not be needed.

Author's response: We've changed text to 'the threshold temperature needed to transition the peatland from a C sink to a C source'. However, we think it's better to keep line 291-292 because they explain how the thresholds are calculated.

Page 12: I would like to see the quantitative specifics provided in Supplement Tables S3 and S4 brought into the main manuscript.

Author's response: These two tables were moved to the main text.

Page 14: A very nice paragraph to describe conditions before 2100.

Table 1.   It is a bit odd to suggest that a transition from one frozen state to another can have large impacts. This interpretive oddity results from the use of mean annual values. Is there another variable that could also be included? For example, days above freezing that could perhaps better explain the results.

Author's response: We've added threshold unfrozen day number to Table 1 (now Table 4). We also explained the method we use to estimate daily temperature is derived from a previous work in Section 2.3.3. In addition, a SI figure 22 was added to show the time series of unfrozen day number.

Line 414: Change "no" to not.

Author's response: 'no' was replaced by 'not'.

Section 4.2 Recent experimental results showing the relationship between warming and nutrient availability could be cited here:

Iversen CM, Latimer J, Brice DJ, Childs J, Vander Stel HM, Defrenne CE, Graham J, Griffiths NA, Malhotra A, Norby RJ, Oleheiser KC, Phillips JR, Salmon VG, Sebestyen SD, Yang X, Hanson PJ (2022) Whole-ecosystem warming increases plant-available nitrogen and phosphorus in an ombrotrophic bog. Ecosystems https://doi.org/10.1007/s10021-022-00744-x

Author's response: We've discussed and cited this article in Section 4.2.

Line 463: The units for Hanson et al. 2020. Data are wrong they should be gC m^{-2} y^{-1} $°C^{-1}$. The implication is that the Hanson et al. results are proportionate to the amount of warming.

Author's response: We've changed the text into 'each 1°C of warming increases C loss rate by 31.3 $gC \cdot m^{-2} \cdot yr^{-1}$.