

Dear Vivek,

We sincerely appreciate the time you devoted to annotating our manuscript. In response, we have revised every section where you requested clarification or additional context; your comments have been invaluable in enhancing the manuscript's quality.

First, every language issue you raised has been corrected in the revised manuscript. Below, we elaborate on several key points; your handwritten comments appear in black, and our responses are shown in blue.

1) Line 122-125: I'm confused again. This indicates 3 pools: usual C, permafrost C that has thawed, permafrost C that has not thawed?

Thank you for your comment. In the UVic ESCM, permafrost carbon is stored in a depth-resolved pool consisting of six discrete layers, each acting as a sub-pool. This structure allows the permafrost carbon pool to contain both thawed and frozen carbon simultaneously. To emphasize this point, we have added the following clarification: "The coexistence of thawed and frozen permafrost carbon is attributed to the depth-resolved soil carbon scheme."

2) Line 214: "total permafrost region soil carbon" is not defined yet. & Line 245: This should come earlier than the first use of "total permafrost region soil carbon" on page 8.

Thank you for pointing this out. We agree that the definition of "total permafrost region soil carbon" should be provided prior to its first use. To address this, we have moved the explanatory sentence – "It is worth noting that the permafrost region for carbon-related variables is defined as the area where permafrost carbon exceeds zero. This differs from the permafrost area, which is defined as the area where soil temperature remains below 0 °C for at least two consecutive years." – to the end of the third paragraph in Section 2.1 (Model Description).

3) Line 355: What does "that" refers to?

Thank you for your comment. We have revised the sentence by replacing "that" with "the expansion" to avoid ambiguity. The revised sentence now reads: "Needleleaf trees expand slowly and continuously in the permafrost region in both overshoot and stabilization scenarios, whereas the expansion of shrubs closely follows the trajectory of global mean temperature."

4) Line 358: Sorry is 62% the result from your model simulations? Why the use of "expected"?

Yes, the 62% value is derived from the output of our model simulations. We initially used "expected" to indicate that this result is slightly above the 24~52% range projected for 2050 by Pearson et al. (2013), and therefore falls within a plausible range. To avoid ambiguity, we have replaced "expected" with "projected" in the revised manuscript.

5) Figure 7: We don't have panel d anymore

Thank you for pointing this out. We have corrected the figure caption to remove the reference to panel d.

6) Line 550: C lost from frozen soils $\neq$ C entering the atmosphere. Why?

Thank you for your question. We agree that the sentence was potentially misleading and have revised it accordingly. As noted by Nitzbon et al. (2024), their estimates of total carbon loss from frozen soils likely represent an upper bound on the actual atmospheric release. This is because Nitzbon et al. (2024) inferred carbon loss based on the presence or absence of permafrost, whereas in reality, permafrost carbon may persist in the soil for some time even after permafrost disappears. To avoid confusion, we have removed the latter half of the original sentence: “, yet only a fraction of that carbon is ultimately released into the atmosphere, as noted by Nitzbon et al. (2024).”

7) Line 603: I think, it's ok to mention the lower number of 1.6 M km²/°C

Thank you for your comment. The value was derived from Liu et al. (2021), where the permafrost sensitivity to climate warming was calculated based on the regional mean warming over permafrost regions, rather than the global mean temperature increase. To ensure conceptual consistency across comparisons, we therefore chose to exclude this figure in the current revision. By the way, we initially followed the interpretation of Liu et al. (2021) as presented in the IPCC AR7 Chapter 9, Page 1283, Left column, Lines 10-14. However, we found that the IPCC AR7 incorrectly interpreted the results of Liu et al. (2021).

8) Line 609: Should this be 2 °C

Thank you for your comment. We agree that this part of the manuscript was not clearly expressed. In fact, two different methods were used to assess the relationship between permafrost area and global mean temperature based on the SSP5-8.5 scenario. We have now clarified this point in Section 3.3 (Linearity of Permafrost Response and Feedback), third paragraph, which reads: “Nitzbon et al. (2024) reported a quasilinear decrease in the equilibrium permafrost extent to global warming, with a rate of approximately 3.5 million km² °C⁻¹. This quasilinear relation holds for global warming ranges from 0 °C to 4 °C, derived from the empirical relationship between the local permafrost fraction and the annual mean global temperature. However, when applying a local regression method across the full SSP5-8.5 trajectory (Fig. 9a), we find that the quasilinear relationship only holds between 1.5 °C and 2 °C. In contrast, when applying a simple linear regression, a quasilinear behavior still holds over the 1.5 °C to 3 °C warming range (Fig. 10a).”

In the sentence at Line 609, we retained the 1.5 to 3 °C range, but clarified the context to avoid confusion. The revised sentence now read: “However, we found that this relationship holds most strongly within 1.5 °C to 3 °C global warming range when using a linear regression approach (Fig. 10a).”

9) Line 632: was this mentioned earlier? Or did I miss this.

Thank you for your careful reading. You are correct that this information was not mentioned earlier in the manuscript. To improve the clarity and logical flow of the results, we have now moved the relevant sentence to an earlier position in Section 3.1 (Lines 272 – 276), where we first report the incomplete recovery of permafrost area under the overshoot scenarios. The revised text reads: “This indicates that permafrost area is nearly reversible and largely follows the global mean temperature trajectory, recovering as temperature reduction, consistent with previous studies (MacDougall, 2013; Lee et al., 2021; Schwinger et al., 2022). The incomplete recovery partly results from slightly higher regional temperatures in permafrost regions. By 2300, the northern high-latitude permafrost regions are 0.01~0.13 °C warmer compared to the SWL-1.5 scenario.”

10) Line 676: Sorry, there are % of what? Atmospheric CO₂ burden or emissions?

Thank you for your question. The percentages refer to the cumulative anthropogenic CO₂ emissions, not atmospheric CO₂ burden. To improve clarity, we have revised the text to read: “To accomplish the 1.5 °C target under the OS-2, OS-3, and OS-4 scenarios, anthropogenic carbon emissions would need to be reduced by amounts equivalent to the permafrost carbon loss. The proportion of carbon removal required to offset permafrost emissions corresponds to 27 [16 to 39] % under OS-2, 10 [6 to 15] % under OS-3, and 7 [4 to 9] % under OS-4, relative to the cumulative carbon removal from the peak warming to the 1.5 °C target sustained until 2300.”

We would also like to note that the percentage values reported in the current version differ from those in the previous version. This revision results from a change in the reference baseline: instead of permafrost emissions to cumulative anthropogenic CO₂ emissions from 1850 to 2300, we now refer only to the cumulative emissions that would need to be removed from the peak warming to reach the 1.5 °C target. This adjustment better reflects the additional carbon removal effort required due to permafrost carbon release in the context of achieving the climate goal.

Your sincerely,

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