Overview

We thank the reviewers for their constructive comments and suggestions. The manuscript will be appropriately revised in response to the reviewers' comments (see the point-by-point expected responses below). As requested by the reviewers, we compared our modeling results with some existing permafrost data sets by calculating evaluation metrics that can be compared directly against matching results reported in the literature. In addition, we also conducted several new simulations that further assess the impact on ALT of the model soil layer configuration, the soil organic carbon content, and its vertical distribution.

In summary, the planned modifications to the text can be categorized as follows:

a) Novelty and added value:
   See R1C1 (i.e., Reviewer 1, Comment 1), R1C2, and R3C6

b) Comparison with other model-generated permafrost data sets:
   See R1C1, R1C2, R3C6, R3C29 and R3C30

c) Rephrasing "optimistic" discussion about ALT results:
   See R1C10, R1C11, R1C12, R3C2, R3C31

d) New sensitivity experiments and uncertainty discussion:
   See R1C3, R1C20, R2C8 and R2C12

e) Add specific evaluation metrics instead of using description words:
   See R3C6, R3C8, R3C24, R3C29 and R3C31

Throughout the discussion below, the text is colored as follows:

Black: Reviewer comment
Blue: Expected author response
Red: Expected text to be inserted into the revised manuscript

For reference, our response to comment "m" by reviewer "n" is labeled "R[n]C[m]".

Reviewer #3

The authors compare model estimates (based on re-analyses data) of active layer thickness (ALT) with different data sources. This includes in situ measurements from an international database and an unpublished approach of airborne P-band estimation. The latter is available over Alaska. General evaluation is made for the northern hemisphere.

In addition, the model input is investigated for linear relationship with its output. The authors seek to find a simplified relationship to explain ALT change over time (driven by degree days, snow water equivalent etc).

General issues

The manuscript addresses an important topic, the modelling of active layer thickness over time. The presentation of the manuscript and setup of the experiment is however problematic.

1) The authors report 'reasonable' or 'good' results with limited and partially missing quantitative reasoning.

R3C1: We will include additional quantitative metrics to better illustrate our results. Please see our responses in R3C6, R3C8, R3C24, R3C29 and R3C31 for further details.

2) The results of the comparison to the unpublished airborne (AirMOSS) approach suggest that it actually does not work (AirMOSS values are all at the same level, not representing the in situ range, Figure 4). The comparison to this unpublished approach should be removed from the manuscript.

R3C2: We thank the reviewer for pointing out this. However, we do not agree with the reviewer regarding this point. We believe the AirMOSS data has value, which is also the opinion of Reviewer #2. We will expand the relevant discussion about the potential use of the AirMOSS retrievals in the manuscript. Please see specifically our response to R1C11, R1C12 and R2C7, with particular attention to the Table R1 (new Table 3 proposed for the revised manuscript).

3) The stated objectives comprise issues regarding active layer thickness. The results section however does also cover permafrost extent.

R3C3: We thank the reviewer for pointing out this. We do not solely focus on ALT. We will modify the statement of our objectives in Section 1:

> "Overall we pursue three scientific objectives: 1) evaluate the relative importance of the factors that determine the spatial variability of ALT, 2) evaluate CLSM-simulated ALT climatology and permafrost extent against observations, and 3) quantify and assess the large-scale characteristics of ALT (in terms of means, interannual variability and trend) in Northern Hemisphere permafrost regions from 1980 through 2017. "

4) In addition, common structure of methods, results and discussion is lacking. Methods are included in the introduction and mostly in the results section. The discussion is largely included in the results section. The ‘approach’ section mostly only includes the dataset description.

R3C4: We will add a new section (“Section 3 Methods”) and will move all the method description to this new section. We will also move some discussion about our results to the last section to supplement other ‘discussion’ of the research findings.

5) Some of the used datasets are not appropriately cited. See detailed comments below

R3C5: We thank the reviewer for pointing out this. We will check our reference list and will correctly cited all of the datasets that we used. Please also see our response in R3C10 and R3C11 for additional details.

6) A main weakness of the manuscript is that the results are not discussed with respect to already published material on permafrost related parameter modelling and on the parameters which are investigated for explanation as drivers of ALT change over time. The role of temperatures and snow water equivalent for active layer thickness is known (what is presented as one of the main results in the abstract). The novelty of the paper is not clear.

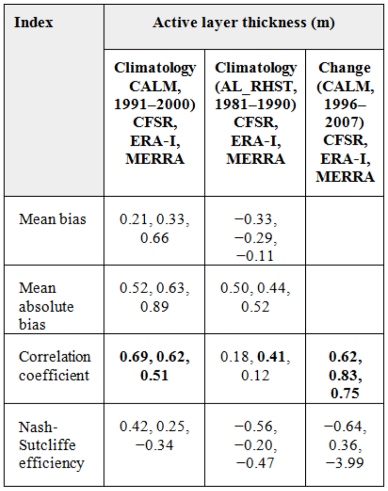
R3C6: We will be adding extensive text that further highlights the novelty of our study. Please see our responses in R1C1 and R1C2. In the discussion below we focus specifically on the comparison between our results and other existing studies, for the reviewer’s interest.

Given that different models run at different spatiotemporal resolutions, and that the simulated results were evaluated using different observation data sets (or using different time periods of the same data set), a direct and credible comparison with existing model-simulated permafrost data sets requires extensive analysis and is not conducted here as it is considered beyond the project scope. Instead, we did a rough comparison with existing permafrost products simulated by land models with reanalysis-based forcing as shown in the table below. (Note that ALT products simulated with climate forcing that is not observation-based are not included here.) We also want to emphasize that many existing studies define permafrost as areas with an ALT less than 3 m (Dankers et al., 2011) or 3.8 m (Guo et al., 2017;Guo and Wang, 2017;Lawrence et al., 2012), i.e., focused on the “near-surface permafrost”. We do not specifically limit ALT within a certain depth, although our simulated results generally are less than or equal to the bottom depth of the 5th soil layer (2.95m). Also, many of these studies evaluate the simulated results for “present-day” (i.e., before 2000). To make a relatively fair comparison with the existing studies, we used the same validating time period.

Table R4 – Existing available ALT products and evaluation metrics over Northern Hemisphere simulated by land surface models with reanalysis-based forcing.

Model and Soil Configuration	Forcing	Spatiotemporal Domain and Resolution	Findings and Conclusions Regarding ALT and Permafrost Extent	Reference

JULES (Joint UK Land Environment Simulator) (total soil depth 3m)	GSWP2 (Global Soil Wetness Project 2) WATCH (WATer and Global Change)	1983–1995 at 1°×1° resolution with GSWP2 covering areas north of 25°N (includes the Tibetan Plateau). 1959–2000 at 0.5°×0.5° resolution with WATCH covering areas north of 45°N (does not include the Tibetan Plateau).	- Captures 97% of the continuous and discontinuous permafrost areas. - Overestimates the total extent; simulates permafrost where it only occurs sporadically or only in isolated patches (25%); overestimates an additional 14% in areas permafrost free. ALT: JULES-simulated ALT is generally too deep compared with CALM observations: mean bias in the GSWP2 run (1990–1995) is 0.81±0.48 m, and 0.53±0.50m in WATCH-GPCC (1990–2000). The Root Mean Square Error (RMSE) is 0.94 and 0.73m, respectively.	Dankers et al. (2011)
ORCHIDEE-MICT land surface model (total soil depth is 38 m)	GSWP3 (Soil Wetness Project Phase 3) CRUNCEP (Climatic Research Unit - NCEP)	Northern Hemisphere (>30° N) at 1°×1° spatial resolution (does not include the Tibetan Plateau). 1901–2007 with GSWP3; 1901–2015 with CRUNCEP.	- Both simulations underestimate permafrost extent when using ALT<3m as the definition of permafrost; CRUNCEP-forced simulation shows better permafrost extent using an alternative definition of permafrost. (No actual bias value provided.) - GSWP3-forced model generally overestimates ALT by more than 1m; CRUNCEP-forced output shows relatively better agreement with the observations. (No actual bias value provided.)	Guimberteau et al. (2018)
CLM 4.5 (50m soil depth)	CRUNCEP (Climatic Research Unit - NCEP)	Northern Hemisphere (includes the Tibetan Plateau). 1901 – 2010 Spatial Resolution: 0.5°×0.5°	(Defines near-surface permafrost as that within the upper 3.8 m of soil.) - Simulated present-day (mean from 1981 to 2000) permafrost distribution; shows good agreement – only discrepancy is on the Tibetan Plateau. Bias in permafrost extent is 2.02 x 10^6 km^2. - Global ALT trend with a correlation coefficient and an	Guo and Wang (2017)

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>The Nash-Sutcliffe Efficiency (NSE) of 0.73 and 0.21, respectively. The simulated trend was smaller than observed trend. (No evaluation for ALT climatology provided.)</td>
<td></td>
</tr>
<tr>
<td>CLM 4.5
(50m soil depth)</td>
<td>CFSR: NOAA Climate Forecast System Reanalysis
ERA-I: European Centre for Medium-Range Weather Forecasts Re-Analysis Interim
MERRA: NASA Modern Era Retrospective-Analysis for Research and Applications</td>
<td>Northern Hemisphere (includes the Tibetan Plateau).
Spatial Resolution: 0.5°×0.5°
1979 -2009</td>
<td>(Permafrost is defined as ground where monthly soil temperature is less than 0°C for 24 consecutive months in at least one layer of the upper 10 soil layers (3.8 m) (Lawrence et al., 2012).)
- The model underestimates the permafrost extent in southern Alaska, northern Western Siberian Plain, and over the Tibetan Plateau.
Specific evaluation metrics:

<table>
<tr><th rowspan="2">Index</th><th colspan="3">Active layer thickness (m)</th></tr>
<tr><th>Climatology CALM, 1991–2000) CFSR, ERA-I, MERRA</th><th>Climatology (AL_RHST, 1981–1990) CFSR, ERA-I, MERRA</th><th>Change (CALM, 1996–2007) CFSR, ERA-I, MERRA</th></tr>
<tr><td>Mean bias</td><td>0.21, 0.33, 0.66</td><td>−0.33, −0.29, −0.11</td><td></td></tr>
<tr><td>Mean absolute bias</td><td>0.52, 0.63, 0.89</td><td>0.50, 0.44, 0.52</td><td></td></tr>
<tr><td>Correlation coefficient</td><td>**0.69, 0.62, 0.51**</td><td>0.18, **0.41**, 0.12</td><td>**0.62, 0.83, 0.75**</td></tr>
<tr><td>Nash-Sutcliffe efficiency</td><td>0.42, 0.25, −0.34</td><td>−0.56, −0.20, −0.47</td><td>−0.64, 0.36, −3.99</td></tr>
</table></td>
<td>Guo et al. (2017)</td>
</tr>
<tr>
<td>CLM3 and CLM4 (offline)
3.5m depth with CLM3 and 3.8m depth with CLM4.</td>
<td>Forced with observed meteorological data based on NCEP-DOE.</td>
<td>Northern Hemisphere (includes Tibetan Plateau);
Simulation period: 1980–1999;
0.9375° latitude × 1.25° longitude</td>
<td>(Focused on shallow-permafrsot with ALT < 3.8 m.)
- CLM3 simulation underestimates permafrost in southern and western Siberia.
- CLM4 simulations show improved permafrost extent.
- In general, ALT is overestimated; CLM4 underestimated ALT in regions of shallow permafrost. (No actual evaluation metrics provided.)</td>
<td>Lawrence et al. (2012)</td>
</tr>
</table>

			- CLM3-simulated continuous and discontinous permafrost extent is 11.1 × 10^6 km^2 for the period 1970–89, which is below 11.8–14.6 × 10^6 km^2 estimate from Zhang et al., 2000. - CLM4-simulated continuous and discontinous permafrost extent is 13.7 × 10^6 km^2 for the period 1970–89.	

Existing studies that evaluated ALT that can be compared with ours include (Dankers et al. (2011) and Guo et al. (2017). Other studies did not report specific evaluation metrics within a common simulation domain as ours, hence, they cannot be used for comparison. Comparing with reported evaluation metrics as shown in Table R5, Figure R8 and Figure R9 reveal that: 1) for the early 1990s (i.e., 1990 – 1995 period), our simulated results show a much better agreement with the observations than when using JULES with GSWP2 forcing as reported in Dankers et al. (2011); 2) for the whole 1990s (i.e., 1990 – 2000) period, our results are better than that using JULES with WATCH-GPCC forcing or when using CLM4.5 with both ERA-I and MERRA forcing as reported in Guo et al. (2017); and 3) our results show a smaller mean absolute bias and a larger correlation coefficient than that using CLM4.5 with CFSR, but show worse performance regarding mean bias and NSE. In addition, all of these existing studies overestimated ALT at the global scale and reveal a positive bias while our results underestimate deep ALT, and hence, reveal a negative bias. However, it is worth noting that our results demonstrate much better agreement against observations for regions of shallow permafrost as shown in Figure R8 and R9. We will add a short discussion along the lines of the following:

> "The existing literature on simulated ALT fields (e.g., Dankers et al. (2011), Lawrence et al. (2012) and Guo et al. (2017)) reveals a general tendency for models to overestimate ALT climatology at the global scale. The CLSM-simulated ALT fields appear to be among the better simulation products."

Table R5 – Summary of evaluation metrics for ALT estimates reported in literature. The same metrics calculated with the simulation results in this study for an identical evaluation period are provided.

Evaluation metrics	(Dankers et al., 2011)* with two different sets of climate forcings				(Guo et al., 2017)[#] with three different sets of climate forcings			
	GSWP2 (1990–1995)	This Study (1990–1995)	WATCH-GPCC (1990–2000)	This Study (1990–2000)	CFSR (1991-2000)	ERA-I (1991-2000)	MERRA (1991-2000)	This Study (1991-2000)
RMSE (m)	0.94	0.18	0.73	0.72	None			

Mean Bias (m)	0.81	0.04	0.53	-0.17	0.21	0.33	0.66	-0.24
Mean Absolute Bias (m)	None				0.52	0.63	0.89	0.36
Correlation Coefficient					0.69	0.62	0.51	0.70
Nash-Sutcliffe Efficiency (NSE)					0.42	0.25	-0.34	0.25

*Evaluation was conducted with annual ALT.

#Evaluation was based on ALT climatology.

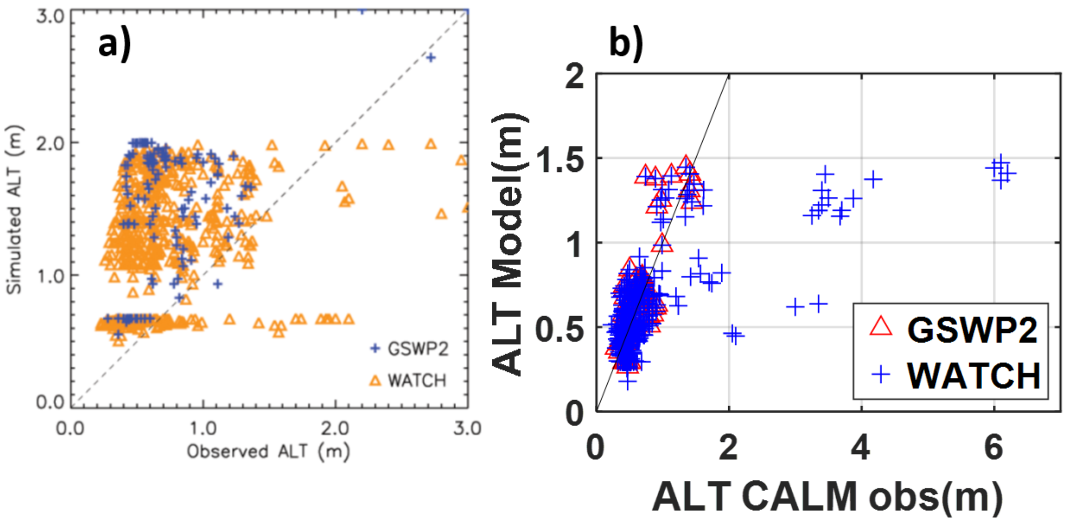


Figure R8: Observed and simulated ALT at CALM observations sites. a) copied from Dankers et al. (2011). The comparison was made for the period 1990–1995 using GSWP2 forcing, and for the period 1990–2000 using WATCH. b) Results from this study.

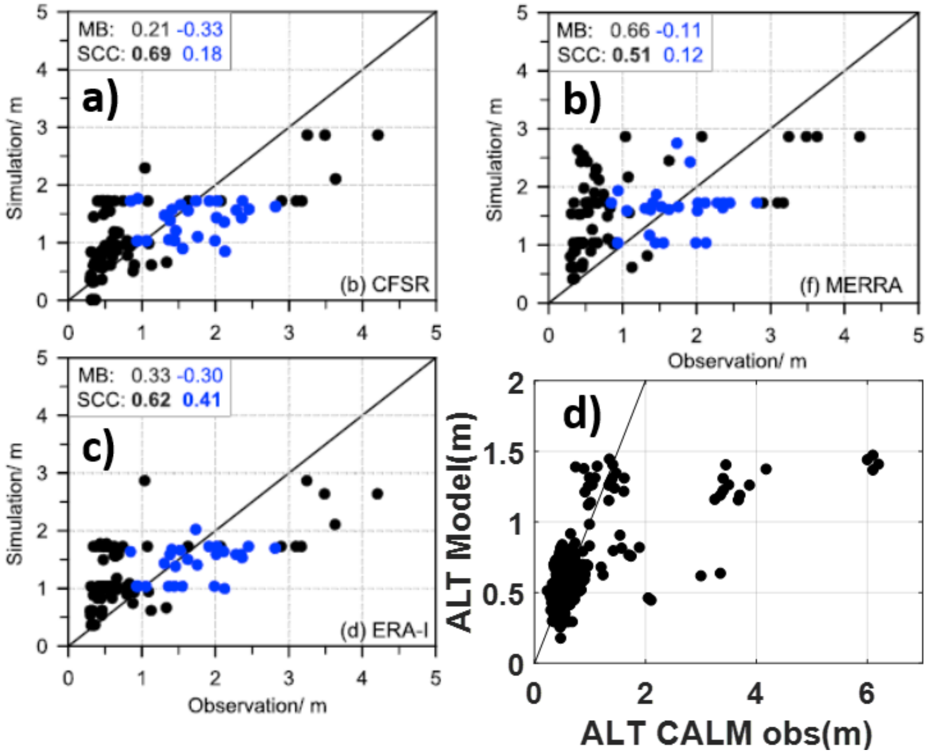


Figure R9: a), b) and c) are copied from Guo et al. (2017). Black dots represent the validating pair of data using CALM observations whereas the blue dots represent the validating pair of data using AL_RHST observations. d) shows comparison results with ALT estimates in this study. All subplots are for the validating period of 1990 to 2000.

In terms of the evaluation of simulated permafrost extent, although it is not fair to compare our results with these existing studies due to differences in simulation domain, we did conduct similar calculations to quantitatively evaluate our simulated permafrost extent against these other studies. In addition, most of these existing studies compare the model simulated permafrost area with that of the total area of continuous and discontinuous permafrost from Brown's map due to their coarse spatial resolution (i.e., at least 0.5°). Given the high resolution (i.e., roughly 9km × 9km) of our simulation results, we compare and discuss our simulated permafrost area with that of the total area of continuous, discontinuous, **and** sporadic permafrost together as shown in Figure 10 in our manuscript. For the revised manuscript, we will incorporate these evaluation results into a new table, as shown below (Table 4 in the revised manuscript). We will also compare the simulated permafrost extent with that of the total area of continuous and discontinuous permafrost area from Brown's map in order to better compare our results with those of existing studies, which is shown in the parentheses in Table R6 below (new Table 4 in the revised manuscript).

Table R6– Evaluation results for simulated permafrost extent. (New Table 4)

Case	CLSM	Obs.	Simulated Area ($\times 10^6$ km^2)	Percentage Relative to Observed
4	No	No	48.8	-

3	Yes	No	1.9	-
2	No	Yes	3.2 (1.7)	18.7% (12.3%)
1	Yes	Yes	13.8 (12.3)	81.3 % (87.7%)

We will also add the following short discussion into the revised manuscript:

> "The specific areas of each type shown in Figure 10a are listed in Table 4. The simulated permafrost extent covers 81.3% of the observation-based area (i.e., the total area of continuous, discontinuous and sporadic permafrost regions), and missed 18.7% of the observed permafrost area. When comparing simulated permafrost extent with only continuous and discontinuous types, these metrics change to 87.7% and 12.3%, respectively. Meanwhile, the permafrost extent is overestimated by 3.2×10^6 km^2."

Regarding the role of temperature and SWE, although it is well known that these two factors affect permafrost, the *relative* contribution of the two is still unclear. This study attempts to quantitatively estimate this relative impact, which, to our knowledge, has heretofore not been done. This, we feel, is indeed one of our useful, novel contributions to the permafrost literature.

Detailed comments

Title: the title is misleading; the paper focuses on active layer thickness what should be reflected in the title

R3C7: We do not solely focus on ALT. Simulated permafrost extent is also evaluated and discussed in the manuscript. We believe our title regarding "variability" implicitly includes both ALT and permafrost extent. In addition, ALT might be too technical to be included in a title since many people know about permafrost but may not know what ALT is. We plan to retain our title as is.

Abstract:

Line 19: 'measurements demonstrates reasonable skill' – what is 'reasonable'? add numbers

R3C8: We will add the following sentence in order to clarify what we mean by "reasonable" skill.

> "Specifically, the RMSE (and bias) of climatological ALT is 1.22 m (and -0.48 m), and is reduced to 0.33 m (and -0.04 m) without the Mongolia sites."

Line 27: 'significant degradation, with ALT increasing up to 0.5 cm/year' – it should be noted that this cannot be confirmed with in situ observations

R3C9: We thank the reviewer for pointing out this. This is very true. Below we provide the same figure as our Figure 14a in the original manuscript but only showing sites at which both the observed and estimated ALT trend is found to be statistically significant. Only four and ten sites are shown below with p value less than 0.05 and 0.10, respectively. Although the estimated and observed trends are closely clustered around the 1:1 line, the limited number of sites shown below cannot assure the accuracy of the estimated trends.

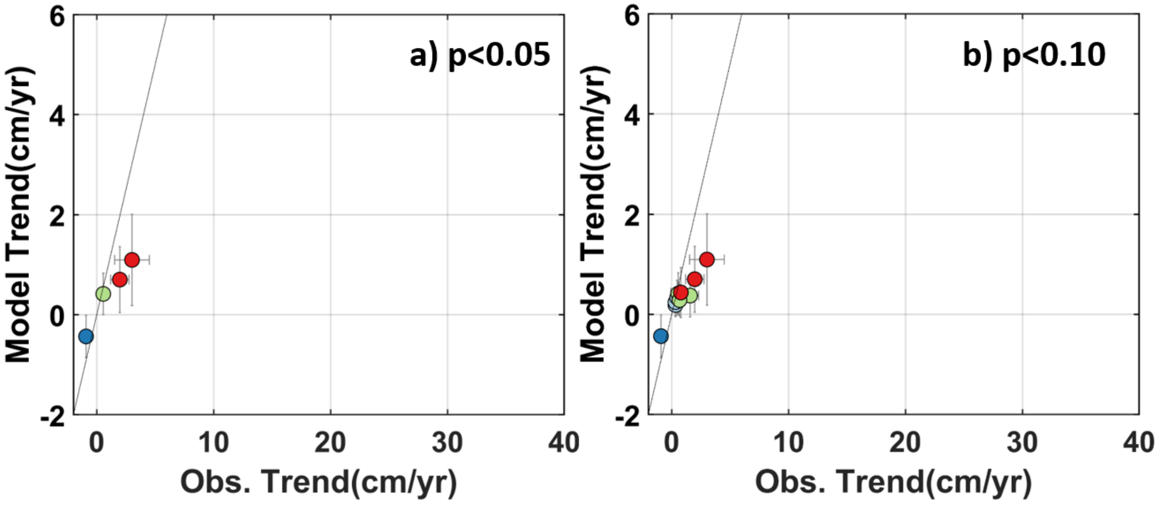


Figure R10: ALT trend from CLSM estimates vs. CALM observations, based on years common to both datasets within the period of 1990 to 2017. The horizontal and vertical error bars represent 95% confidence intervals of observed ALT trend (regression slope) and CLSM-simulated ALT trend, respectively. This current figure is similar to Figure 14 in the original manuscript, but only showing sites with both observed and estimated trends that are statistically significant at a) 0.05 and 0.10 level.

For the manuscript, we will add an additional description of the significance of estimated trends into the caption of Figure 14, and we will add the following to the discussion in Section 4.5:

> "However, the comparison with in-situ observations is not able to adequately assess the accuracy of such simulated ALT trends, given that only a very few observational sites show trends that are statistically significant."

We will also add a sentence into the abstract as shown below:

> "Moreover, only four (ten) points remained when screening out sites at which either the observed or estimated ALT trend is not statistically significant at the 0.05 (0.10) level. The limited number of sites with meaningful trends cannot assure the accuracy of the estimated trends."

Page 5, line 9: NCSCDv2 – citation missing, follow instructions of https://bolin.su.se/data/ncscd/

R3C10: We sincerely apologize for missing the important references. We thank the reviewer for pointing out this. We will add the references for NCSCDv2:

> "… from the Northern Circumpolar Soil Carbon Database version 2 (NCSCDv2, https://bolin.su.se/data/ncscd/) (Hugelius et al., 2013a;Hugelius et al., 2013b)."

Page 6, line 24: Brown et al. 2002: the reference is missing in the list

R3C11: We are sorry for failing to include this reference. We will add it.

Page 7, line 30 following: this paragraph belongs to methods

R3C12: Will be done as suggested.

Page 8, line 9: remove 'relatively'

R3C13: Will be done as suggested.

Page 9, first paragraph: this belongs to discussion

R3C14: Will be done as suggested.

Page 9, line 17 following: introduce this comparison in the methods section

R3C15: Will be done as suggested.

Page 9, line 22: provide correlation analyses results as table

R3C16: These results only consist of three correlation coefficients. Therefore, instead of adding these values into a table, we will add these correlation coefficients to Figure 5 for each variable for greater clarity.

Page 9, line 23: which SOC value did you use? Is it representative for the upper soil layer?

R3C17: We used spatially varying SOC provided by NCSCDv2, and not a constant SOC everywhere. Please see section 2.1 and Tao et al. (2017) for more details.

Page 10, line 4-28: this all belongs to the methods section

R3C18: We will move these paragraphs to the new method section (Section 3).

Page 11, line 7: spell out LAI

R3C19: We have spelled out LAI at the place it first appears (Page 10 Line 16 in the original manuscript) and thus keep LAI as used here.

Page 12, line 6-12: move to methods

R3C20: Will be done as suggested.

Page 12, line 19: 'permafrost areas shown in Fig. 1b are well confined within the cold side ..' this cannot be seen. Add outlines to map

R3C21: The 273.15K isotherm actually is shown in the figure (i.e., the edge of dark green block). We will add the boundary containing continuous and discontinuous permafrost regions into Figure 8d. The original Fig. 8d showed mean Tair all over the Northern Hemisphere. We will modify it and only show mean Tair over the simulation domain in order to better illustrate the results.

Page 13, up to line 7: to methods; what is the reasoning for the static time period approach?

R3C22: We will move the method description to the new Section 3.3. We are not sure what the reviewer means by “static time period”. We evaluated the full 37-year period in order to best leverage all of the available observations. We will also modify equation (1) and (2) in the original manuscript (and equation (2) and (3) in the revised manuscript) as follows:

> “$$T_{cum} = \sum_{N=2}^{N=38} T_{pos}(N) \quad , \qquad (1)$$
>
> where
>
> $$T_{pos}(\mathrm{N}) = \begin{cases} T_{air}(t) - T_f & if\ T_{air}(t) > T_f \\ 0 & if\ T_{air}(t) \leq T_f\text{’} \end{cases} \qquad (2)$$
>
> The summation in Eq. (2) for year N is computed from 1 September of year (N-1) to 31 August of year N.”

Page 13 – move explanation of linear regression analyses to methods

R3C23: Will be done as suggested.

Page 14, line 14: ‘geographically thin disagreements’ – quantify this

R3C24: It is quite hard to quantify this, but we will attempt to do so with the following modification:

> “Aside from western Siberia, the geographically thin disagreements (i.e., about a few degrees latitude) between the simulated and observed permafrost extents toward the south in Figure 10a (green and blue areas at the southern edge of permafrost regions) are not as much a concern, since the comparison in such areas is muddied by the interpretation of “isolated” permafrost in the observational map (Figure 10 b).”

Page 14, line 28 following: this is methods

R3C25: We will modify and move these sentences to the new method section (Section 3.4).

Page 14, line 18: this error may seem small in absolute numbers, but ALT is much thinner than for the Mongolian sites. The error is still relatively large.

R3C26: We recognized this behavior, and hence we discussed the model performance in high-latitude regions separately from that in mid-latitude regions. We also explicitly emphasized the large error for the Mongolian sites and discussed the possible reasons for the underestimation. We conducted some new sensitivity tests and will add the results into the manuscript with relevant discussion. Please see our response in R2C8d and R3C6 for details.

Page 14, line 20-26: this belongs to discussion

R3C27: We thank the reviewer for this suggestion, but we believe this paragraph should stay here since it describes the results.

Page 15, first two paragraphs of section 3.5 – this all belongs to methods

R3C28: We will modify and move these paragraphs to the new methods section (Section 3.4).

Page 17, 21: 'shows good general agreement' – this is not really the case, quantify the agreement and compare with other published results

R3C29: We calculated the bias in percentage (please see R3C6 for details), and we will modify as follows:

> "The spatial distribution of CLSM-simulated permafrost shows general agreement with the observation-based permafrost map of Brown et al. (2002), capturing 81.3% of total areas of continuous, discontinuous and sporadic types while capturing 87.7% of the total area of continuous and discontinuous types."

Page 17, line 29: 'The simulated ALTs agree well with the in-situ observations' – not really, see my comment for page14, line18; how do your results compare to other published results?

R3C30: Our results are among the best existing permafrost products. In particular, our results demonstrate much better agreement against observations for regions of shallow permafrost (as shown in Figure R8 and R9) compared to other existing results. Please see details in R3C6.

Page 18, lines 1-2: 'retrievals from airborne remote sensing for 2015 and the corresponding simulated ALT exhibit reasonable accuracy vs. in situ measurements' – this is not clear from the material presented.

R3C31: Point taken. We will modify this sentence as follows:

> "In northern Alaska, ALT retrievals from airborne remote sensing for 2015 and the corresponding simulated ALT exhibit limited skill versus the in-situ measurements. At the model scale, the mean bias for the simulated results is better (-0.05 m) than that for the retrievals (-0.12 m), but the opposite is true for the correlation coefficient against observations (0.27 for the model vs. 0.61 for the retrievals). At the in-situ site scale, however, the ALT retrievals show a very weak correlation

> coefficient with the observations (0.05). Excluding sites that have ALT measurements exceeding the radar sensing depth (~ 60cm), the evaluation metrics for ALT retrievals become better than that for simulated ALT at the model scale. The remotely sensed ALT estimates generally show lower levels of spatial variability than the simulated ALT estimates, and their spatial patterns differ considerably. Such differences may be cause for concern, but they should decrease as both approaches evolve and improve. It is important to document the performance of the two approaches and to consider them side by side during their evolution given their potential for estimating permafrost in coming years. The most accurate future estimates of permafrost may indeed result from their joint application, such as through the downscaling of model results with higher resolution retrievals."

Figure 5: what is the red rectangle?

R3C32: The red rectangle highlights an example to illustrate the anti-correlated relationship between ALT and organic carbon content. We discussed this point in section 4.2. We will also add the following sentence to the caption of this figure:

> "The red rectangle crossing a) and b) highlights a portion of the domain that shows an anti-correlated relationship between organic carbon content and modelled ALT (see Section 4.2)."

Figure 7: convert to table

R3C33: Since the values are already provided on the figure, we feel that converting it to a table would not help much. We opt to keep the figure as is.

Reference

Alexeev, V. A., Nicolsky, D. J., Romanovsky, V. E., and Lawrence, D. M.: An evaluation of deep soil configurations in the CLM3 for improved representation of permafrost, Geophys Res Lett, 34, 10.1029/2007gl029536, 2007.

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