Author's Responses to RC1's comments on *"Brief communication: Improving ERA5-Land soil temperature in permafrost regions using an optimized multi-layer snow scheme"*

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The authors would like to thank the reviewer for constructive feedback, and the thorough assessment of the manuscript. Below we provide a point-to-point response to each comment, reviewer comments are given in black, responses are given in blue. Additionally, we have included details of how we intend to address these changes in a revised submission.

This short communication is easy to read and follow. The conclusion is very clear and also important. Generally, I am willing to recommend its publication after the following comments are considered.

- For the evaluation in Figure 2, the improvement seems to fail on the Tibetan Plateau. Except for very thin snow as a reason, perhaps the comparison itself has an impact? The comparison is based on site (OBS) vs. grid (SIM) scale? if so, such comparison may have partial impacts because of very complex terrain of the Tibetan Plateau.
  Response: We agree scale gap could be a possible reason, especially over the Tibetan Plateau. The worse performance in revised simulation is thought to because of underestimated near-surface air temperature rather than snow scheme. The near-surface air temperature over the TP is significantly underestimated by about -5.8 ± 3.7°C in winter (DJF, see Table 2). This generally could account the underestimated soil temperature, i.e., from -3.3 to -2.7°C.
  In addition, Orsolini et al. (2019) reported that excessive snowfall might be the primary factor for the large overestimation of snow depth and cover in ERA5(-land) reanalysis. In Sec 5.1, we intend to revise as below to clarify.

  "On the Tibetan Plateau, the soil temperature in Exp. MLS-Dis+Den is found to have a worse performance compared to ERA5L. This is because T_a is significantly underestimated by about -5.8 ± 3.7°C over the Tibetan Plateau, which could account for the cold bias of soil temperature, i.e., from -3.3 to -2.7°C (Table 2). While the new MLS reduced overestimated snow depth (Figure 2I), it suppressed snow insulation and hence enhanced soil temperature cold bias. Previous studies indicated that excessive winter precipitation in ERAL(-Land) might be an additional uncertainty for the remarkable overestimation of snow depth over the TP Orsolini et al. (2019)."

  In addition, we indented to reformulated Figure 2 in order to give detailed time-series and spatial information of soil temperature bias, as suggested by the editor.

- I think that the diagnostic method for near-surface permafrost needs to be introduced more detailed. For instance, "permafrost is identified as ground where monthly soil temperature is less than 0°C for 24 consecutive months in at least one layer of the simulated upper 4 soil layers", as the statements from (Guo and Wang, 2017, https://doi.org/10.1002/2017JD027691).
  Response: In the second paragraph of Sec.4, we intend to revise as below to clarify.

  "Near-surface permafrost regions were diagnosed from the mean annual ground temperature of the fourth soil layer of reproduced reanalyses, i.e., soil temperature is less than 0 °C for two consecutive years, and is compared to the Circum-Arctic Map of Permafrost and Ground-Ice Conditions (hereafter referred to as the IPA map, Brown et al., 1997)".

- For the evaluation in Figure 3, I think that the authors should add more discussions on why the simulated permafrost extent is still smaller than the IPA map. For instance, different periods for generating the simulation and IPA map; the simulation is only the results at 0∼1.9 m depth, may be different from the IPA map.

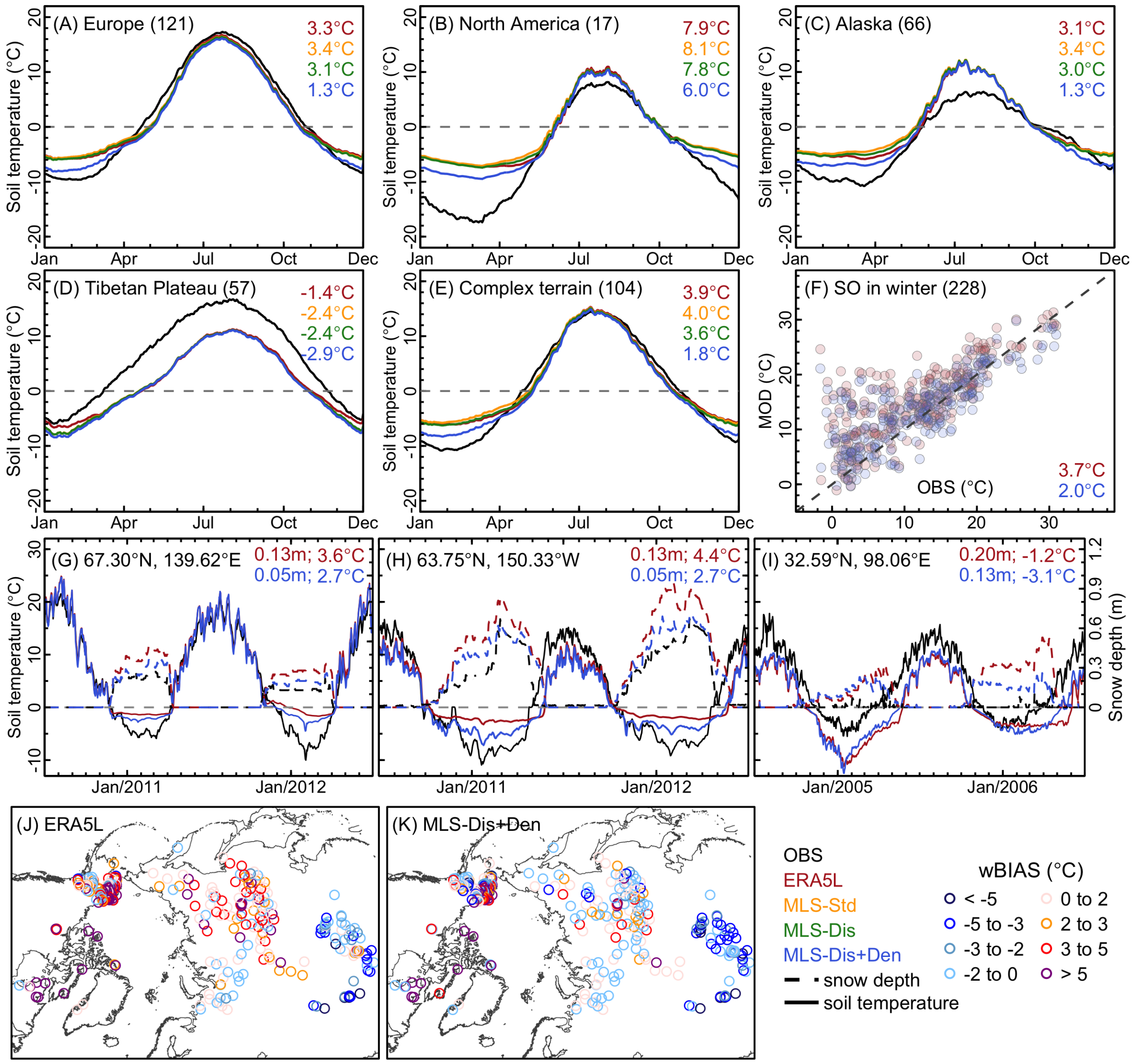

Figure 1: Aggregated daily soil temperature (2001–2018) for 0.07–0.28 m depth in different permafrost regions (A–E), and winter (DJF) surface offset (SO, F). The number of unique grid cells where observed sites are located is given in the bracket. Daily time-series of specific sites from Europe (G), Alaska (H), and the Tibetan Plateau (I) are present for detailed evaluation. Color numbers are estimated soil temperature (in °C) and snow depth (in m) bias in winter for simulation experiments. The spatial soil temperature weighted bias (wBias) is shown for ERAL (J) and for the experiment of MLS-Dis+Den (K).

Response: In section 5.2, we intend to add the following sentences to clarify.

"Besides to the model uncertainties, such as the shallow soil profile, the smaller simulated permafrost area compared to the IPA map could be traced to the different periods represented, i.e., a few decades prior to 1990 for the IPA map and 2001–2018 for ERA5L."

- For simulation experiment, the period for spin-up (initiation) should be described. Because soil temperature are analyzed in this study and if they reach a stability in the simulation. In my opinion, a recent study shows that this is important for permafrost simulation, especially for the Tibetan Plateau.
  Response: Xue et al. (2021) recently reported the possible influences of initialized land surface temperature on seasonal simulations, and we agree unsuitable spin-up would result in significant uncertainties.
  The offline simulation experiments in this study were all initialised from ERA5 on 1 January 1979. Therefore a 20-year spin-up period is considered before analysing the data. We intend to add the model initialization and spin-up period in Sec.3 Model configuration and experiment.

References

Brown, J., Ferrians, O., Heginbottom, J., and Melnikov, E.: Circum-Arctic map of permafrost and ground-ice conditions, Circum-pacific map series CP-45, scale 1:10,000,000, Tech. rep., U.S. Geological Survey in Cooperation with the Circum-Pacific Council for Energy and Mineral Resources, Washington, DC, 1997.

Orsolini, Y., Wegmann, M., Dutra, E., Liu, B., Balsamo, G., Yang, K., de Rosnay, P., Zhu, C., Wang, W., Senan, R., and Arduini, G.: Evaluation of snow depth and snow cover over the Tibetan Plateau in global reanalyses using in situ and satellite remote sensing observations, The Cryosphere, 13, 2221–2239, https://doi.org/10.5194/tc-13-2221-2019, 2019.

Xue, Y., Yao, T., Boone, A., Diallo, I., Liu, Y., Zeng, X., Lau, W., Sugimoto, S., Tang, Q., Pan, X., van Oevelen, P., Klocke, D., Koo, M.-S., Lin, Z., Takaya, Y., Sato, T., Ardilouze, C., Saha, S., Zhao, M., Liang, X.-Z., Vitart, F., Li, X., Zhao, P., Neelin, D., Guo, W., Yu, M., Qian, Y., Shen, S., Zhang, Y., Yang, K., Leung, R., Yang, J., Qiu, Y., Brunke, M., Chou, S. C., Ek, M., Fan, T., Guan, H., Lin, H., Liang, S., Materia, S., Nakamura, T., Qi, X., Senan, R., Shi, C., Wang, H., Wei, H., Xie, S., Xu, H., Zhang, H., Zhan, Y., Li, W., Shi, X., Nobre, P., Qin, Y., Dozier, J., Ferguson, C., Balsamo, G., Bao, Q., Feng, J., Hong, J., Hong, S., Huang, H., Ji, D., Ji, Z., Kang, S., Lin, Y., Liu, W., Muncaster, R., Pan, Y., Peano, D., de Rosnay, P., Takahashi, H., Tang, J., Wang, G., Wang, S., Wang, W., Zhou, X., and Zhu, Y.: Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and Experimental design, Geoscientific Model Development Discussions, pp. 1–58, https://doi.org/10.5194/gmd-2020-329, 2021.