Point-by-point response to referees

We thank the reviewer for the insightful and constructive comments. We have made point-by-point responses and/or revisions according to your suggestions and instructions. We recall the comments of the reviewer in black, followed by our reply in blue.

Responses to Referee #1

Report #1

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

Thank you for your comments and effort you have put into reviewing the manuscript. The manuscript has been substantially revised following the two referee's suggestions. Please see List of changes at the end of this response.

Responses to Referee #2

Report #2

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

It's my pleasure to review gmd-2020-142 "Assessing the simulated soil thermal regime from Noah-MP LSM v1.1 for near-surface permafrost modeling on the Qinghai-Tibet Plateau" by Li et al. I don't think the authors have appropriately addressed my previous comments, and thus major revision is still recommended. I will echo my previous major comments below.

Response: Thanks very much for your time regarding our manuscript. We already conducted all the necessary analysis according to your comments.

For a more comprehensive assessment, we have added the two physical processes in the revised manuscript as suggested, i.e., the snow sublimation from wind (SUB) and combination scheme by Li et al. (2020) (CMB). The general behaviors, influential processes, and sensitivities of the augmented Noah-MP for snow cover events, soil temperature and soil liquid water content have been tested and discussed in the revised manuscript.

Attachment is our detailed response to your concerns. With these revisions, we believe the quality of the manuscript has been greatly improved. We hope the reviewer can find that the comments have been addressed adequately, and we are happy to address additional concerns.

1. I note that there is a paper recently published by the same author to improve the performance of Noah-MP simulations on the same site. It will be interesting the authors firstly add their improvements, and then design more numerical experiments to test the uncertainties of different parameterization options. Since one additional site, soil moisture and snow measurements are available, the authors are suggested to also use these measurements to test the Noah-MP's performance. For the frozen soil, the soil moisture and soil temperature are fully coupled, which are also affected by the snow process, so it's also important to evaluate the performance of Noah-MP in simulating these variables.

I don't think "including augmentation work is out of scope of this paper". As shown in the paper published by the same author (Li, X., et al. (2020). Improving the Noah-MP model for simulating hydrothermal regime of the active layer in the permafrost regions of the Qinghai-Tibet Plateau. Journal of Geophysical Research: Atmospheres, 125), the cold bias noted for the Noah-MP (also found in this paper) is related to the underestimation of snow sublimation rate and inappropriate parameterizations of thermal roughness (z0h) and under-canopy aerodynamic resistance (ra,g). The authors showed in their previous publication that only introducing new parameterizations of snow sublimation, z0h and ra,g can improve the cold bias. Therefore, I don't found the necessary to test only the combination schemes of default Noah-MP if the new parameterizations are not included.

Response: Thank you for your comments.

We are sorry that we did not explain our previous work clearly. In our previous work, we only tested one selected combination of Noah-MP options (the options in bold in Table 2 in the study of Li et al. (2020)). Strictly, we didn't conclude that only by introducing new parameterizations of snow sublimation, z_{0h} and $r_{a,g}$ can improve the cold bias since there are many other combinations are not assessed, which is one of our main purposes of the previous version of the manuscript.

We understand the referee's concerns. In the revised manuscript, we have added two physical processes as suggested for a more comprehensive assessment, i.e., the snow sublimation from wind (SUB) and combination scheme by Li et al. (2020) (CMB) (Table 1), in which users can turn on or off the snow sublimation from wind and the combination of thermal roughness (z_{0h}) and under-canopy aerodynamic resistance ($r_{a,g}$), respectively. Our main conclusion is that the SUB process together with the snow/soil temperature time scheme (STC) play a dominant role for snow simulation. The combination of z_{0h} and $r_{a,g}$ helps to elevate soil temperature. Details can be seen in Section 3.2.1, 3.2.2 and 3.3.

With these revisions, we believe the reviewer and potential readers can understand the differences between the present and our previous studies, and the novelty of this study is more clear.

In addition, I don't agree with the authors that "only focus on one site is enough to provide a reference for simulating permafrost state on the Tibetan Plateau". As also noted by the authors, there may be different environmental controlling factors among the sites, so including additional sites will make the conclusions more useful and general for the permafrost simulation on the Tibetan Plateau.

Response: We agree that add more sites would strengthen our conclusions.

We also tested Noah-MP model at the BLH station. Our main findings at BLH site are basically consistent with that at TGL site (see below). However, we realized that this will make our manuscript very long. Our main goal is 1) to investigate the general performance and sensitivity of Noah-MP model with all possible combinations for soil hydrothermal simulations, and 2) to present a reference to better understand the land surface processes in the permafrost regions of the QTP. We tried our best to make this manuscript concise and we are afraid that add one more site would be distractive to potential readers from our main goals. Therefore, we would rather focus on one site in this manuscript.

The results and conclusions at BLH sites are attached in the supplementary file as follows:

Our main findings at BLH site are:

(1) Noah-MP tend to overestimate snow cover events at BLH site with large uncertainties during the cold months (Nov.-Mar). Moreover, snow cover events are mostly influenced by the STC and SUB process (Figure 3), and the combination of STC(1) and SUB(2) tend to produce better results (Figure 8). The small influence of physical processes during the warm season (Figure 3c) is because there are limited snow events, and its inability of reproducing snow cover in May (Figure 1).

(2) Noah-MP generally underestimate STs with relatively large gaps during the snow-affected months (Nov.-Mar.), and the simulated ST in the snow-affected months (Nov.-Mar.) showed relatively wide uncertainty ranges (Figure 2). STs is mostly influenced by the snow processes, i.e. the STC and SUB process (Figure 4), especially during the cold season. In the warm season, the SFC and RUN process dominate the simulation of STs (Figure 4c). The combination of roughness length for heat and under-canopy aerodynamic resistance contributes to elevated soil temperature (Figure 9).

(3) Noah-MP totally underestimate SLW at BLH site (Figure 2). The RUN process dominates the SLW at most layers simulation with limit impacts.

- **General performance of the ensemble simulation**

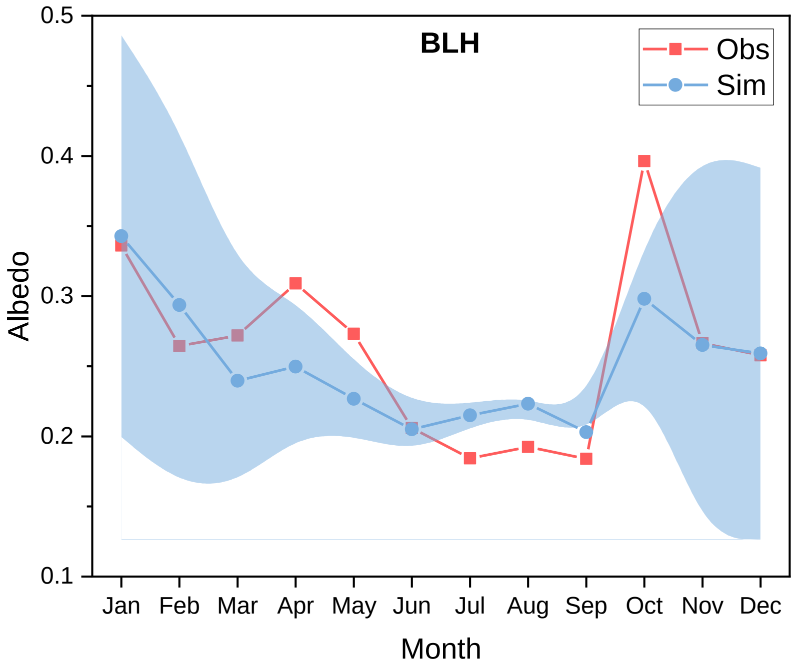

Figure 1. Monthly variations of ground albedo at BLH site for observation (Obs), and the ensemble simulation (Sim). The light blue shadow represents the standard deviation of the ensemble simulation.

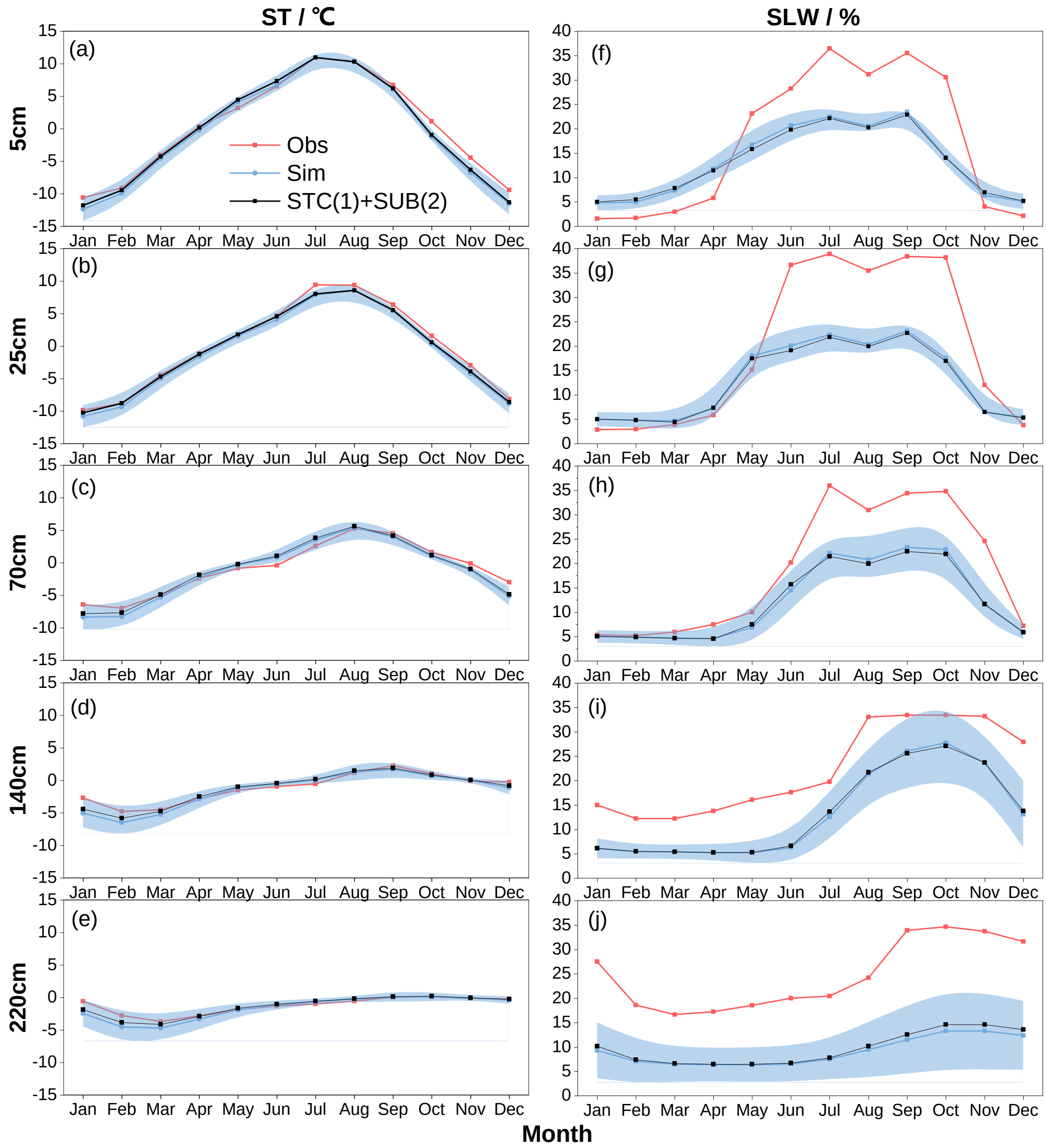

Figure 2. Monthly soil temperature (ST in °C) and soil liquid water (SLW in %) at (a, g) 5 cm, (b, h) 25 cm, (c, i) 70 cm, (d, j) 140 cm, (e, k) 220 cm, (f, l) 300 cm at BLH site. The light blue shadow represents the standard deviation of the ensemble simulation. The black line-symbol represents the ensemble mean of simulations with STC(1) and SUB(2).

- **Influence degrees of physical processes**

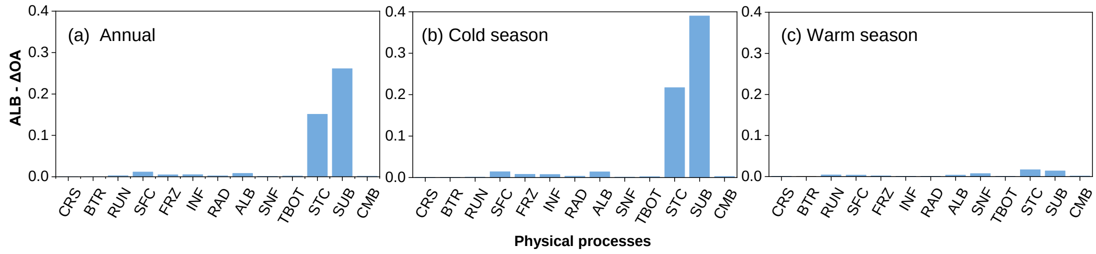

Figure 3. The maximum difference of the mean overall accuracy (OA) for albedo (ALB-ΔOA) in each physical process during the (a) annual, (b) cold season, and (c) warm season at BLH site.

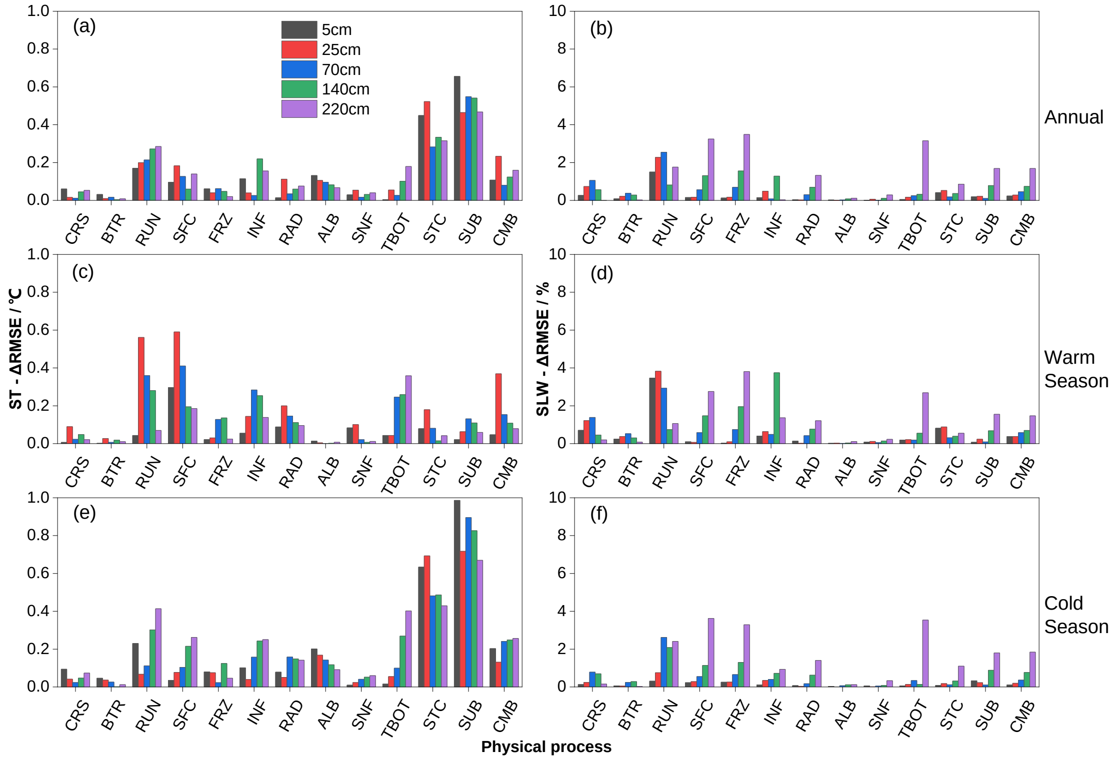

Figure 4. The maximum difference of the mean RMSE for (a, c and e) soil temperature (ST-$\Delta\overline{RMSE}$ in °C) and (b, d and f) soil liquid water (SLW-$\Delta\overline{RMSE}$ in %) in each physical process during the (a and b) annual, (c and d) warm, and (e and f) cold season at different soil depths at BLH site.

- **Sensitivities of physical processes and general behaviors of parameterizations**

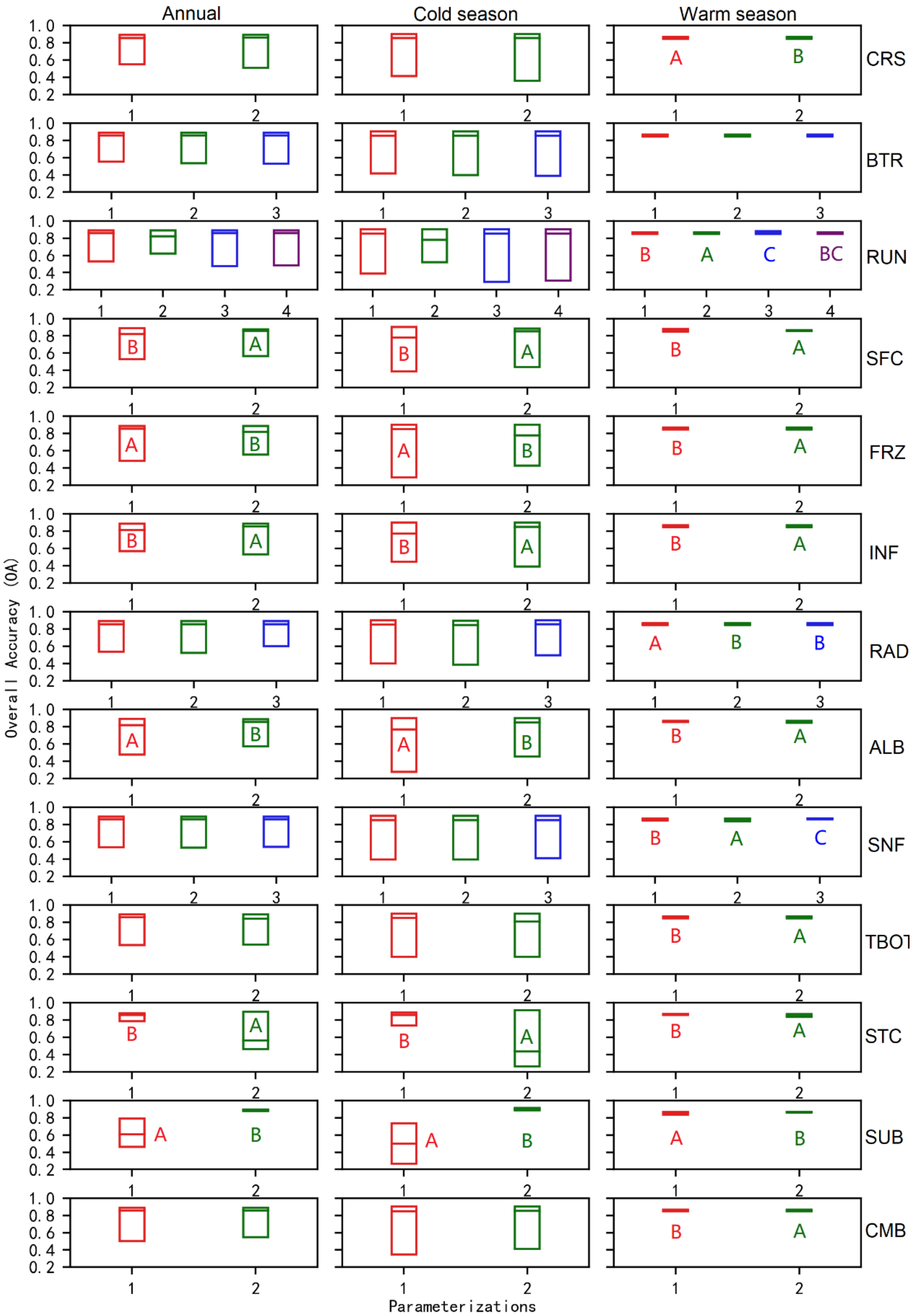

Figure 5. Distinction level for overall accuracy (OA) of snow cover events (SCEs) during the annual, warm, and cold seasons in the ensemble simulations at BLH site.

Limits of the boxes represent upper and lower quartiles, lines in the box indicate the median value.

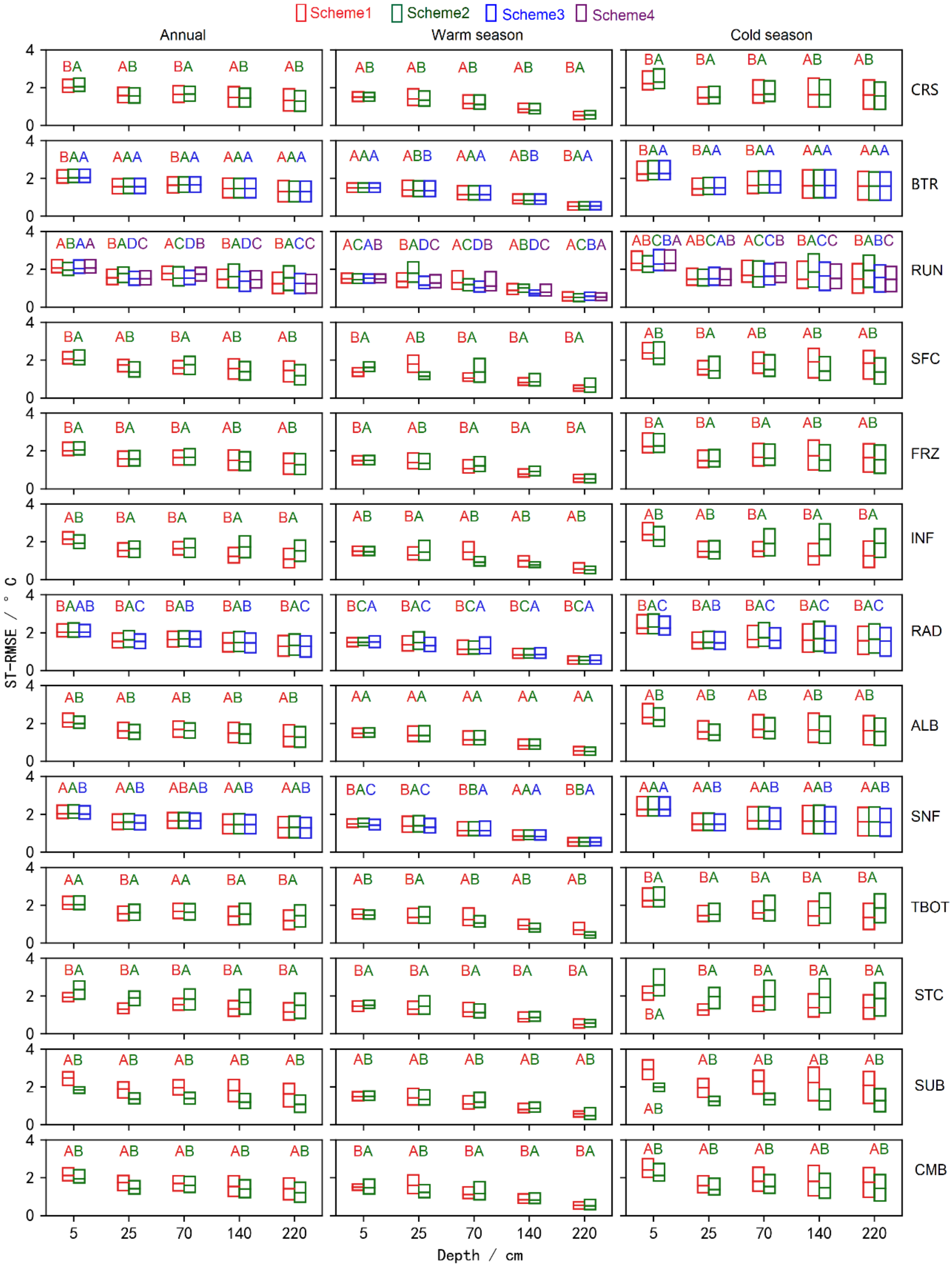

Figure 6. Distinction level for RMSE of ST at different layers during the annual, warm, and cold seasons in the ensemble simulations at BLH site. Limits of the boxes represent upper and lower quartiles, lines in the box indicate the median value.

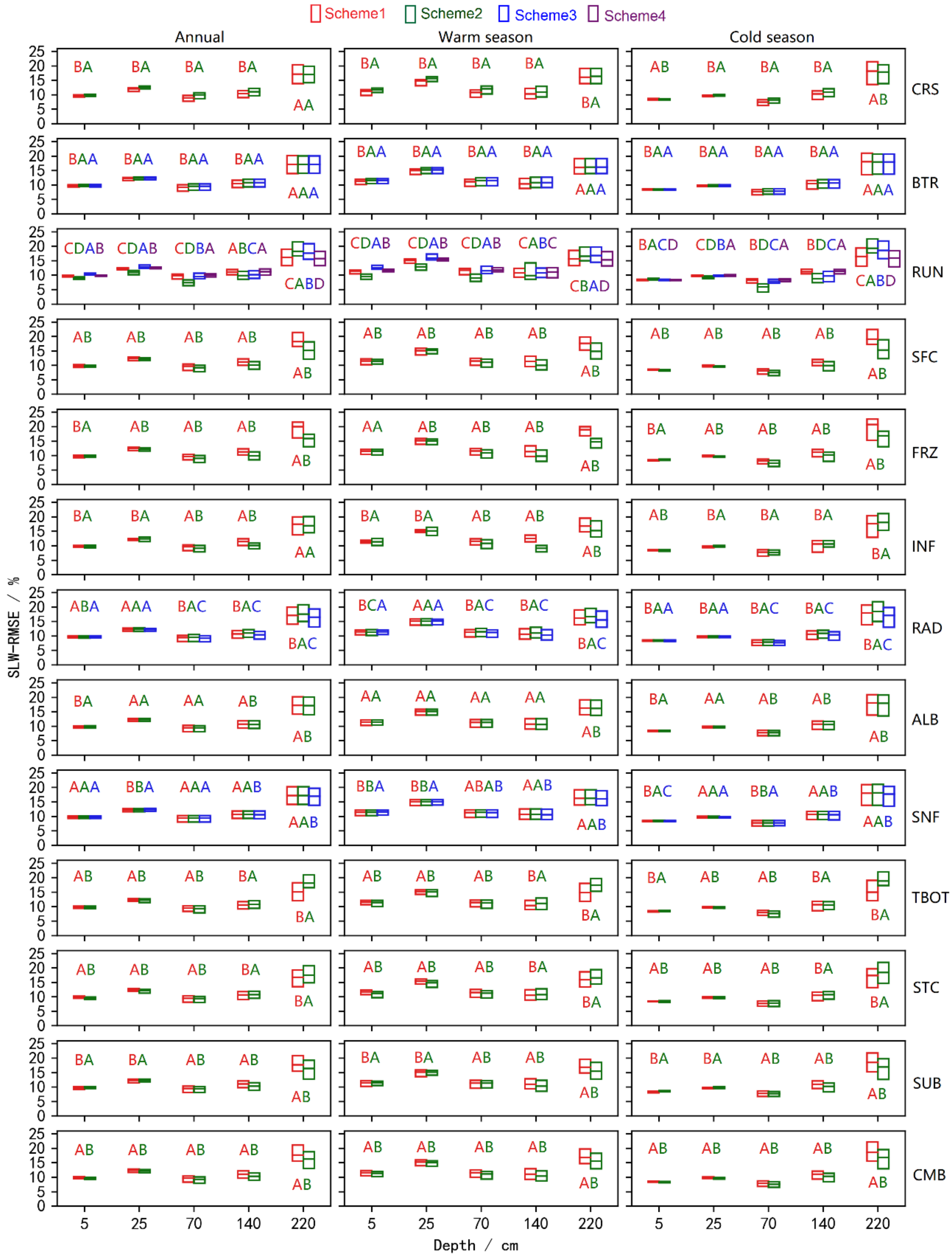

Figure 7. Distinction level for RMSE of SH2O at different layers during the annual, warm, and cold seasons in the ensemble simulations at BLH site. Limits of the boxes represent upper and lower quartiles, lines in the box indicate the median value.

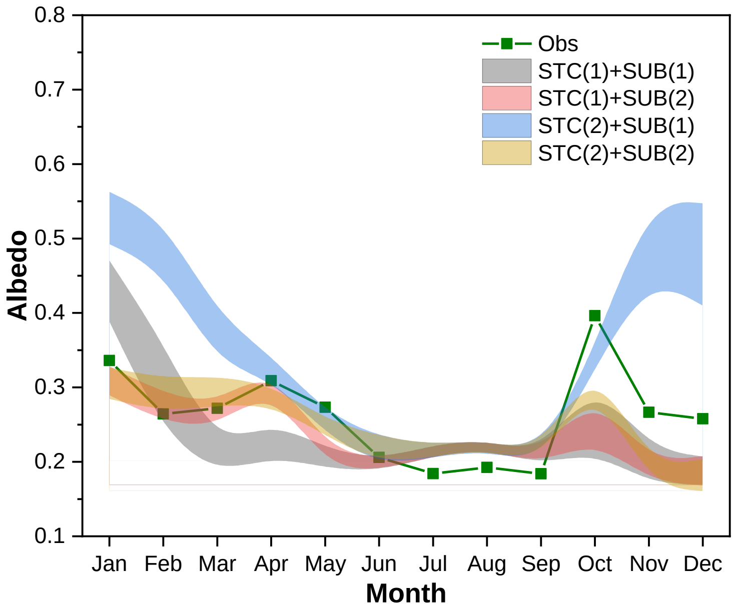

Figure 8. Uncertainty interval of ground albedo at BLH site in dominant physical processes (STC and SUB) for snow cover event simulation.

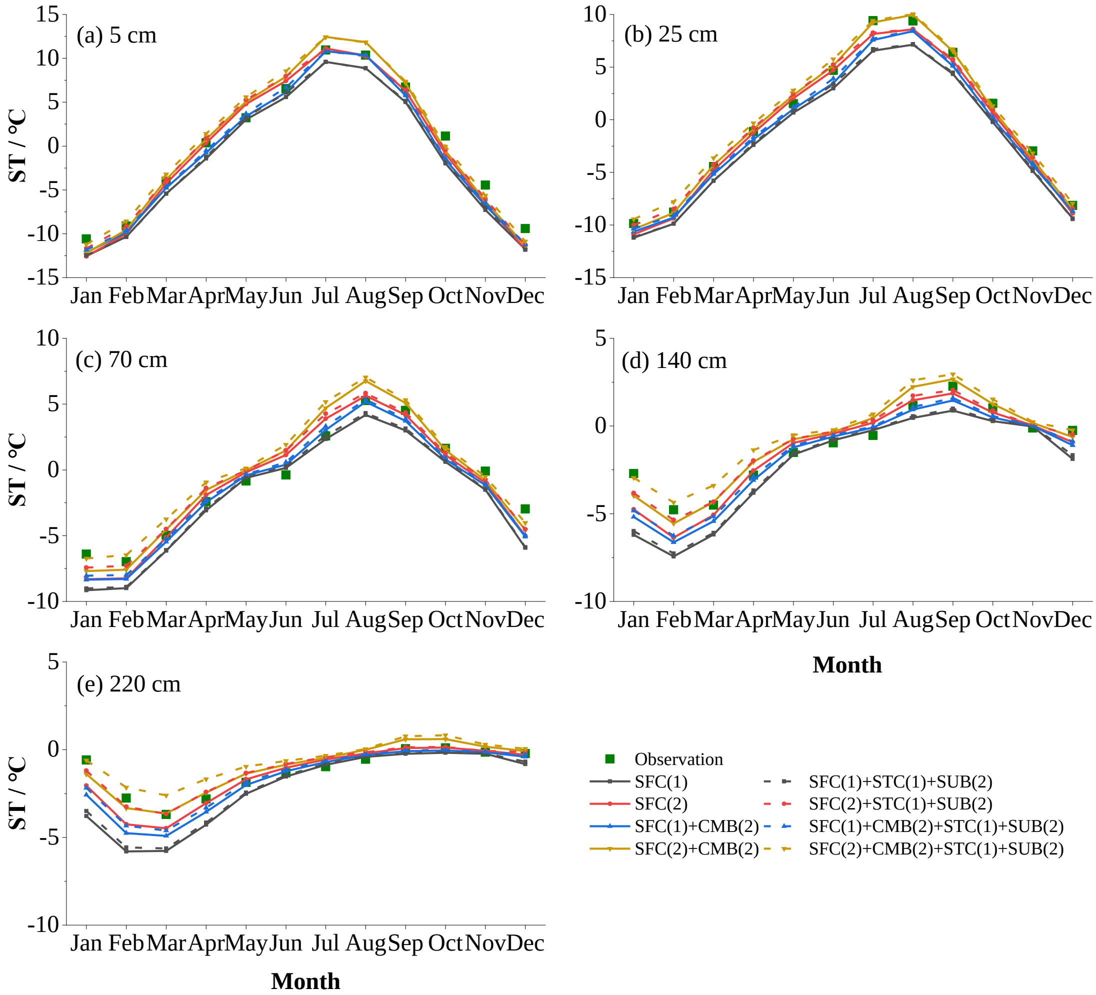

Figure 9. Monthly soil temperature (ST in °C) at (a) 5 cm, (b) 25 cm, (c) 70 cm, (d)

140 cm, (e) 220 cm, (f) 300 cm for the SFC process that consider the CMB(2) and STC(1)+SUB(2) processes or not.

Also, since the soil moisture and soil temperature are fully coupled in the permafrost areas, I think both soil moisture and soil temperature should be discussed in detail, and thus the title can be also revised accordingly.

Response: The general behaviors, influential processes, and sensitivities of Noah-MP for soil temperature and soil moisture (represented by soil liquid water content since soil ice could not be recorded using the observation equipment) are tested and discussed in the revised manuscript. Accordingly, the title has been revised as "Assessing the simulated soil hydrothermal regime of active layer from Noah-MP LSM v1.1 in the permafrost regions of the Qinghai-Tibet Plateau".

2. As shown by the authors, “Noah-MP greatly overestimates snow cover both in magnitude and duration, inducing huge cold bias and large uncertainties in soil temperatures”, and these results are contrary to the reality. I don’t think this is the reason to ignore the snow process, since snow is widely presented in the permafrost areas. Instead, the authors need to include their new parameterization of snow sublimation in previous publication, and then test its performance together with the ALB and SNF options.

Response: Thank you for your comments. We considered the snow sublimation, ALB and SNF options in the revised version. We found that snow cover events are mostly affected by the snow sublimation process (SUB) and the snow/soil temperature time scheme (STC). The influence of ALB and SNF on snow cover events is significant but limited. Moreover, the performance orders followed SUB(2) > SUB(1), STC(1) > STC(2), ALB(2) > ALB (1), SNF(3) > SNF(2) >SNF(1).

The manuscript has been greatly changed, we would not copy the text below. Please refer to Table 1, Section 3.2.1, 3.2.2 and 3.3 for details.

3. It's still strange to me that the impact of RUN is so important for the soil temperature simulations at both cold and warm seasons. So, it will be more useful the authors investigate both the soil moisture and temperature simulations in detail, then the authors may provide appropriate explanation on this.

Response: One thing should be noted that we use soil liquid water (SLW) as an alternative to investigate the soil moisture (SLW + ice) since soil ice could not be recorded using the observation equipment.

Soil moisture refers to the total water in the soil. In the warm season, soil moisture is equal to the SLW. In the cold season, the soil moisture (SLW + ice) was nearly identical to SLW at the end of the warm season.

Our results showed that the four schemes of RUN process performed differently for SLW simulation in the warm season (Figure. S1) and thus soil moisture (SLW + ice) in the cold season.

Different SLWs in the warm season result in the difference of the surface energy partitioning and thus different soil temperatures. Generally, higher estimation of SLWs induce greater sensible heat and thus smaller soil temperature (Gao et al., 2015). In the cold season, much of the liquid water freezes into ice, which would greatly influence the thermal conductivity of frozen soil considering thermal conductivity of ice is nearly four times that of the equivalent liquid water. Therefore, the impact of RUN is important for the soil temperature simulations at both warm and cold seasons.

To be clear, we added relevant explanations in section 4.2.2 of the revised version.

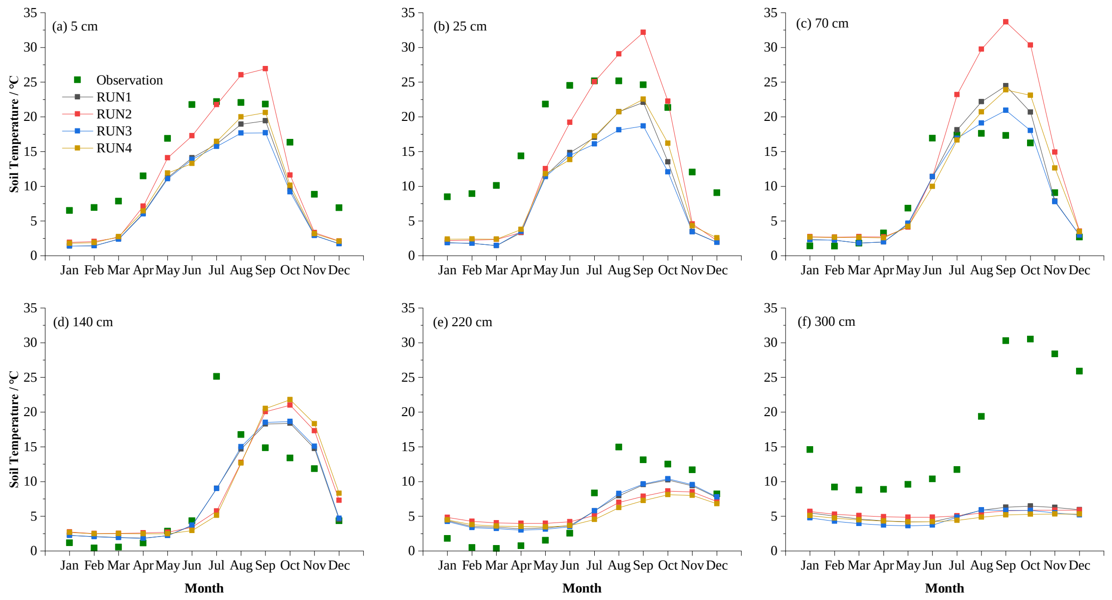

Figure. S1 Monthly soil liquid water (SLW in %) at (a) 5 cm, (b) 25 cm, (c) 70 cm, (d) 140 cm, (e) 220 cm, (f) 300 cm for the RUN process.

References:

Gao, Y., Kai, L., Fei, C., Jiang, Y., and Lu, C.: Assessing and improving Noah-MP land model simulations for the central Tibetan Plateau, J. Geophys. Res.-Atmos., 120, 9258-9278, https://doi.org/10.1002/2015JD023404, 2015.

4. Detailed information is needed on how the authors revise the soil moisture and heat flow equations when the simulation depth was extended to 8.0 m and soil column was discretized into 20 layers. How the authors define the bottom boundary for the soil moisture and heat flow simulations?

Response: The equations for soil moisture and temperature are not modified and followed the default Richards' equation and 1-d heat conduction equation, respectively. The lower boundary conditions follow the default settings of Noah-MP.

For the heat flow simulation, the bottom boundary condition depend on the scheme in TBOT process: (1) zero heat flux; or (2) soil temperature at 8 m depth (usually using the annual-mean 2-m air temperature) (Niu and Yang, 2011).

For the soil moisture simulation, the recharge of groundwater is not considered because of the existence of permafrost. The bottom boundary condition depend on the scheme in RUN process: (1) SIMGM: TOPMODEL-based runoff with the simple groundwater (Niu et al., 2007); (2) SIMTOP: TOPMODEL-based runoff with an equilibrium water table (Niu et al., 2005); (3) Schaake96: Infiltration-excess-based surface runoff with free drainage (Schaake et al., 1996); (4) BATS: BATS runoff with free drainage (Yang & Dickinson, 1996).

What we have modified to the model itself is setting the corresponding soil parameters for each layer instead of using the same values. Technically, we changed the soil parameter variables from REAL types into REAL ARRAY types, and calculate soil hydrothermal parameters of each layer using a loop structure.

References:

Niu, G., & Yang, Z. (2011). The community Noah land-surface model (LSM) with multi-physics options: User's guide. http://www.jsg.utexas.edu/noah-mp/files/Users_Guide_v0.pdf

Niu, G.-Y., Yang, Z.-L., Dickinson, R. E., Gulden, L. E., & Su, H. (2007). Development of a simple groundwater model for use in climate models and evaluation with Gravity Recovery and Climate Experiment data. Journal of Geophysical Research, 112, D07103. https://doi.org/10.1029/2006JD007522

Niu, G.-Y., Yang, Z.-L., Dickinson, R. E., & Gulden, L. E. (2005). A simple TOPMODEL-based runoff parameterization (SIMTOP) for use in global climate models. Journal of Geophysical Research, 110, D21106. https://doi.org/10.1029/2005JD006111

Schaake, J. C., Koren, V. I., Duan, Q. Y., Mitchell, K., & Chen, F. (1996). Simple water balance model for estimating runoff at different spatial and temporal scales. Journal of Geophysical Research, 101(D3), 7461–7475. https://doi.org/10.1029/95JD02892

Yang, Z.-L., & Dickinson, R. E. (1996). Description of the Biosphere-Atmosphere Transfer Scheme (BATS) for the soil moisture workshop and evaluation of its performance. Global and Planetary Change, 13(1-4), 117–134. https://doi.org/10.1016/0921-8181(95)00041-0

List of changes

1. Revised title as " Assessing the simulated soil hydrothermal regime of active layer from Noah-MP LSM v1.1 in the permafrost regions of the Qinghai-Tibet Plateau"
2. Two physical processes, i.e., the snow sublimation from wind (SUB) and combination scheme by Li et al. (2020) (CMB) are included to obtain a more comprehensive assessment. The general behaviors, influential processes, and sensitivities of the augmented Noah-MP for snow cover events, soil temperature and soil liquid water content during warm and cold seasons are tested and discussed in the revised manuscript.
3. The purpose of this study is assess the model structure of Noah-MP without considering the uncertainties of forcing data and model parameters. Only VEG(1) is adopted in the VEG process.
4. Deleted the optimal combination part.
5. Newly added section 3.3, in which the influence of snow cover and surface drag coefficient on soil hydrothermal dynamics are analyzed.
6. Discussed the snow cover on the QTP and its influence on soil hydrothermal regime in section 4.1
7. All typos have been corrected.
8. All "soil thermal" in the manuscript has been revised as "soil hydrothermal"