Thanks for reviewer's valuable comments and suggestions, which greatly helps improve the quality of our manuscript. We have carefully revised the manuscript accordingly. Our detailed point-by-point responses are provided below.

Comments on "Optimization of snow cover fraction parameterization in the Community Land Model: implementation and preliminary validation over Tibetan Plateau" (egusphere-2025-6490)

General comment:

This study shows a systematic overestimation of wintertime snow cover fraction (SCF) over Tibetan Plateau (TP) by the Community Land Model version 5 (CLM5), and proposes an optimized SCF parameterization scheme through incorporating the effects of non-growing-season vegetation (withered grass stems) and topographic characteristics, and modifying the accumulation parameter (kaccum) and the melt parameter (Nmelt). The optimized scheme is evaluated through preliminary simulations over the TP. According to the results presented, the optimized scheme substantially reduces SCF overestimation and improves the simulation of surface albedo and surface temperature. Overall, the manuscript is generally well organized and clearly written. The proposed optimization has the potential to contribute to improvements of snow cover and related surface energy budgets simulations in CLM5. However, several aspects of the methodology and interpretation still require clarification before the manuscript can be considered for publication. I recommend a moderate revision.

Major comments:

Physical basis of the optimized parameterization scheme seems unclear. This study proposes modifying kaccum by introducing the influence of non-growing-season vegetation (withered grass stems) and topographic relief. While the idea is plausible, the physical reasoning behind the selected functional form is not sufficiently explained. The authors are encouraged to clarify why these specific factors are expected to control subgrid snow accumulation probability and how the mathematical form of the parameterization was derived.

Reply: Thank you for your comment. In this study, the optimization of the snow cover fraction (SCF) parameterization scheme, which comprehensively considers the effects of topographic relief and withered grass stems, can be well supported by physical mechanisms. Specifically, the underlying surface heterogeneity over the Tibetan Plateau (TP) is primarily characterized by complex topography and short vegetation, with alpine grasslands covering most of the region. In recent decades, the TP has experienced significant greening, accompanied by an increase in non-growing-season short vegetation (i.e., withered grass stems, WGS), which substantially affects the land surface energy budget and snow cover processes. Therefore, topographic relief, represented by the standard deviation of topography (σ_{topo}), and WGS, represented by the stem area index (SAI), are regarded as the key factors controlling snow accumulation and snowmelt processes.

Regarding the mathematical forms, the equations for the probability distribution factor (k_{accum}) and the revised factor (F) in the optimized SCF parameterization scheme were empirically determined from their statistical relationships with topographic relief (σ_{topo}) and SAI , while remaining physically interpretable (Figure R1).

Over barren land, k_{accum} is represented by a power function of σ_{topo}. Under relatively flat terrain (small σ_{topo}), snowfall is distributed more uniformly, resulting in higher SCF. As terrain relief increases, snow preferentially accumulates in topographic depressions, reducing SCF. However, this suppressing effect gradually weakens under highly complex terrain because snow cover over the TP is generally shallow. Over grassland, both σ_{topo} and SAI jointly suppress snow distribution; therefore, k_{accum} is parameterized using a linear equation based on $\sigma_{topo} \times SAI$, which represents their combined effects.

The revised factor F is introduced to improve the representation of snow depletion. Over barren land, F increases linearly with σ_{topo}. Small σ_{topo} values correspond to stronger corrections to SCF overestimation, whereas under complex terrain, terrain shading partially offsets enhanced melting on sunlit slopes, causing F to approach 1 and thereby weakening the correction effect. Over grassland, withered grass stems enhance snowmelt and dominate the depletion process, resulting in a negative relationship between F and SAI. To further account for the nonlinear combined effects of σ_{topo} and SAI, F is parameterized using an exponential function based on a combined factor (SAI^2 / σ_{topo}).

In the revised manuscript, we have added a physical explanation of the optimized scheme.

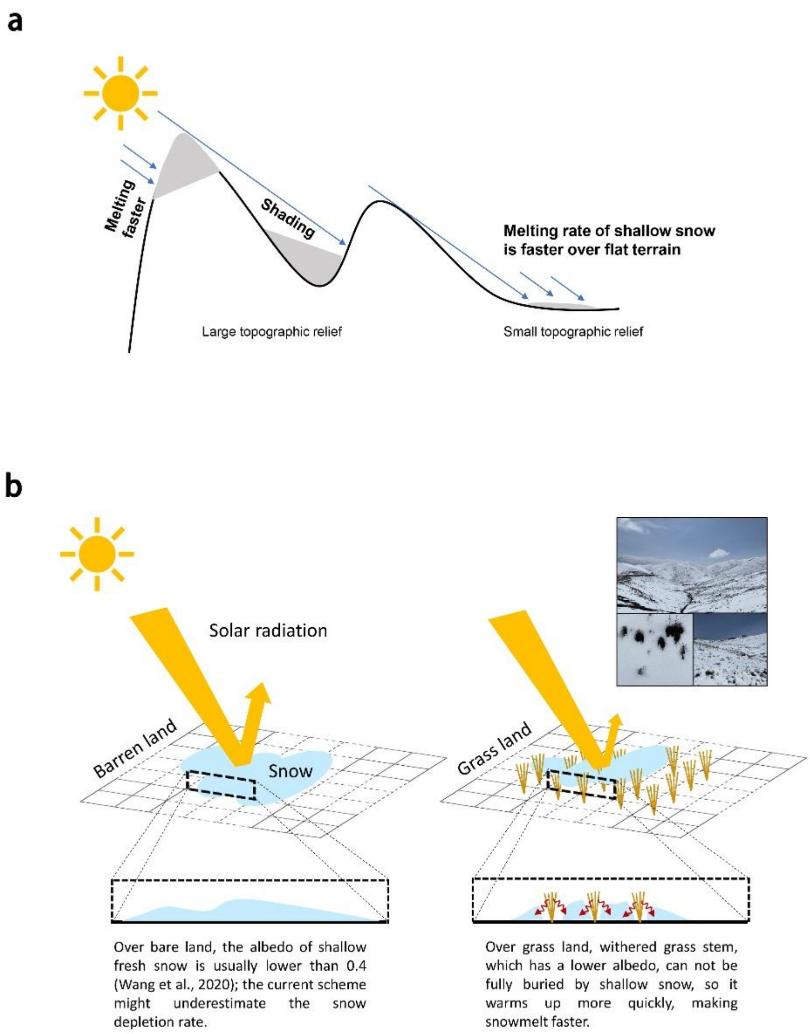

Figure R1. Schematic diagram of (**a**) effects of topographic relief and (**b**) short vegetation (i.e., withered grass stems) on snow cover.

Universality of the optimized scheme and its applicability beyond the TP should be discussed. Currently, the validation is conducted only over the TP. Given that CLM5 is widely used in globe and it's implied for other models, it is important to discuss the potential applicability of the optimized parameterization in other regions. Whether the parameters are region-specific or globally applicable, possible limitations when applied to different vegetation types also need be discussed.

Reply: Thanks for your comment. Indeed, this study focuses on the TP, where the snow cover biases in CLM5 are most pronounced and climate projections remain highly uncertain. Therefore, we selected the TP as a representative region and optimized the SCF parametrization scheme for environments characterized by shallow snow cover and short vegetation.

We believe that the optimized scheme has a certain degree of universality and potential applicability to other regions of the globe, particularly in areas with complex topography, shallow snow cover, and short vegetation (e.g., herbaceous plants, shrubs) whose stems, branches, and withered components cannot be completely buried by snow.

Meanwhile, we acknowledge the limitations of the optimized scheme. The coefficients in Eq. (6) and Eq. (10) (e.g., 1.15, −0.55, -5×10^{-4}, 0.18, 3.3, 9.5, 0.49, and −0.004) may vary to some extent with spatial resolution. Nevertheless, different subregions were selected to test the robustness of the optimized mathematical forms and to evaluate the uncertainties associated with coefficient variations, which are generally less than 10%.

We have added discussions on the universality, potential applicability, and possible limitations of the optimized scheme in the revised manuscript.

More evaluations of the optimized scheme should be added. The evaluation mainly focuses on SCF, surface albedo, and surface temperature. While these variables are relevant indicators of snow processes, the evaluation could be strengthened by including additional snow-related variables, such as snow depth or snow water equivalent (SWE).

Reply: Thank you for your comment. We have added evaluations of surface shortwave and longwave radiation, as well as surface sensible and latent heat fluxes. In addition, extra analyses of snow-related variables, including snow depth and snow water equivalent, have also been incorporated.

Minor comments:

Line 98: “0.05° × 0.05° dataset” should be “0.05° × 0.05° and 500 m spatial resolution dataset”.

Reply: Thanks. Corrected.

It’s suggested to use snow water equivalent instead of snow depth in section 2.4, if the data is available.

Reply: Thank you for your suggestion. In fact, a daily snow water equivalent dataset at 5 km resolution over the Tibetan Plateau (1981–2020) is available from TPDC (https://data.tpdc.ac.cn/zh-hans/data/517e80f6-67b9-4a25-81f7-2d4a78b182c1). However, this dataset is derived from the snow depth dataset. In addition, changes in snow depth can be used as a proxy for snowmelt (Yang et al., 2023), and snow water equivalent is not directly used in the SCF parameterization. Therefore, we retained the use of snow depth in Section 2.4.

Figure 1: It's suggested to analyze Fig. 1 in section 3.1 for better understanding the original SCF parameterization scheme, which might be the foundation for the proposed optimization.

Reply: Thanks. Done.

Lines 142-143: it's better to add references to support this perspective.

Reply: Thanks. Added.

In section 3.4: more detailed information of experimental design should be given, such as integration step, output frequency, component set.

Reply: Thanks. More detailed information on the experimental design has been added to the revised manuscript.

Please carefully proofread the manuscript for minor grammatical issues, and consider simplifying several long or complex sentences to improve.

Reply: Thanks. We have carefully proofread the manuscript and improved the readability of the English writing.