Response to Anonymous Referee #1

Thank you for your recognition of our work. We will respond to your comments item by item.

1. This study select eight different intensity of snow events to evaluate the universal applicability. It is enough, but why you choose these snow events?

Response

Heavy snowfall processes have a large impact on stock farming on the Tibetan Plateau. And the rate of snowmelt varies widely depending on the heterogeneous underlying surfaces. Albedo is strongly determined by snowfall and snowmelt. This makes it necessary to carry out numerical experiments on heavy snow events i.e., moderate-to-heavy snowfall and snowstorm over the heterogeneous Tibetan Plateau to assess how reliably the improved albedo scheme to characterize different snowfall intensities and snowmelt processes. That’s why eight different intensities of snow events on the heterogeneous eastern and southern Tibetan Plateau were selected in our study.

2. The snow albedo parameterization scheme is referred to Oerlemans and Knap (1998). What changes have been made in this albedo scheme used in snow events over the Tibetan Plateau.

Response

Oerlemans and Knap (1998) used ground observations on a glacier to calculate parameters in the albedo scheme, while satellite-retrieval of reflectance and albedo products as well as modelled snow depth over the whole Tibetan Plateau were used to calculate parameters in the scheme in our study. And, Oerlemans and Knap (1998) only focused on a glacier and snow-free albedo is albedo of ice. In our work, we combined all the MODIS land use types over the Tibetan Plateau to average the bare ground albedo as snow-free albedo when calculating parameters in the scheme.

Oerlemans, J. and Knap, W. H.: A 1 year record of global radiation and albedo in the ablation zone of Morteratschgletscher, Switzerland, J. Glaciol., 44, 231-238, 1998.

3. The improved snow albedo scheme shows much better performance in land-atmospheric interaction simulations at fine resolution such as 1 km. This study configures five snow events with 1 km resolution simulations, and three snow events with 5 km resolution simulations. Why not configure all the snow events to 1 km resolution?

Response

Conducting numerical experiments at high resolution i.e., 1 km is beneficial to the complex topographic Tibetan Plateau. We attempted to two nested modeling of 5 km and 1 km resolution for all eight selected snow events. However, the extremely steep terrain on the central and southern Tibetan Plateau led to model instability and failure for 3 snowfall events when a relatively fine horizontal resolution of 1 km was used, while the calculations remained stable when the resolution was increased to 5 km. We therefore used two nested modeling of 5 km and 1 km resolution for 5 snowfall events, and a single modeling of 5 km resolution for 3 snowfall events.

Response to Referee #2: Zhu, Enda

The paper "Improved parameterization of snow albedo in WRF+Noah. Part II: Applicability to snow estimates for the Tibetan Plateau" systematically and comprehensively evaluates the impact of the improved snow albedo scheme on climate simulation, which is the 2nd part of the research about model development. The authors guide the readers through a series of logical and interesting organized set of analysis. Overall the paper addresses a relevant subject that is well suited for the Hydrology and Earth System Sciences. While the overall quality of the paper is good, there are a few minor shortcomings that need to be addressed before it is published. Some suggestions or questions are listed below.

Response

Thank you very much for your recognition of our research. We will respond to your comments item by item in order to improve the quality of this manuscript.

Suggestion:

1. In the manuscript, you mentioned the MODIS snow albedo many times, but didn't explain how to use the MODIS snow albedo in the development of scheme. Maybe you have described it in the 1st part; however, I think you still need some illustration in this paper.

Response

Thanks for your careful comment. We agree with you. We add some illustration about the development of the new improved snow albedo scheme. Please see **Line 202-209**, which is "The new improved snow albedo was developed based on conversion formula from MODIS narrowband spectral reflectance to broadband albedo following Liang (2000) and albedo calculation formula about fresh snow, firn and bare ground albedo, snow age and depth following Oerlemans and Knap (1998). MODIS broadband albedo and WRF modeled snow depth and age were used to estimate the related parameters i.e., firn albedo and scales of snow depth and age through nonlinear fitting of the above albedo calculation formula. The final nonlinear fitting results produced the new improved snow albedo scheme, seeing the equations (3) and (4)." Also the related reference is added in **Line 725-726**.

Liang, S.: Narrowband to Broadband conversions of land surface albedo: I. Algorithms, Remote Sens. Environ., 76, 213-238, 2000.
Oerlemans, J. and Knap, W. H.: A 1 year record of global radiation and albedo in the ablation zone of Morteratschgletscher, Switzerland, J. Glaciol., 44, 231-238, 1998.

2. In the work, you mainly focus on the snow of the Tibet Plateau or the plateau above 1000m. I am not familiar with the snow albedo process. Therefore, could you explain what the difference between snow on the Tibet Plateau and plains such as Northeast China?

Response

Our research interest is about the extreme weather on the Tibetan Plateau. That is why we only focus on heavy snow events over the Tibetan Plateau in this study.
The atmospheric circulation systems above the Tibetan Plateau are different from those in the eastern plain of China. Therefore, the snow events on the Tibetan Plateau has particularity in terms of temporal and spatial snow distribution and synoptic systems. The maximum snowfall amount and severe snowfall in the Northeast China mainly takes place in winter. And snowfall is more frequent in the mountainous areas than the plain areas in Northeast China. The snowfall on the Tibetan Plateau mainly occurs in March and April in the circulation transition season from winter to summer. Due to the convergence of high elevated terrain and forced uplift, the southerly warm and humid airflow carrying abundant water vapor meets with the northerly cold airflow, resulting in strengthening the upward movement and extreme snowfall processes. However, the nature of snow albedo effects is geographically independent.

3. Because of the steep terrain, the simulation of event 3, 7, 8 is instability. And you mentioned the cold biases in the other 5 events simulation have been reduced (L278-281). But in the Fig. 2, I think the cold biases have been alleviated in all 8 events. Could you explain why you think the cold bias in the 3 events (3, 7 and 8) has not been corrected? In fact, comparing the green line and black line (Fig. 2), I think the new scheme resulted in a warm bias in the event 2, 3, 4 and 5, especially at lower temperature.

Response

Thanks for such the careful comment. The cold biases have been alleviated in all 8 snow events, which is illustrated in **Line 274-276,** "In all eight modeling experiments, implementing the improved snow albedo scheme in the WRF model greatly reduces the cold bias that occurs when the default Noah snow albedo scheme is used". We revise the sentence to be "Where the default Noah scheme results in a warm bias at the observed lower air temperature for EXP1 and EXP3" in **Line 276-277**. In addition, we add a sentence to express the new scheme causing a warm bias, which is "Compared with cold bias caused by the default Noah albedo scheme at the observed lower air temperature, the improved snow albedo scheme results in a warm bias for EXP2, EXP4 and EXP5" in **Line 279-281**. The sentence in **Line 284-287** means that the most remarkable alleviation of cold bias appears in finer resolution (1 km) simulations when using the improve albedo scheme for EXP1, EXP2, EXP4, EXP5 and EXP6.

4. When comparing the in situ observation with model simulation, it is necessary to explain how to interpolate the grid points to station points in the method part.

Response

Thanks for your comment. We have added the interpolation method in **Line 260-262 in the Section 2.3**, which is "In order to compare WRF simulations against in situ observations, sampling the gridded model estimates and interpolating to given ground stations' locations were done by bi-linear interpolation of the four surrounding model grid points".

5. You said the finer resolution (1km) is a better choice (L319), but the RMSE of 1km

resolution is larger than 5km resolution simulation for EXP6. In addition, the correlation coefficients of finer resolution simulation are even smaller than the coarser resolution (EXP2, EXP4, EXP5 and EXP6). Could you explain these phenomena or please discuss it in the discussion part?

Response

The correlation coefficients of 1 km or 5 km resolution simulation are around 0.8. Under these high correlation coefficients, the RMSE could be used to decide the performance of the default Noah or the improved albedo schemes. Among all snow events simulation, the RMSE of 1 km resolution simulation larger than that of 5 km resolution only appears in the EXP6 when applying the default Noah snow albedo scheme. However, it is certain that the RMSE of 1 km resolution simulation is lower than that of 5 km resolution for all EXPs when applying the improved snow albedo scheme. Thus we replace the expression "regardless of which albedo scheme is implemented" with "by implementing the improved albedo scheme" in **Line 327-328**.

The correlation coefficients of finer resolution simulation are smaller than the coarser resolution for EXP2, EXP4, EXP5 and EXP6. This is related to the abnormally complex and steep high-elevated mountainous terrain of the Tibetan Plateau. The WRF model does not consider the complex terrain very well, which is easy to increase the simulation error of the change trend of meteorological elements after interpolation under the finer resolution complex terrain.

6. In Fig. 4(a), marking the EXP1-8 on X-axis might be easier to understand and you'd better explain the meaning of the box-and-whisker plot, such as 75% or 25%. Additionally, you said there are 27 stations in domains 01, but why are there only 17 black or red points in Fig. 4 (c)?

Response

Thank you very much for your comment. As to Figure 4, our intention is not to analyze each snow event simulation, but to conduct an overall analysis of 8 EXPs. Therefore, there is no need to mark each EXP in Fig. 4a. Also, a clear explanation of X-axis has been given in the caption of Fig. 4a, for example "horizontal axis denotes samples from EXP1 to EXP8".

We add illustration to the caption of box-and-whisker plot in Fig. 4b, and make more explanation to Fig. 4c. Based on Fig. 4a, we average the observed albedo values every 0.05 segments, i.e., 0-0.049, 0.05-0.099, 0.1-0.149, 0.15-0.199,⋯⋯, 0.85-0.899, 0.9-0.949, 0.95-0.999, accordingly average the model estimates at the same time as the observations, and finally plot the Fig. 4c. There is no observations falling in the above 3 segments, and the above 17 segments have averaged values. That is why only 17 black or red points in Fig. 4c. Please see **Line 374-378**.

Minors:

1. There are two "two" in the L183.

Response

Thank you for your careful review. We delete a "two" in **Line 183**.

2. I think the max decrease in air temperature RMSE is 2.03 (L307) (Table 3).

Response

You are absolutely right. We have corrected the sentence to "Compared with when the default Noah snow albedo scheme is used, the maximum decrease in air temperature RMSE when the new scheme is used reaches 2.03 °C, which represents an improvement of 28.1 %" in **Line 311-313**.