Referee #2

"In this paper, the authors study the impact of snow grain shape and black carbon (BC)-in-snow mixing state on snow albedo and BC-snow radiative effects. The authors update the SNICAR model by introducing new sets of parameterizations for snow optical properties based on snow grain shape and BC-in-snow mixing state. The updated SNICAR model is used to reproduce spectral observations of pure and BC contaminated snow, and is applied to field observations across Tibetan Plateau to illustrate the impact of snow grain shape and BC-in-snow mixing state on regional BC-snow radiative effects. The discussions and figures are clear and well organized in general."

We thank the reviewer for his/her constructive comments and suggestions, which help to improve the manuscript. Below is a point-by-point response to the comments.

Specific Comments:

1. Table 1: For field observations that did not measure underlying ground albedo, the authors assume an albedo of 0 for SNICAR computation; while the underlying ground albedo rarely reach 0 even for dark soil. The snow depth for some of these measurements is shallow, that some light may penetrate through the snowpack. Is there any reason that the authors assigned 0? Perhaps consider adjusting underlying ground albedo to see if this will impact the comparisons show in Figure 6 and 7.

Response: Thank you for the comments. We have conducted additional sensitivity simulations for the three cases without measurements of underlying ground albedo by using values of 0.1 and 0.2 for visible and NIR bands, respectively, based on observations over the TP. For the Painter et al. (2007) and Brandt et al. (2011) cases, the differences by using different underlying ground albedos are negligible due to thick snow optical depths. For the Meinander et al. (2013) case with relative thin snow layers, the relative differences by using different underlying ground albedos are still small (<5%) due to large snow grain sizes and hence thick optical depths. We have included these discussions in the track-change manuscript as follows:

Lines 337–338: "*Thus, we assumed black underlying ground (albedo = 0) in the two cases, which has negligible effects on albedo estimates due to thick snow optical depths.*"

Lines 392–395: "*Compared with assuming a black underlying ground, we find that using a non-black underlying ground albedo typically observed over the Tibet (Qu et al., 2014) only leads to very small (<5%) relative differences in albedo calculations in the Meinander et al. (2013) case.*"

2. Table 1: For field studies that report snow effective radius, how did they define/measure/derive the snow effective radius? Do they use similar assumptions as the spherical snow grain in SNICAR?

Response: Thank you for the comments. Snow grain sizes reported by the field studies are retrieved by different methods. For the Painter et al. (2007), Hadley and Kirchstetter (2012), and Pedersen et al. (2015) cases, they retrieved snow grain sizes by matching results of snow radiative transfer models with measured NIR snow albedo spectra. For the Grenfell et al. (1994), Meinander et al. (2013), and Svensson et al. (2016) cases, they determined snow grains sizes by visual estimates with tools (e.g., hand lens with macro-photograph or mm-grids with magnifier). We note that these different measuring methods could introduce uncertainties to the measured snow grain sizes. Moreover, the snow grain size from visual estimates in field studies also differs from the snow effective size (i.e., surface area-weighted mean radius) defined in SNICAR, which could introduce additional uncertainties to snow albedo calculations and comparisons with observations. We have included these discussions in the revised manuscript (Lines 428–434) as follows:

"We note that the snow grain sizes reported by the aforementioned field studies are retrieved by different methods, including matching snow model results with measured albedo spectra (Painter et al., 2007; Hadley and Kirchstetter, 2012; Pedersen et al., 2015) and visual estimates with tools (Grenfell et al., 1994; Meinander et al., 2013; Svensson et al., 2016) that are not equivalent to the snow effective size (i.e., surface area-weighted mean radius) defined in SNICAR. This could introduce uncertainties to snow albedo calculations and model-observation comparisons."

3. Lines 325-326: the authors say they "made reasonable assumptions for cases when measurements are absent". The readers may wonder what are these "reasonable assumptions" and how did authors justify these assumptions. Perhaps including some details on, for example, how to assign underlying ground albedo (comment 1) when measurement is absent, and etc.

Response: Thank you for the comments. Following the reviewer's suggestion, we have included more details, including which parameters are based on observed values and which parameters are assumed as well as some justifications of these assumptions. We have also conducted sensitivity simulations to investigate effects of assumed underlying ground albedo (see the response to Comment #1). The additional discussions have been included in the track-changed manuscript (Lines 332–346 and 386–395). Please see the response to Reviewer #1, Comment #3 for details.

4. Table 2: The zeros in albedo reduction values can be distracting that prevent direct comparisons across regions; perhaps consider keeping only the non-zero digits and modify the unit.

Response: Thanks for the comment. Following the reviewer's suggestion, we have modified the values using the expression of scientific notation in the revised Table 2.

5. Lines 340-342: in Figure 6a, as the authors mentioned, the snow grains created in Hadley and Kirchstetter (2012) tend to be spherical, yet the nonspherical grain assumption yields better results. What does this imply for future modeling/field works regarding snow grain shape and snow grain size? Does this mean even if the snow grain shape is relatively well observed in the field, the snow radiative transfer modeling based off the observed grain shape may not improve the snow modeling? Or in another word, to what extend should radiative modeling rely on field observed snow grain shapes since it seems, from figure 6b, the model can always adjust snow grain size to match observations, no matter what grain shape it adopted.

Response: Thanks for the comments.

(1) The snow grains created in Hadley and Kirchstetter (2012) tend to be spherical. However, based on their microscopic images (Fig. S3 in their study), the grains are not perfectly spherical and there are still a portion of grains with either spheroid or aggregating shapes. This is probably why assuming nonspherical grains in our model yields slightly better results than assuming purely spherical grains (Fig. 6a in this study).

(2) Our results do not imply that the snow albedo modeling based on observed grain shape may not improve model results. Instead, one of our key findings/points in this study is that it is necessary to account for realistic/observed snow grain shape in order to accurately estimate snow albedo, which has been supported by the improved model results using nonspherical snow grains (see Sect. 3.4). However, each parameter used in snow modeling could be associated with uncertainties. It is likely that using the observed grain shape may not improve model results when the uncertainties/biases in other model parameters are large. Thus, accurate estimates of snow albedo require constraining all the model parameters together by observations. In summary, this study points toward an imperative need for improved measurements and model characterization of snow shapes.

(3) We agree that the snow grain size can always be adjusted to make model results match observations, whatever the grain shape is assumed. However, this could lead to the issue of getting right answers (e.g., albedo) for wrong reasons (e.g., grain size) due to the lack of grain shape information. Moreover, we have shown that assuming different snow grain shapes can lead to substantial variations in the optimal grain sizes determined by matching observed albedo spectra (Figs. 6b and 7d). This highlights the necessity of accounting for realistic grain shapes in snow size retrievals, which can effectively reduce the uncertainty in retrieved grain sizes. In addition, for the purpose of weather and climate forecasts, snow and climate modeling rely on observed/realistic snow grain shape to produce accurate albedo predictions and associated climate feedbacks.

6. Figure 6b and 7d: it seems that the model simulations fail to capture the drop of snow albedo around 0.25 um observed by Brandt et al., 2011. Is there any explanation?

Response: Thanks for pointing it out. This is because of the uncertainty in ice refractive indices at short wavelengths. The ice refractive indices used in this study result in too weak snow absorption at wavelengths <400 nm and hence lead to model overestimates in albedo at these wavelengths. We have included the discussions in the track-change manuscript (Lines 368–380). Please see the response to Reviewer #1, Comment #4 for details.