Review Comments for "Radiative feedbacks of dust-in-snow over East Asia in CAM4-BAM" by Xie et al.

The authors systematically investigated the responses of dust emissions, transport, and deposition to dust direct and in-snow radiative effects over East Asia. This work could help to improve the understanding of dust radiative effects and feedbacks in this region. The manuscript is generally well written and particularly I like Figure 13 which concisely summarizes the possible dust-in-snow radiative feedback. I have a few comments for improving the manuscript. Although most of my comments are minor, they need to be addressed properly before the manuscript can be considered for publication.

1. Page 2, Lines 11-13: As the authors mentioned, Kok et al. (2017) showed that inaccurate dust size distribution could lead to nontrivial biases in modeled DRF. Is it accurate enough by using the Bulk Aerosol Model (BAM) scheme embedded in CAM to represent dust size distributions as done in the present study?

2. Page 2, Lines 24-34: A number of recent references on advancing the understanding of BC/dust-in-snow effects are missing here. For example, several studies (e.g., Flanner et al., 2012; Liou et al., 2014; Dang et al., 2016; He et al., 2017b, 2018a) have shown the significant impacts of snow grain shape (spherical vs. nonspherical) and aerosol-snow mixing state (internal vs. external) on BC/dust-snow albedo forcing. Further studies also investigated the effects of snow grain packing (e.g., He et al., 2017a) and aerosol size distribution in snow (e.g., Schwarz et al., 2013; He et al., 2018b) on aerosol-snow interactions. Since the aerosol-in-snow effect is the focus of this study, I suggest including these recent references here. In addition, in terms of BC/dust deposition over the TP (Lines 32-34), some latest observational studies (e.g., Lee et al., 2017; Li et al., 2018; Zhang et al., 2018) can also be included here.

References:

Dang, C., Q. Fu, and S. Warren: Effect of Snow Grain Shape on Snow Albedo, J. Atmos. Sci., 73, 3573–3583, doi: 10.1175/JAS-D-15-0276.1, 2016.

Flanner, M. G., X. Liu, C. Zhou, J. E. Penner, and C. Jiao: Enhanced solar energy absorption by internally-mixed black carbon in snow grains, Atmos. Chem. Phys., 12(10), 4699–4721, doi:10.5194/acp-12-4699-2012, 2012.

He, C., Y. Takano, and K.-N. Liou: Close packing effects on clean and dirty snow albedo and associated climatic implications, Geophys. Res. Lett., 44, doi:10.1002/2017GL072916, 2017a.

He, C., Takano, Y., Liou, K.-N., Yang, P., Li, Q., and Chen, F.: Impact of snow grain shape and black carbon-snow internal mixing on snow optical properties: Parameterizations for climate models. Journal of Climate, 30, 10,019–10,036, doi:10.1175/JCLI-D-17-0300.1, 2017b.

He, C., Liou, K.-N., Takano, Y., Yang, P., Qi, L., and Chen, F.: Impact of grain shape and multiple black carbon internal mixing on snow albedo: Parameterization and radiative effect analysis. J. Geophys. Res.-Atmos., 123, 1253–1268, doi:10.1002/2017JD027752, 2018a.

He, C., Liou, K.-N., and Takano, Y.: Resolving size distribution of black carbon internally mixed with snow: Impact on snow optical properties and albedo. Geophysical Research Letters, 45, 2697–2705, doi:10.1002/2018GL077062, 2018b.

Lee, W.-L., K. N. Liou, C. He, H.-C. Liang, T.-C. Wang, Q. Li, Z. Liu, and Q. Yue: Impact of absorbing aerosol deposition on snow albedo reduction over the southern Tibetan plateau based on satellite observations, Theor. Appl. Climatol., 129(3-4), 1373-1382, doi:10.1007/s00704-016-1860-4, 2017.

Li X., S. Kang, G. Zhang, B. Que, L. Tripatheea, R. Paudyal, Z. Jing, Y. Zhang, F. Yan, G. Li, X. Cui, R. Xu, Z. Hu, C. Li. Light-absorbing impurities in a southern Tibetan Plateau glacier: Variations and potential impact on snow albedo and radiative forcing. Atmospheric Research, 200, 77-87, doi:10.1016/j.atmosres.2017.10.002, 2018.

Liou, K. N., Y. Takano, C. He, P. Yang, R. L. Leung, Y. Gu, and W. L. Lee: Stochastic parameterization for light absorption by internally mixed BC/dust in snow grains for application to climate models, J. Geophys. Res.-Atmos., 119, 7616–7632, doi:10.1002/2014JD021665, 2014.

Schwarz, J. P., Gao, R. S., Perring, A. E., Spackman, J. R., & Fahey, D. W. (2013). Black carbon aerosol size in snow. Scientific Reports, 3(1), 1356.

Zhang, Y., Kang, S., Sprenger, M., Cong, Z., Gao, T., Li, C., Tao, S., Li, X., Zhong, X., Xu, M., Meng, W., Neupane, B., Qin, X., and Sillanpää, M.: Black carbon and mineral dust in snow cover on the Tibetan Plateau, The Cryosphere, 12, 413-431, doi:10.5194/tc-12-413-2018, 2018.

3. Page 3, Line 9: Please remove “by” before “to explain”.

4. Page 4, Lines 2-4: A recent study (He et al., 2018c) has updated a number of new features into the SNICAR model, including the effects of snow grain shape and aerosol-snow mixing state based on a set of new parameterizations (He et al., 2017b), which showed important impacts on aerosol-in-snow forcing. It seems that the authors here assumed external mixing between aerosols and spherical snow grains, which may not represent the realistic snowpack situation. It would be better if the authors could add some discussions on this important issue.

References:

He, C., Flanner, M. G., Chen, F., Barlage, M., Liou, K.-N., Kang, S., Ming, J., and Qian, Y.: Black carbon-induced snow albedo reduction over the Tibetan Plateau: Uncertainties from snow grain shape and aerosol-snow mixing state based on an updated SNICAR model, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2018-476, in review, 2018c.

5. Page 4, Lines 6-7: The authors focused on dust over the Tibetan Plateau by using a model spatial resolution of ~1 degree. However, this resolution may not be able to resolve the complex topography of the Tibetan Plateau and may cause some uncertainty in the simulations. Could the authors add some discussions on this aspect?

6. Page 4, Lines 12-13: The authors neglected the radiative properties of other aerosols, which may cause some biases in estimating dust-in-snow forcing. For example, Flanner et al. (2009) suggested that co-existing BC and dust may lead to smaller albedo reduction/forcing caused by dust (or BC) compared with dust (or BC)-only situation. Could the authors elaborate a little on this?

7. Page 4, Line 24: Please change “is” to “are”.

8. Page 4, Lines 27-28: Could the small wet deposition of dust be due to the weak solubility of dust?

9. Section 2.2: (1) In terms of dust AOD, the authors only showed model results but no evaluation against observations, which seems not consistent with the section title “Model evaluation”. It would be better if the authors could show some model evaluations on dust AOD (e.g., compare with satellite AOD during dust events). If this would take too much additional work, at least the authors could provide some references showing the evaluation of dust AOD using this model. (2) The authors showed some biases in modeled SCF, which may directly translate into biases in dust-in-snow forcing. How would this bias affect the final results/conclusions? Could the authors add some discussions on this?

10. Section 3.1: The authors showed that the change in dust emissions induced by SRF+DRF is 5.98 Tg/season, which is contributed by two competing effects (-8.8 Tg/season caused by DRF and 14.78 Tg/season caused by SRF). It seems that the response of dust emissions to dust radiative effects is linear (5.98= -8.8+14.78), which may not be very intuitive, since some nonlinear processes (e.g., transport, deposition, circulation, etc.) are involved in this radiative feedback (Fig. 13). Could the authors add some comments on this?

11. Page 6, Lines 13-14: Another element in this positive feedback process is that increasing surface temperature leads to stronger snow aging and hence larger snow grain sizes, and finally reduces snow albedo.

12. Page 7, Lines 1-10: Could the authors put their SRF effects into the context? For example, are the results and conclusions shown here different from previous studies? If so, how different are they and why?

13. Page 8, Line 11: Another reason for the largest SRF in MAM could be that the snow cover/depth reaches the maximum over TP in early spring, along with the largest dust deposition, leading to the largest SRF.

14. Page 8, Line 21: It seems that the authors did not show results for the expansion of dust source region area caused by SRF in this manuscript.