Response to Reviewer #3:

General comments:

This is an interesting scientific paper in which the authors investigated the radiative feedbacks of dust in snow over East Asia by using CAM4 model simulations. The results are helpful for the scientists to understand the impact of dust-in snow on radiation balance and climate over East Asia. However, some details and figures should be supplemented and explained before published. (see specific comments).

Response: Thank the Reviewer very much for the positive comments.

Specific comments:

part of this study focus on TP, e.g. Fig.1~4, while other results are presented over East Asia, I suggest to present these results in a consistent way.

Thank the Reviewer very much. Because Figures 1-4 are mainly used to compare the climate (including surface temperature, snow cover fraction and so on) and dust properties over the TP, these figures are focused on the TP. However, dust-in-snow over the TP can affect the climate and dust cycle over a much larger region (e.g., the whole East Asia). Hence, the other figures include a larger region to order to investigate its climate effects.

Sec.2.2. have you assessed the modeled AOD against satellite retrievals? The model results and conclusions in this study really depend on the modeled dust AOD. Additionally, absorption AOD (AAOD) also need to be assessed.

Thanks. In the Reference (Xie et al., 2018), the improved CAM4-BAM was used to evaluate the East Asian dust, including surface dust concentrations and the AOD, based on local observational sites from CAWNET (Zhang et al., 2012) and CARSNET (Che et al., 2015). Additionally, scatter and absorption of dusts exerts a radiative forcing for surface, TOA, and Atmosphere, which has also been discussed detailedly in the Reference (Xie et al., 2018). In this manuscript, we focus on comparing the surface temperature and snow cover fraction in order to investigate dust-in-snow forcing.

Reference

Che, H., Zhang, X. Y., Xia, X., Goloub, P., Holben, B., Zhao, H., … Blarel, L. (2015). Ground-based aerosol climatology of China: Aerosol optical depths from the China Aerosol Remote Sensing Network (CARSNET) 2002–2013. Atmospheric Chemistry and Physics, 15(8), 7619–7652.

Xie, X., Liu, X., Che, H., Xie, X., Wang, H., Li, J., … Liu, Y. (2018). Modeling East Asian dust and its radiative feedbacks in CAM4-BAM. Journal of Geophysical Research: Atmospheres, 123, 1079–1096. https://doi.org/10.1002/2017JD027343

Zhang, X. Y., Wang, Y. Q., Niu, T., Zhang, X. C., Gong, S. L., Zhang, Y. M., & Sun, J. Y. (2012). Atmospheric aerosol compositions in China: Spatial/temporal variability, chemical signature, regional haze distribution and comparisons with global aerosols. Atmospheric Chemistry and Physics, 12, 779–799.

p.4, line.28. ‘ It is noted that the dry deposition of dusts is much larger than the wet deposition probably because of less rain over Northwest China’. It should be straightforward to present the comparison of precipitation to confirm this statement.

Response: Figure S1 shows the percentage of the dust wet deposition to the total deposition in the MAM. Over Northwest China, it has the smallest percentage of dust wet deposition and it has larger percentage of dust wet deposition over the Ocean. Hence, we can conclude that the less rain determines the small wet deposition over Northwest China based on the spatial distribution of the percentage.

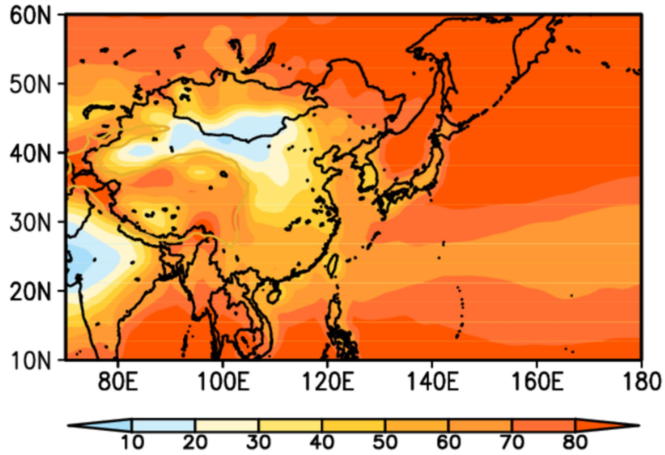

Figure S1, Percentage of dust wet deposition to the total deposition (wet+dry deposition) in the MAM.

p.4 line.33. what is CRU? It should be explained before you cite it.

Taken.

Sec.3.1 and Fig.5: how do you define the term trans in Fig.5?

Response: The dust transport Q is the vertically integrated dust flux, which is similar to the water vapor transport,

$$Qu = \frac{1}{g}\int_{ps}^{100} au\,\mathrm{d}p$$

$$Qv = \frac{1}{g}\int_{ps}^{100} av\,\mathrm{d}p$$

$$Q = (Qu^2 + Qv^2)^{1/2}$$

where a, u, v, and g represent dust mass concentration, zonal wind, meridional wind, pressure and gravitational acceleration, respectively. ps is the surface pressure. Hence, in our manuscript, we have added the corresponding descriptions *"defined as the vertically integrated dust flux, which is similar to water vapor transport."*

p.5, line 30: 'Figures 5c, 5f, 5i and 5l show the changes in dust cycle induced by the dust total radiative forcing. The dust emissions are significantly enhanced (in Figure 5c) by the dust total radiative forcing over East Asia …', what are the physical mechanisms? It would be helpful to provide the dust emission scheme in the model and explain in detail why the dust EF enhance the dust emission.

Yes, It is a very good suggestion. In the previous paper (Xie et al., 2018), we have shown the total vertical dust flux F_d (unit: kg m^{-2} s^{-1}) from the soil during saltation is calculated as

$$F_d = C_{MB}\eta f_{bare}\frac{\rho}{g}u_*^3\left(1-\frac{u_{*t}^2}{u_*^2}\right)\left(1+\frac{u_{*t}}{u_*}\right), (u_* \geq u_{*t}), \quad (1)$$

$$F_d = 0, (u_* < u_{*t}), \quad (2)$$

More atmospheric instability and larger 10 m wind speed can both enhance the dust emission flux by increasing u_*. Our further analysis reveals that these results are mainly due to the regional climatic feedbacks induced by SRF over East Asia. By reducing the snow albedo over the TP, the dust-in-snow mainly warms the TP to enhance its thermal effects by increasing the surface sensible and latent heat flux, and then increases the aridity and westerly winds over Northwest China, in turn enhances the East Asian dust cycle.

p.6, line 12-15:'The decrease in snow albedo mainly results from a positive feedback process: absorbing aerosols deposited on snow -reducing surface albedo -increasing surface net solar radiation -increasing surface temperature -reducing snow fraction and depth-finally reducing surface albedo…'. I would suggest to present the physical variables listed above to support your conclusions. For example, surface net solar radiation, etc.

Thanks very much for the Reviewer. The physical variables are shown in the corresponding figures. The increasing surface forcing has been shown in the Figure 7c, the increasing surface temperature has been presented in Figure 7d, and the reducing snow cover has been shown in Figure 8a.

p.6, line 20: the authors mentioned that dust emissions are influenced by PBL mechanism, but never show that how PBL changes and how it modify the dust emission.

Response: It is good suggestion. The dust direct radiaitive forcing (DRF) reduces the dust emissions by the PBL mechanism, which has been detailedly described in the previous paper. In this manuscript, we focus on investigating the dust-in-snow radiative forcing (SRF) and its feedbacks on the regional climate and the dust cycle over East Asia, only compared with DRF's results.

p.7, line 2: above -15%, change to 15% since you have stated it is decrease.

Taken.

p.7, line 3: '…, and then expands the dust source region area…', where can you see the expanding?

As we know, dust emissions are primarily a function of surface wind speed, vegetation (and snow) cover, and soil erodibility. The decreases in vegetation and snow cover in the modeled grids can enhance the dust emissions by expanding the dust source area of the corresponding grids. Additionally, Figure 2 also shows that the total dust source area in our simulations is also expanded, due to the decreased snow cover by SRF. Hence, SRF can results in the expansion of dust source region area by reducing snow cover evidently.

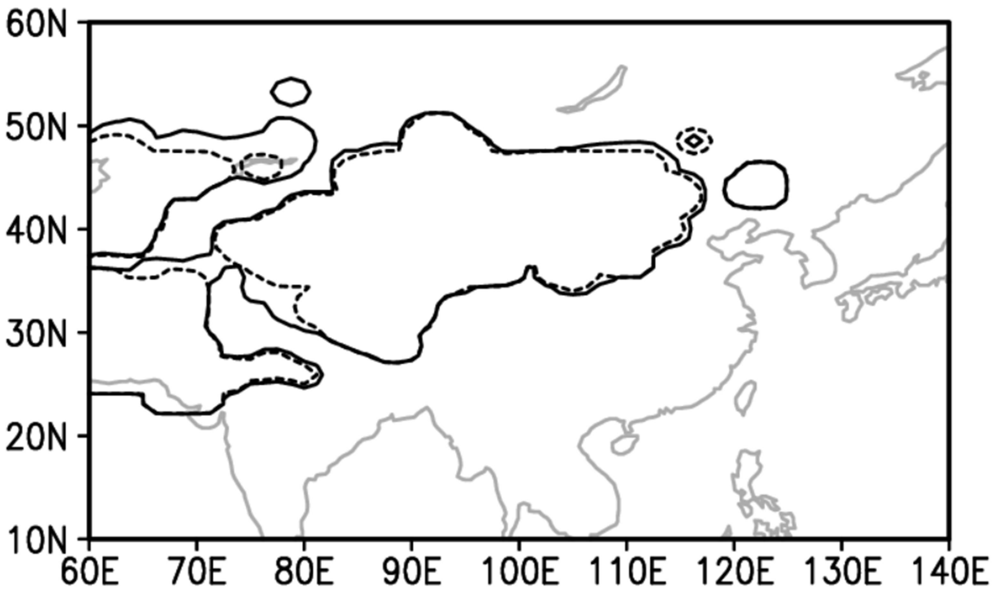

Figure S2, Dust source area defined as emission flux>0 kg/m2/s with Case 1 (Real line) and Case 2 (dotted line).

Line 14: this is NOT recently, this is actually over 5 years ago.

Taken.

Line 18: please define Omega before use it.

Taken.

p.8 and Fig.12, please also give the total dust emission and the percentage of dust emissions induced by SRF to the total emission.

Response: It is noted that Table 2 shows the dust emissions for DRF, SRF and DRF+SRF. The change in dust emissions induced by DRF is -8.80 Tg season^{-1}, whereas the change induced by SRF is +14.78 Tg season^{-1}, the total change by DRF+SRF is 5.98 Tg season^{-1} in Table 2. The sign of changes induced by DRF and SRF is absolutely opposite. Hence, the percentage (247%) of dust emissions induced by SRF to the total emission is meaningless.

Table 2. The March-April-May (MAM) averaged dust emissions (Tg season^{-1}) , transport (g m^{-1} s^{-1}), dry deposition (Tg season^{-1}), and wet deposition (Tg season^{-1}) over the East Asian dust source area (75°E–115°E and 25°N–50°N) in Case1, Case2, and Case3, as well as their corresponding differences between these three experiments.

	Dust emission	Dust transport	Dry deposition	Wet deposition
Case1	122.40	1.08	68.92	36.99
Case2	107.62	1.01	61.59	35.33
Case3	116.42	1.09	65.33	35.96
DRF (Case2–Case3)	−8.80 (−7.6%)	−0.07 (−6.4%)	−3.74 (−5.7%)	−0.63 (−1.8%)
SRF (Case1–Case2)	14.78 (13.7%)	0.07 (6.9%)	7.33 (11.9%)	1.66 (4.7%)
DRF+SRF (Case1–Case3)	5.98 (5.1%)	−0.01 (−0.9%)	3.59 (5.5%)	1.03 (2.9%)