Review of "Snow-darkening versus direct radiative effects of mineral dust aerosol on the Indian summer monsoon: role of the Tibetan Plateau" by Shi et al.

This paper examines the dust snow-darkening (SDE) and direct radiative effects (DRE) on Indian summer monsoon (ISM) with global climate model simulations. The authors found that dust SDE (DRE) tends to induce a warming (cooling) over Tibetan Plateau, and weakens (intensifies) the ISM. The main findings of this manuscript are contradictory to previous studies, but the authors did not provide convincing explanations. Thus, this manuscript needs careful revisions to meet the standard of Atmospheric Chemistry and Physics and resubmitted.

Major comments:

The Indian summer monsoon is primarily driven by the thermal contrast between land and ocean (Wang et al., 2000). The up troposphere meridional temperature gradient south of Tibetan Plateau is one of the key controls of the Indian summer monsoon (Li and Yanai, 1996). An up troposphere warming over TP tends to increase the meridional temperature gradient, and intensifies the Indian summer monsoon (Wu et al., 2005; Liu et al., 2001). Previous studies show that both DRE and SDE of absorbing aerosols could induce a warming around TP and intensify the Indian summer monsoon (EHP effect), which is in general consistent with the observed relationship. In this study, however, the authors found the Indian summer monsoon is intensified (weakened) associated with cooling (warming) over TP, which is just opposite to previous studies. The authors should carefully check the model settings and give some explanations.

The authors found that the dust SDE induced TP warming tends to weakens Indian summer monsoon, which is opposite to what found in Qian et al. 2011. The authors stated that the opposite response is due to the difference in TP warming center distribution. Lau et al. 2010 found that aerosol SDE could produce an "elevated-heat-pump (EHP)" effect and increase the precipitation over Indian in May. Their results is in generally consistent with Qian et al. 2011, although the warming center is over western TP. The authors should provide convincing explanations why the response to dust SDE in this study is contradictory to previous studies.

The dust DRE impacts on Indian summer monsoon is also inconsistent with previous studies, and the results are difficult to understand. The authors found dust DRE could induce a significant cooling over TP, and the cooling is attributed to snow-albedo feedback. The dust AOD is very small over TP (less than 0.05), which implies very weak DRE. How such small DRE produce strong snow-albedo feedback over TP? The feedback processes should be detailed explained. More confusing thing is that the Indian summer monsoon (ISM) is intensified associated with the TP cooling, which is similar to the response induced by TP warming (Lau et al., 2006). The authors simply explained it as a response to downward motion right over TP, which is not convincing. Please provide detailed explanations and supportive reference.

In this study, the CAM4 was run with prescribed climatological SST and sea ice. The SST response to aerosol forcing (slow response) is not taken into account. Many previous works showed that the slow response can play a dominant role in the total response of Indian summer monsoon to aerosol forcing (Ganguly et al., 2012). Many previous studies investigated dust impacts on ISM with coupled simulations (e.g. Qian et al, 2011). It could be a possible reason why the monsoon response is opposite to previous studies. Thus, the authors should run coupled simulations and make a comparison with current results.

This study investigate the dust impacts on Indian summer monsoon. However, only the dust effect during the monsoon onset periods (May and June) is investigated. The Indian summer monsoon is from June to August (or September). Please show the monsoon response in July and August, for the dust concentration is still high in Indian at that time (Gu et al., 2016). The response of ISM could be quite different in July and August, for dust DRE impacts could be more important at that time. Only with an examination of the response in entire monsoon period, the title of this manuscript could be appropriate.

Other comments:

Page 1, Line 2："have" should be "has".

Page 4, Line 6-7：Please give more explanations on "snow-darkening and direct radiative feedbacks". Does it mean the permit of dust snow-darkening and direct radiative effects in simulations? What is the meaning of feedback?

Page 5, Line 13: Please provide references for the two branches of Indian summer monsoon.

Page 5, Line 25: If EXP1-EXP2 equals to the impacts of dust SDE, please use the dust SDE in the rest of manuscript for consistency. So do the cases for EXP2-EXP3.

Page 5, Line 26: Please clarify the definition of "Indian monsoon area".

Page 5, Line 28: Indian summer monsoon lasts from June to August. Please show the precipitation change in July and August, as well.

Page 6, Line 9：Why dust SDE induces significant cooling over Tibetan Plateau? The dust AOD is very small over Tibetan Plateau.

Page 6, Line 15：Why is the southern branch of the monsoon westerly significantly decreased？

Page 8, Line 10: Please show the dust snow forcing (outputted by SNICAR), dust deposition (dry and wet), and dust concentration in snow over TP and their seasonal variation. A comparison with previous studies (e.g., Qian et al., 2011) is also needed.

Page 8, Line 23: Please explain the feedback.

Page 8, Line 23: Dust aerosols could absorb both shortwave and longwave radiative fluxes. Why the longwave radiative flux change is negative?

Page 8, Line 34: The dust AOD is very small over TP (less than 0.05), which implies very weak DRE. How such weak DRE produce significant snow cover increase and surface cooling over TP? It could not be simply attributed to snow-albedo feedback.

Page 9, Line 19-30: In Lau et al. 2010, they found that TP warming tends to increase the Indian precipitation in May, and the warming center is located at western TP. Their result is consistent with Qian et al. 2010, but different with the results of this manuscript. Explanations are needed here.

Page 10, Line 12: How could downward motion right over TP induce an upward motion over Indian？ Is it noticed any previous studies? Please provide more explanations as well as the references.

Figures:

Figure 2 and Figure 3 could be put in the supplement, for they are too many figures for this manuscript.

Figure 4：Please use the specific date in figure 4 (e.g. May 1st).

Figure 4：Please specify the regions of precipitation change.

Figure 5：Please display the precipitation and surface temperature with different color tables.

Figure 5 and so on: Please show “SDE” and “DRE” in figure title.

Figure 5 to Figure 10: There are too many figures for this part. Decide what is important and put the rest in supplement.

References:

Ganguly, D., P. J. Rasch, H. Wang, and J.-h. Yoon (2012), Fast and slow responses of the South Asian monsoon system to anthropogenic aerosols, Geophysical Research Letters, 39(18), L18804, doi:10.1029/2012GL053043.

Gu, Y., Xue, Y., De Sales, F., Liou, K. N.: A GCM investigation of dust aerosol impact on the regional climate of North Africa and South/East Asia, Clim. Dyn., 46, 2353–2370, 2016.

Lau, K. M., Kim, M. K., and Kim, K. M.:. Asian monsoon anomalies induced by aerosol direct forcing: the role of the Tibetan Plateau, Clim. Dyn., 26, 855–664, 2006.

Lau, K.-M., Kim, M. K., Kim, K.-M., and Lee, W. S.: Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols, Environ. Res. Lett., 5, 025204 doi:10.1088/1748-9326/5/2/025204, 2010.

Li, C., and M. Yanai (1996), The Onset and Interannual Variability of the Asian Summer Monsoon in Relation to Land–Sea Thermal Contrast, Journal of Climate, 9(2), 358-375, doi:10.1175/1520-0442(1996)009<0358:TOAIVO>2.0.CO;2.

Liu, X., and M. Yanai (2001), Relationship between the Indian monsoon rainfall and the tropospheric temperature over the Eurasian continent, Quarterly Journal of the Royal Meteorological Society, 127(573), 909-937, doi:10.1002/qj.49712757311.

Qian, Y., Flanner, M., Leung, L., and Wang, W.: Sensitivity studies on the impacts of Tibetan Plateau snowpack pollution on the Asian hydrological cycle and monsoon climate, Atmos. Chem. Phys., 11(5), 1929–1948, doi: 10.5194/acp-11-1929-2011, 2011.

Wu, B. (2005), Weakening of Indian summer monsoon in recent decades, Advances in Atmospheric Sciences, 22(1), 21-29, doi:10.1007/BF02930866.

Wang, B., R. Wu, and K.-M. Lau (2001), Interannual Variability of the Asian Summer Monsoon: Contrasts between the Indian and the Western North Pacific–East Asian Monsoons, Journal of Climate, 14(20), 4073-4090, doi:10.1175/1520-0442(2001)014<4073:Ivotas>2.0.Co;2.