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The revised manuscript entitled "Modulation of springtime surface sensible heating over the Tibetan Plateau on the interannual variability of East Asian dust cycle" by Xiaoning Xie, Anmin Duan, Zhengguo Shi, Xinzhou Li, Hui Sun, Xiaodong Liu, Xugeng Cheng, Tianliang Zhao, Huizheng Che, and Yangang Liu

We thank the ACP Handing Editor (**Professor Kari Lehtinen**) for his hard work and the two anonymous referees for their constructive suggestions to improve our manuscript significantly. We greatly appreciate the generally positive comments from both the two Reviewers (Reviewer #1 and Reviewer #2), and have addressed all the concerns, with point-by-point responses detailed below (reviewers comments in red color and our responses in blue color). We have uploaded the file of "Response to reviewers.pdf".

Best wishes,

Xiaoning Xie

Response to Reviewer #2:

Synopsis & General remarks:

The authors present a research on the interannual variability of East Asia dust cycles by using the model CAM4-BAM, the surface meteorological data in TP and the global reanalysis from MERRA-2 as observations. They have found the interesting relations between the dust cycle variability in East Asia and the MAM surface sensible heating from Tibetan Plateau (TPSH) which has triggered two anticyclonic anomalies in the dust source area and in the downwind North Pacific Ocean. This kind of anomalous circulations finally enhances the surface wind at 10-m which is absolutely determined to enhance the dust emissions as the 10-m wind is the key input for dust emission in the dust product scheme MB95 used in CAM4-BAM. The manuscript is written in a well structure way and in fluent and concise English. The results are reasonable and interest. This work also gives us a clue to pin down the relations between the dust cycling and the regional climate in East Asia from the long time scale point of view, especially the importance role of the TP.

Taklimakan and the Gobi desert are the two major dust sources in East Asia. The dust is emitted mostly as the cold wind with the Siberian High comes through these two areas. As the cold air mass in East Asia is mostly dominated by the position of polar vortex in north Hemisphere and absolutely also influenced by the huge complex terrain of TP. So the authors should be careful to draw the conclusion the TP is the dominating factor for all the variabilities of the dust cycling in East Asia.

Verdict. Some major and some minor revisions have to be done. In particular, the authors need to be on alert about the conclusions they get.

Response: Thank Reviewer #2 very much for the positive comments and constructive suggestions. Yes, I absolutely agree with the Reviewer' comments about dominating factor of dust storm activities. Observations show a significant decreasing trend form 1970 and an increase trend from 1995 to 2003 in dust activities. Hence, there exists a decadal change in dust activities, which is mainly related to polar vortex activities (Qian et al., 2002; Zhao et al., 2004; An et al., 2018). Hence, we believe that polar vortex activities have a dominated role in determining eastern Asian dust storms. Through our analysis of observations and model, we claimed that TPSH can modulate the interannual variability of the eastern Asian dust cycle, showing that is a non-negligible factor.

1. Page 4 Line 9: As the TPSH index is very important in this manuscript, please add how you get it by the bulk aerodynamics method in detail to make it more readable.

Yes, we have added the corresponding description about the bulk aerodynamics method in page 4. The data includes historical four times daily observations of ground surface temperature (T_s), surface air temperature (T_a), and wind speeds at 10 m above the surface (V_{10m}) from 1980-2008, mainly over the central and eastern TP. The surface sensible heating flux (SH) is obtained from the above three meteorological parameters by the bulk aerodynamic method (Duan et al., 2011; 2017), which is expressed as follows,

$SH = C_p \rho C_{DH} V_{10m} (T_s\text{-}T_a)$,

where C_p is the specific heat of dry air at constant pressure (C_p=1005 J $kg^{-1}K^{-1}$), ρ is air density, and the parameter C_{DH} is the drag coefficient for heat.

2. Page5 Line10: How do you set you simulation time period? Is it the same time period as 1980-2008 of MERRA-2 except the spin up time? Please clarify.

Yes，the time period of the observed results about TPSH and MERRA-2 is from the year 1980 to 2008. As noted in the third comment, observations show a significant decreasing trend form 1970 and an increase trend from 1995 to 2003 in dust storm activities. In order to remove the decadal trend in climate and dust activities, we conducted the CAM4-BAM model with fixed present-day climatological mean SST and sea-ice concentration, as well as greenhouse gases during the 30 simulated years. The simulated year does not represent real time year. Hence, we can only check the relationship between TPSH and dust concentration, and do not compare the simulated results with year by year observations. The corresponding description has been added in the Section 2 "The numerical experiment was conducted with fixed present-day climatological mean sea-ice concentrations, and sea surface temperature (SST), as well as fixed present-day greenhouse gases during the whole simulated period." and "A numerical experiment was integrated over 37 years with 7 years for spin up, including the aerosol direct effect and snow-darkening effect of absorbing aerosols. Note that the simulated year does not represent real time year, hence we can only check the relationship between TPSH and dust concentration, and do not compare the simulated results with year by year observations."

3. Section 3.2: Researches have shown that the dust emission trend in East Asia is decreasing since 1970 but with a small increase trend from 1995 to 2003. The results in Figure 3f is consistently showed this small increase trend while the model results in Figure 3c didn't. This is also reasonable that the correlation coefficient in Figure3F is much smaller than that in Figure 3c. In this case, the authors should investigate and

try to explain the difference with the information of other factors such as the activity of the polar vortex, an important factor that influence the cold air mass activities then hence the dust emission activities in the targeting region.

Yes, I agree with the Reviewer's comment. Observations show a significant decreasing trend form 1970 and an increase trend from 1995 to 2003 in dust storm activities. Hence, there exists a decadal change in dust storm activities, which is mainly related to polar vortex activities (Qian et al., 2002; Zhao et al., 2004; An et al., 2018). Our observed result also show similar decadal change in dust concentration, especially in Figure 3f, as mentioned by the Reviewer. In order to remove the decadal trend in climate and dust, we conducted the CAM4-BAM model with fixed present-day climatological mean SST and sea-ice concentration, as well as fixed greenhouse gases during the 30 simulated years. The simulated year does not represent real time year. Hence, we can only check the relationship between TPSH and dust concentration, and do not compare the simulated results with year by year observations. Hence, our simulated results do not have the decadal change in dust activities, compared with observed results in Figure 3f.

4. Section 3.3：In figure 6d-6f, there are remarkable dust emissions in west and central TP, this not consistent with the normal dust sources distributions in East Asia in other researches. Maybe there are some errors in the source data, please clarify.

Yes, it is evident that there are no large deserts over the western and central TP. However, there exist many aeolian desertified lands over the region (Li et al., 2018). These aeolian desertified lands over the western and central TP can contribute regional dust emissions. Our simulated result is similar with the recent results from the Chinese Unified Atmospheric Chemistry Environment for Dust (CUACE/Dust) (in Figure 2, An et al., 2018), which is an operational mesoscale numerical model to forecast sand and dust storms in East Asia.

5. Section 4: All the meteorological results related to the TPSH's potential mechanisms of the effects on dust cycle are deduced from the model result. Have you

ever evaluated the basic parameters of temperature and wind with the routine meteorological measurements or the reanalysis in the targeting region? As the differences in temperature and in wind from Figure7-10 are quite small which may be in the same range of or be noised by the bias of the modelling.

Yes, the updated CAM4-BAM model has been evaluated against CRU, MODIS data or NCEP2 reanalysis for surface temperature, snow cover, and atmospheric circulation in our recent works (Xie et al., 2018; Shi et al. 2019). These results shown that the model can mainly capture the spatial pattern of these meteorological variables including surface temperature, snow cover and atmospheric circulation. Secondly, our results about differences between strongest and weakest TPSH in atmospheric temperature and atmospheric circulation are absolutely consistent with ones based sensitivity experiment with and without TPSH (Figures 7 and 8 in Duan et al., 2017). Based on these two points, we believe the feedbacks of temperature and atmospheric circulations due to TPSH are reliable.

6. Page9 Line28-29: As there is no detail evidence from the manuscript for the dust deposition on SNOW and so for the feedbacks, please be careful to draw the conclusion.

I have added one figure about dust-in-snow effect and the corresponding discussions in the Section 5. Our results show that, compared to the weakest TPSH years, the MAM dust cycle in the strongest TPSH years are much more vigorous over East Asia. In the strongest TPSH years, much more dusts deposited on snow over TP (Figure 12a) show larger dust-in-snow forcing (Figure 12b) and then further enhance the regional dust cycle through the above positive feedback loop of dust-in-snow.

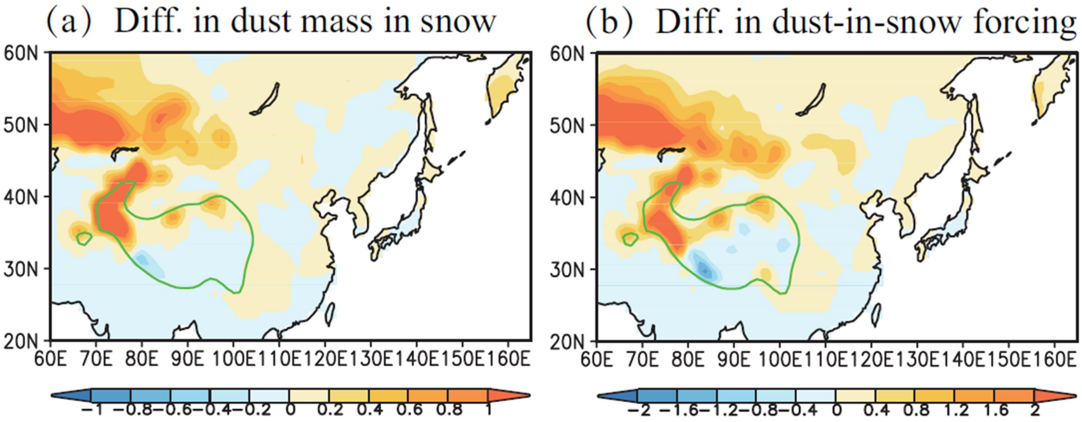

Figure S2. Spatial distribution of the MAM composite difference between the strongest and weakest TPSH years (strongest-weakest) for the model in (a) dust mass in snow column (g m^{-2}) and (b) dust-in-snow forcing (W m^{-2}). The green-contour area indicates the plateau above 2500 m.

1. Page3 Line 34: Is the ‘CAM-BAM’ right? Should it be ‘CAM4-BAM’? Please check.

Taken.

2. Page5 Line 27-28: For the sentence ‘ It presents …, 30 model years, respectively’, it is repeated described, please delete it.

Taken.

3. Page8 Line18-20: For the sentence ‘According to … with the significant increase in TPSH’, it is not logically right. Please find another way to describe it and make it more readable.

Taken

4. Page 19: The ‘C” is missing in the figure caption.

Taken.

5. Page 21: Please use the same dust concentration scale for Figure 3b and Figure 3e,

for Figure 3c and figure 3f, to make it more readable. Do you mean the dots in the black box? They are not very clear in Figure 3a and Figure 3d as the dots look like some lines. Please clarify.

Yes, we have revised the Figure 3 with the same scale for dust concentrations for Figure 3b and Figure 3e, and for Figure 3c and figure 3f, respectively. Additionally, the dots should be the slanted lines and have been revised.

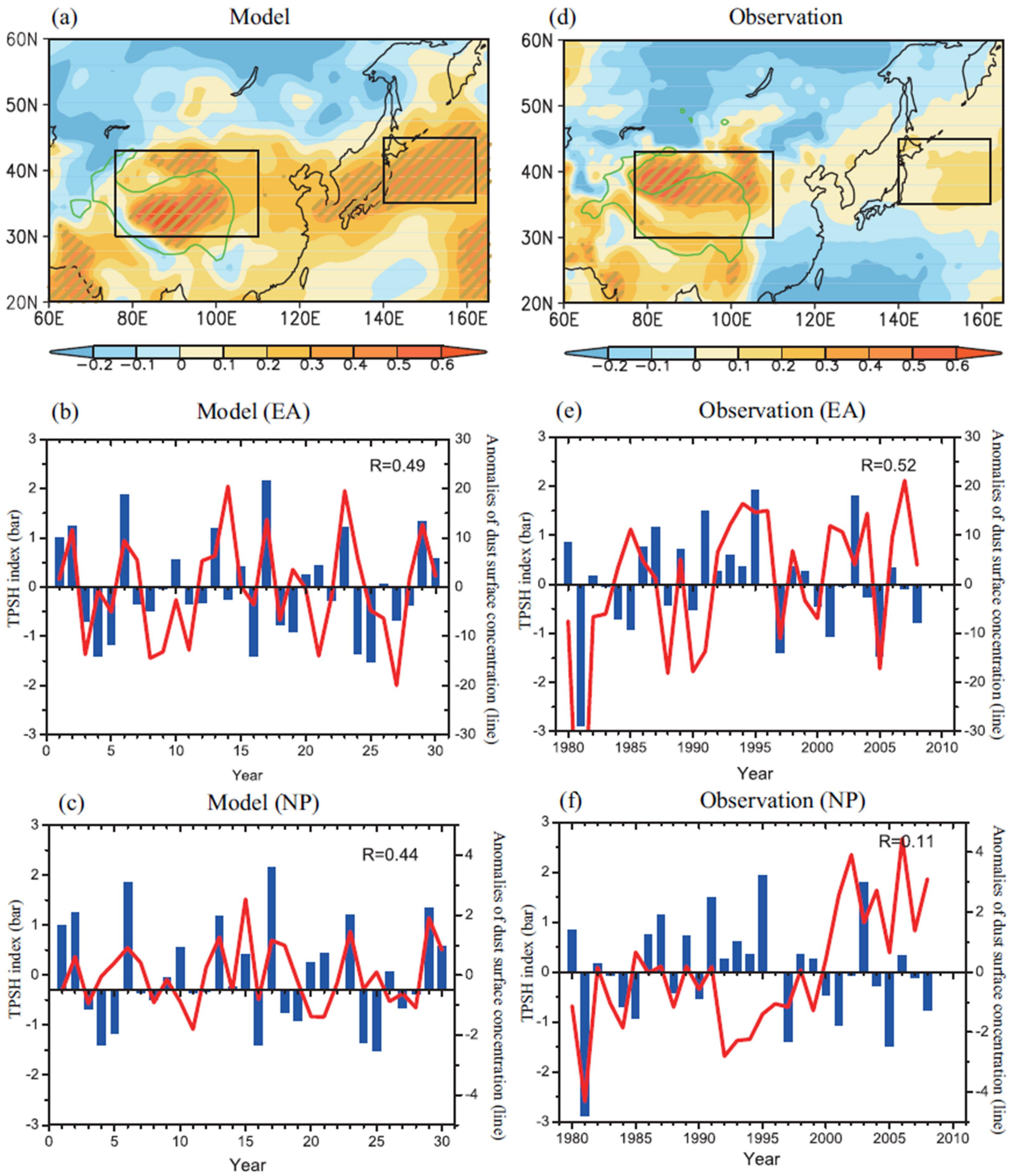

Figure 3. Spatial distribution of the correlation coefficients between the index of sensible heat over the TP (TPSH index) and the anomalies of surface dust concentration in MAM for the 30 year CAM4-BAM simulation and (b) the observed TPSH index (Duan et al., 2017) and the anomalies of the MERRA-2 surface dust

concentration for the years of 1980-2008, and the corresponding time series of regionally averaged surface dust concentration (red line) over East Asian dust source area (b for model and e for observations) and over northwestern Pacific (c for model and f for observations) and the TPSH index (blue bars). Here the slanted lines in the grey (a, d) represent the grid points where the changes pass the two-tailed t test at the 5% significance level and the green-contour area indicates the plateau above 2500 m.

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