To reviewer #2

Dear Professor:

Thank you for your kind comments for our manuscript entitled "**What caused the interdecadal shift of the ENSO impact on dust mass concentration over northwestern South Asia**", submitted to Atmospheric Chemistry and Physics. We appreciate your valuable comments and suggestions to improve it. We are sincerely grateful for giving us the opportunity to improve our work. With regard to your comments and suggestions, we wish to reply as follows:

Comment 1: Most of the arguments in this manuscript are mainly based on a series of sliding correlations (Figures 3, 4, 8, 11 & 12) and scatter diagrams (Figures 6, 7 & 9), without any analysis of dynamical processes associated with atmospheric circulation and climate elements. In fact, dust activities are mainly controlled by the local surface wind, precipitation or soil moisture (e.g., Goudie and Middleton, 1992). The teleconnection between the South Asian dust anomaly and the ENSO cycle is achieved through various mechanisms including the Walker Circulation variation (e.g., Huang et al., 2020). The existing analysis in this manuscript is not enough to establish the causal relationship between ENSO and the regional dust activities.

Response: Thank you so much for pointing out this to help us to improve our work. It is true that the analysis on influence mechanism is insufficient, which leads to great uncertainty in the relationship between ENSO and dust activities. According to your helpful suggestions, we compared the effect of ENSO and the considered influence factors (i.e., Atlantic SSTA index, Indian ocean SSTA index, and PDO) on the atmospheric circulation and climate elements, e.g., local precipitation, soil moisture, wind field, and velocity potential, to further verify the effects of those influence factors on the ENSO-dust relationship.

More specifically, for the influence mechanism of Atlantic SSTA index (ASGI), we compared the effect of North and South Atlantic SSTA with ENSO signal removed on the geopotential height at 850hPa/300hPa and zonal/meridional wind at 300hPa during the two study periods (Figs. 6-7), the results indicated that the response of atmospheric circulation on North and South Atlantic SSTA index modulated the ENSO-dust relationship. Besides, we compared the effect of ASGI and ENSO on local climate elements (soil moisture, precipitation, NDVI, wind field, and velocity potential) to prove that ASGI and ENSO exhibited the opposite effect on dust activities in the first period (Figs. 8-9).

As for the influence mechanism of Indian ocean SSTA index (TWISST), we compared the effect of TWISST and ENSO on local climate elements (soil moisture, precipitation, NDVI, wind field, and velocity potential) to prove the impact of TWISST on the ENSO-dust relationship (Figs. 12-14).

While for the influence mechanism of PDO, we compared the convection and its effect on dust activities between negative and positive phase of PDO as well as that between negative and positive phase of ENSO, the analogous effect of in-phase PDO and ENSO proved that PDO can strengthen the impact of ENSO on dust activities when it was in phase with ENSO (Fig. 16).

Comment 2: This study discussed various factors influencing the interdecadal change of the ENSO-dust relationship, such as tropical Atlantic SST, Indian ocean SST, Eurasian continent temperature (or land-sea thermal contrast) and PDO. However, the role of some factors is unclear or unconvincing because the analysis is too superficial. Instead of dealing with so many factors in general, it is better to focus on one most important factor for in-depth discussion. So, I suggest deleting all parts related to factors insignificant for modulating the ENSO-dust relationship in the text and adding the relevant process analyses. For example, how does Atlantic SST affect the downstream dust? In particular, why can the spring SST control the summer dust? How can the large-scale SSTA affect the regional dust activities in northwestern South Asia far away from the SSTA region?

Response: Thank you so much for pointing out this to help us to improve our work. Our original intention was to explore the possible large-scale atmospheric factors that contributed to the interdecadal change of ENSO-dust relationship, next, we aimed to compare the effect of the three ocean SSTA pattern on the interdecadal change of this relationship since the significant influence of the three ocean SSTA pattern were found. Thus, we would like to keep these three subsections. However, we deleted the part related to factors insignificant for modulating the ENSO-dust relationship, i.e., the section discussing the effect of Eurasian continent and Indian Ocean thermal contrast. In addition, in order to avoid the random relationship, we added the analysis on the influence mechanism by examining their impacts on precipitation, soil moisture, NDVI, and wind, as that was stated in the response to the first comment.

Comment 3: In some figure captions (e.g., Figures 5 and 10), the months in which the SST are used should be clearly indicated. This is very important for how to explain the lag correlation between the SST and the dust. It seems that the March-May SST in the Atlantic Ocean while the September-May SST in the Indian Ocean has been used. However, the manuscript failed to give the physical mechanism through which the preceding SSTA affects the dust activity in the subsequent summer. Although several literatures have been cited to try to explain the possible connection between the two, for example, Atlantic SST affects the Indian monsoon (e.g., Rong et al., 2010; Kucharski and Joshi, 2017), most of these literatures only discuss the simultaneous correlation between the SST and the monsoon, rather than the lag correlation.

Response: Thank you so much for pointing out this to help us to perfect the results. We added months in which the SST are used in the figure captions, e.g., in Figures 3 and 5-7, the tropical SSTA was taken from spring (Mar.-May); in Figures 6-9 and 12-14, the geopotential height, soil moisture, precipitation, wind, and velocity potential were taken from the dust season (Jun.-Jul); in Figure 11, the tropical Indian SST was taken from the dust season (Jun.-Jul); in Figure 16, the velocity potential and wind were taken from the dust season (Jun.-Jul) and the PDO was taken from winter (Nov.-Jan.).

For the Atlantic, the SST averaged from Mar. to May was used in this study. We stated the reason as “According to Tokinaga et al. (2019), the Atlantic Niña pattern develops and is most sensitive to ENSO in spring, thus the SST averaged from Mar. to

May was used in this section” (lines 229-230). Previous studies also reported that the response of Atlantic to ENSO was strongest in spring, and this study also discussed the response of Atlantic SSTA to the two types of ENSO, thus we utilized the SST from Mar. to May.

As for the Indian ocean, the SST was the average of Jun.-Jul. that was synchronous with the dust season. We stated the reason as “Du et al. (2009) indicated that the North Indian Ocean warming displayed two peaks in Nov.–Dec.(-1) and Jun.–Aug.(0), with the second peak larger in magnitude. Cherchi and Navarra (2013) also pointed out that the connection between ISM and Indian ocean SST pattern was mostly confined in summer and autumn. Besides, compared to Atlantic, the Indian ocean is closer to the South Asian dust source, thus it takes less time to transmit the signal (partially through wave train propagation) from the Indian ocean to the dust source than that from the Atlantic. Given all of that, the Indian ocean SST used in this study was the summer average that was concurrent with the dust season (Jun.–Jul.)” (lines 308-315).

Overall, we only analyzed the impact of Atlantic, Indian ocean and Pacific SSTA in the season with the strongest signals, and failed to analyze the effect of those factors in various seasons. Besides, the physical mechanism of the lag effect was not discussed in detail and we just verified their impact on dust by examining their effects on some atmospheric circulation and climate elements. However, the mechanism of the lag effect was not in the scope of this study. We will consider it in the future work since it is a big question of this study.

Comment 4: In Line 132 of the text, it is mentioned that “the DUSMASS used in this study is averaged from June to July and May is neglected to weaken the disturbance of seasonal climatological differences”. Actually, it is very important to understand the difference of ENSO impact on the pre-monsoon and monsoon season dust activities. This should be moderately discussed in the manuscript.

Response: Thank you so much for this creative suggestion. It is true that there is difference of ENSO impact on the pre-monsoon and monsoon season dust activities. According to your suggestion, we analyzed the interdecadal change of the correlation between ENSO and pre-monsoon dust activities, to find that the correlations were all insignificant during each period without significant interdecadal change. Thus we added the following statement: “The dust activities analyzed in this study were from the dust season, i.e., Jun.–Jul., which were part of monsoon season (Jun.–Sep.) (Babu et al., 2013), however, the dust activities during pre-monsoon season (Mar.–May or Apr.–May) were also a hot topic (Babu et al., 2013; Lakshmi et al., 2017, 2019). Therefore, we analyzed the interdecadal change of the ENSO impact on DUCMASS during dust season (Jun.–Jul.) and pre-monsoon (Mar.–May or Apr.–May) separately, to find that the significant interdecadal change occurred only when the DUCMASS during dust season was considered. As for that during pre-monsoon season, there should be some other factors that influenced its interdecadal change, which will be discussed in the future study”. Considering that there is no more detail about the ENSO impact on pre-monsoon season dust activities, we added this statement into Sect. 4.3 rather than in a separate subsection.

Thank you again for your careful reading of our manuscript. We hope that the changes having been made to the manuscript meet to your satisfaction.

References:

Babu SS, Manoj MR, Moorthy KK, et al. Trends in aerosol optical depth over Indian region: Potential causes and impact indicators[J/OL]. Journal of Geophysical Research Atmospheres, 2013, 118(20): 11,794-11,806. DOI:10.1002/2013JD020507.

Cherchi A, Navarra A. Influence of ENSO and of the Indian Ocean Dipole on the Indian summer monsoon variability[J/OL]. Climate Dynamics, 2013, 41(1): 81-103. DOI:10.1007/s00382-012-1602-y.

Du Y, Xie SP, Huang G, et al. Role of air-sea interaction in the long persistence of El Niño-induced north Indian Ocean warming[J/OL]. Journal of Climate, 2009, 22(8): 2023-2038. DOI:10.1175/2008JCLI2590.1.

Lakshmi NB, Babu SS, Nair VS. Recent Regime Shifts in Mineral Dust Trends over South Asia from Long-Term CALIPSO Observations[J/OL]. IEEE Transactions on Geoscience and Remote Sensing, 2019, 57(7): 4485-4489. DOI:10.1109/TGRS.2019.2891338.

Lakshmi NB, Nair VS, Suresh Babu S. Vertical structure of aerosols and mineral dust over the Bay of Bengal from multisatellite observations[J/OL]. Journal of Geophysical Research: Atmospheres, 2017, 122(23): 12,845-12,861. DOI:10.1002/2017JD027643.

Tokinaga H, Richter I, Kosaka Y. ENSO Influence on the Atlantic Niño, Revisited: Multi-Year versus Single-Year ENSO Events[J]. Journal of Climate, 2019, 32(14): 4585-4600.