1 Response to Reviewer #1's comments

The manuscript by Thanh Le and Deg-Hyo Bae attempt to investigate the influences of El Niño Southern Oscillation (ENSO) on global dust activities by using the historical simulations of Global Climate Models (GCMs) from CMIP6 and developing the multivariate predictive model. The authors find that the ENSO displays significant impacts on dust deposition and transportation, while exhibits almost no impact on the dust emission of major dust sources. These findings emphasize the important role of ENSO in global dust activities. Overall, this paper is well written, and their findings exhibit promising potential for the predictions of future dust events. I would like to recommend an acceptation after these comments as follows are addressed.

Response: We thank the reviewer for your comments. We modified the manuscript based on your suggestions as below.

Major comments:

1.1 (1) To estimate the influences of ENSO on dust deposition, the authors selected the multivariate predictive model that has already considered the contribution of past dust deposition events and the confounding factors. In the multivariate predictive model, three factors, including Indian Ocean Dipole, Southern Annular Mode, and the North Atlantic Oscillation, have been considered as the major confounding factors that may display important roles in global dust deposition. However, the authors didn't elaborate on the reasons why they only selected the above three factors. I suggest the authors to provide sufficient justification for selecting the three factors to improve the reliability and robustness of the predictive model and their corresponding findings.

Response: We thank the reviewer for raising this point. We added the following sentences to Section 2.2 to explain the selection of the three factors Indian Ocean Dipole, Southern Annular Mode, and the North Atlantic Oscillation:

"The climate modes SAM, the IOD and the NAO are the important sources of global climate variability (Hurrell et al., 2003; Luo et al., 2012; Roxy et al., 2015). For instance, the NAO is the prominent mode of atmospheric circulation variability over the North Atlantic and surrounding regions (Delworth et al., 2016; Hurrell et al., 2003) and variations in NAO are crucial for the environment and society (Hurrell et al., 2003). The IOD affects climate extremes over the Indian Ocean and surrounding areas (Abram et al., 2008; Kripalani et al., 2009; Kripalani and Kulkarni, 1997) and might cause severe economic consequences (Ummenhofer et al., 2009). The SAM is the major mode of atmospheric circulation variability in the southern Hemisphere (Cai et al., 2011; Raphael and Holland, 2006). In addition, changes in these modes may affect the variations of ENSO (Abram et al., 2020; Cai et al., 2011, 2019; Le et al., 2020; Le and Bae, 2019). Nevertheless, it is likely that these factors may alter the influences of ENSO on dust activities."

1.2 (2) In Tables S1, a total of 12 global climate models (GCMs) from the Coupled Model Intercomparison Project Phase 6 (CMIP6) are selected to estimate the influences of ENSO on dust deposition. However, I cannot find the criteria for selecting these GCMs which are generally required for a scientifically sound paper. In addition, three models and one model in Table S2 cannot provide the od550dust and emidust, respectively. Why were these models kept instead of eliminating them?

Response: We thank the reviewer for raising this point. We selected all the models with accessible dust deposition data. Considering the total models is somewhat low (i.e., 12 models), we kept all these models. To our knowledge, dry and wet deposition of dust are key variables which directly affect local environment, thus we selected all models having these data.

We add the following sentences to Section 2.1 to clarify this point:

"We limited our study to all the models having both dry dust and wet dust data (i.e., there is total of 12 models with accessible dry dust and wet dust data as described in Table S2). Dust deposition on land and ocean surface are important metrics to assess the impacts of dust activities on ecosystems and environment (Bao et al., 2017; Fan et al., 2006; Jickells et al., 2005; Jiménez et al., 2018; Kanakidou et al., 2018; Schulz et al., 2012). Additional data of od550dust and emidust supplied by these 12 models provide further understanding of ENSO impacts on dust activities."

1.3 (3) In the Discussion part, the authors listed the possible reasons for the influences of ENSO on the dust deposition. In my opinion, ENSO also plays significant role in modulating the atmospheric circulation patterns that could substantially affect the spatial pattern of dust deposition. I think that it will be very interesting if the authors could discuss some impacts of atmospheric circulation patterns induced by ENSO on the dust deposition and transportation.

Response: We thank the reviewer for this suggestion. We added the following sentences to the Section 4 Discussion as below:

"As dust particles might be carried by winds between different regions (Guo et al., 2017; Yang et al., 2017), the influences of ENSO on global atmospheric circulation and rainfall (Yeh et al., 2018) lead to ENSO-induced changes in spatial pattern of dust deposition. For example, ENSO impacts on winds and precipitation over the tropical Pacific (Dai and Wigley, 2000; Le and Bae, 2020) contribute to the causal effects of ENSO on dry and wet dust deposition over this region (Figure 1). In addition, ENSO atmospheric teleconnections over Australia, North and South Americas (Ashok et al., 2007; Garfinkel et al., 2013; Taschetto and England, 2009; Yu and Zou, 2013) play an important role on dust deposition in these regions (Figure 1)."

1.4 (4) The two paragraphs in the section of Methods have only one sentence, I thus suggest the authors to combine them into one paragraph.

Response: We thank the reviewer for this suggestion. These two paragraphs are reorganized. In addition, we moved part of the supplementary to Section 2.2 to further clarify the Methods used in this study:

"We use the following multivariate predictive model (Mosedale et al., 2006; Stern and Kaufmann, 2013) to estimate the causal links between the ENSO and dust deposition:

$$\boldsymbol{X_t = \sum_{i=1}^{p} \alpha_i X_{t-i} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{m} \sum_{i=1}^{p} \delta_{j,i} Z_{j,t-i} + \varepsilon_t} \quad (1)$$

where X_t is the annual mean (or seasonal mean) dust deposition for year t, Y_t is the ENSO index, and $Z_{j,t}$ is the confounding factor j for year t. In the predictive model presented in equation 1, while assessing the effect of Y on X (i.e., the contribution of the term $\sum_{i=1}^{p} \beta_i Y_{t-i}$ in predicting X), the possible influence of past X events are considered by adding the term $\sum_{i=1}^{p} \alpha_i X_{t-i}$. Thus, the causal influence of Y on X, if detected, is robust and the impact of past X events are accounted in the analyses. Here, m is the number of confounding factors and $p \geq 1$ is the order of the multivariate predictive model. The optimal order p is computed by minimizing the Schwarz criterion or the Bayesian information criterion (Schwarz, 1978). The optimal orders may be different for each model.

Here we take into account the impacts of confounding factors and therefore provide further information of the real-world teleconnections. In the analyses, we use three different confounding factors; hence, m is equal to 3. The noise residuals ε_t and the regression coefficients α_i, β_i and $\delta_{j,i}$

are computed by using the multiple linear regression analysis of the least squares method. We detrend and normalize all the climate indices."

Specific comments:

1.5 L24: "feedback" can be revised to "feed back"

Response: We thank the reviewer for pointing this out. We corrected to "have impacts" to avoid confusing the readers.

1.6 L32: Some important references can be cited here to strengthen the statement concerning the role of dust on environment, including https://doi.org/10.1029/97JD00260; https://doi.org/10.1016/j.atmosenv.2017.07.036; https://doi.org/10.1029/2019JD030758

Response: We thank the reviewer for this suggestion. We included these references to line 32 and other places in the Introduction:

"…and environments (Guo et al., 2017; Li et al., 2019; Perry et al., 1997; Xu et al., 2017; Zhang et al., 2018)."

1.7 L40: "earth" -> "Earth"

Response: We corrected as your suggestion.

1.8 L46-47: what is the difference

Response: We thank the reviewer for raising this point. We further clarify the role of other modes on the linkage between ENSO and global dust activities in Section 2.2 as below:

"In the analyses, we investigated the confounding effects of other main climate modes (i.e., the SAM (e.g., Cai et al., 2011), the IOD (Saji et al., 1999; Webster et al., 1999), and the NAO (Hurrell et al., 2003)) on the links of ENSO and dust activities. The climate modes SAM, the IOD and the NAO are the important sources of global climate variability (Hurrell et al., 2003; Luo et al., 2012; Roxy et al., 2015). For instance, the NAO is the prominent mode of atmospheric circulation variability over the North Atlantic and surrounding regions (Delworth et al., 2016; Hurrell et al., 2003) and variations in NAO are crucial for the environment and society (Hurrell et al., 2003). The IOD affects climate extremes over the Indian Ocean and surrounding areas (Abram et al., 2008; Kripalani et al., 2009; Kripalani and Kulkarni, 1997) and might cause severe economic consequences (Ummenhofer et al., 2009). The SAM is the major mode of atmospheric circulation variability in the southern Hemisphere (Cai et al., 2011; Raphael and Holland, 2006). In addition, changes in these modes may affect the variations of ENSO (Abram et al., 2020; Cai et al., 2011, 2019; Le et al., 2020; Le and Bae, 2019). Nevertheless, it is likely that these factors may alter the influences of ENSO on dust activities."

1.9 L116: "original"-> "originated"

Response: We corrected as your suggestion.

1.10 Lines 44-46 of the Supplement, this paragraph only has one sentence. I suggest the authors to combine Lines 44-51 into one paragraph.

Response: We combined the lines 44-51 (Supplement) into one paragraph as your suggestion.

2 Response to Reviewer #2's comments

This paper aims to investigate the effect of ENSO on global dust emissions, concentration, and deposition. A multivariate predictive model and the Ganger causality test were used to analyze dust-relevant output from 12 CMIP6 models.

General Comments

A major and critical shortcoming of this paper, in current form, is the lack of detailed presentation of methodology, results, and discussion. The paper seems to be written hastily.

Response: We thank the reviewer for your comments. We agree with the reviewer that some parts of the manuscript need improvement. We modified the manuscript based on your suggestions as below.

2.1 Methodology: Authors only provide a few lines about their approach, and refer readers to their previous works and the supplementary document. However, a brief description of the method should be presented in this section.

Response: We thank the reviewer for raising this point. We moved part of the supplementary to Section 2.2 to further clarify the Methods used in this study as follows:

"We use the following multivariate predictive model (Mosedale et al., 2006; Stern and Kaufmann, 2013) to estimate the causal links between the ENSO and dust deposition:

$$X_t = \sum_{i=1}^{p} \alpha_i X_{t-i} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{m} \sum_{i=1}^{p} \delta_{j,i} Z_{j,t-i} + \varepsilon_t \quad (2)$$

where X_t is the annual mean (or seasonal mean) dust deposition for year t, Y_t is the ENSO index, and $Z_{j,t}$ is the confounding factor j for year t. In the predictive model presented in equation 1, while assessing the effect of Y on X (i.e., the contribution of the term $\sum_{i=1}^{p} \beta_i Y_{t-i}$ in predicting X), the possible influence of past X events are considered by adding the term $\sum_{i=1}^{p} \alpha_i X_{t-i}$. Thus, the causal influence of Y on X, if detected, is robust and the impact of past X events are accounted in the analyses. Here, m is the number of confounding factors and $p \geq 1$ is the order of the multivariate predictive model. The optimal order p is computed by minimizing the Schwarz criterion or the Bayesian information criterion (Schwarz, 1978). The optimal orders may be different for each model.

Here we take into account the impacts of confounding factors and therefore provide further information of the real-world teleconnections. In the analyses, we use three different confounding factors; hence, m is equal to 3. The noise residuals ε_t and the regression coefficients α_i, β_i and $\delta_{j,i}$ are computed by using the multiple linear regression analysis of the least squares method. We detrend and normalize all the climate indices."

2.2 Additionally, authors stated that they studied confounding effects of other climates modes, namely NAO, SAM, and IOD. First, what is the basis for choosing these modes(?), and second, no analysis or sensitivity test regarding this treatment was provided.

Response: We thank the reviewer for raising this point. We added the following sentences to Section 2.2 to explain the selection of the three factors Indian Ocean Dipole, Southern Annular Mode, and the North Atlantic Oscillation:

"The climate modes SAM, the IOD and the NAO are the important sources of global climate variability (Hurrell et al., 2003; Luo et al., 2012; Roxy et al., 2015). For instance, the NAO is the prominent mode of atmospheric circulation variability over the North Atlantic and surrounding regions (Delworth et al., 2016; Hurrell et al., 2003) and variations in NAO are crucial for the environment and society (Hurrell et al., 2003). The IOD affects climate extremes over the Indian Ocean and surrounding areas (Abram et al., 2008; Kripalani et al., 2009; Kripalani and Kulkarni, 1997) and might cause severe economic consequences (Ummenhofer et al., 2009). The SAM is the major mode of atmospheric circulation variability in the southern Hemisphere (Cai et al., 2011; Raphael and Holland, 2006). In addition, changes in these modes may affect the variations of

ENSO (Abram et al., 2020; Cai et al., 2011, 2019; Le et al., 2020; Le and Bae, 2019). Nevertheless, it is likely that these factors may alter the influences of ENSO on dust activities."

2.3 Finally, what is the basis for choosing these 12 models as data crucial for these analyses are missing in three of them (table S2)?

Response: We thank the reviewer for raising this point. We selected all the models with accessible dust-related data. Considering the total models is somewhat low (i.e., 12 models), we kept all these models. To our knowledge, dry and wet deposition of dust are key variables which directly affect local environment, thus we selected all models having these data.

We add the following sentences to Section 2.1 to clarify this point:

"We limited our study to all the models having both dry dust and wet dust data (i.e., there is total of 12 models with accessible dry dust and wet dust data as described in Table S2). Dust deposition on land and ocean surface are important metrics to assess the impacts of dust activities on ecosystems and environment (Bao et al., 2017; Fan et al., 2006; Jickells et al., 2005; Jiménez et al., 2018; Kanakidou et al., 2018; Schulz et al., 2012). Additional data of od550dust and emidust supplied by these 12 models provide further understanding of ENSO impacts on dust activities."

2.4 Results and Discussion: Results were presented and discussed in a highly qualitative manner without any in-depth analysis as required in a manuscript with an archival value. Authors only reported the fraction of total "affected area" over ocean and land, but this number alone is not useful in understanding the true impact of ENSO on dust activities in different regions of the globe.

Response: We thank the reviewer for raising this point. The "affected area" provide important information on the scale of ENSO impacts. The purpose of this work is to provide simple and robust conclusions about the causal effects of ENSO on global dust activities. To our knowledge, these analyses are lacking, and the results described here have not been shown before. We should note that we also provided information on the impacts of ENSO on dust activities at regional scale, as well as the consistency between models in simulating the connection between ENSO and dust activities.

2.5 As expected, individual models show drastically different results (figures 4-6), but conclusions of the paper were based only on the ensemble mean results with minimal discussion about the difference between models. Note that the chosen models use different dust emissions and deposition, as well as dust size partitioning schemes, so ensemble mean results must be interpreted with caution.

Response: We thank the reviewer for raising this point. The use of ensemble mean is widely used and is expected to reduce the uncertainty related to the connection between ENSO and dust activities. In fact, despite using different aerosol model, there is high agreement (i.e., denoted by stippling in Figures 1 and 2) between models for the results. Our conclusions are mainly based on this high consistency.

We partly discussed the difference between models in Section 4 as below:

"Regarding the consistency across models, the response of dust emission to ENSO is much stronger in the models INM-CM5-0, MIROC-ES2L, and UKESM1_0_LL compared to other models (Figure 6). This difference might be due to the use of different dust schemes and soil properties in this model which lead to higher dust emissions (Mulcahy et al., 2020; Zhao et al., 2022). As models use different parameters to estimate dust emissions (Thornhill et al., 2020), this discrepancy leads to low consensus across models in modeling the response of dust emissions to ENSO (Figures 3 and 6)."

2.6 Finally, several conclusions of the work are not supported by the current results, for example, "ENSO may initiate dust activities in …. (line 93)", "dust deposited in the South Pacific and the Southern Ocean might be originated from central Australia and southern South America (line 117)", "weak causal impacts of ENSO on regional dust emissions of major dust sources (Figure 3) may indicate the important role of human influences in igniting local dust activities… (line 132)".

Response: We thank the reviewer for raising this point. We removed the lines 93 and 117 to avoid confusing the readers.

We rewrote line 132 as this line serves as a discussion rather than a conclusion as below:

"Substantial influences of ENSO on dust emission over central Australia (Figure 3) suggest an agreement with earlier work (Marx et al., 2009), while we observe weak causal impacts of ENSO on regional dust emissions of major dust sources (Figure 3)."

"Previous studies indicate the important role of human influences in igniting local dust activities (Duniway et al., 2019; Webb and Pierre, 2018)."

Specific Comments

2.7 Line 15 and all other places through the manuscript: Caution must be practiced with the term "concentration" as the relationship between dust concentration and dust AOD depends on the pre-defined and assumed dust particle size distribution, which is different in different models.

Response: We thank the reviewer for raising this point. We removed the term "concentration" to avoid confusing the readers.

2.8 Line 15 and all other places through the manuscript: Change "transportation" to "transport"

Response: We thank the reviewer for raising this point. We corrected as your suggestion.

2.9 Line 57: "Dry and wet deposition is related to different types of dust and aerosol." Not clear what authors mean here.

Response: We thank the reviewer for raising this point. We removed this sentence to avoid confusing the readers.

2.10 Line 82: How are "areas affected by ENSO" defined? What are the criteria considerd?

Response: We thank the reviewer for raising this point. We added the following sentence to clarify the criteria for computing the areas affected by ENSO:

"In Figure 2b, the areas influenced by ENSO are computed as the areas limited by the cyan contour line as shown in Figures 1 and 2a (i.e., *p*-value is lower than 0.33 or ENSO is unlikely to exhibit no causal effects on dust activities over these regions)."

2.11 Line 116: Change "original" to "originated"

Response: We corrected as your suggestion.

2.12 Figure 1: What is the significance of studying dry and wet deposition separately in figure 1, as paper provides no insightful comparison between the two?

Response: We thank the reviewer for raising this point. As we introduced in Section 2.1, dry and wet deposition are related to different processes of dust deposition. Hence, direct comparison is not necessary. We combined the results in 1 Figure as these dust deposition processes are complementing for each other.

2.13 Figure 2(b) and S2: There two figures don't provide any addition information beyond just one number mentioned in the text, so they should be removed.

Response: We thank the reviewer for raising this point. We think these Figures provide quick summary and illustration for the Text. Hence, we would like to keep these Figures.

2.14 Table S1 and S2: Should be merged into one table

Response: We thank the reviewer for this suggestion. We would like to keep these Tables separately to avoid a too big Table. It would make the presentation easier.

2.15 The following recent publication might be of interest to the authors: https://acp.copernicus.org/articles/22/2095/2022/

Response: We thank the reviewer for this suggestion. We include this publication as a reference.

3 Response to Reviewer #3's comments

The paper presents an analysis on the influence of the El Niño–Southern Oscillation (ENSO) on the global dust activities (emission, concentration and transportation and dry and wet deposition) based on CMIP6 historical simulations. The manuscript is structured and concise and the topic is of scientific interest, therefore I would encourage publication provided that the following point are addressed:

Response: We thank the reviewer for your comments. We modified the manuscript based on your suggestions as below.

General comments:

3.1 Among the key results that are emphasized by the manuscript (abstract included) there is the suggestion of the role of human activity in the intensity of dust emission as a consequence of a lack of clear causal impact of ENSO on dust availability. This point does not seem to be clearly explained, nor properly supported in the discussion. Also, it is not clear why is the human activity the only other possible factor considered when finding a weak role of ENSO in regional dust emissions over major dust sources.

Response: We thank the reviewer for raising this point. We agree that the role of human activity on global dust activities is not supported by the results of this manuscript. This discussion is only the inference of the main results as shown in Figures 3 and 6. We removed this conclusion in the abstract to avoid confusing the readers. We also rewrote this discussion in Section 4.

3.2 Lines 35-38 list a series of references mentioning studies who observed the ENSO influences on dust activities but only one of them is then compared with the results of the manuscript itself (Marx et al 2009) regarding the emission over Australia. The reader is left questioning if there is any other agreement/disagreement with the previous studies.

Response: We thank the reviewer for raising this point. We added the following sentences to Section 4 Discussion to further discuss our results in relation with previous works as below:

"The causal impacts of ENSO on dust deposition over South America (Figure 1) are consistent with previous studies (Boy and Wilcke, 2008; Shao et al., 2013). Figures 1 and 2 show an agreement with recent works for the potential influences of ENSO on dust activities over regions from Arabian Peninsula to Central Asia (Huang et al., 2021) and East Asia (Jeong et al., 2018)."

3.3 The methodology section is way too brief and not explicative, totally referring to the text S1 of the supplementary. I would encourage to better explain the methods and/or move part of the supplementary in this section.

Response: We thank the reviewer for this suggestion. We moved part of the supplementary to Section 2.2 as below:

"We use the following multivariate predictive model (Mosedale et al., 2006; Stern and Kaufmann, 2013) to estimate the causal links between the ENSO and dust deposition:

$$\boldsymbol{X_t = \sum_{i=1}^{p} \alpha_i X_{t-i} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{m} \sum_{i=1}^{p} \delta_{j,i} Z_{j,t-i} + \varepsilon_t} \quad (3)$$

where X_t is the annual mean (or seasonal mean) dust deposition for year t, Y_t is the ENSO index, and $Z_{j,t}$ is the confounding factor j for year t. In the predictive model presented in equation 1, while assessing the effect of Y on X (i.e., the contribution of the term $\sum_{i=1}^{p} \beta_i Y_{t-i}$ in predicting X), the possible influence of past X events are considered by adding the term $\sum_{i=1}^{p} \alpha_i X_{t-i}$. Thus, the causal influence of Y on X, if detected, is robust and the impact of past X events are accounted in the analyses. Here, m is the number of confounding factors and $p \geq 1$ is the order of the multivariate predictive model. The optimal order p is computed by minimizing the Schwarz criterion or the

Bayesian information criterion (Schwarz, 1978). The optimal orders may be different for each model.

Here we take into account the impacts of confounding factors and therefore provide further information of the real-world teleconnections. In the analyses, we use three different confounding factors; hence, *m* is equal to 3. The noise residuals ε_t and the regression coefficients α_i, β_i and $\delta_{j,i}$ are computed by using the multiple linear regression analysis of the least squares method. We detrend and normalize all the climate indices."

3.4 I was wondering also if there is any way to mention how significant is the ENSO variation on dust activities with respect to the total global dust activity, for example the AOD variation due to ENSO with respect to the global AOD average.

Response: We thank the reviewer for raising this point. We agree that we could compute the significance of ENSO impacts on global mean AOD. While this single indicator is useful, it is however too general and might confusing the readers as ENSO impacts are dependent on specific region. In our opinion, the maps of ENSO impacts shown in Figure 2a might provide better illustration and details. For this reason, we have not tried to estimate the impacts of ENSO on global mean AOD.

Specific comments:

3.5 Lines 68-70: The authors mention the "confounding influence" of SAM, IOD and NAO but should explain at least briefly why and how those modes can be relevant on their study.

Response: We thank the reviewer for raising this point. We added the following sentences to Section 2.2 to explain the selection of the three factors Indian Ocean Dipole, Southern Annular Mode, and the North Atlantic Oscillation:

"The climate modes SAM, the IOD and the NAO are the important sources of global climate variability (Hurrell et al., 2003; Luo et al., 2012; Roxy et al., 2015). For instance, the NAO is the prominent mode of atmospheric circulation variability over the North Atlantic and surrounding regions (Delworth et al., 2016; Hurrell et al., 2003) and variations in NAO are crucial for the environment and society (Hurrell et al., 2003). The IOD affects climate extremes over the Indian Ocean and surrounding areas (Abram et al., 2008; Kripalani et al., 2009; Kripalani and Kulkarni, 1997) and might cause severe economic consequences (Ummenhofer et al., 2009). The SAM is the major mode of atmospheric circulation variability in the southern Hemisphere (Cai et al., 2011; Raphael and Holland, 2006). In addition, changes in these modes may affect the variations of ENSO (Abram et al., 2020; Cai et al., 2011, 2019; Le et al., 2020; Le and Bae, 2019). Nevertheless, it is likely that these factors may alter the influences of ENSO on dust activities."

3.6 Lines 80-91: I do not understand the choice of using the "total earth surface" percentage quantity as a parameter. Especially, this does not make much sense to me when dividing the study on land areas and ocean areas. It would already give more information by dividing in % of total ocean surface when considering ocean areas, and % of total land surface when considering land.

Response: We thank the reviewer for raising this point. We think choosing only one parameter "total earth surface" may reduce the confusion. In addition, we may convert the areas between "total earth surface", "total land areas" and "total oceans areas" (i.e., "total land areas" is approximately 29.2% of "total earth surface" and "total ocean areas" is approximately 70.8% of "total earth surface").

We modified these sentences to clarify this point as your suggestion:

"Over oceans, the areas affected by ENSO are estimated at approximately 17.6%, 32.3%, and 20.7% of total earth surface (i.e., 24.9%, 45.6% and 29.2% of total ocean areas) for deposition of dry dust, dust aerosol optical depth, and deposition of wet dust, respectively (Figure 2b). The land areas affected by ENSO are estimated at approximately 5.1%, 7.5%, and 6.8% of the total earth surface (i.e., 17.5%, 25.7% and 23.3% of total land areas) for deposition of dry dust, dust aerosol optical depth, and deposition of wet dust, respectively (Figure 2b).

The causal effects of ENSO on seasonal mean dry dust deposition are shown in Figure S1. The largest impacts of winter (DJF) ENSO are observed in the following spring (MAM), with approximately 3.4% of total earth surface over land (i.e., 11.6% of total land areas) and approximately 16% of total earth surface over the ocean (i.e., 22.6% of total ocean areas) are affected (Figure S2). The impacts of ENSO on dry dust deposition gradually decrease in the following summer, fall, and winter (Figures S1 and S2). In particular, the influences of ENSO on winter dry dust deposition are mainly limited in Antarctica (approximately 0.5% of total earth surface or 1.7% of total land areas) and the tropical Pacific (approximately 0.7% of total earth surface or 1% of total ocean areas)."

3.7 Section 3.2: The authors should explain why there are a different number of models compared for the different cases (12 models for the ENSO effect on dry deposition, 9 for the aerosol optical depth, 11 for the dust emission)

Response: We thank the reviewer for raising this point. We selected all the models with accessible dust deposition-related data. Considering the total models is somewhat low (i.e., 12 models), we kept all these models. Dry and wet deposition of dust are key variables which directly affect local environment, thus we selected all models having these data.

We add the following sentences to Section 2.1 to clarify this point:

"We limited our study to all the models having both dry dust and wet dust data (i.e., there is total of 12 models with accessible dry dust and wet dust data as described in Table S2). Dust deposition on land and ocean surface are important metrics to assess the impacts of dust activities on ecosystems and environment (Bao et al., 2017; Fan et al., 2006; Jickells et al., 2005; Jiménez et al., 2018; Kanakidou et al., 2018; Schulz et al., 2012). Additional data of od550dust and emidust supplied by these 12 models provide further understanding of ENSO impacts on dust activities."

3.8 Line 122: It would be worth to mention briefly what is meant by "marine productivity"

Response: We thank the reviewer for this suggestion. We clarify this sentence as below:

"Significant impacts of ENSO on atmospheric aerosol loading (Figures 2a and 5) may lead to a strong response of marine productivity (i.e., the production of organic matter in the ocean from carbon dioxide by phytoplankton) to ENSO. For example, there is strong correlation between aerosol optical depth and iron deposition and satellite chlorophyll (Carslaw et al., 2010; Jickells et al., 2005)."

3.9 Line 134-136: The paper mention before that there is little consensus of the models on the impact of ENSO on dust emissions. Would it be still possible to draw any relevant conclusion on the effect of ENSO on dust emissions, including the suggestion of the possible anthropogenic impact on dust emissions?

Response: We thank the reviewer for raising this point. We agree that there is still large uncertainty regarding the effect of ENSO on dust emissions and robust conclusion is not feasible. We added the following sentence to Section 4 to clarify this point:

"As the consistency between models is low (Figure 3), large uncertainties remain for the causal impacts of ENSO on dust emissions."

We agree that the role of human activity on global dust activities is not supported by the results of this manuscript. This discussion is the inference of the main results as shown in Figures 3 and 6. Here, we tried to discuss this point rather than drawing a conclusion. We rewrote this discussion to avoid confusing the readers.

We also added the following sentence to Section 4 to motivate further works:

"Hence, the impacts of human activities and changes in land use on regional dust emissions might be a topic of future works."

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