Response to Comments of Reviewer 1

Manuscript number: egusphere-2024-955

Author(s): Falei Xu, Shuang Wang, Yan Li, and Juan Feng

Title: Synergistic effects of previous winter NAO and ENSO on the spring dust activities in North China

General comments:

This study investigated the impacts of preceding boreal winter North Atlantic Oscillation (NAO) and El Niño-Southern Oscillation (ENSO) on the following spring dust activities over North China during 1980-2022. The authors demonstrated that the significant impacts of NAO and ENSO on the dust activities over North China is only manifested in the negative phases, and discussed the physical mechanism involved to illustrate why the negative phases of NAO and ENSO show a synergistic effect on the following dust events in North China. The message is conveyed clearly and the topic is interesting. The results of this study provide an insight to further understand the dust activities over North China. The conclusions are substantiated based on composite analyses. If published, this work could serve as a valuable reference for dust weather. However, it needs to be minor revised before accepted this paper for publication in ACP with addressing those comments listed below:

Response:

Thanks to the reviewer for the helpful comments and suggestions. We have revised the manuscript seriously and carefully according to the reviewer's comments and suggestions. The point-to-point responses to the comments are listed as follows.

Specific comments are as follows:

1. The NAO is a large-scale seesaw in atmospheric mass between the subtropical high and the polar low. It is the dominant mode of atmospheric circulation variability in the North Atlantic sector throughout the year. The definition of the NAO index derived using EOF is commonly employed to depict the variation of NAO. However, the SLP difference between 35°N and 65°N within the Atlantic section is used to define the NAO index. A full comparison of the NAO index is necessary to establish the robustness of result.

Response:

Thank you for the comments.

The NAO index (NAOI) employed in the manuscript, is defined as the differences of normalized sea level pressures regionally zonal-averaged over the North Atlantic sector (Li and Wang, 2003). The NAO index captures well large-scale circulation features of the NAO, and is essentially a measure of the intensity of zonal winds across the central North Atlantic between 35°N to 65°N. A systematic comparison of six NAO indices (Rogers, 1984; Barnston and Livezey, 1987; Moses et al., 1987; Hurrell, 1995; Jones et al.,1997; Li and Wang, 2003), shows that the NAOI employed in the manuscript provides a much more faithful and optimal representation of the spatial-temporal variability associated with the NAO, suggesting the NAOI maybe as a suitable choice for describing and monitoring variability of the broad-scale NAO and for diagnosing relationships between the NAO and global climate variations (Li and Wang, 2003).

We also employ the NAOI produce by Hurrell (1995) and Jones (1997), which have been used in many studies (e.g., Wang et al.,2022; Najibi et al., 2023; Parry et al., 2023), for correlation analysis with the NAOI used in this manuscript. A good agreement with correlation coefficients of 0.96 and 0.94 between these two indices and the NAOI used in this manuscript (Figure R1). As well as, using the NAOI provided by Hurrell (1995) and Jones (1997), the asymmetric impact and the synergistic effects with ENSO on dust activities over North China of NAOI still remain (Figures R2-R4). Therefore, the robustness of the results will not be affected by the NAOI verified by above process. We have added the description into the revised manuscript, as “And we use the NAOI provided by Hurrell (1995) and Jones (1997), which have been used in many studies (e.g., Wang et al.,2022; Najibi et al., 2023; Parry et al., 2023), for correlation analysis with the NAOI used in this work and find a good agreement with a correlation coefficient of 0.96 and 0.94. As well as, using the NAOI provided by Hurrell (1995) and Jones (1997), the asymmetric impact and the synergistic effects with ENSO on dust activities over North China of NAO still remain (figure not shown). This point indicates that the result would not be affected by choice of NAOI”, as shown in Lines 152-154.

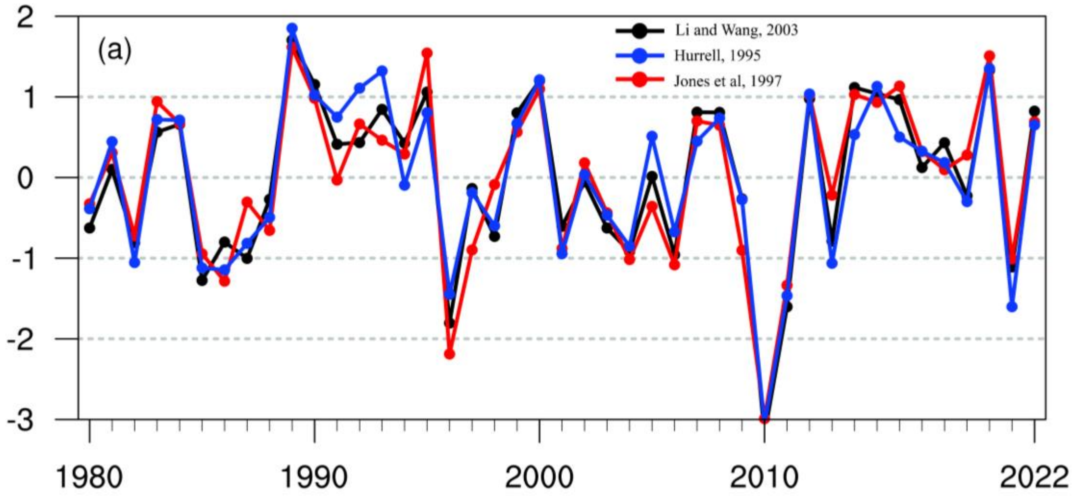

Figure R1. (a) The winter NAOI used in the manuscript (black line) and provided by Hurrell (blue line) and Jones (red line) during 1980-2022.

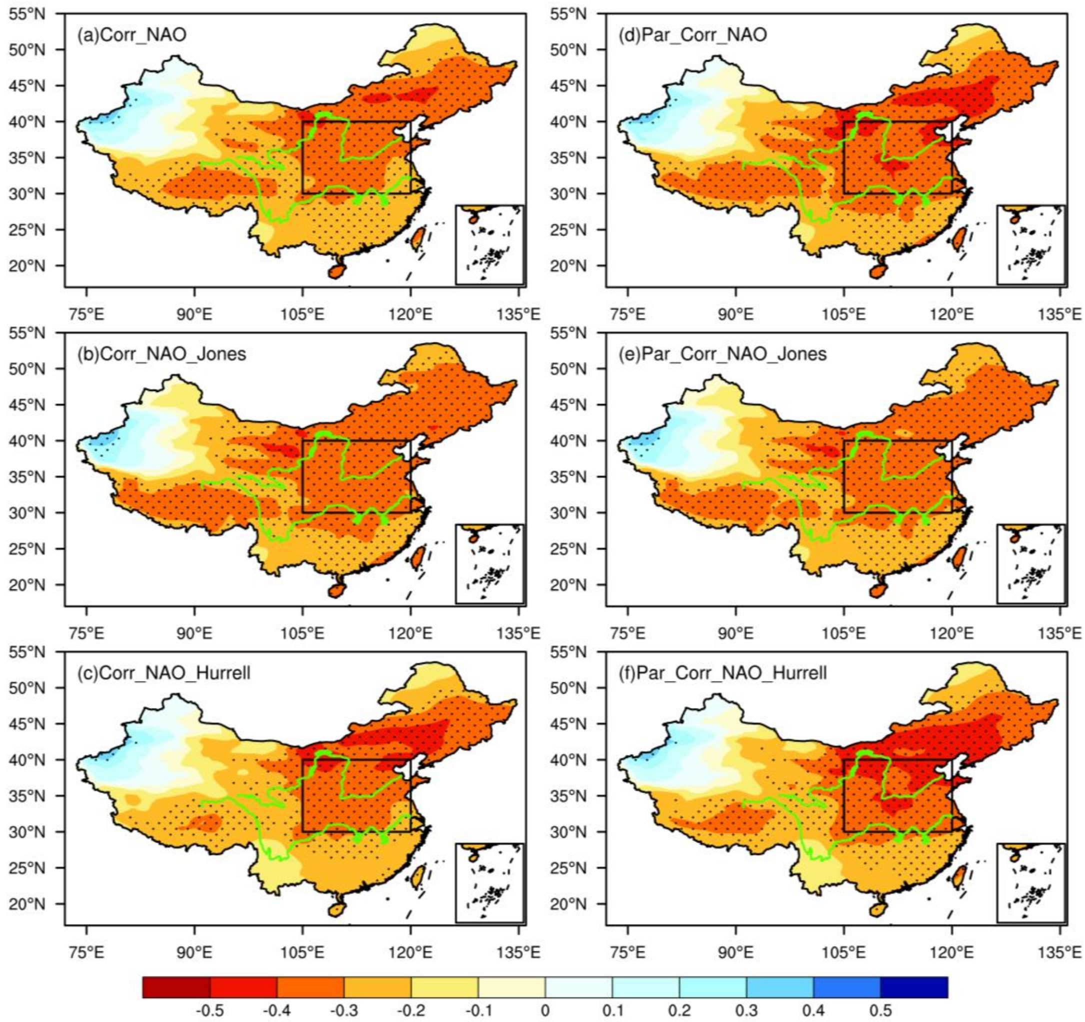

Figure R2. Spatial distribution of correlation coefficients between the previous winter NAOI and spring dust content (a). (b-c) As in (a), but for the NAOI produce by Jones and Hurrell, respectively. (d-f) As in (a-c), but for the partial correlation after removing the effect of ENSO. The black box represents North China. Stippled areas are statistically significant at the 0.1 level.

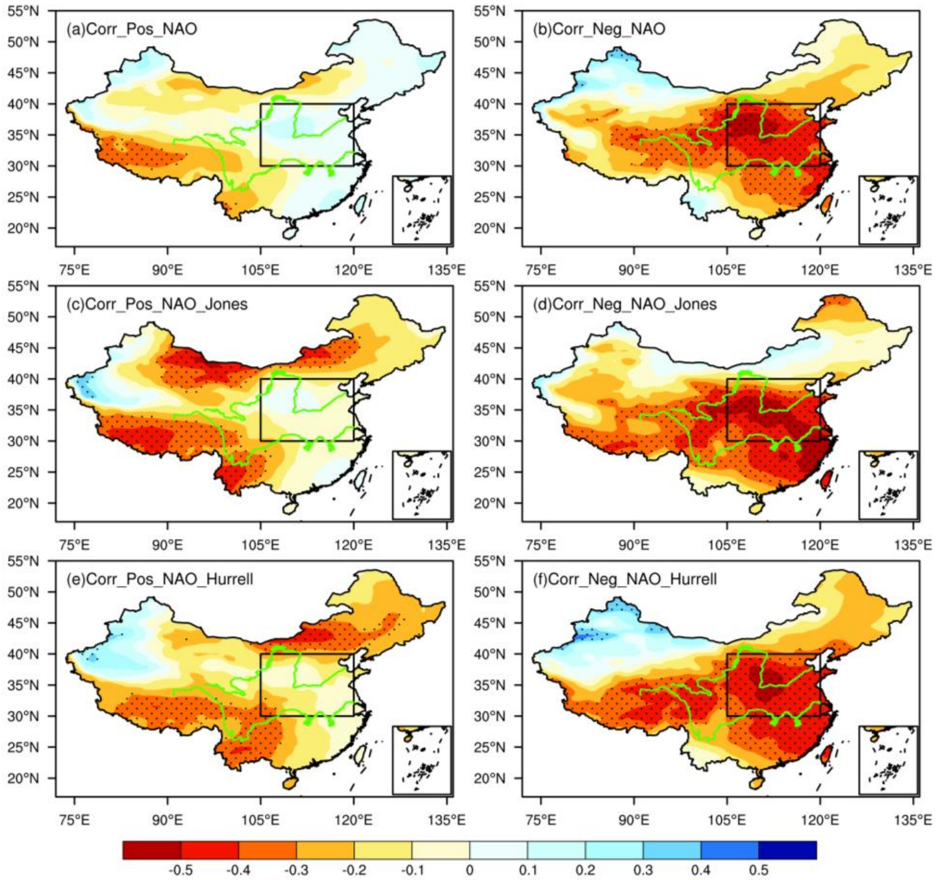

Figure R3. Spatial distribution of correlation coefficients between (a) positive and (b) negative NAOI values and dust content. (c-d) and (e-f), As in (a-b), but for the NAOI produce by Jones and Hurrell, respectively. The black box represents North China. Stippled areas are statistically significant at the 0.2 level.

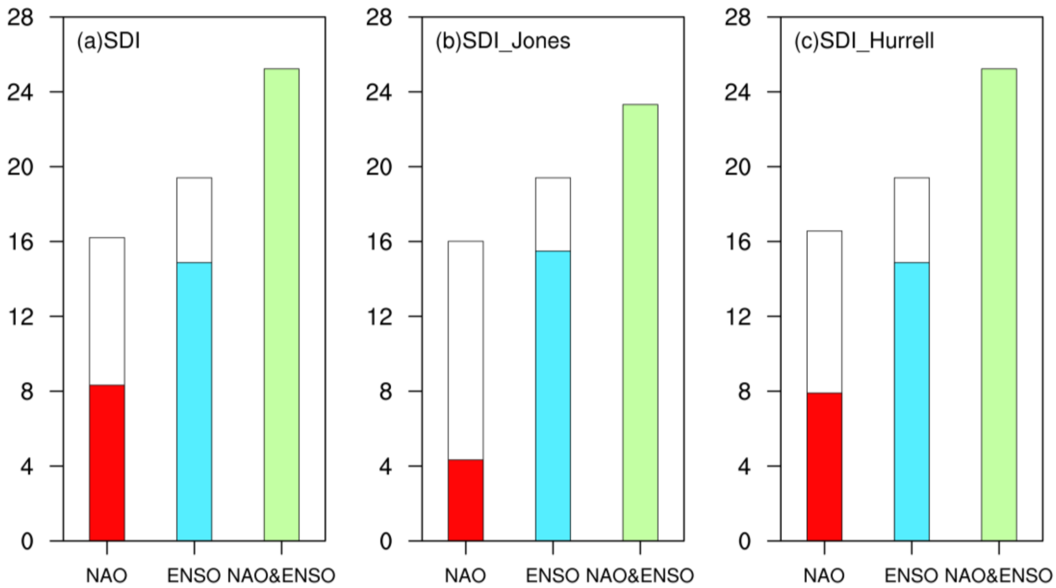

Figure R4. Spring dust content over North China during the negative NAO, negative ENSO phases, and concurrent negative phases of NAO and ENSO. Transparent bars represent negative phases of the NAO and ENSO, filled bars indicate negative phases of the NAO and ENSO occurring separately and co- occurring (a). (b-c) As in (a), but for the NAOI produce by Jones and Hurrell, respectively (unit: mg m^{-2}).

2. The authors focus on the relationship between preceding winter NAO and ENSO and dust weather in late spring. The introduction mentions that "the impacts of winter NAO and ENSO on the climate in China is more pronounced" by citing results from previous work. However, it is unclear whether the cross-seasonal impacts also apply when exploring the relationship between NAO, ENSO and dust weather in North China. Therefore, it would be better to provide some references to explain why we should investigate the impacts of previous winter of NAO and ENSO on spring dust weather.

Response:

Thank you for the comments.

The standard deviation of the NAO peaks during December, January, February, and March. By analyzing the trend of the three-month average standard deviation, we observe that it is highest during the preceding winter. This indicates that the NAO exhibits stronger variability in boreal winter compared to other seasons (Figure R5 a). Similarly, ENSO also shows greater variation during boreal winter (Figure R5 b). Based on these findings, we have chosen to focus on the relationship between NAO, ENSO during the previous winter period, and spring dust activities over North China.

Previous studies have found that previous NAO and ENSO play important role in impacting the following climate over North China, particular the cross-seasonal impacts (e.g., Zheng et al., 2016; Feng et al., 2019; Sun et al., 2021). We have examined the role of previous autumn, winter and simultaneous spring NAO and ENSO on the spring dust aerosols over North China, and it is found the influences of NAO and ENSO on the spring dust aerosols are most significant in the previous winter (Figure R5 c-h). Thus, the role of previous winter NAO and ENSO on the spring dust aerosols over North China are discussed in the present work.

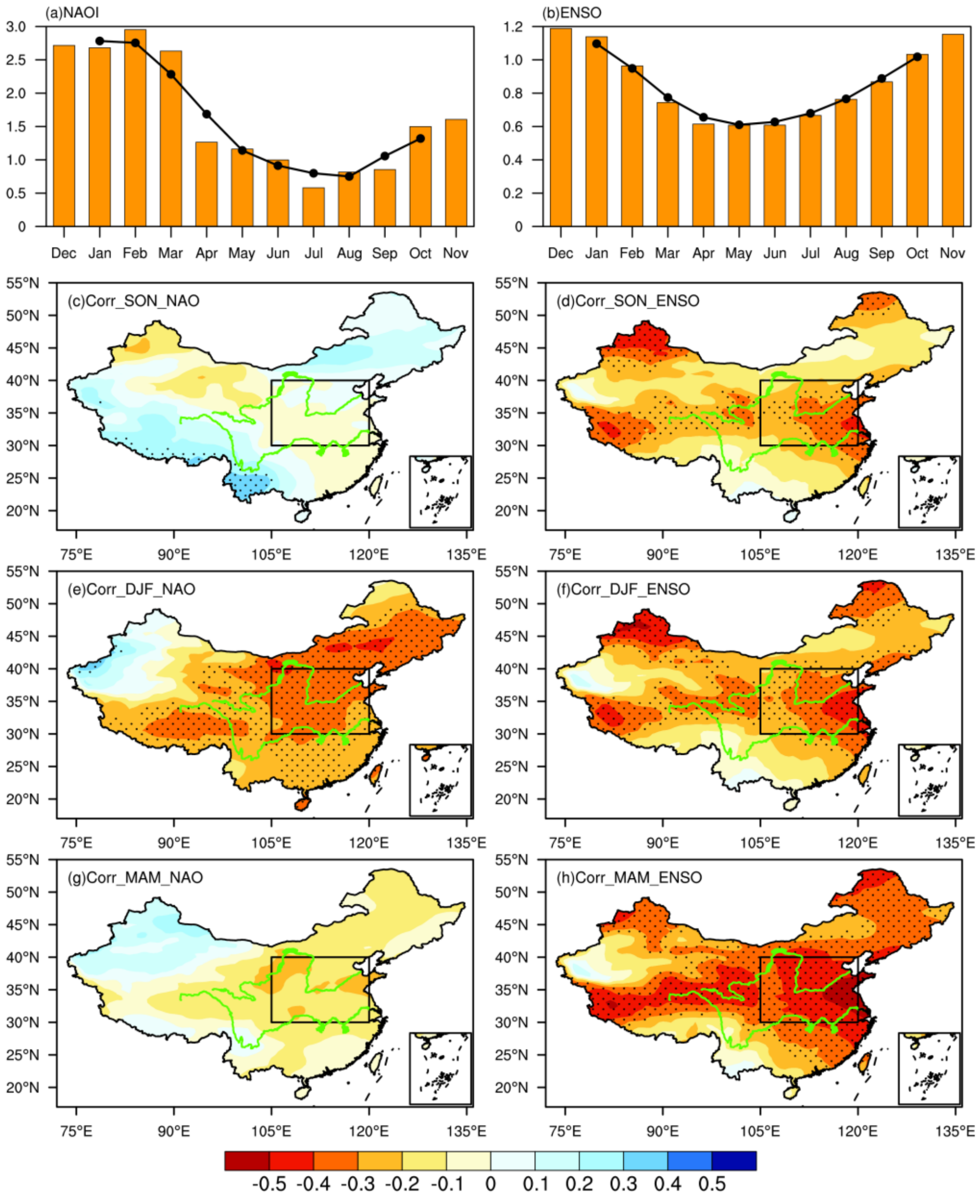

Figure R5. The monthly standard deviation of the (a) NAOI and (b) Ni ño3.4 index, respectively. Black line represents the trend of the three-month average standard deviation. Spatial distribution of correlation coefficients between the previous autumn NAOI and spring dust content (c). (d) As in (c), but with Ni ño3.4 index. (e-f) and (g-h), As in (c-d), but for the previous winter and simultaneous spring NAOI and Ni ño3.4 index. The black box represents North China. Stippled areas are statistically significant at the 0.1 level.

3. In the paper, the authors primarily discuss the effect of NAO and ENSO negative phases on the dust activities over North China. However, given the various phases combinations between these two factors, a more detailed explanation as to why only the negative-negative combinations are considered.

Response:

Thank you for the comments.

As shown in Fig. 2 of the manuscript, we have examined the role of different phases of NAO and ENSO on the dust aerosols over North China, and it is found the influences of the positive phases of NAO and ENSO on the dust aerosols are insignificant. “The results indicate that the relationship between NAO/ENSO and dust in North China also exhibits significant asymmetry, i.e., with weaker (stronger) correlations during positive (negative) phases of NAO and ENSO, where significant correlations only appear in the negative phases of NAO and ENSO” (Lines 216-219 in the revised manuscript).

The correlation coefficients between previous winter NAO, ENSO and spring dust aerosol content over North China under different phases are given in Table R1. It further explains that the influence of the negative phases of NAO and ENSO on the dust activities over North China is more significant than when they are in the positive phases. Based on the above discussion, we considered the effect of NAO and ENSO on dust aerosols over North China when they are in the negative phases.

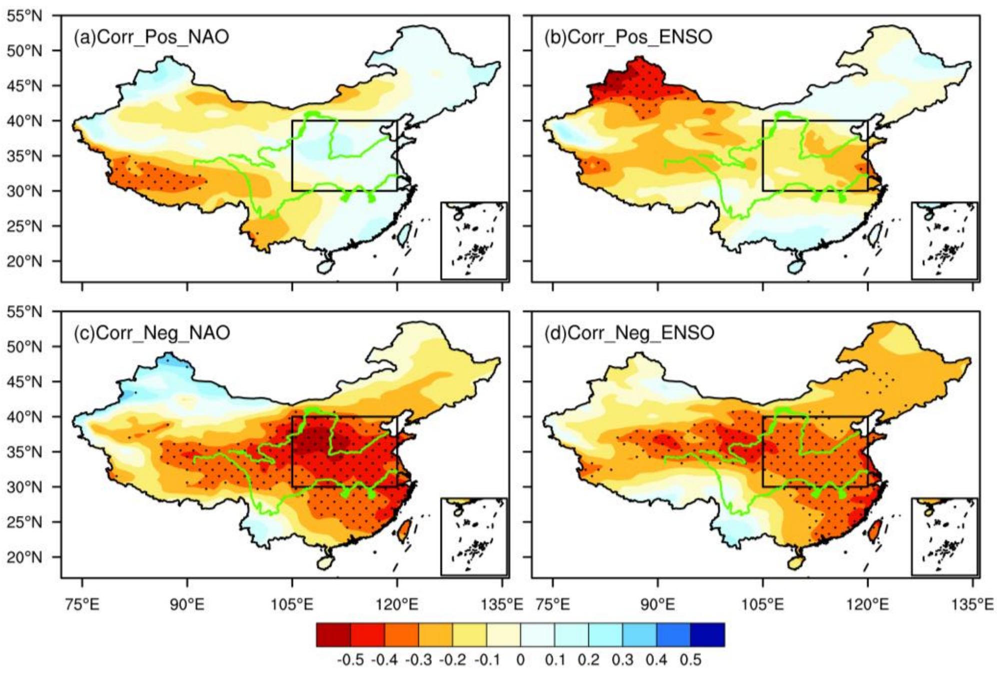

Figure 2 of Manuscript. Spatial distribution of correlation coefficients between (a) positive and (c) negative NAOI values and dust content. (b) and (d), As in (a) and (c), respectively, but for the Niño3.4 index. Stippled areas are statistically significant at the 0.2 level.

Table R1. Correlation coefficients between the NAOI, ENSO index and regional average dust aerosol content over North China in spring under different phases. * indicates significant at the 0.1 level.

	Correlation coefficients
DJF_NAO+ & MAM _DUST	0.05
DJF_NAO- & MAM _DUST	-0.46*
DJF_ENSO+ & MAM _DUST	-0.16
DJF_ ENSO + & MAM _DUST	-0.36*

4. In Figures 1-2, the authors illustrate the relationship between NAO, ENSO and dust weather over North China through the spatial distribution of correlation coefficients, and that the relationship is only manifested when NAO and ENSO are in negative phases. A quantitative analysis is needed to further establish the robustness of the result.

Response:

Thank you for the comments.

We have adopted the reviewer's comment and added the quantitative analysis of NAO, ENSO on the dust aerosol concentration over North China. And we have added the description into the revised manuscript, as "Notably, North China is situated at the center of the maximum correlation, with correlation coefficients of -0.36 and -0.35 between NAO and ENSO, respectively" as shown in Lines 193-194. As well as, the correlation coefficients of NAO, ENSO during different phases and dust aerosol concentration over North China in Figure 2 are described as "Based on the scatter distribution of spring dust index (SDI) under different phases of NAO and ENSO, it is noted that the correlation coefficients between NAOI and SDI during the positive and negative phases of NAO are -0.46 and -0.05, respectively, indicating that the significant influence of NAO on the dust in North China mainly occurs during its negative phase. Similarly, the correlation distribution between the ENSO and SDI also shows that the influence of ENSO is more pronounced during its negative phase" (Lines 222-227 in the revised manuscript).

5. From Fig 3 and Table 1, it is evident that there are two types when NAO and ENSO are in their negative phases: negative phases of the NAO and ENSO, and negative phases of the NAO and ENSO occurring separately (remove the years with concurrent negative phases of NAO and ENSO). Furthermore, the subsequent composite analyses in the study, focus on the cases with negative phases of the NAO and ENSO. The authors should explain why they have made this choice.

Response:

Thank you for the comments.

As shown in Figure 3c of manuscript, when the NAO is in its negative phase, including alone occurrence and in conjunction with negative phase of ENSO, the anomalous values of dust content over North China is 8.32 mg·m^{-2} and 16.21 mg·m^{-2}, respectively. Similarly, the anomalous dust content over North China is 14.88 mg·m^{-2} and 19.40 mg·m^{-2} for the case of ENSO (Figure R6).

The above results show that no matter what kind of NAO and ENSO negative phase occurs, the increase in dust aerosol concentration over North China can be observed. The samples in the case of NAO negative phase is 8 and 15, respectively, and it is of 9 and 16 in the case of ENSO. In order to not only retain the characteristics of the negative phases of NAO and ENSO, but also make our results statistically characteristic, we selected the case of enough samples of the negative phases of NAO and ENSO to consider. We have added the description into the revised manuscript, as "To enhance the robustness of statistical analysis, we aim to select representative sample. Consequently, we focus on cases exhibiting negative phases of both the NAO and ENSO", as shown in Lines 244-246.

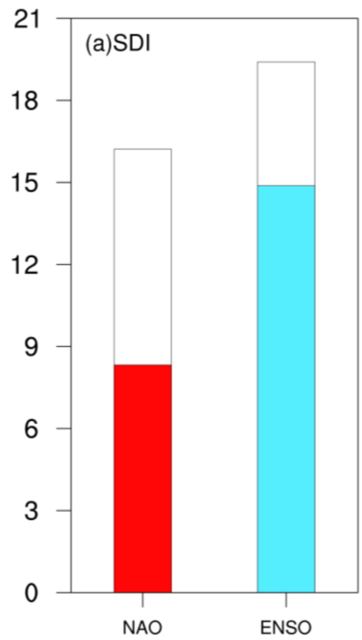

Figure R6. (a) Spring dust content over North China during the negative NAO, negative ENSO phases, and concurrent negative phases of NAO and ENSO. Transparent bars represent negative phases of the NAO and ENSO (unit: mg m^{-2}).

6. In Figs 4 c, f, and i, the variations in the near-surface wind field caused by anomalies of Siberian High, lead to dust emissions from the source areas. However, the depiction of the wind field anomalies appears unclear. It is recommended to modify the Figs to highlight the variations in the wind field.

Response:

Thank you for the comments and suggestions.

We have revised the figures to highlight the variations in the near-surface wind field caused by anomalies of Siberian High (SH). "In the sea level pressure field, during the negative phase of the NAO, the intensification of the SH typically accompanied with strong northerlies and dry conditions, favoring for the transport of dust, thereby supplying abundant material sources for dust activities in North China (Figure 4c of Manuscript). In the negative ENSO phase, more significant cyclonic circulation anomalies occur over the Western North Pacific (Figure 4f of Manuscript). When both the NAO and ENSO are in their negative phases, the strength and influence extent of the SH are more pronounced compared to that when the NAO sole is in negative phase (Figure 4i of Manuscript)" (Lines 302-312 in the revised manuscript).

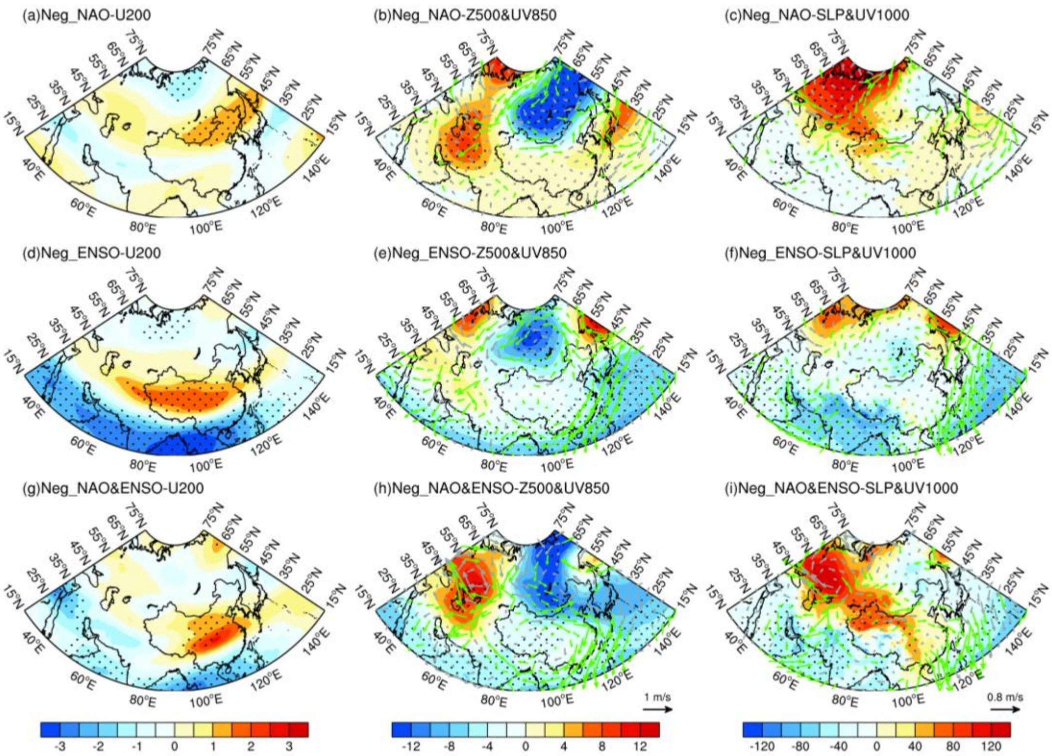

Figure 4 of Manuscript. Upper, (a) 200 hPa zonal wind anomalies (shading, unit: m s-1), (b) 500 hPa geopotential height (shading, unit: gpm) and 850 hPa wind field anomalies (arrows, unit: m s-1), (c) sea-level pressure (shading, unit: Pa) and 1000 hPa wind field anomalies (arrows, unit: m s-1) during the negative NAO phases. Middle-Lower, as in the upper, but during the negative ENSO phases and concurrent negative phases of NAO and ENSO, respectively. Stippled areas and green arrows are statistically significant at the 0.2 level.

7. In Table 2, the value of correlation coefficients between the previous winter NATI and spring NATI are similar in scenarios of ENSO- phase (when the negative phase of ENSO occurs alone) and NAO- & ENSO- phase (when the negative phases of both NAO and ENSO co-occur). However, if there exists a synergistic effect of NAO and ENSO on the dust weather, the correlation in the scenario where both NAO and ENSO negative phases co-occur should be higher than when the negative phases of NAO and ENSO occur separately. The authors should have provided a more detailed explanation to clarify this point.

Response:

Thank you for the important comments.

It is seen that the correlation coefficients between the previous winter NATI and the subsequent spring NATI remain consistent across both scenarios (ENSO- phase, NAO- & ENSO- phase), we would like to clarify this point into the following considerations.

The steps of NAO during the previous winter to affect the spring dust activities over North China divided into the following: 1) The NAO during the previous winter stimulates NAT; 2) The NAT can last from previous winter to spring due to the thermal persistence of the sea surface temperature; 3) The spring NAT modulates the circulation pattern over North China through teleconnection wave trains, which ultimately affects the spring dust activities over North China.

It is seen from Table 2 in the manuscript that although in the case of ENSO- phase and NAO- & ENSO- phase, the correlation coefficients of NATI in the previous winter and spring NATI are similar, both of which are 0.69. However, in the process of stimulating NAT by NAO in the previous winter, the correlations between NAO and NAT is higher during NAO- & ENSO- phase (0.66) than ENSO- phase (0.52). This suggests that the NAO significantly drives the NAT in the case of NAO- & ENSO- phase. The above discussion illustrates the synergistic effect of NAO and ENSO on the dust activities over North China (Lines 415-425 in the revised manuscript).

Table 2 of Manuscript. Correlation coefficients between the NAOI and NATI in three different categories. * indicates significant at the 0.1 level.

	DJF_NAO & DJF _NATI	DJF_NATI & MAM_NATI
NAO^- phase	0.41*	0.51*
$ENSO^-$ phase	0.52*	0.69*
NAO^- & $ENSO^-$ phase	0.66*	0.69*

8. The main mechanism for the impact of the winter NAO on the spring dust is the maintenance of the North Atlantic SST anomalies from winter to spring, consistent with previous findings (Chen et al. 2020; Wu and Chen 2020; Song et al. 2022). Several discussions could be added.

Response:

Thank you for the comments.

We have quoted the work into the revised manuscript, as “which allows the previous NAO signal to exert a long-term influence on the subsequent weather and climate in China (e.g., Chen et al., 2020; Wu and Chen, 2020; Song et al., 2022)", as shown in Lines 372-374.

9. There are lots of clerical errors, i.e.,

   Line 17-18, sea surface temperatures (SST) in the North Atlantic

   Line 220, with regard to the description of the graphs, there may be some errors that"(b) and (d) As in (a) and (b) "-> "(c) and (d) As in (a) and (b)".

   The authors should carefully check the whole manuscript.

Response:

Thanks to the reviewer for the comments. We have checked the whole manuscript and revised the errors.

References:

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Response to Comments of Reviewer 2

Manuscript number: egusphere-2024-955

Author(s): Falei Xu, Shuang Wang, Yan Li, and Juan Feng

Title: Synergistic effects of previous winter NAO and ENSO on the spring dust activities in North China

General comments:

Using multi-reanalysis datasets, the authors investigated the effects of the previous winter NAO and ENSO on the spring dust aerosols over North China. The pronounced influence of NAO and ENSO on dust aerosols was predominantly observed during their negative phases. Furthermore, this analysis examined meteorological conditions, atmospheric dynamics, and wave energy transport, elucidating the synergistic impacts of these negative phases on subsequent dust activities. The findings enhance our understanding of the formation mechanisms of dust events in North China. I recommend that this manuscript be accepted after minor revisions, as this study fits well within the scope of Atmospheric Chemistry and Physics.

Response:

Thanks to the reviewer for the helpful comments and suggestions. We have revised the manuscript seriously and carefully according to the reviewer's comments and suggestions. The point-to-point responses to the comments are listed as follows.

Specific comments are as follows:

1. The study primarily utilizes MERRA-2 reanalysis data for analyzing dust activities over North China. It is essential to assess whether the MERRA-2 data accurately captures dust activities in North China. Please provide further details on the reliability of the reanalysis.

Response:

Thank you for the comments.

Previous studies have demonstrated the accuracy and applicability of MERRA-2 reanalysis data for studying the evolution of dust events in Asia. "Its analytical results are similar to those obtained from MODIS, OMPS, CALIPSO, and Himawari-8 data (Kang et al., 2016; Yao et al., 2020; Wang et al., 2021)" (Lines 131-135 in the revised manuscript).

Additionally, we further employ the datasets from the China National Meteorological Centre, which include observations of floating dust, blowing dust, and dust storms, to validate the MERRA-2 reanalysis data. The frequency of dusty weather recorded at these stations has been converted into a Dust Index (DI) (Wang et al., 2008; Equations 1), effectively representing the concentration of dust aerosols.

$$\mathrm{DI} = 9 \times \mathrm{DS} + 3 \times \mathrm{BD} + 1 \times \mathrm{FD} \tag{1}$$

Where DS, BD, and FD represent the frequency of dust storms, blowing dust, and floating dust, respectively. Additionally, DI denotes the concentration of dust aerosols at each station.

We found that the variations of the DI and MERRA-2 dust aerosols concentration during the four seasons all show similar spatial characteristics. Especially for the dust source in Northwest China and the spring dust aerosols over North China, the spatial distribution characteristics are relatively consistent (Figure R1). The above results indicate that the MERRA-2 aerosol reanalysis data can simulate the spatiotemporal distribution characteristics of dust aerosol concentration in China, which is applicable and effective for us to understand the variations in dust aerosol concentration in China.

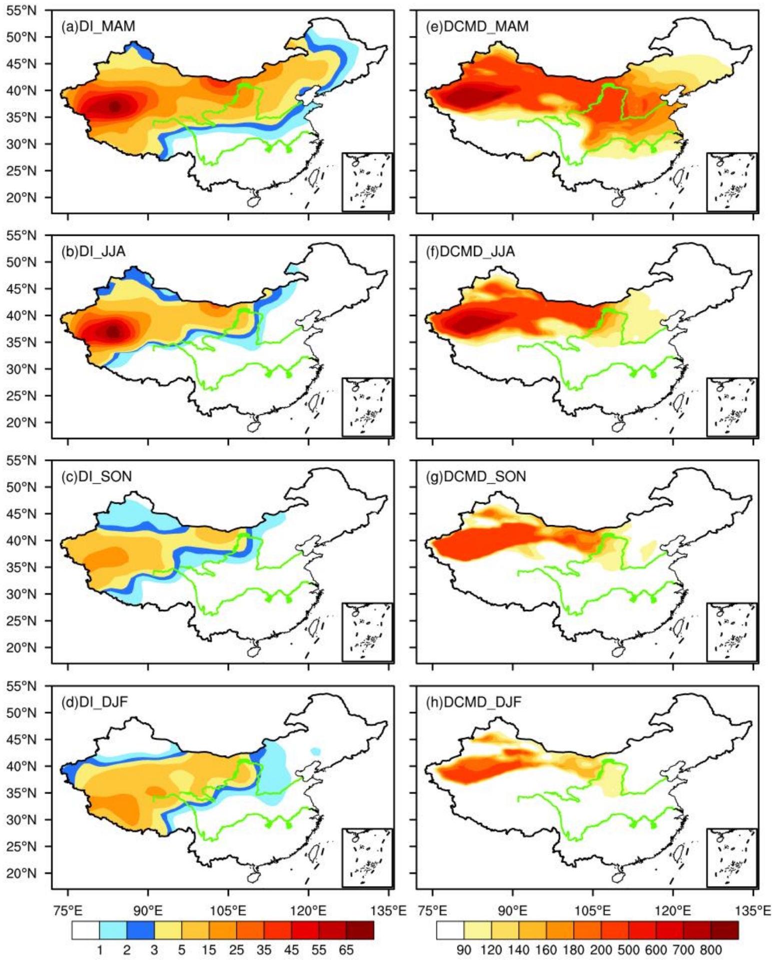

Figure R1. (a-d) Seasonal distribution of DI from station data, (e-h) As in (a-d), but for dust column mass density from MERRA-2 reanalysis data during 1980-2018 (units: mg m^{-2}).

2. The preceding role of NAO and ENSO on the spring dusty weather over North China is investigated, and it is of interest why the preceding role is focused. And whether their simultaneous role in the dust content is significant or not.

Response:

Thank you for the comments.

Previous studies have found that previous NAO and ENSO play important role in impacting the following climate over North China, particular the cross-seasonal impacts (e.g., Zheng et al., 2016; Feng et al., 2019; Sun et al., 2021). Moreover, the one season ahead signals can provide as the useful predictors for the spring dust activities in North China.

The standard deviation of the NAO peaks during December, January, February, and March. By analyzing the trend of the three-month average standard deviation, we observe that it is highest during the preceding winter. This indicates that the NAO exhibits stronger variability in the winter compared to other seasons (Figure R2 a). Similarly, ENSO also shows greater variation during boreal winter (Figure R2 b). Based on these findings, we have chosen to focus on the relationship between NAO, ENSO during the pre-previous winter period, and spring dust activities over North China.

We have examined the role of previous autumn, winter and simultaneous spring NAO and ENSO on the spring dust aerosols over North China, and it is found the influences of NAO and ENSO on the spring dust aerosols are most significant in the previous winter (Figure R2 c-h). Thus, the role of previous winter NAO and ENSO on the spring dust aerosols over North China are discussed in the present work.

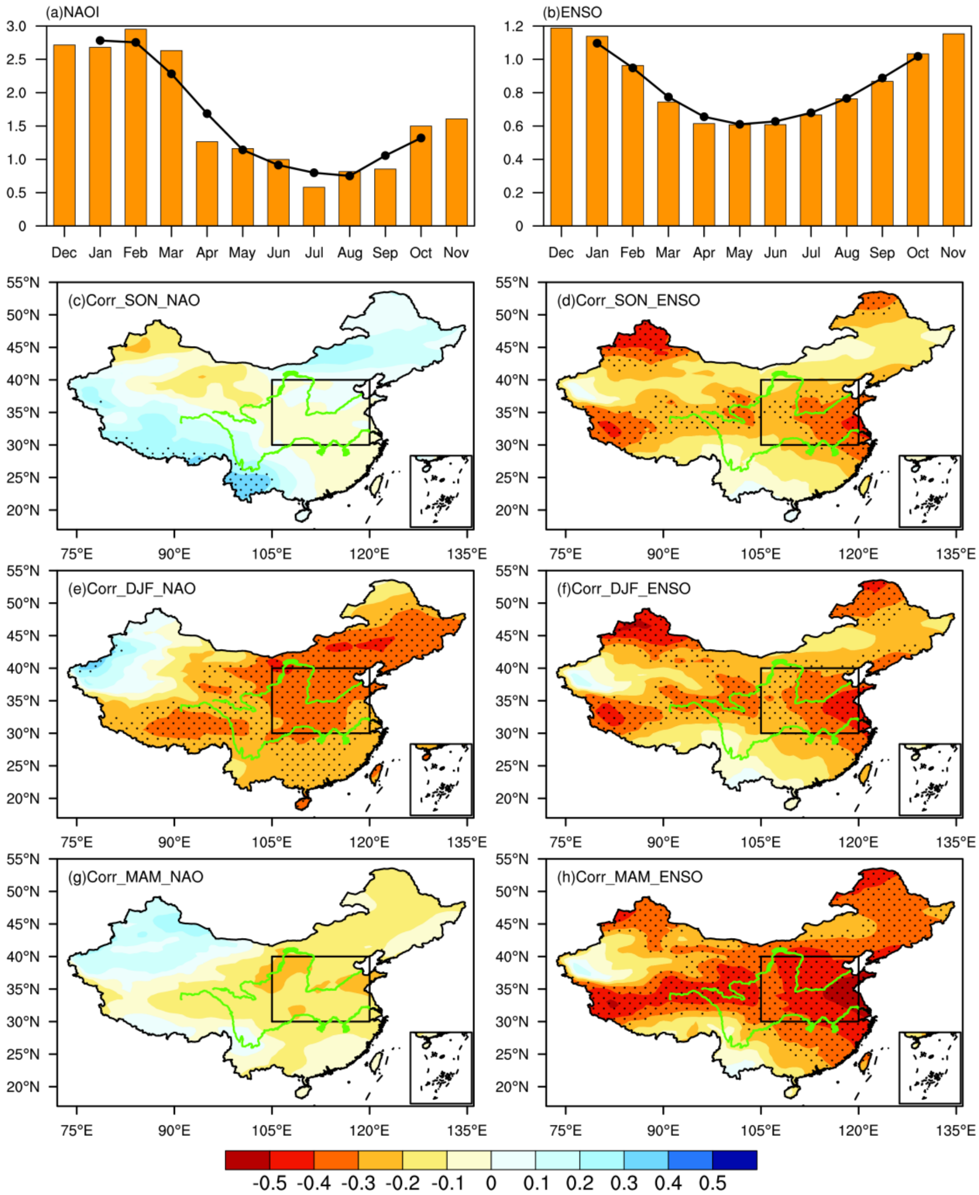

Figure R2. The monthly standard deviation of the (a) NAOI and (b) Niño3.4 index, respectively. Black line represents the trend of the three-month average standard deviation. Spatial distribution of correlation coefficients between the previous autumn NAOI and spring dust content (c). (d) As in (c), but with Niño3.4 index. (e-f) and (g-h) As in (c-d), but for the previous winter and simultaneous spring NAOI and Niño3.4 index. The black box represents North China. Stippled areas are statistically significant at the 0.1 level.

3. Dust aerosols are important components of atmospheric aerosols, alongside other constituents such as sulfates, nitrogen oxides, black carbon, and so on. Why did the authors choose the dust aerosols in North China as the research objects to be discussed and studied? Please explain and justify this point.

Response:

Thank you for the comments.

The dust aerosols are characterized by their significant role within the broader category of atmospheric aerosols. Dust aerosols originate from the mechanical breakdown of rocks and soil into fine particles, which are subsequently transported by the wind (Wang et al., 2018). They are noteworthy for their ability to influence climate systems by affecting solar radiation and cloud formation (e.g., Sokolik and Toon, 1996; Sassen et al., 2003; Zhang et al., 2019). Dust aerosols can pose a formidable threat to socio-economic development, natural ecological environment, as well as human health and safety (e.g., Zhao et al., 2020; Yin et al., 2021; Li et al., 2023). The study of dust aerosols is essential, because understanding their properties and dynamics helps us to better predict weather patterns, assess climate change impacts, and implement effective environmental and public health policies.

4. Line 36-37, "The Gobi Desert in East Asia, especially for the Mongolian Plateau and North China, is a major source of dust". Whether the author is trying to express the meaning of Northern China here, Northern China and North China are two different meanings, please confirm and revise.

Response:

Thank you for the comments. We have checked the whole manuscript and revised similar errors.

5. Line 77-78, the authors mentioned that "NAO and ENSO often co-occur and have complex interactions". As well as by citing previous work, the facts of a possible relationship between the two factors are enumerated. However, the authors have not thoroughly explored their relationship. It is suggested that further details be provided to enhance the understanding.

Response:

Thank you for the comments.

The relationship between the NAO and the ENSO remains unclear. Statistical analyses largely indicate no significant linear association between them. For instance, a correlation analysis of the NAO and ENSO indices during period 1950-2000 shows that their correlation coefficient is only 0.09, suggesting a weak linear correlation (Wang, 2002). Additionally, a significant correlation exists between the La Niña events in autumn and the positive phase of the NAO. However, this is not the case during El Niño events (Pozo-Vazquez et al., 2005).

Recent researchers have further detected the relationship between the NAO and the ENSO, particularly following the identification of two distinct types of ENSO events: the Eastern Pacific (EP) and Central Pacific (CP) El Niño events. It is suggested that the EP El Niño can transmit the Pacific signal to the North Atlantic through a subtropical bridge mechanism, potentially triggering a negative phase in the NAO. However, this relationship is not notably significant (Graf and Zanchettin, 2012). Moreover, the atmospheric circulation in the North Atlantic region reacts differently to the two types of La Niña events. During an EP La Niña, when the North Atlantic jet is weakened, the NAO tends to be in a negative phase. Conversely, CP La Niña would strengthen the North Atlantic jet, and the NAO is more likely to exhibit a positive phase (Zhang et al., 2015).

The above discussion suggests that there may be a nonlinear link between NAO and ENSO, and the relationship between them is still inconclusive and requires further study. Therefore, this paper analyzes the synergistic effect of NAO and ENSO on dust activities over North China.

6. In Figure 3 (a), it is notable that there is a point during the negative phase of the NAO that deviates from the majority of the points, potentially qualifying it as an outlier. If this point is removed from the sequence, it is important to verify whether the relationship between the NAO and dust aerosol content remains robust.

Response:

Thank you for the important comments.

It is important to consider whether the influence of the negative phase of the NAO on dust activities in North China persists after removing the outlier. When the outlier is excluded, we observe a reduction in the correlation between the two factors, yet a significant correlation remains and passes the 0.2 statistical significance test (Figure R3). This suggests that the impact of the NAO on dust activities in North China is robust during its negative phase.

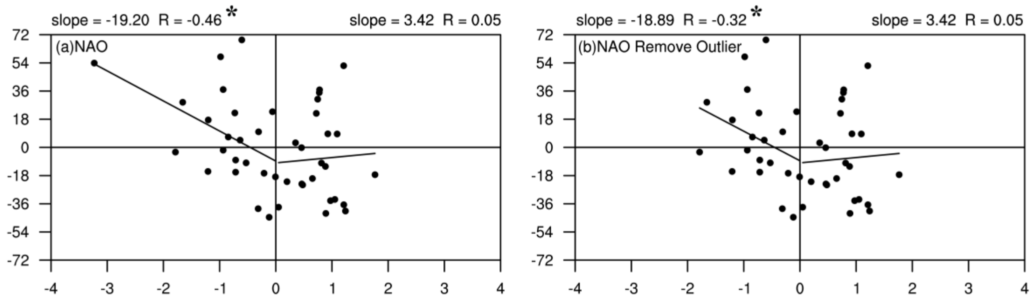

Figure R3. Scatterplots of the spring dust content in North China against previous winter (a) NAOI and (b) NAOI (Remove Outlier). Also shown are lines of best fit for positive and negative NAO/Niño3.4 index values and correlation coefficients (R), slope (slope), * indicates significant at the 0.2 level.

7. In Figure 5, by describing the precipitation and humidity fields under different scenarios, the authors illustrate the synergistic effect of NAO and ENSO on dust activities in North China. However, the large values of the variables in the graphs do not seem to be well highlighted. Consider modifying the color-coded intervals to enhance the reader's understanding of the section.

Response:

Thank you for the comments and suggestions. We have revised the figures to highlight large values of the precipitation and humidity fields under different scenarios. "When the NAO is in its negative phase, humidity in the spring dust source regions and North China generally reduced, particularly in areas near the dust source regions, indicating that these areas are conducive to dust transport and prone to causing dust weather in North China (Figure 5a of Manuscript). As for the precipitation, there is more spring precipitation in the northwest region of China, while precipitation in the Mongolia and the North China is relatively less (Figure 5b of Manuscript). In the negative ENSO phase, the variation in humidity is similar to that during the negative

NAO phase, but with a greater amplitude (Figure 5c of Manuscript), indicating that ENSO has a stronger impact on the humidity conditions in North China. Moreover, the precipitation shows a significant abnormal decrease over Mongolia and North China, which is highly conducive to dust activities and the generation of dust weather (Figure 5d of Manuscript). When both the NAO and ENSO are in the negative phases, the humidity anomalies in the dust source regions and North China are more intense than the individual factor (Figure 5e of Manuscript). The variation in precipitation are similar to those in humidity, the reduction in precipitation in the dust source regions and North China exceeds the sole role (Figure 5f of Manuscript)" (Lines 335-348 in the revised manuscript).

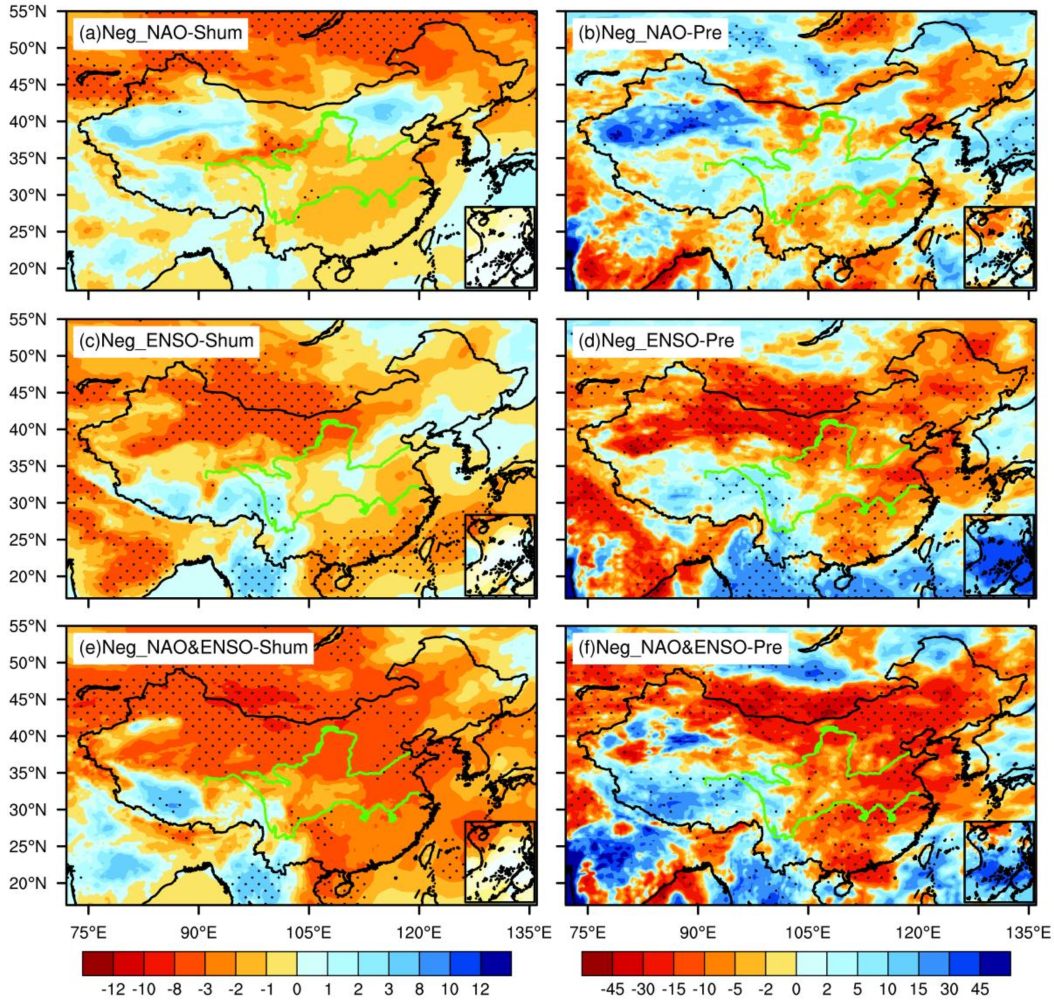

Figure 5 of Manuscript. Upper, composite percentage anomalies of (a) specific humidity and (b) precipitation during negative NAO phases. Middle-Lower, as in the upper, but during negative ENSO phases and concurrent negative phases of NAO and ENSO, respectively. Stippled areas are statistically significant at the 0.2 level.

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