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Responses to Referee #3

The El Niño (ENSO) is an irregular periodic variation in sea surface temperature in the tropical Pacific Ocean, affecting the Walker Circulation and displacing the convective area. It can lead to significant anomalies in atmospheric general circulations and weather conditions, which may further impact on haze pollutions in China. In this article, authors used the state-of-the-science Energy Exascale Earth System Model version 1 (E3SMv1) to estimate the impacts of El Niño with short and long durations on PM2.5 during winter in China. They further investigated underlying mechanisms of PM2.5 variations controlled by ENSO-related circulation and precipitation changes. The results are helpful to improve the understanding of modulation of aerosol pollution in China by El Niño over the study region. I think the manuscript can be accepted after the following concerns are addressed.

We thank the reviewer for all the insightful comments. Below, please see our point-by-point response (in blue) to the specific comments and suggestions and the changes that have been made to the manuscript, in an effort to take into account all the comments raised here.

General Comments:

1. The Introduction should be more concise. The authors should work further to reduce the main text to exclude any unnecessary contents like "clean air actions", and explain how spatiotemporal variations of aerosol in China controlled by ENSO-related changes in not only in wind speed and precipitation, but Walker Circulation and convections as well in more detail.

Thanks for the suggestion. We have pruned the introduction as follows: "In order to alleviate air pollution, a comprehensive and better scientific understanding of all factors that can affect aerosol concentrations and haze pollution in China is required." We agree with the reviewer that spatiotemporal variations of aerosols in China are also controlled by atmospheric circulation, which we have presented in the introduction. However, the ENSO-related changes in Walker circulation and the associated convections are more related to the aerosols over the tropics. Because we focused on aerosols in China, we did not discuss these factors in the manuscript.

2. The authors intended to show the difference of El Niño with short and long durations in section 2.2, where the background climates are quite different. Thus more discussion on their difference in climatological means (e.g. general circulation, temperature, precipitation, humidity and wind) are recommend.

In section 2.2, we only showed the definition of SD and LD El Niño. The differences in climatology have been discussed in the results in details when analyzing their impact of aerosol distributions in China.

Minor suggestions:

1. Line 92, "Based on haze day counting mainly using atmospheric visibility, many studies found" may be replaced with "Many studies counted haze days based on atmospheric visibility and found".

Revised.

2. Line 96, "several studies … from satellite retrievals". Insert some references there.

We have inserted the following references after the sentence: "several studies … from satellite retrievals (Jeoung et al.,2014; Sun et al., 2018)".

3. Line 141, "… have different impacts on the aerosol distribution in China". Insert a suitable reference at this point.

This statement is our inference based on the different effects of El Niño events with different durations on the meteorological fields over China and is what we showed as the main results and one of the highlights in this study. It has not been examined in any previous study.

4. Why not used the observed $PM_{2.5}$ data during 2014-2017? Please check whether the number of stations is 1657.

Since all other external forcings, including insolation, greenhouse gas concentrations, and emissions of aerosol and precursor are kept at year 2014 levels in E3SM modeling, we used the $PM_{2.5}$ data from December 2014 to February 2015 (the nearest winter available) to evaluate the model performance in simulating winter aerosol concentration and distribution in China. We have confirmed the number of available stations is indeed 1657 over December 2014–February 2015.

5. Please identify the simulation period in this study.

As we described in the manuscript, the simulations in our study were driven by climatological average of monthly SST and SIC over 1870-2017 or monthly SST representing composite SD and LD El Niño events. All simulations were integrated for 20 years. All other external forcings, including insolation, greenhouse gas concentrations, and emissions of aerosol and precursor are kept at present-day conditions (year 2014). The simulations using E3SM earth system model here are performed at present-day conditions instead of a certain year in chemical transport models or air quality models.

6. It is recommended to list a table to introduce the experiments.

Thanks for the suggestion. We have added the following table in the revised manuscript.

Table 1. Experimental design.

Experiments	**Model Configuration**
CLIM	Climatological SST
SD	Climatological SST + $\Delta SST_{SD\ El\ Niño}$
LD	Climatological SST + $\Delta SST_{LD\ El\ Niño}$
SD_emis	Same as SD but turn off the emissions from South and Southeast Asia
CLIM_emis	Same as CLIM but turn off the emissions from South and Southeast Asia

7. Precipitation can exert notable scavenging effects on PM_5 concentrations, whilst weak precipitation might increase $PM_{2.5}$ concentrations by hygroscopic increase associated with increased humidity. Therefore, it is recommended to examine the relative humidity anomalies in section 3.2, which might be able to explain opposite pattern of precipitation and wet deposition anomalies.

It is possible that increase in relative humidity accelerates the chemical transformation of secondary aerosols (Yang et al., 2015), leading to the $PM_{2.5}$ anomaly pattern and the positive relationship between the precipitation and aerosol concentration. Therefore, we showed the differences in DJF mean surface BC and POM concentrations in Fig. A. The spatial differences in primary aerosols of BC and POM between El Niño and climatological means and between SD and LD El Niño events are almost the same as $PM_{2.5}$, indicating that change in water vapor is also not the main reason for the aerosol changes in China during El Niño events. We have added the description in the manuscript as "Water vapor can accelerate the chemical transformation of secondary aerosols (Yang et al., 2015), but the primary aerosols showed the same spatial differences in near-surface concentration as $PM_{2.5}$ (not shown), indicating that change in water vapor is also not the main reason for the aerosol changes in China during El Niño events.". In addition, the mass concentration showed in this study is dry aerosol mass. The water uptake will not influence the aerosol mass here.

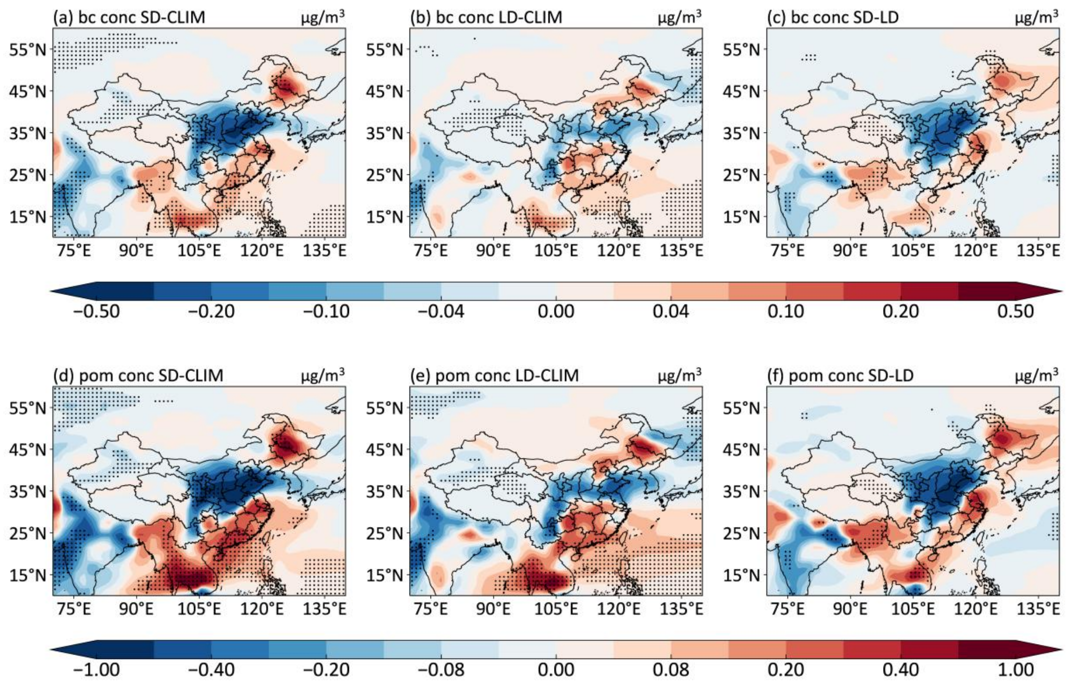

Figure A. The composite differences in DJF mean near-surface BC and POM concentrations (µg m^{-3}) between SD and CLIM, LD and CLIM, and SD and LD. The stippled areas indicate statistical significance with 90% confidence from a two-tailed T-test.

8. *It is recommended to show probability density distributions of PM_{10}.*

PM_{10} is largely contributed by dust aerosol. However, dust aerosols have large uncertainties in models related to its emission parameterization. In addition, $PM_{2.5}$ is more harmful to human health than PM_{10}. So, in this study we focused on $PM_{2.5}$ rather than PM_{10}. The impacts of El Niño on dust will be investigated in our future work. We have added it in discussion section.

Reference:

Yang, Y. R., Liu, X. G., Qu, Y., An, J. L., Jiang, R., Zhang, Y. H., Sun, Y. L., Wu, Z. J., Zhang, F., Xu, W. Q., and Ma, Q. X.: Characteristics and formation mechanism of continuous hazes in China: a case study during the autumn of 2014 in the North China Plain, Atmos. Chem. Phys., 15, 8165–8178, https://doi.org/10.5194/acp-15-8165-2015, 2015.

Jeoung, H., Chung, C. E., Van Noije, T., and Takemura, T.: Relationship between fine-mode AOD and precipitation on seasonal and interannual time scales, Tellus B Chem. Phys. Meteorol., 66, https://doi.org/10.3402/tellusb.v66.23037, 2014.

Sun, J., Li, H., Zhang, W., Li, T., Zhao, W., Zuo, Z., Guo, S., Wu, D., and Fan, S.: Modulation of the ENSO on Winter Aerosol Pollution in the Eastern Region of China, J. Geophys. Res. Atmos., 123, 11,952-11,969, https://doi.org/10.1029/2018jd028534, 2018.