Dear editor and referee #2,

Thank you very much for your time and attentions on this work. The constructive comments and suggestions are very useful to improve our manuscript. Following are point-by-point responses to referee #2's comments. All the line numbers mentioned in responses are referred to the manuscript with changes marked.

(1) L99-106, radiation absorption by aerosols can either suppress or enhance convection via altering CAPE depend on the heating vertical profile and the elevation where the convection initiates. Please see the discuss and the schematic of Wang et al. (2013, "New Directions: Light Absorbing Aerosols and Their Atmospheric Impacts").

Reply: We have added this sentence "Absorbing aerosols in the boundary layer warm the atmosphere and cool the surface, which leads to the increase of atmospheric convective inhibition energy and the rise of convection condensation level (CCL), meanwhile the absorbing aerosols also leads to the increase of convective available potential energy above CCL. Once the lifting condition overcomes the convective inhibition energy, strong convective activity will be triggered (Wang et al., 2013)." and deleted the sentence "Absorbing aerosols block solar radiation from reaching the surface through radiative effects, which tends to inhibit the development of convection." The details can be seen L97-103 of the revised manuscript.

(2) L178-179, it is not surprising to see good agreement between MERRA2-Aero and MODIS AOD, as MERRA2-Aero assimilates MODIS AOD product. Can the authors obtain the AOD from an independent satellite, such as MISR, to confirm the variability of the AOD near Sichuan?

Reply: Figure S1 shows the spatial distribution of AOD based on the monthly data of MEERA2 and MISR data sets from 2005 to 2017. It can be seen from Fig S1 that the AOD spatial distribution of MISR is very close to that of MERRA, but the AOD value of MISR is smaller than that of MERRA2. Wei et al. (2019) suggest that there is a good consistency between MISR and MODIS AOD products in southwest China by using multi-satellite data comparison. The details can be seen L202-208 of the revised manuscript.

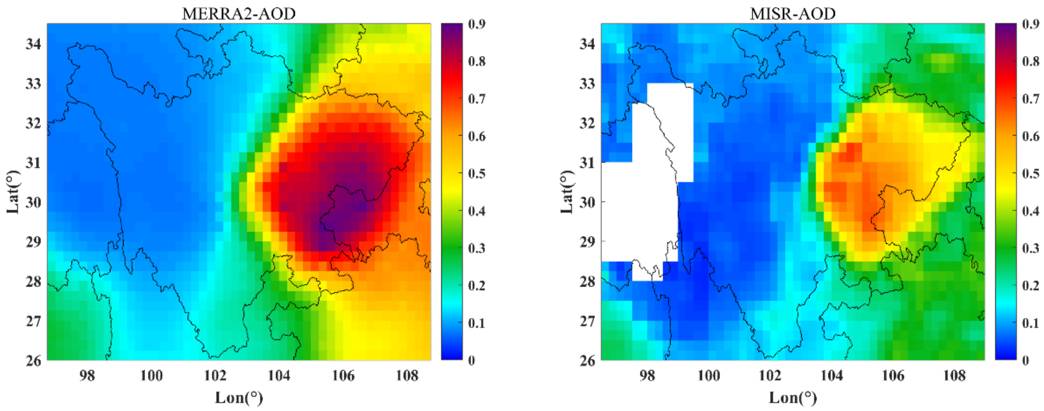

Figure S1. The spatial distribution of annual mean AOD based on MERRA2 and MISR data sets from 2005 to 2017

(3) The uncertainty of cloud product from ERA5 over Southwest China seems unclear. Can the author make comparison of liquid/ice content between ERA5 and MODIS?

Reply: Due to the low spatial resolution (1°×1°) of MODIS monthly cloud product, we chose the cloud product of CLARA-A2 (0.25°×0.25°) for comparison with the cloud product of ERA5. CLARA-A2 is the second edition of the Satellite Application Facility on Climate Monitoring (CM SAF) cloud, albedo, and surface radiation dataset. The CLARA-A2 record provides cloud properties, surface albedo, and surface radiation parameters derived from the Advanced Very High-Resolution Radiometer (AVHRR) sensor (Karlsson et al., 2017; Karlsson and Håkansson, 2018). Figure S2 shows the spatial distribution of liquid water path (LWP) and ice water path (IWP) based on the monthly data of ERA5 and CLARA-A2 data sets from 2005 to 2015. LWP is high in the east and low in the west of Sichuan, while LWP in ERA5 is obviously lower than that of CLARA-A2 in the northwest of Sichuan. The spatial distribution of IWP in the two data sets are close, LWPs in northwestern Sichuan are higher than that in eastern and southern Sichuan.

We compared LWPs and IWPs of CLARA-A2 and ERA5 data sets, and overall, the cloud products of the two data sets were similar. For the continuity of data, LWP and IWP in ERA5 were selected in this study. We have added the above texts to the revised manuscript and the following figure to the supplement as figure S2. The details can be seen L230-236 of the revised manuscript.

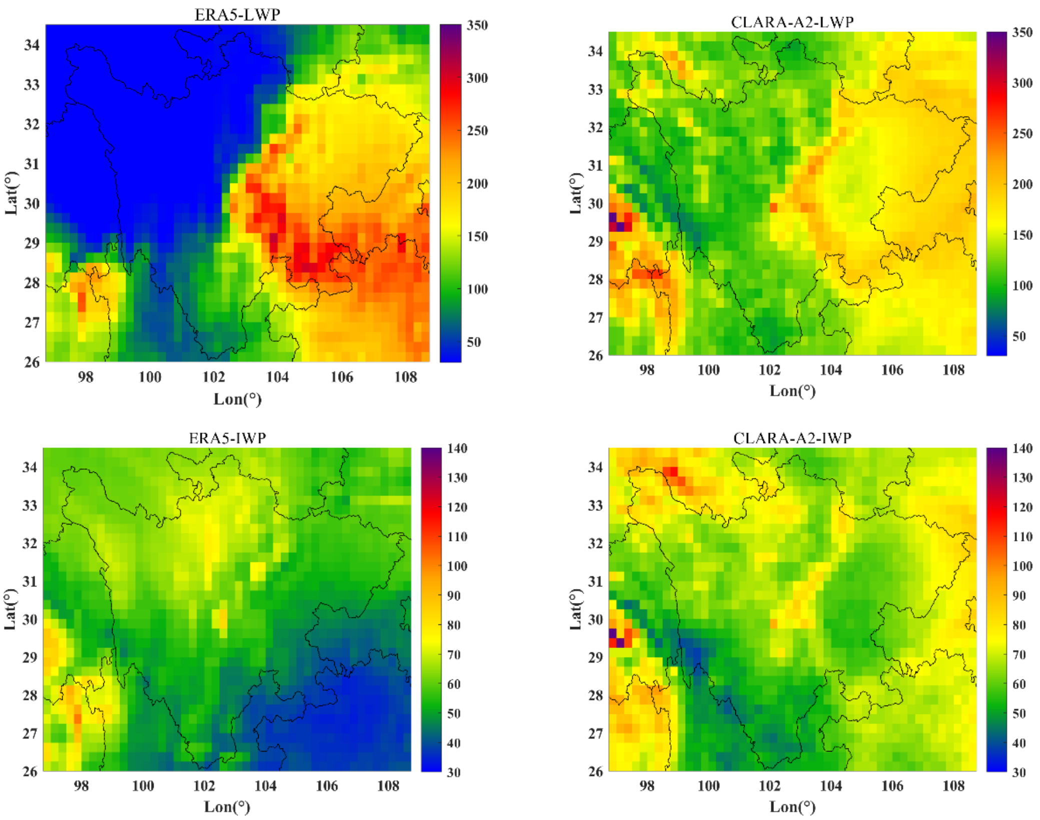

Figure S2. The spatial distribution of annual mean LWP and IWP based on ERA5 and CLARA-A2 data sets from 2005 to 2015

(4) Figs. 3,5-7. for the correlations between the time series of monthly mean data, do they mainly reflect the seasonality? Are they still significant if you remove the seasonality and look at anomalies (interannual variability) only?

Reply: To eliminate the interference of seasonality on the effects of aerosols on lightning, Pearson correlation coefficients between anomalies of total AOD and CG lightning and anomalies of sulfate AOD and CG lightning were implemented. As can be seen from the comparison between Fig. 3 and Fig. 4, the correlation coefficients between the anomalies of AOD and lightning are significantly lower than those between AOD and lightning. While in an overall view, there is still a positive correlation between aerosols and lightning in the plateau region, and a negative correlation between aerosols and lightning in the basin region, especially for sulfate aerosols. This further verifies that aerosols have the potential to stimulate lightning activity in the plateau region and inhibit lightning activity in the basin region. The specific physical relationship will be further discussed below. The above discussion and the following figure as Figure 4 have been added to the revised manuscript. The details can be seen L344-364 of the revised manuscript.

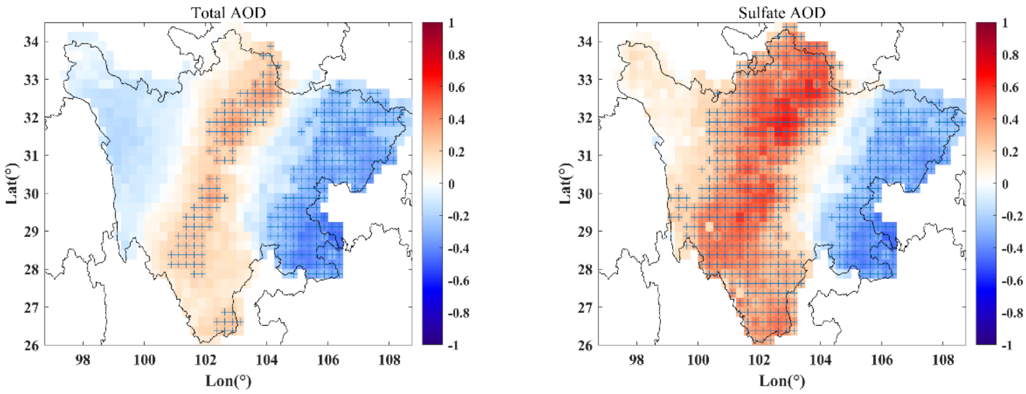

Figure 4. Pearson correlation coefficients between anomalies of total AOD and CG lightning (left panel) and anomalies of sulfate AOD and CG lightning (right panel) based on monthly data from 2005 to 2017. Crosses in the figure indicate grid boxes that have passed the 90% significance test.

Fig. S3 shows the correlation coefficients between the anomalies of CAPE, RH, SHEAR, CBH, TCLW, and TCIW and CG lightning. Compared with Figure 6 in the revised manuscript, the correlation coefficients are obviously smaller, especially in the basin region. The significances of the correlation between CG lightning and environmental factors are weakened, especially SHERA, CBH, and TCLW in the basin region. The above discussion has been added to the revised manuscript, and the following figure has been added to the supplement as Figure S3. The details can be seen L413-417 of the revised manuscript.

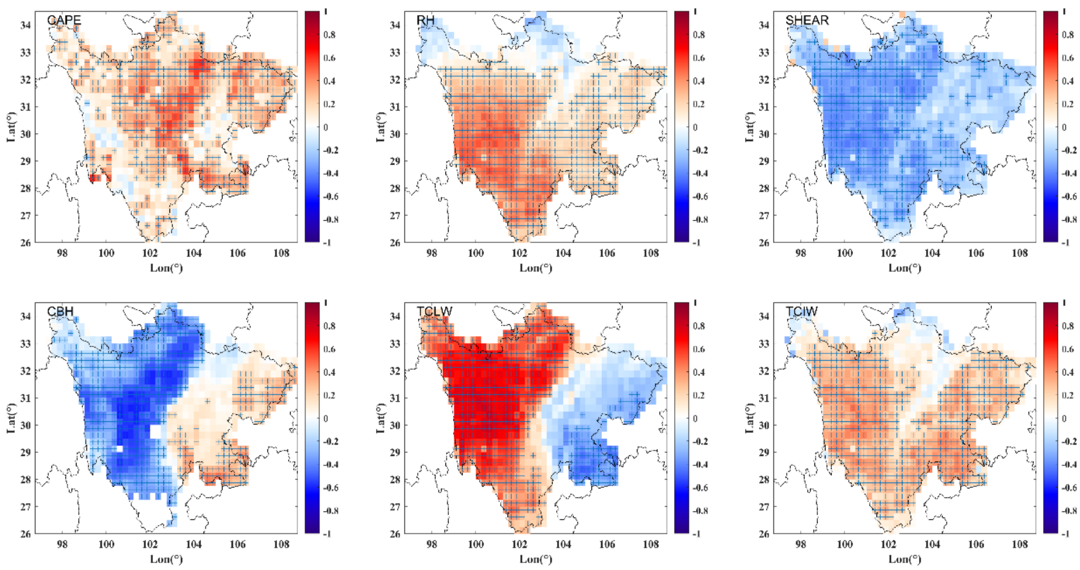

Figure S3. Pearson correlation coefficients between the anomalies of CAPE, RH, SHEAR, CBH, TCLW, and TCIW and CG lightning. Crosses in the figure indicate grid boxes that have passed the 95% significance test.

In the revised manuscript, we recalculated the partial correlation coefficient between meteorological factors and lightning, which is shown in Figure 7 in the revised manuscript. We used partial correlation coefficients to discuss the dependence of lightning on a meteorological factor relatively independently. The partial correlation coefficients in Figure 7 in the revised manuscript is small, while the partial correlation calculated by using the anomalies of variables is not significant.

(5) Figs, 6 and 7, how are the partial correlation coefficients calculated and how are they different from the total correlation coefficient? My understanding is the partial correlation is a measure of the dependence between two variables where the influence from other possible controlling variables (like meteorological parameters in this case) is removed. This method has been used in many previous aerosol-cloud studies (e.g. Zhao et al., 2019, "Ice nucleation by aerosols from anthropogenic pollution"). It seems the definition of partial correlation here is somewhat different with my understanding.

Reply: Figure 6 and Figure 7 in the original manuscript mainly aimed at analyzing the dependence of CG lightning on thermodynamic factors and cloud-related factors, so we analyzed the partial correlation between CG lightning and thermodynamic factors (CAPE, RH, and SHEAR) as well as lightning and cloud-related factors (CBH, TCLW, and TCIW), respectively. Based on your comment and Zhao et al. (2019), we recalculated the partial correlation coefficients between six meteorological factors (CAPE, RH, SHEAR, CBH, TCLW, and TCIW) and CG lightning in order to analyze the contribution of individual meteorological factor by eliminating the potential dependence on other meteorological factors. The corresponding discussion was modified, and the following figure was added to the revised manuscript as Figure 7. The details can be seen L436-449 of the revised manuscript.

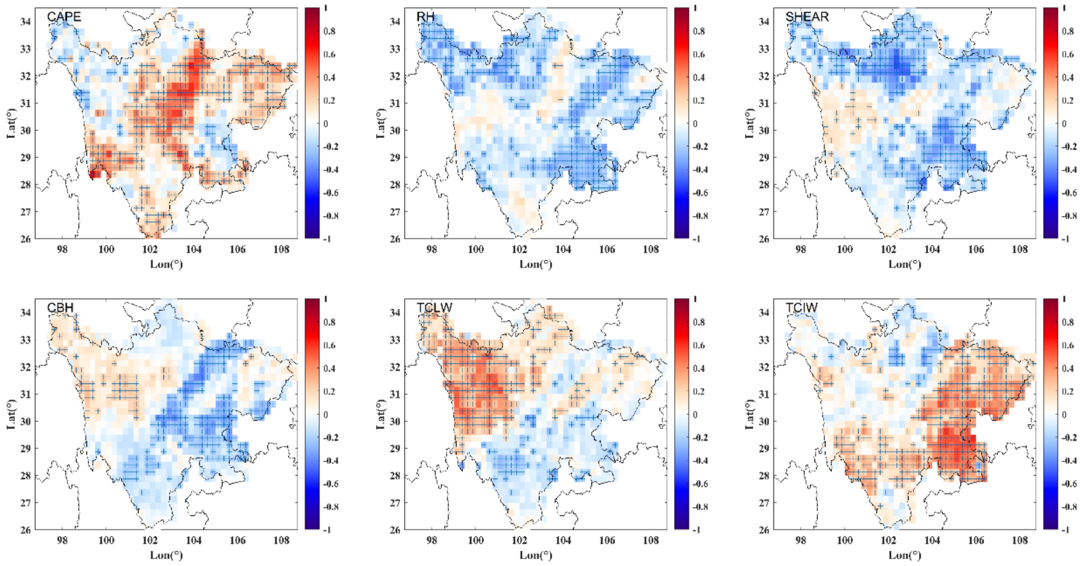

Figure 7. Partial correlation coefficients between CG lightning and meteorological factors, i.e., CAPE, RH, SHEAR, CBH, TCLW. Crosses in the figure indicate grid boxes that have passed the 95% significance test.

(6) L318-319, Liu et al. (2019, "Non-Monotonic Aerosol Effect on Precipitation in Convective Clouds over Tropical Oceans") examined satellite data and also reported a tipping point of precipitation response to aerosol perturbations, which occurs at AOD of 0.3.

Reply: We have added this reference in the revised manuscript. The details can be seen L378 of the revised manuscript.

(7) L330, please remove "Compared with the effect of aerosols on lightning activity", as there is no comparison in this sentence.

Reply: It has been removed.

(8) Section 3.5 is confusing. The observed monthly and regional means of lightning density were used to build the multi-variate linear regression model. Then what's the point to compare the modeled lighting density with the observed one again? Please clarify.

Reply: In this study, we discussed the relationship between lightning density and seven influence factors, including CAPE, RH, SHEAR, CBH, TCLW, TCIW, and AOD. We used Pearson correlation and partial correlation analysis methods to analyze the relative contributions of various influence factors to lightning activity. On this basis, we use multiple linear regression method and stepwise regression method to establish a model, which is used to test whether the seven influencing factors can reproduce the characteristics of lightning activity, and verify the influence factors that contribute more to lightning activity in the plateau and basin region. Previous study (Wang et al., 2018) also used similar methods to discuss the contribution of influence factors to lightning activity in Africa.

(9) L574, please be specific what are the thermodynamic differences.

Reply: The thermodynamic difference between the basin region and the plateau region mainly refers to the difference of CAPE. CAPE in the basin region is significantly higher than that in the plateau region, which leads to more vigorous lightning activity in the basin region (Qie et al., 2003). It has been revised accordingly in the revised manuscript. The details can be seen L655-656 of the revised manuscript.

Reference:

Karlsson, K. G., Anttila, K., Trentmann, J., Stengel, M., Meirink, J. F., Devasthale, A.: CLARA-A2: the second edition of the CM SAF cloud and radiation data record from 34 years of global AVHRR data. Atmos. Chem. Phys., 17, 5809–5828. https://doi.org/10.5194/acp-17-5809-2017, 2017.

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Qie, X., Toumi, R., Zhou, Y. J.: Lightning activity on the central Tibetan Plateau and its response to convective available potential energy, Chinese Science Bulletin, 48(3), 296–299, https://doi.org/10.1007/BF03183302, 2003.

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Wang, Q., Li, Z., Guo, J., Zhao, C. and Cribb, M.: The climate impact of aerosols on the lightning flash rate: is it detectable from long-term measurements?, Atmos. Chem. Phys., 18(17), 12797–12816, https://doi.org/10.5194/acp-18-12797-2018, 2018.

Wei, J., Peng, Y., Mahmood, R., Sun, L. and Guo, J., 2019. Intercomparison in spatial distributions and temporal trends derived from multi-source satellite aerosol products. Atmos. Chem. Phys., 19, 7183–7207, https://doi.org/10.5194/acp-19-7183-2019, 2019.

Zhao, B., Wang, Y., Gu, Y., Liou, K.N., Jiang, J.H., Fan, J., Liu, X., Lei, H., Yung, Y.L.: Ice nucleation by aerosols from anthropogenic pollution. Nat. Geosci., 12, 602–607, https://doi.org/10.1038/s41561-019-0389-4, 2019.