Dear Editor

Thanks for your comments towards improving our manuscript. We have addressed all your comments. Our author responses (AR) are marked in blue and the revisions in the manuscript are marked in red.

Please follow the guidelines for abstract and the conclusion section: https://www.atmospheric-chemistry-and-physics.net/policies/guidelines_for_authors.html.

AR: Thanks for your suggestion and we have revised the abstract and conclusion section. Regarding the abstract, we have followed the instruction and added the research background and gap into the abstract. Additionally, the revised abstract is less than 250 words according to the instruction. Additionally, we have removed the repeated part in last version and the revised abstract (238 words) is listed as follows.

Black carbon (BC) significantly influences climate, air quality, and public health, and long-term observations are essential for understanding its adverse effects. While previous studies have primarily focused on spatiotemporal variations, deeper insights from such datasets remain uncovered. Using 13 years (2008–2020) of continuous measurements of equivalent black carbon (eBC) in China, this study reported the spatial-temporal variations of eBC and its sources, including solid fuel (eBC_{sf}) and liquid fuel combustion (eBC_{lf}). The results showed that eBC and its sources exhibited higher concentrations in eastern and northern China compared to western and southern China. Seasonal variations of eBC and eBC_{sf} generally showed lower values during summer and higher values during winter at most stations. Long-term trends indicated that eBC and eBC_{lf} decreased most rapidly at urban stations, while eBC_{sf} declined faster at rural stations. Comparisons of eBC concentrations and trends between this study and global observations revealed higher eBC levels but lower reduction rates in China. These long-term observations showed that the model simulations performed well in simulating spatial distribution but poorly in capturing inter-annual variations. The weather-normalized eBC concentrations showed potential for adjusting emission estimates. The normalized results also suggested that emission control was the dominant driver of the BC reduction. This decrease was primarily driven by reductions from solid fuel combustion at rural and background stations. This study provides insights for reducing uncertainties in black carbon emission inventories and improving model performance in simulating surface concentrations.

Regarding the conclusion section, we have revised the Conclusion to summarize the main findings, including key quantitative results, and to discuss their implications for reducing uncertainty in future BC modeling. The structure has been adjusted to align with journal guidelines by consolidating the results and discussion into distinct sections. Minor content edits were also made for clarity and focus. The revised Conclusion is listed as follows.

In this study, 13 years of continuous measurements of black carbon aerosol were analyzed from 48 stations in China. Using station-specific AAElf and AAEsf, the sources of eBC were apportioned. The levels, spatial-temporal characteristics, and trends of black carbon aerosol were reported, and the key findings of this unique dataset are listed as follows.

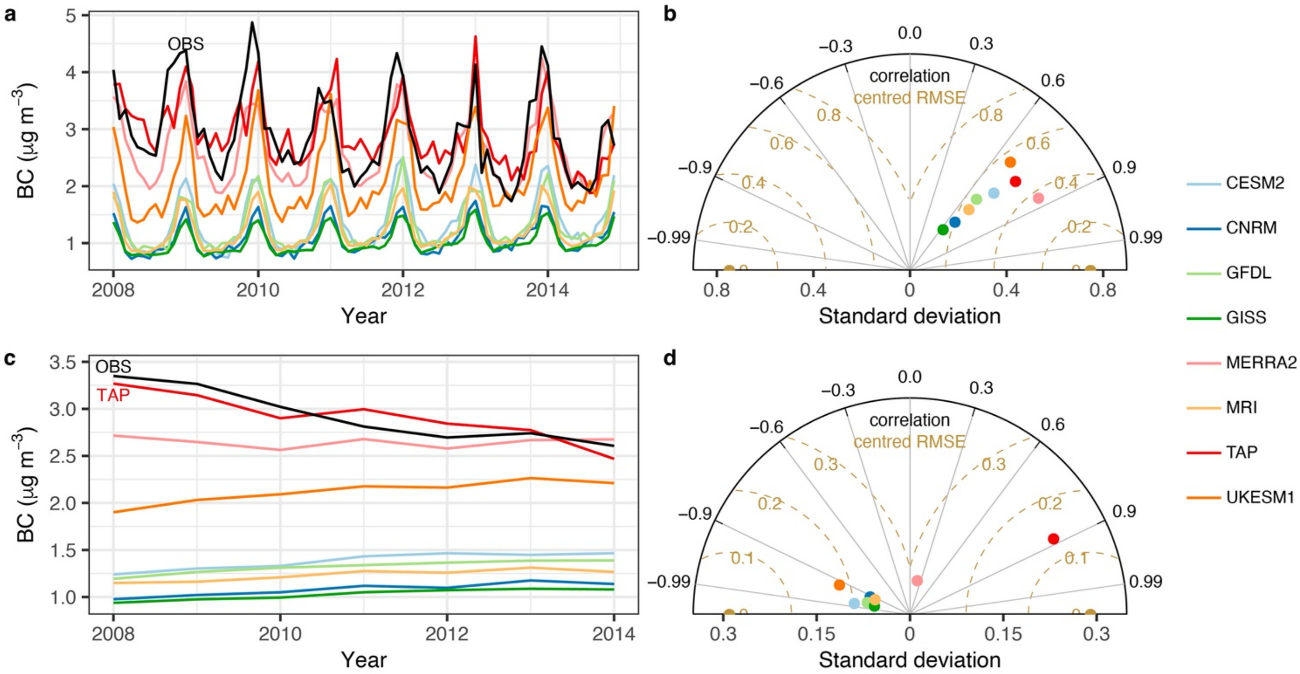
Observations of black carbon aerosols from 2015–2017 showed averages of 2.05 ± 2.85 μg m^{-3}, 1.08 ± 1.73 μg m^{-3}, 0.97 ± 1.52 μg m^{-3}, and 1.33 ± 0.29 for eBC, eBC_{lf}, eBC_{sf}, and $AAE_{370-950}$, respectively, in China. Long-term trends of eBC, eBC_{sf}, and eBC_{lf} indicated reductions from 2008 to 2020, with mean slopes of −0.17 ± 0.20 μg m^{-3} yr^{-1} for eBC, −0.12 ± 0.14 μg m^{-3} yr^{-1} for eBC_{lf}, and −0.06 ± 0.09 μg m^{-3} yr^{-1} for eBC_{sf} on a national scale. Spatial distributions of eBC and eBC_{sf} were higher in eastern and northern China compared to western and southern regions. Among different types of stations, urban stations exhibited the highest eBC values, while baseline stations had the highest fractions of eBC_{sf} and $AAE_{370-950}$. The seasonal variations of eBC, eBC_{sf}, and $AAE_{370-950}$ typically showed the lowest values in summer and the highest in winter. However, some stations recorded abnormally high eBC levels during summer, which were associated with biomass burning and dusty weather events. The spatial-temporal patterns of BC in China can be explained by its emission variations and meteorological conditions. The weather normalized BC concentrations showed that emission reductions were the primary driver, accounting for 89% of the decrease in eBC, 87% in eBClf, and 62% in eBC_{sf}. Urban stations showed the most rapid declines in eBC_{lf}, with the ratio of eBC_{lf} to eBC_{sf} trends exceeding 1, indicating that reductions in liquid fuel combustion emissions were the main contributor to BC decreases in urban areas. In contrast, rural and baseline stations exhibited the fastest declines in eBC_{sf}, suggesting that emission reductions from solid fuel combustion were the dominant factor in these regions.

This study provides valuable insights from China's long-term observations of BC aerosol, with significant implications for refining emission inventories and reducing model uncertainties. The comparison between observations and simulations revealed that most models failed to capture the inter-annual variation while the simulation with MEIC inventory was capable to reproducing the spatial and temporal variations of BC. Therefore, BC emissions from MEIC is recommended for modeling BC concentrations in China. Furthermore, a systematic model underestimation of BC was found particularly at rural stations, which emphasized the need to refine both emission source strengths and deposition processes to improve model accuracy. This study showed that the weather normalization is a promising technique for refining BC emission inventories, as the weather normalized BC concentrations showed a stronger correlation with the reported BC emissions than raw observations. Further analysis revealed a higher correlation between emissions and concentrations of BC from liquid fuel combustion. To reduce uncertainties in BC emissions, a target effort to improving accuracy of emission from the solid fuel combustion sub-sector is needed, including the collection of accurate BC emission factors from biomass and coal burning, as well as updating activity data in rural areas.

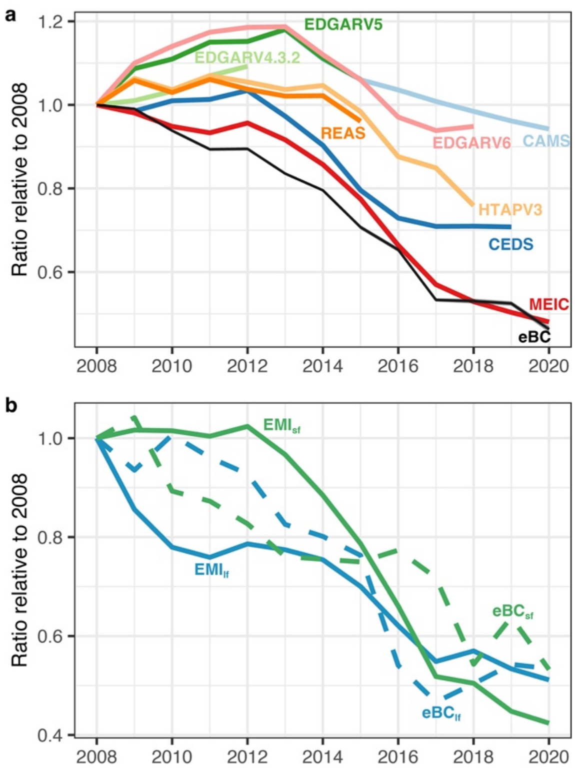
Notification to the authors:

Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly with the next file upload request. -> Fig. 8, 9, 10

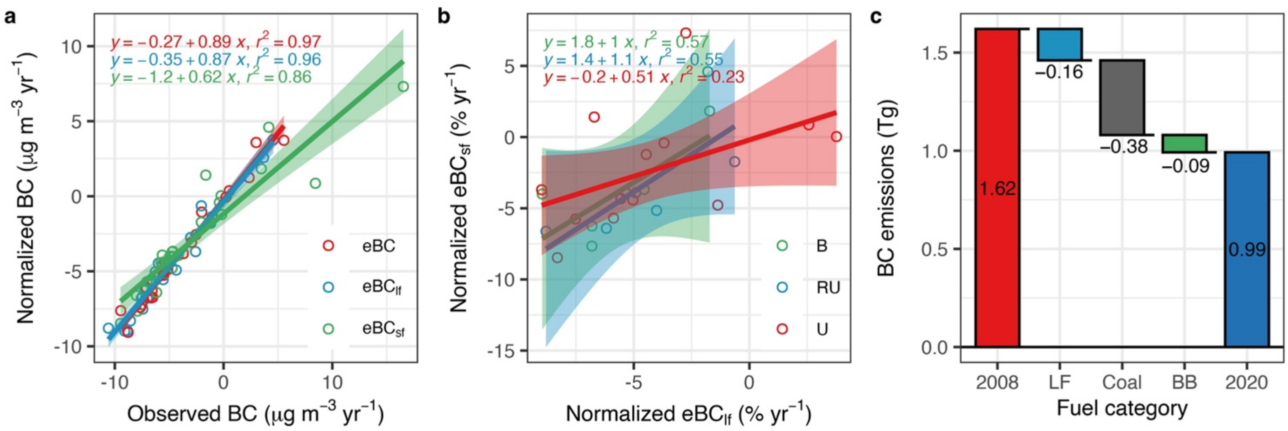
AR: Thanks for your reminder and we have revised the color schemes of Fig. 8, 9, and 10 as follows.



Revised Fig. 8.



Revised Fig. 9.



Revised Fig.10.