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The revised manuscript entitled "Distinct responses of Asian summer monsoon to black carbon aerosols and greenhouse gases" by Xiaoning Xie, Gunnar Myhre, Xiaodong Liu, Xinzhou Li, Zhengguo Shi, Hongli Wang, Alf Kirkevåg, Jean-Francois Lamarque, Drew Shindell, Toshihiko Takemura, and Yangang Liu.

We thank the ACP Handing Editor (Professor Jianzhong Ma) for his hard work and the two anonymous referees for their constructive suggestions to improve our manuscript significantly. We greatly appreciate the generally positive comments from both the two Reviewers (Reviewer #1 and Reviewer #2), and have addressed all the concerns, with point-by-point responses detailed below (reviewers comments in red color and our responses in blue color). If you have any questions, please do not hesitate to contact me via email at xnxie@ieecas.cn. Thank you very much for your kindness and hard work.

Best wishes,

Xiaoning Xie, Gunnar Myhre, Xiaodong Liu, Xinzhou Li, Zhengguo Shi, Hongli Wang, Alf Kirkevåg, Jean-Francois Lamarque, Drew Shindell, Toshihiko Takemura, and Yangang Liu.

Response to Reviewer #2:

General comments:

This study compares the influence of BC and GHGs on Asian summer monsoon based on the PDRMIP simulations, and the physical mechanisms that influence the responses are discussed as well. The topic is really interesting and the manuscript is well organized and presented, while I think the manuscript can be further improved by considering. I suggest the paper to be published after a major revision, and my specific comments are listed below.

Response: Thank Reviewer #2 very much for the positive comments and constructive suggestions. We have addressed all the specific comments with point-by-point responses listed below.

1. Three sub-regions are defined for discussions, and dots with different colors are suggested to differ the three regions.

Taken. According to the Reviewer's comment, the three monsoon regions are shown including East Asian, South Asian, and western North Pacific monsoon regions in Figure 1.

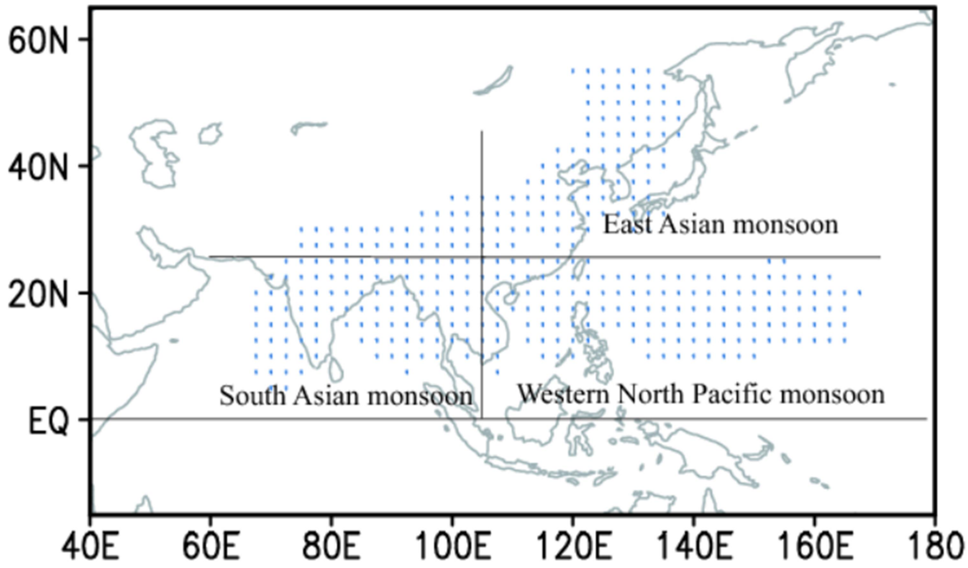

Figure 1. Spatial distribution of the Asian monsoon region (stippled, blue) including East Asian, South Asian, and western North Pacific monsoon regions based on the CMAP data from 1979-2011.

2. It is interesting and expected to find the uncertainties related to the BC_10 is larger than those of CO2_2, and would the authors give more discussions on the possible of the uncertainties?

Yes, we have added some discussions on the possible reasons of more uncertainties due to BCx10 experiments. This larger uncertainty of BCx10 is mainly due to large uncertainty in BC-induced ERF as shown in Figure 13. This positive correlation in Figure 13b indicates that the aerosol-induced ERF over the Asian region mainly dominates the ASM P-E changes for the individual GCMs, where larger positive (negative) ERF increases (decreases) the ASM P-E more substantially. Hence, the larger uncertainty of aerosols in ASM P-E is mainly resulted from large uncertainty in ERF. We have added the corresponding descriptions in the revised manuscript.

3. CMAP precipitation and the corresponding references should be given. Is there also precipitation in NCEP2, and why different "observations" are used in Figure 2 (even if the variables are different)?

According to the Reviewer's comments, we have added the reference about the CPC Merged Analysis of Precipitation (CMAP) for 1979-2011 (Xie and Arkin, 1997). The CMAP precipitation is often used to validate the model precipitation. NCEP-DOE Reanalysis 2 (labeled by NCEP2) is an improved version of the NCEP Reanalysis I model that fixed errors and updated paramterizations of physical processes (https://psl.noaa.gov/data/gridded/data.ncep.reanalysis2.html). This reanalysis mainly includes 3-d wind field, mainly based on model to perform data assimilation, whereas it does not include the variable of precipitation. Hence, observations of precipitation are based on CMAP, whereas observations of wind field are from NCEP2 data.

4. I found Section 4 really interesting, and would really suggest the authors to extend the corresponding discussions. For example, the authors simply mentioned that "Our analysis suggests that there are obvious differences in the spatial distribution between BC and GHG-induced ERF, although both of them induce positive radiative forcings at the TOA" for Figure 8. How the differences are introduced, and how such differences would further influence the ASM? Maybe the spatial distributions of BC and CO2 concentration differences introduce the differences. Thus, I suggest to include the BC and CO2 concentration distribution in the figure as well. This is not directly related to this study, but may be helpful to better understand the forcing. Meanwhile, I noticed that there are some regions with negative forcing, and how such forcing is introduced? This is just one example, and I suggestion the section to be discussed in more details. However, this is just my personal suggestion, and it is

totally up to the authors' choices.

Thank the Reviewer for his constructive suggestions. The greenhouse gas CO2 is well-mixed. Hence, the CO2 concentration is almost the same for everywhere, leading to uniform radiative forcing. Spatial distribution of BC concentration in PDRMIP has been shown in Figure S1 from the Reference (Stjern et al., 2017), which is absolutely same as our results (because we used the same PDRMIP data). These exists larger BC burden over India, China, and Central Africa in Figure S1. As the Reviewer mentioned, this pattern leads to the similar spatial distribution of ERF in Figure 8. Additionally, instantaneous radiative forcing (IRF) and effective radiative forcing (ERF) are often used to describe aerosol radiative forcing in the IPCC AR5 terminology, where ERF is recommended in IPCC AR5 (Boucher et al., 2013). ERF is defined as the change in net radiative long-wave (LW) plus short-wave (SW) fluxes at TOA in the fSST simulations, which includes fast responses (e.g., cloud feedback, water vapor feedback, and so on). Therefore, IRF due to BC shows positive values for everywhere in Figure 5 from the Reference (Stjern et al., 2017). However, ERF indicate complex changes with negative forcing over several regions due to fast responses (Stjern et al., 2017).

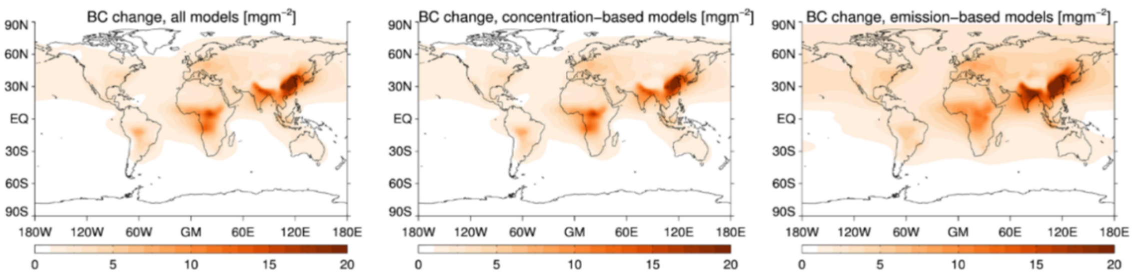

Figure S1. BCx10 minus BASE BC burden changes for the median of all nine models (left), the five models using concentration-based perturbation simulations (middle) and the four models using emission-based perturbation simulations (right). This Figure is absolutely from Figure S1 based on PDRMIP (Stjern et al., 2017).

5. The spatial variations of the variables should be better discussed. Maybe the standard deviation over space can be discussed and given as well.

Spatial distribution of MJJAS △(P-E) and the corresponding standard deviation due to BCx10AISA, SO4x5, and SO4x10ASIA was shown in Figure S2. The figure shows similar spatial pattern for △(P-E) and its standard deviation, where larger values in △(P-E) corresponds to larger standard deviation. Hence, its standard deviation can provide additional information. The increase in P-E in BCx10ASIA is true over almost the East Asian monsoon region, whereas the decreases in P-E are shown for SO4x5 and SO4x10ASIA over this region. However, spatial distribution of △(P-E) is inconsistent mainly due to regional dynamic responses related to complexity of Asian summer monsoon, as shown in many references e.g., Zhou et al. (2009).

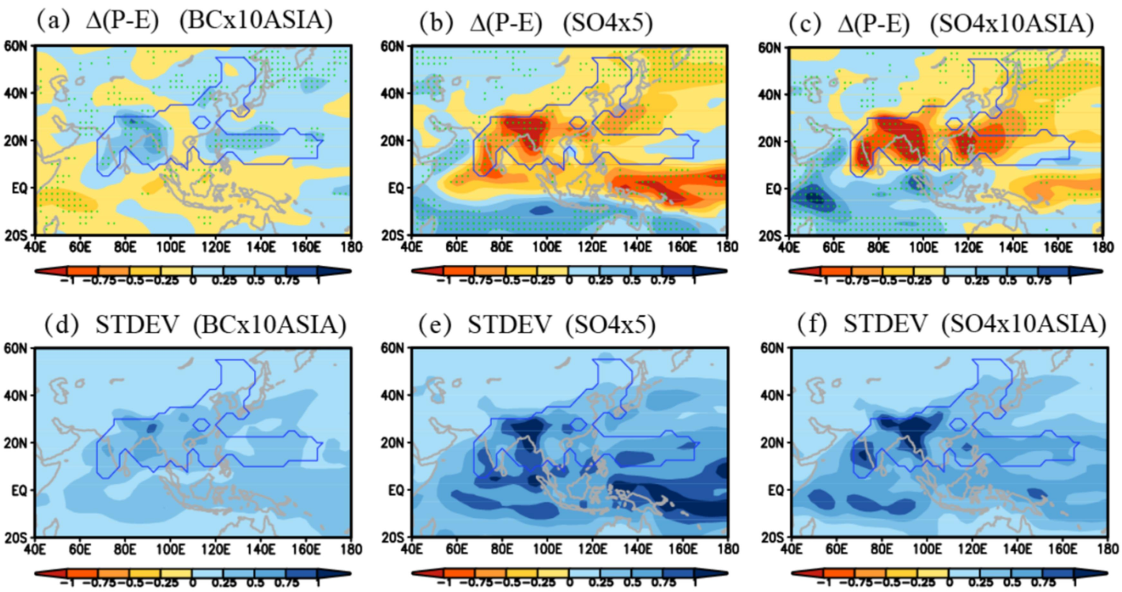

Figure S2. Changes in the MJJAS precipitation minus evaporation (△P-E), unit: mm day^{-1} and the corresponding standard deviation (STDEV) for (a, d) increasing Asian BC, (b, e) global SO4, and (c, f) Asian SO4. Dotted regions (a, b, and c) indicate where MMM is more than 1 standard deviation away from zero. The areas within the blue line represent the Asian monsoon region.

6. SO4_5 is used, whereas, for the ASIA case, the SO4_10ASIA is considered, which makes the comparison less meaningful.

Firstly, the experiments of SO4x5 and SO4x10ASIA are performed in the PDRMIP project in Table S2 (Myhre et al., 2017; Liu et al., 2018). We only show the results about aerosol experiments about SO4x5 and SO4x10ASIA in PDRMIP project (Figure 12). Additionally, it also shows the regression of the P-E versus the regional ERF for global aerosols and for Asian aerosols in Figure 13b. This regression makes the comparisons between SO4x5 and SO4x10ASIA meaningful.

Table S2 Model simulations about aerosols analyzed in the current study.

Experiment	BCx10	BCx10ASIA	SO4x5	SO4x10ASIA
Specifications	BC increased by 10 times globally	BC over Asia increased by 10 times	SO4 increased by 5 times globally	BC over Asia increased by 10 times

7. Labels for the markers should be given in Figure 13(b)

Thank the Reviewer for his suggestions. Labels for the markers have been added in the Figure 13b.

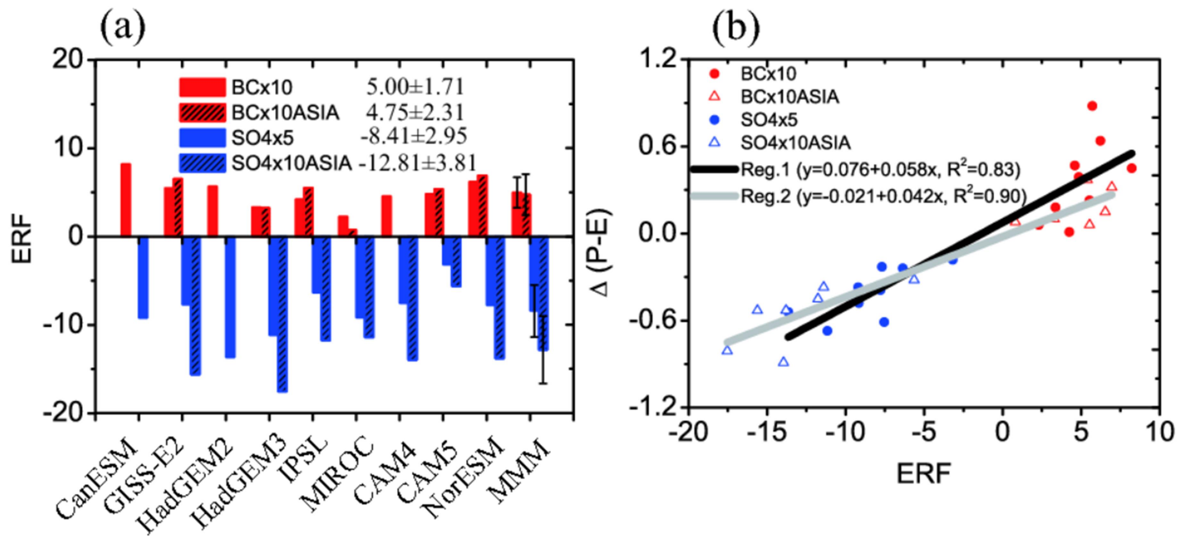

Figure 13. (a), MJJAS domain-averaged effective radiative forcing over the Asian region with 60-125E and 10-42.5N (ERF, unit: W m^{-2}) under increasing global (BCx10 and SO4x5) and Asian aerosols (BCx10ASIA and SO4x10ASIA), where error bars of multi-model mean (MMM) represent the standard deviation. (b), Regression of the domain-averaged change in MJJAS precipitation minus evaporation over the Asian monsoon region (△(P-E), unit: mm day^{-1}) versus the regional ERF for global aerosols (Reg.1) and for Asian aerosols (Reg.2).

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