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Responses to Reviewer #2

This study investigated the regional climate responses, non-linearity, and short-term transient responses to BC emission. The topic is of interest and the method scientifically sounds.

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

Major comments

1)There is no model evaluation in this study. How does the model in terms of the aerosol species or climate variables? Some statistical evaluations are useful to warrant the confidence in interpreting the model results.

Response:

Previous studies have extensively evaluated the CAM5 model simulations of concentration, deposition, vertical profile and optical properties of BC (Wang et al., 2013; Wang et al., 2015; Zhang et al., 2015a,b; Liu et al., 2016; Yang et al., 2017, 2018a,b)), as well as climate variables (Hurrell et al., 2013; Yang et al., 2016a,b). The model can simulate well the BC aerosol and climate variables in most regions of the globe, but was reported to underestimate BC concentrations over China (Yang et al., 2018a) and the Arctic (Wang et al., 2013) (although this earlier study used a different emissions dataset), implying a possible underestimate of climate responses to BC emissions in this study. We have added these texts in the methods section.

2) The authors mainly analyzed the results from the annual scale. Are there any substantial differences in a finer temporal scale, i.e., daily or monthly or seasonal?

Response:

Thanks for the suggestion. We have added Figures S2 and S3 as below to show the seasonal and monthly surface air temperature change. Since that the climate response and variability are normally longer than daily scale, we skipped the daily information. We have also added texts in the manuscript to illustrate the seasonal difference that “The seasonal mean surface air temperature responses present similar spatial patterns (Figure S2), but slightly different magnitudes (Figure S3). Over the Arctic, the warming due to Arctic BC emissions is weakest in boreal summer. This is because the smaller summer sea ice and snow fraction in the Arctic weakens BC snow/ice-albedo forcing.

However, in the mid-latitudes, warming is strongest in boreal summer for both Arctic and mid-latitude BC emissions, because of stronger summer solar insolation and, therefore, stronger BC heating in the atmosphere."

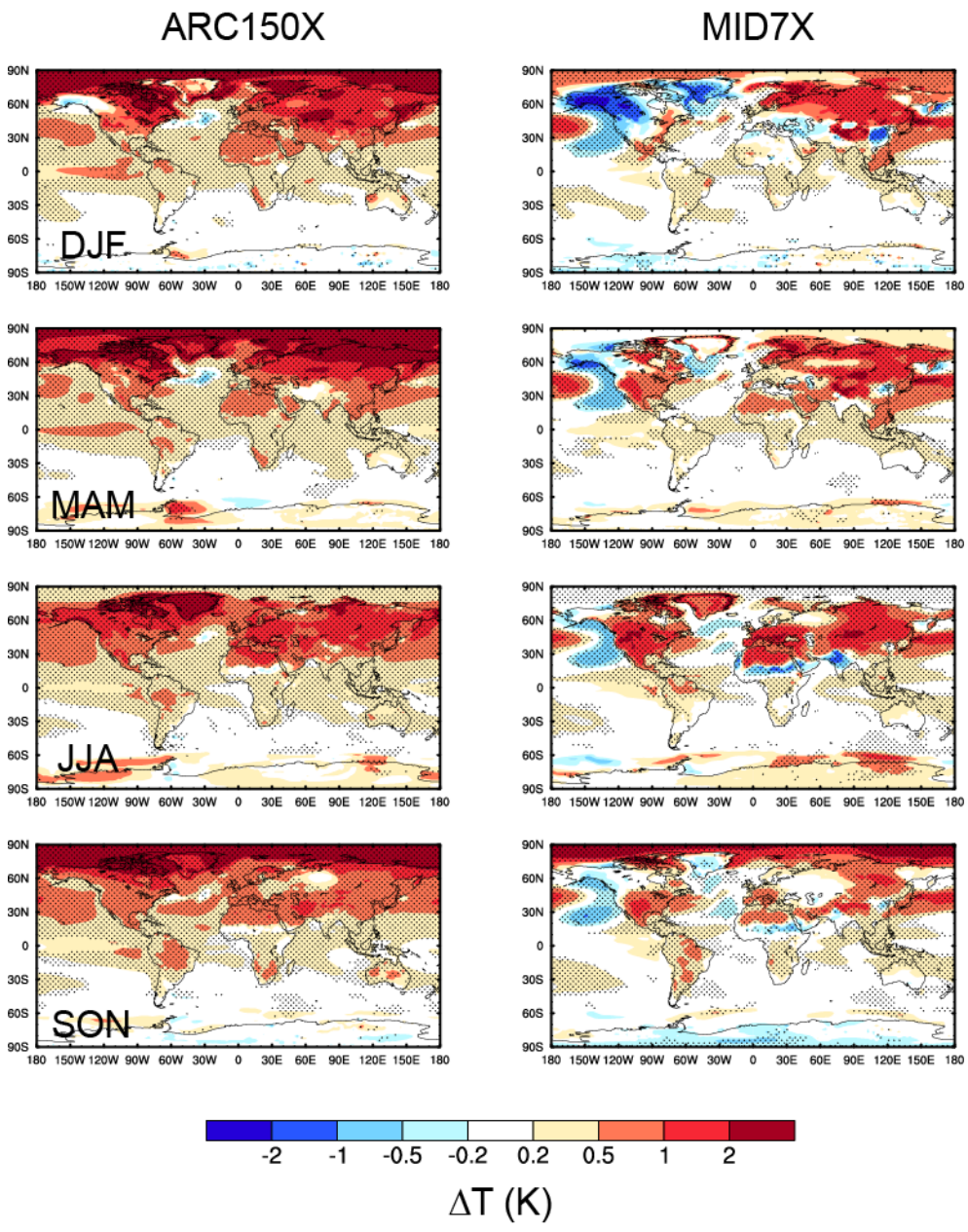

Figure S2. Spatial distribution of changes in December-January-February (DJF), March-April-May (MAM), June-July-August (JJA) and September-October-November (SON) (from top to bottom) mean surface air temperature (K) for ARC150X (left) and MID7X (right) compared to PD. The dotted areas indicate statistical significance with 95% confidence from a two-tailed Student's t test.

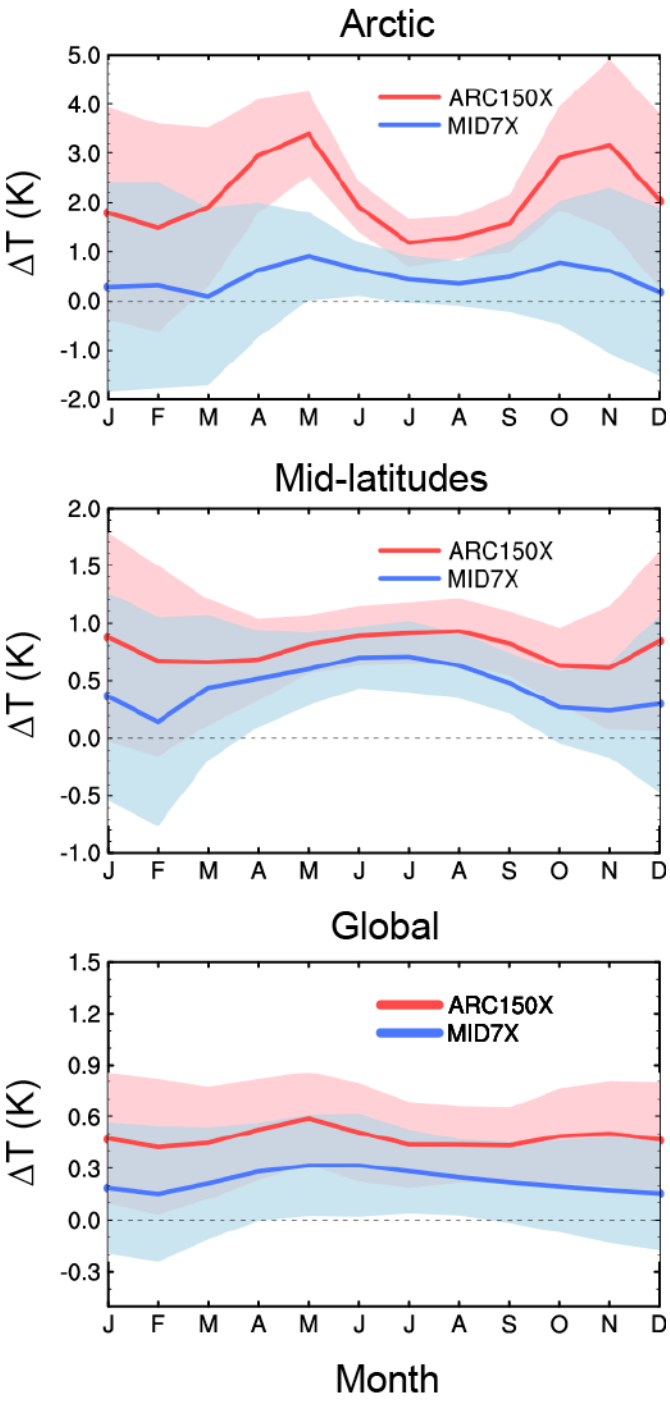

Figure S3. Changes in Arctic (top), mid-latitude (middle) and global (bottom) monthly mean surface temperature (K) for ARC150X/MID7X compared to PD.

Minor comments:

2)Line 283: due to their 30 times larger: how to get the value of 30?
Response:

Revised to “Mid-latitude emissions, however, are likely to have a larger present-day impact overall due to their 35 times larger preindustrial to present-day emission increase (2.874 Tg yr^{-1}) than Arctic emissions (0.082 Tg yr^{-1}).”

3) Figures 4-7: The captions need to be revised to explain the meaning of the dots. In Figure 2, it says that “The dotted areas in left panels indicate statistical significance with 95% confidence from a two-tailed Student’s t test.” Probably the dots in figures 4-7 share the same meaning. Please clarify.
Response:

Yes. Clarified in Figure 4-7.

4) Page 10, Line 194: Both mass and number of BC
Response:

CAM5 predicts both mass and number mixing ratios of aerosols, which requires both the mass and number emissions. That is why we mentioned here that “Both mass and number of BC emissions are perturbed proportionally.”

5) Line 273-274: from Figure 3, we can see some substantial changes in the south hemisphere. What does this mean? Were the emissions scaled in the south hemisphere as well?
Response:

We only scaled BC emissions in the Arctic and mid-latitudes of the Northern Hemisphere, respectively. Energy balance is not like the short-lived BC aerosol, which is mainly located near its sources. With the strong BC perturbation in the whole Arctic and mid-latitudes, energy balance will be changed not only in the regions where it is perturbed, but in the global scale, because the perturbation changes the latitudinal temperature gradient and therefore the poleward heat transport in both Northern and Southern Hemisphere.

6) Line 446-447: Large scale surface temperature from current-day BC emissions is statistically indistinguishable from zero. The authors’ statement is based on global scale. Since the variability is large, are there any features (i.e., larger change in some areas) in different locations?
Response:

Thanks for the suggestions. Yes, there are significant temperature changes regionally. “PD emissions produce statistically significant surface air temperature changes over only limited regions in the Northern Hemisphere. Decreased temperatures are found over eastern China, South Asia, North

Atlantic Ocean, and North American Arctic, partly due to cloud changes driven by BC rapid adjustments. Increased temperatures are found over the Tibetan Plateau, Greenland and high-latitude land regions likely because of the BC snow/ice-albedo effect". To make it clearer, we have also revised the text as "Although statistically significant surface temperature changes are found regionally, as mentioned above, large-scale global surface temperature change from current-day BC emissions is statistically indistinguishable from zero".

7) Line 522: BC direct radiative effects and snow/ice-albedo forcings have much larger signal to noise ratios: Could you please explain a bit more what the larger signal to noise ratio mean?

Response:

Changed to "aerosol burdens, BC direct radiative effects and snow/ice-albedo forcings have much larger signal to noise ratios, i.e. ratio of mean response to standard deviation (Table 1)"

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