#RC 1

Black carbon (BC) is one of the major air pollutions severely threatening public health despite of its relatively low contribution to total PM mass, not only due to its toxicity but also its nature of light absorption. Because of this, BC is able to alter boundary layer stability and structure, which further influence the ventilation of pollutants. Previous studies have demonstrated the importance of this BC light absorption effect in surface layer pollution in many China megacities. This study use APEC Blue period as a natural lab to further quantify this impact using a fully coupled model. The scope fit well with ACP. The manuscript is well written, the results are scientific interesting and politically meaningful supported by sound methodology. I feel this work is suitable for publication after addressing a few minor concerns.

Reply:

- We thank the reviewer for careful reading and valuable suggestions, which are important to improve the quality of our manuscript.

Minor concerns:

1) Calculation of aerosol optical properties has been well described for the external mixture and internal homogeneous mixture (volume-weighted average). I feel the calculation details of core-shell mixture should also be elaborated, given core-shell is the main mixture style discussed in this paper. Please also provide the information of how complex reflective index is defined for each component, especially for organics.

Reply:

- Thanks for this suggestion. We added descriptions of core-shell calculation in the revised manuscript.
- “For core-shell internal mixing, similar averaging processes are applied to the core and shell separately. The scattering efficiency, absorption efficiency and asymmetry parameter are then obtained using the core-shell Mie theory documented in Toon and Ackerman (1981). Core-shell Mie calculation requests core radius, shell radius, refractive index of core and refractive index to shell as inputs (Toon and Ackerman, 1981).”

Toon, O. B. and Ackerman, T.P.: Algorithms for the calculation of scattering by stratified spheres, Appl. Opt., 20, 3657-3660, 1981.

- For reflective index for each component, we added Table S1 to list it, including OC.

Table S1. Complex refractive index for major aerosol components in WRF-Chem

Components	real	imaginary
BC	1.85	0.71
Dust	1.55	0.006
Organics	1.45	0
NH_4Cl	1.50	0
NH_4NO_3	1.50	0
NH_4HSO_4	1.47	0
NA_2SO_4	1.50	0

2) There are many ways/definitions of boundary layer top. How boundary layer top is defined and hence its height is estimated?

Reply:

- Different PBL schemes in WRF use different ways to determine the PBL top. For example, the MYJ scheme determines the PBL height using the TKE profile. It defines the top of the PBL to be the height where the TKE decreases to a prescribed low value (Janjic 2001). We used YSU scheme, and it defines the top of the PBL as the height where the bulk Richardson number calculated above the level of neutral buoyancy first exceeds a critical Richardson number (Hong et al., 2010).

Hong, S.Y., 2010. A new stable boundary-layer mixing scheme and its impact on the simulated East Asian summer monsoon. Quarterly Journal of the Royal Meteorological Society, 136(651), pp.1481-1496.

- We have added this information in the revised manuscript.

3) line 283. Do you mean reduce PBLH by 8.2m on average?

Reply:

- Yes, 8.2 on average.
- In the revised manuscript, we added the following description: “on average during the APEC week”.

4) There is some nice discussion about the PBL-PM2.5-O3 interactions. I think some chemical reasons also influence ozone. Such as, reduce of PM2.5 could enhance the surface layer photolysis therefore increase ozone especially for heave polluted area/periods, and the co-reduction of NOx and the regime of NOx (Chen et al., 2021).

References:

Chen, Y., Beig, G., Archer-Nicholls, S., Drysdale, W., Acton, J., Lowe, D., Nelson, B. S., Lee, J. D., Ran, L., Wang, Y., Wu, Z., Sahu, S. K., Sokhi, R. S., Singh, V., Gadi, R., Hewitt, C. N., Nemitz, E., Archibald, A., McFiggins, G., and Wild, O.: Avoiding high ozone pollution in Delhi, India, Faraday Discussions, 10.1039/D0FD00079E, 2021.

Reply:

- Thanks for this suggestion. We discussed the influence of photolysis in the manuscript, as listed below.
- “However, inhibited PBL development does not necessarily lead to enhanced levels of near surface O_3, as the formation of O_3 is also affected by changes in aerosols and photolysis reactions above the ground. As displayed in Figure 4e, near surface O_3 concentrations in urban Beijing decrease in response to BC absorption.”

- “The responses of O_3 to reduced light absorption of BC during APEC are in the opposite direction (Gao et al., 2018c), compared to those for $PM_{2.5}$. Strong absorption of BC tends to enhance photolysis above the aerosol layer, but to reduce photolysis near the ground. Figure 7d, 7g illustrate the changes in O31D and NO2 photolysis rates with emission reductions inferred from an external mixing assumption. With emission control implemented, photolysis rates near the ground are enhanced due to lower light absorption of BC, while the photolysis rates above the aerosol layer are reduced. Similar patterns but with larger values are found using the core-shell model (Figure 7e, 7h). The responses of O3 are generally in line with the responses of O31D and NO2 photolysis rates (Figure 7a, 7b).”
- Yes, we agree that changes in sources would also affect ozone. We interpret the changes with respect to optical properties, and emission levels were kept at the same level, as stated in equations (1-5). Thus, sources and chemical reasons would not affect our results.
- We added the discussions on chemical reasons in the manuscript: “O_3 is also affected by changes in aerosols and photolysis reactions above the ground (Chen et al., 2021).”

$$\Delta_{BC-Ext-NOCTL} = NOCTL_{Ext} - NOCTL_{Ext-nobc} \quad (1)$$

$$\Delta_{BC-Ext-CTL} = CTL_{Ext} - CTL_{Ext-nobc} \quad (2)$$

$$\Delta_{BC-CS-NOCTL} = NOCTL_{CS} - NOCTL_{CS-nobc} \quad (3)$$

$$\Delta_{BC-CS-CTL} = CTL_{CS} - CTL_{CS-nobc} \quad (4)$$

$$\Delta_{BC-CS-CYSN} = CYSN_{CS} - CYSN_{CS-nobc} \quad (5)$$

5) Just curious that in Fig. 5h, why reduction of emission could lead to a strong enhance of pollutants in the northwest? Is there some interactions between PM and dynamic lead to the re-distribution of pollutants? This may be out of the scope of this study, therefore do not expect authors’ full answer here. Some discussion would be appreciated and may be an interesting topic for future study.

Reply:

- We checked the emissions from both natural sources and human activities. The reduction in emissions lead to absorption induced changes in meteorological variables, which is stronger when we use C-S model (fig. 5g). As a result, emissions in wind-blown dust have been changed in the northwest. Yes, it could be an interesting for future study.
- In the revised manuscript, we added one sentence to discuss it: “It was noted that PM2.5 concentrations was enhanced in northwest China, particularly when we used C-S model. This is related absorption-modulated natural emissions of windblown dust.