Response to Anonymous Referee #1

Major comments:

1) Throughout the paper, it is unclear whether the authors are discussing the whole diameter of the BC-containing particles or the diameter of the BC core within the BC-containing particles. In the reviewer's opinion, "BC mass size distribution (BCMSD)" usually refers to the size distribution of BC cores. However, this study seems to refer to the size distributions of whole particles containing BC and non-BC material, which is difficult to understand unless it is clearly explained. When the authors state that "the mass size distribution of BC is bimodal," the readers may assume that the mass size distribution of BC core is bimodal. In the case of this paper, can it mean that the BC core size is not bimodal, but there are two distinct groups of BC cores containing thin and thick coatings?

Response: Thank you for your comments. In this study, BC mass size distribution (BCMSD) refers to the size distribution of whole particles containing both BC and non-BC material. We clarify it in the revised manuscript. "The mass size distribution is bimodal" means that there are two distinct groups of BC-containing particles with respect to the size of the whole particle. We make it clear in the revised manuscript. It is possible that the BC core size is not bimodal, but there are two distinct groups BC cores containing thin and thick coatings.

2) More explanations on assumptions of mass absorption cross section (MAC) values to derive eBC mass concentration are needed, although a previous study is referred to in the manuscript. For example, even though the whole particle size is 700 nm, the MAC value should differ depending on whether the BC core is 700 nm (bare BC) or the BC core is 200 nm (thickly coated BC). If the uncertainty in the size-resolved MAC assumed in this study is large, the associated uncertainty in the size-resolved eBC mass concentrations is also considerable. Since the size-resolved absorption data is closer to the raw data, are these data more reliable and can be more central to the discussion in this paper?

Response: Thank you so much for your comments. We add more explanation of assumptions and associated uncertainty in deriving MAC in the revised manuscript. Although size-resolved absorption data is closer to the raw data, optical parameters related to radiative transfer, such as particle scattering, have to be calculated based BC mass, and emission inventory data usually associate with BC mass, not BC absorption. Therefore, BC mass is discussed in this study rather than BC absorption.

3) In section 2.3, the authors explain the assumptions needed for estimates of DRF, but it is unclear whether these assumptions are consistent with the observations obtained in this study. How are the temporal changes

in size distribution and mixing states of BC-containing particles incorporated into the estimate?

Response: Thank you for your comments. Theses assumptions are consistent with the observations obtained in this study. Take DRF estimated at time t_0 of May 25th 2021 as an example, size-resolved eBC mass concentration (eBCMSD) and size-resolved particle number concentration ($N_{\text{size-resolved}}$) measured at t_0 are used as boundary condition at ground level to construct parameterized vertical aerosol profile. When calculating aerosol optical parameters at each level, mixing states of BC-containing particles are assumed to be the same at each level, each time and each D_p. With abovementioned eBCMSD, $N_{\text{size-resolved}}$ and mixing state at each level, aerosol optical parameters can then be determined based on Mie theory. Therefore, mixing state is fixed in this study. eBCMSD and $N_{\text{size-resolved}}$ are varied with level and time based on observation. We add more explanation in the revised manuscript to make it clear.

4) Clarifications of these points and English proofreading throughout the manuscript are required.

Response: Thanks for your comments. We make corresponding changes in the revised manuscript.

Specific comments:

1) L24: "Size distribution" cannot be expressed as high or low. Concentrations are high or low.

Response: Thanks for your comments. "lower (higher) level of eBCMSD" is changed into "smaller (bigger) value of eBCMSD".

2) L37: "Absorption of BC increases light extinction". The wording needs to be corrected.

Response: Thank you for your suggestion. "Absorption of BC increases light extinction" was revised into "light absorption by BC reduces atmospheric visibility".

3) L51: "reported that" is repeated.

Response: Thanks for your comments. One repeated "reported that" is removed.

4) L101: In this study, BC-containing particles smaller than 200 nm are not considered when calculating the "bulk" eBC mass concentrations. However, their contribution to total eBC mass concentrations is not negligible (as suggested by Figure 2). This can lead to an overestimate of the mass fractions of eBC>700 within the total eBC mass concentrations. Clarifications are needed.

Response: Thanks for your comments. We discuss the uncertainty in $f_{m,>700}$ associated with limited size range

in the revised manuscript.

5) L103: D_p0 is not defined.

Response: Thanks for your comments. D_{p0} is removed in the revised manuscript.

6) L146-149: Are these assumptions consistent with the observations obtained in this study? It is difficult to understand how the measurement values are incorporated into the DRF estimate.

Response: Thanks for your comments. These assumptions are consistent with the observation obtained in this study. The measurement values are used to calculate aerosol optical parameters, such as aerosol extinction coefficient, asymmetry factor and single scattering albedo. These optical parameters are then feed into radiative transfer model for DRF calculation. We add more explanation in the revised manuscript to make it clear.

7) L169: The size-resolved absorption (Figure 5a3) is monomodal, but the eBCMSD (Figure 5a1) is bimodal, indicating a strong influence of the assumed size-dependent MAC. Some more explanation should be given for deriving the size-dependent MAC.

Response: Thanks for your comments. We add more explanation for deriving size-dependent MAC in the revised manuscript.

8) L174-175: These are dm/dlogD values rather than eBCMSD.

Response: Thanks for your comments. We add "value" after "eBCMSD" in the revised manuscript.

9) L193-194: It seems obvious since the eBC mass concentration ranges for clean and transition periods were defined as such.

Response: Thanks for your comments. This sentence is removed in the revised manuscript.

10) L243: Any reference for interpretation or comparison? (e.g., Liu, D.et al., Contrasting physical properties of black carbon in urban Beijing between winter and summer. Atmospheric Chemistry and Physics 19, 6749-6769, https://doi.org/10.5194/acp-19-6749-2019, 2019)

Response: Thanks for your suggestion. The study by Liu et al. (2019) offers a valuable interpretation and is cited in this study.