Supporting information for

Enhanced heating rate of black carbon above planetary boundary layer over megacities in summertime

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| Parameter                          | Input value                                                                 |
|-----------------------------------|------------------------------------------------------------------------------|
| Radiative transfer solver         | DISORT, 12-streams, delta-m method                                           |
| Gas absorption parameterization   | LOWTRAN/SBDART parameterization                                              |
| Wavelength range                  | 250-2550nm                                                                  |
| Atmosphere                        | Standard Mid-latitude Summer atmosphere                                      |
| Aerosol                           | All profiles use 200m altitude bin                                           |
|                                   | AOD profile derived from in-situ PCASP measurement, also applying an exponential $\lambda$-dependent function |
|                                   | SSA profile derived from in-situ PCASP and SP2 measurement                  |
|                                   | Asymmetry factor (g) profile derived from in-situ PCASP measurement          |
|                                   | Henyey-Greenstein phase function                                            |
| Location                          | 34.04°N, 117.48°E                                                          |
| Time                              | Aircraft profile time 9:30, 12:00 or 14:30                                   |
| Solar zenith angle                | Effective solar zenith angle                                                 |
|                                   | Using aircraft profile time and location                                     |
| Surface albedo                    | IGBP surface type 13 (Urban)                                                 |
| Cloud                             | One dimensional water cloud profile [Hu and Stamnes, 1993], liquid water content (LWC) and effective radius is derived from FCDP measurement |
|                                   | Cloud cover is 0.15 according to aircraft camera                             |

Table S1. Input parameters for radiative transfer calculation.
| Parameters                                              | Instrument                                                      | Additional information |
|--------------------------------------------------------|-----------------------------------------------------------------|------------------------|
| Wind speed/direction, temperature, RH                  | Aircraft Integrated Meteorological Measurement System (AIMMS-20) | Wing-mounted           |
| Size distribution 0.12-2.5μm                          | Passive Cavity Aerosol Spectrometer Probe (PCASP-100X)          | Wing-mounted           |
| Size distribution 0.006 -0.52μm                        | Engine Exhaust Particle Sizer (EPS)                             | In the cabin           |
| Cloud liquid water content                             | Fast cloud droplet probe (FCDP)                                | Wing-mounted           |
| rBC mass, size distribution and mixing state           | Single particle soot photometer (SP2)                          | In the cabin           |

Table S2. Summary of the instruments and measured parameters in this study.
Fig. S1. (a) Pressure chart and wind field at geopotential height 700hpa, with the black square marking the flight region for Xuzhou summer flight 20180714. (b) Flight patterns in 0713-0715. From top to bottom panel on each figure: solar elevation angle with night time in red shade (elevation angle <0°), and the grey bars mark the periods when vertical profiles were performed; wind direction and wind speed profiles measured by the wind profile radar located close to Xuzhou.
Fig. S2. Lidar extinction measured at Huaian and Hefei on 0714 and 0715. The circles mark the aerosol layer above the PBL observed in the early afternoon.

Fig. S3. MODIS cloud images in the visible, and AOD (the image colour), in 0713, 0714 and 0715. The black square marks the region of flight path.
Fig. S4. Size distributions at altitude 1-2km for flight 20180715 midday profile, including the size distribution from EPS (d=6-550nm), the PCASP (d=0.12-2.5\(\mu\)m), uncoated and coated rBC size distribution from the SP2. The dash lines show the lognormal fitting on the uncoated and coated rBC size distribution.
Xuzhou summer
Beijing summer

Fig. S5. Vertical profiles of in-situ measured temperature, potential temperature and relative humidity for three campaigns. The large and small markers denote the PBL and FT respectively. The cloud layer was detected by the FCDP measurement during Xuzhou campaign, shown in blue lines in the middle panel. The right panel shows a typical picture of clouds taken by aircraft camera on 0714 and 0715 respectively.
Fig. S6. Vertical profiles of number concentration of Aitken mode particles (8-100nm measured by the EPS), accumulation mode particles (measured by the PCASP), PM$_1$ derived from the PCASP and the effective diameter ($D_{eff}$) from the PCASP for Xuzhou campaign.
Fig. S7. Vertical profiles of BC-related properties using identical legends with Fig. 2 but for the flight 0713 during Xuzhou campaign. For Beijing winter and summer campaigns, only rBC mass loading and coating information are shown.
Fig. S8. Input parameters (AOD, SSA and g) at λ=870nm for Libradtran radiative transfer calculation during Xuzhou campaign.
Fig. S9. Modelled actinic flux, direct and diffuse irradiances for Xuzhou campaign, the dash lines show the irradiance without aerosol input.
Fig. S10. Example for the calculation of BC heating power in the PBL during Xuzhou flight 20180714. From top to bottom: λ-segregated actinic flux; BC mass absorption cross section (MAC) for uncoated and coated BC; BC core size-resolved absorption power at each λ.