Supplement of

Simulated impacts of vertical distributions of black carbon aerosol on meteorology and PM$_{2.5}$ concentrations in Beijing during severe haze events

Donglin Chen et al.

Correspondence to: Hong Liao (hongliao@nuist.edu.cn)

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Table S1. The values of $hs$ for each flight.

| Flight date and time | $hs$ value |
|----------------------|------------|
| 2016/12/11 16:20     | N/A        |
| 2016/12/12 13:05     | 0.82       |
| 2016/12/12 15:39     | 0.96       |
| 2016/12/16 15:47     | 0.53       |
| 2016/12/17 15:59     | 0.35       |
| 2016/12/18 14:22     | 0.79       |
| 2016/12/19 16:09     | 0.48       |
Table S2. Statistical metrics for PM$_{2.5}$, SO$_2$, NO$_2$, CO and O$_3$ on clean days and in two haze events.

| Periods          | Variables | SIM  | OBS  | R    | MB   | NMB  | MFB  |
|------------------|-----------|------|------|------|------|------|------|
| Clean days       | PM$_{2.5}$ (μg m$^{-3}$) | 64.4 | 35.3 | 0.15 | 29.1 | 82.5% | 84.1% |
|                  | SO$_2$ (ppbv)   | 5.5  | 3.6  | -0.02| 1.9  | 53.4% | 18.8% |
|                  | NO$_2$ (ppbv)   | 28.8 | 20.8 | 0.55 | 7.9  | 38.0% | 38.5% |
|                  | CO (ppmv)      | 11.0 | 14.2 | 0.64 | -3.1 | -22.0%| -50.7%|
|                  | O$_3$ (ppbv)   | 0.9  | 0.7  | 0.18 | 0.2  | 30.0% | 37.6% |
|                  | PM$_{2.5}$ (μg m$^{-3}$) | 186.1| 179.8| 0.64 | 6.3  | 3.5%  | 8.0%  |
| Two haze events  | SO$_2$ (ppbv)   | 9.1  | 9.9  | 0.29 | -0.7 | -7.4% | -13.5%|
|                  | NO$_2$ (ppbv)   | 57.2 | 48.2 | 0.70 | 8.9  | 18.5% | 12.5% |
|                  | CO (ppmv)      | 4.6  | 3.2  | 0.88 | 1.4  | 43.0% | -39.4%|
|                  | O$_3$ (ppbv)   | 2.2  | 2.4  | 0.30 | -0.2 | -9.3% | -8.4% |
Table S3. Statistical analyses of the performance of CTRL (with original BC vertical profiles) and that of VerBC_obs (with modified BC vertical profiles) in simulating meteorological parameters. The values in RED indicate better performance in VerBC_obs than in CTRL.

| Obs/Sim  | Obs | CTRL | VerBC_obs | MB   | NMB   |
|----------|-----|------|-----------|------|-------|
|          |     |      |           |      |       |
| T2 (°C)  | 0.2 | 0.4  | 0.2       | 0.2  | 0.0   |
| RH2 (%)  | 65.5| 65.6 | 67.7      | 0.0  | 2.2   |
| WS10 (m s⁻¹) | 1.8 | 1.4  | 1.8       | -0.4 | -0.1  |
| WD10 (°) | 105.2| 109.0| 116.1     | 3.8  | 10.9  |
| PBLH (m) | 152.2| 197.2| 181.2     | 45.0 | 29.0  |
|          |     |      |           |      |       |
| T2 (°C)  | -1.1| 0.0  | 0.2       | 1.2  | 1.3   |
| RH2 (%)  | 65.3| 55.2 | 57.3      | -10.1| -8.0  |
| WS10 (m s⁻¹) | 1.4 | 1.4  | 1.1       | 0.0  | -0.3  |
| WD10 (°) | 196.2| 165.7| 173.0     | -30.5| -23.2 |
| PBLH (m) | 101.9| 145.6| 135.8     | 43.7 | 33.9  |

The first pollution event

The second pollution event
Table S4. Statistical analyses of the performance of CTRL (with original BC vertical profiles) and that of VerBC_obs (with modified BC vertical profiles) in simulating PM$_{2.5}$ concentrations. The values in RED indicate better performance in VerBC_obs than in CTRL.

| Obs/Sim | Obs  | CTRL | VerBC_obs | CTRL | VerBC_obs | CTRL | VerBC_obs | MB     | NMB    |
|---------|------|------|-----------|------|-----------|------|-----------|--------|--------|
| Dec 11  | 159.7| 214.1| 235.9     | 0.81 | 0.93      | 54.4 | 76.2      | 34.1%  | 47.7%  |
| Dec 12  | 212.3| 185.9| 189.6     | 0.04 | 0.24      | -26.4| -22.7     | -12.4% | -10.7% |
| Dec 16  | 100.7| 117.7| 115.3     | 0.56 | 0.65      | 17.0 | 14.6      | 16.9%  | 14.5%  |
| Dec 17  | 184.7| 190.8| 192.9     | 0.63 | 0.82      | 6.0  | 8.2       | 3.3%   | 4.4%   |
| Dec 18  | 219.5| 190.4| 199.8     | 0.38 | 0.38      | -29.1| -19.6     | -13.2% | -9.0%  |
| Dec 19  | 208.4| 217.8| 220.5     | 0.84 | 0.89      | 9.4  | 12.1      | 4.5%   | 5.8%   |
Figure S1. The calculated percentage of BC mass column burden in each layer below 2488 m in the model during the severe haze events by observed BC vertical profiles (a-f) and different exponential decline functions (g-l).
Figure S2. Observed (black dot) and simulated (red line) temperature (°C) profiles in Beijing at 8 am and 8 pm LT during 11-19 December 2016.
Figure S3. Horizontal distribution of observed and simulated AOD at 550 nm averaged 11-19 December 2016.
Figure S4. Comparisons of simulated hourly $T_2$ (°C), hourly $RH_2$ (%), 3-hourly PBL height (m), 6-hourly $WS_{10}$ (m s$^{-1}$) and daily $WD_{10}$ (°) from CTRL (original BC vertical profiles; red lines) and VerBC_obs (modified BC vertical profiles; green lines) experiments with observations (black circles) in Beijing during two pollution events (11-12 December and 16-19 December 2016).
Figure S5. Direct radiations of BC at the surface (SUF), in the atmosphere (ATM) and at the top of atmosphere (TOA) in Beijing averaged 12 and 16-19 December in six sensitivity experiments (VerBC_hs1-6).
Figure S6. The spatial distributions of changes in wind at 10 m due to BC DRE with two exponential functions (VerBC_hs1,6 minus NoBCrad) and one observed transport vertical profile (VerBC_RT minus NoBCrad) average 0:00-11:00 LT (a, d, g), 12:00-18:00 LT (b, e, h), and 19:00-23:00 LT (c, f, i).