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The impact threshold of the aerosol radiative forcing on the boundary layer structure in the pollution region

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This file includes:

S1. Introduction to other datasets:

The virtual potential temperature (θ_v) and pseudo-equivalent potential temperature (θ_{se}) are calculated with Equations (1) and (2), respectively:

$$\theta_v = T\left(1+0.608q\right)\left(\frac{1000}{P}\right)^{0.286} \tag{1}$$

$$\theta_{se} = T\left(\frac{1000}{P}\right)^{0.286}\exp\left(\frac{r_s L_v}{c_{pd}T}\right) \tag{2}$$

where T is the air temperature, q is the specific humidity, P is the air pressure, r_s is the saturation mixing ratio, L_v is the latent heat of vaporization at 2.5×10^6 J kg^{-1}, and c_{pd} is the specific heat of air of 1005 J kg^{-1} K^{-1}. All the relevant parameters can be calculated from the temperature and humidity profile data obtained with the MWR, and the values of θ_v and θ_{se} at different altitudes can be then further obtained.

The hourly TKE is calculated by instantaneous three wind components sampled by Doppler wind lidar every five seconds, shown as Equations (3)-(6). The calculated TKE profile has a spatial resolution ranging from 1-20 m up to 0.3 km and a spatial resolution of 25 m from 0.3 to 3 km, at a temporal resolution of one hour.

$$\mathrm{TKE} = \frac{\sqrt{\delta_u^2+\delta_v^2+\delta_w^2}}{2} \tag{3}$$

The one-hour vertical velocity standard deviation (δ_w^2) and one-hour horizontal wind standard deviation (δ_u^2, δ_v^2) are calculated with Equations (4)-(6), respectively

$$\delta_w^2 = \frac{1}{N-1}\sum_{i=1}^{N}(w_i-\overline{w})^2 \tag{4}$$

$$\delta_u^2 = \frac{1}{N-1}\sum_{i=1}^{N}(u_i - \bar{u})^2 \quad (5)$$

$$\delta_v^2 = \frac{1}{N-1}\sum_{i=1}^{N}(v_i - \bar{v})^2 \quad (6)$$

where N is the number of records per hour, w_i is the vertical wind velocity (m s^{-1}) at i_{th} level, $u_i(v_i)$ is the horizontal wind speed (m s^{-1}) at i_{th} level, $\overline{w}$ is the mean vertical wind speed (m s^{-1}), and $\bar{u}$ ($\bar{v}$) is the mean horizontal wind speed (m s^{-1}) (Banta et al., 2006; Wang et al., 2019).

Figures S1-S4:

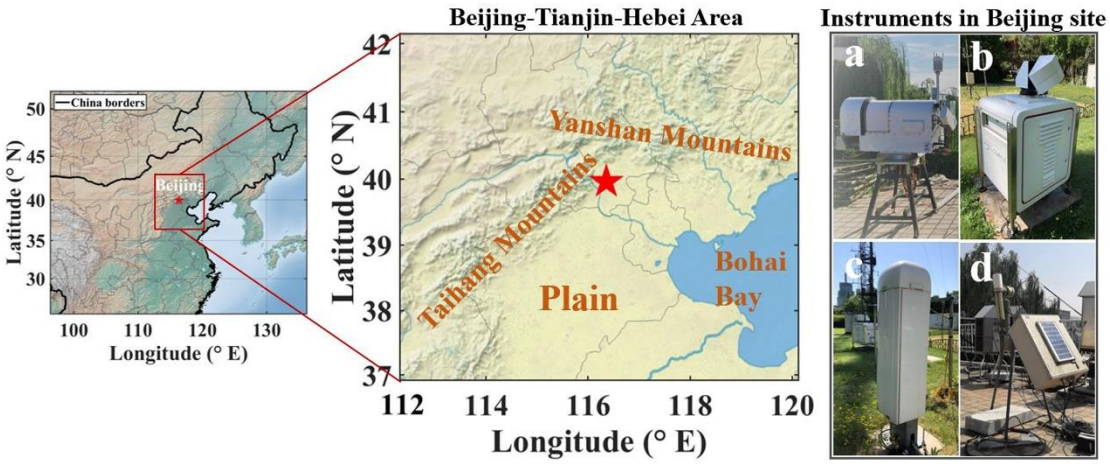

Figure S1. Left panel is the topographic distribution of most China with Beijing marked by a red star, the middle graph shows the Beijing-Tianjin-Hebei region with the Yanshan Mountains to the north, the Taihang Mountains to the west, and Bohai Bay to the east, and the right panel is the observation instruments with (a) microwave radiometer, (b) wind profile lidar, (c) ceilometer, and (d) sun-photometer used in this study.

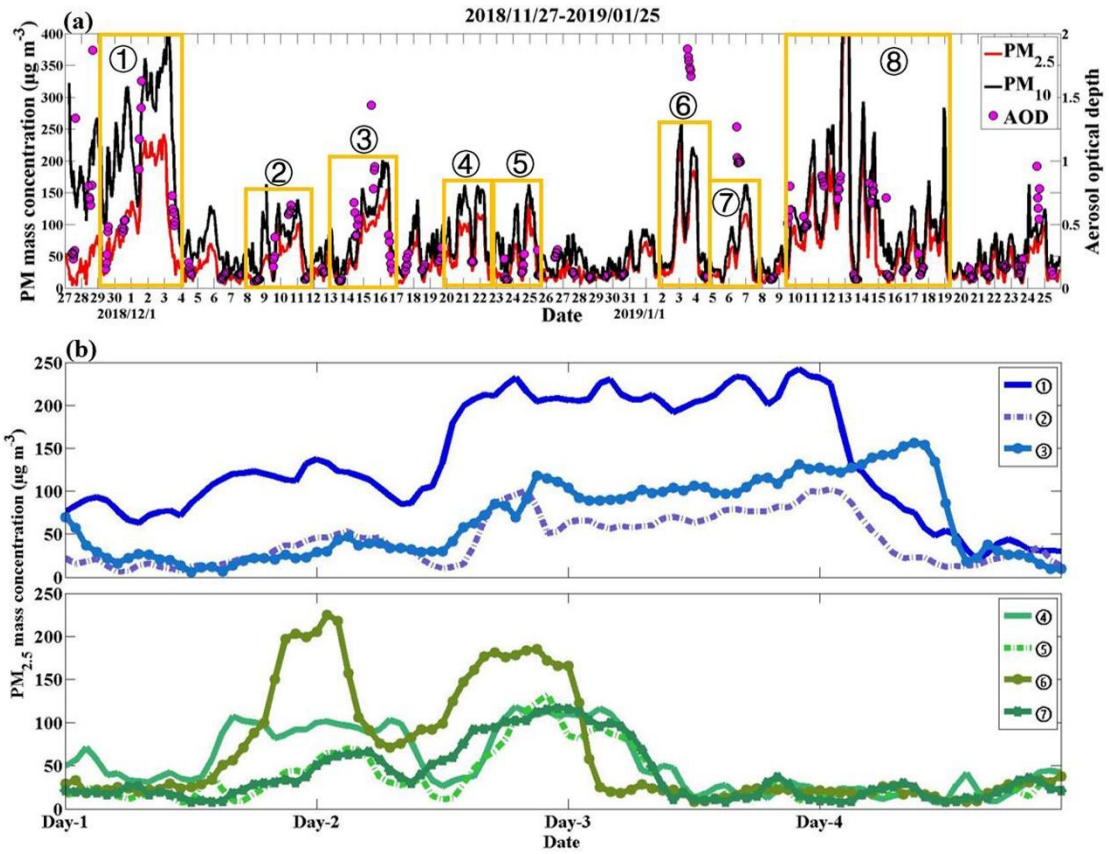

Figure S2. (a) Temporal evolutions of the PM mass concentration ($PM_{2.5}$: solid red lines; PM_{10}: solid black lines) and aerosol optical depth (AOD; pink circles) from 27 November 2018 to 25 January 2019 in Beijing, with circled boxes represent typical haze pollution episodes named by ①-⑧. (b) Temporal evolutions of the $PM_{2.5}$ mass concentration during typical haze pollution episodes ①-⑦ in Beijing in winter.

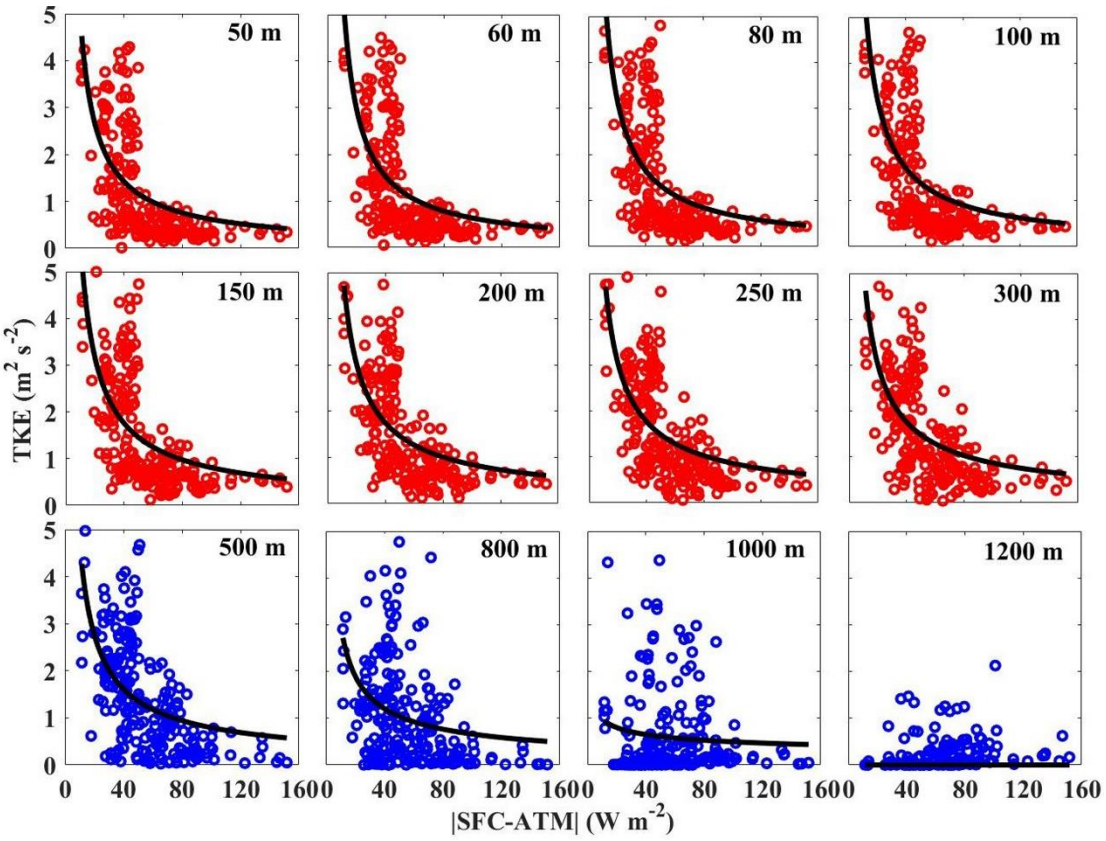

Figure S3. Scatter plots of the absolute difference of aerosol radiative forcing at the surface and interior of the atmospheric column (|SFC-ATM|; *x*) versus turbulence kinetic energy (TKE; *y*) at different altitudes. The calculated hourly data used above were collected over a two-month period in Beijing from 27 November 2018 to 25 January 2019.

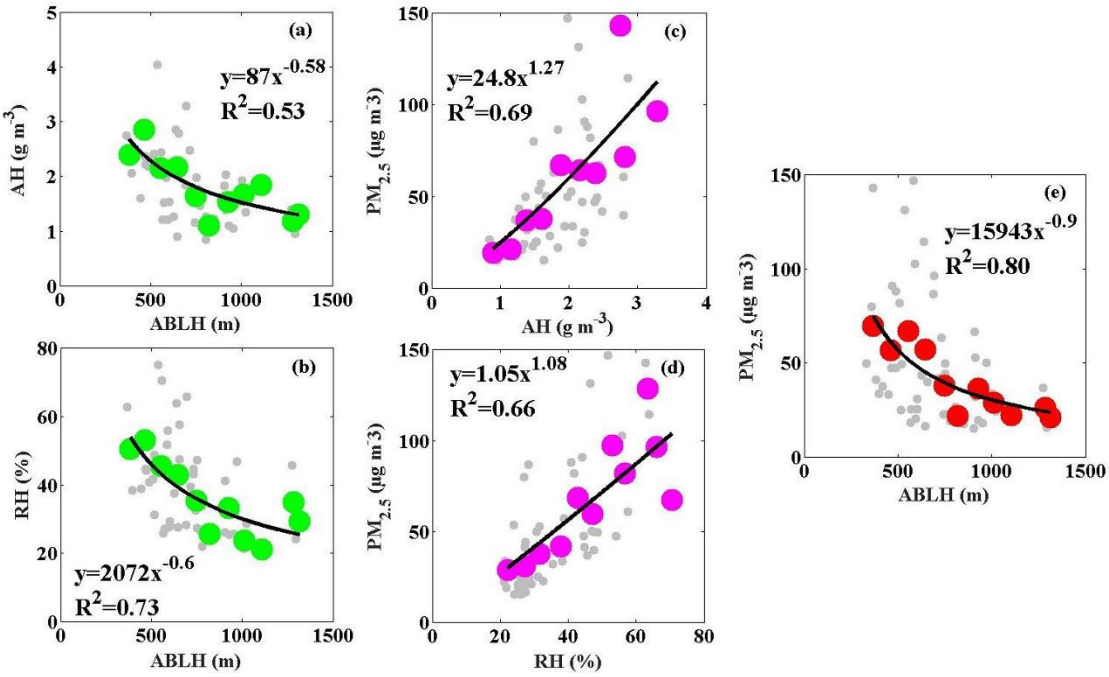

Figure S4. Scatter plots between the atmospheric boundary layer height (ABLH), water vapor density (AH), relative humidity (RH), and $PM_{2.5}$ concentration. (a) ABLH vs. AH; (b)…. The calculated daily data used above were over a two-month period in Beijing from 27 November 2018 to 25 January 2019 (gray dots: daily data; other dots: mean data).

Table S1-S2:

Table S1. Equations ($y = ax^b$) and correlation coefficient (R^2) of the fitted curves in Figure S5 and Figures 4-5.

	|SFC-ATM| vs. TKE			mean |SFC-ATM| vs. mean TKE			TKE vs. ABLH		
H (m)	a	b	R^2	a	b	R^2	a	b	R^2
50	43.13	-0.92	0.40	46.90	-0.97	0.91	844.19	0.18	0.13
60	53.77	-0.96	0.40	60.47	-1.02	0.92	827.38	0.19	0.14
80	57.23	-0.96	0.41	66.45	-1.02	0.93	816.67	0.18	0.13
100	51.93	-0.92	0.40	61.69	-0.99	0.93	805.28	0.19	0.14
150	40.46	-0.85	0.41	46.10	-0.91	0.92	792.45	0.22	0.15
200	33.10	-0.79	0.39	35.78	-0.84	0.91	785.18	0.24	0.15
250	32.09	-0.78	0.41	35.64	-0.84	0.92	782.58	0.23	0.14
300	30.64	-0.78	0.40	33.68	-0.82	0.92	789.77	0.21	0.13
500	29.08	-0.78	0.34	41.96	-0.92	0.88	828.54	0.19	0.17
800	13.45	-0.65	0.14	26.54	-0.89	0.82	895.95	0.15	0.18
1000	1.96	-0.30	0.01	6.77	-0.67	0.53	944.42	0.05	0.05
1200	4.03	-12.40	0.02	0.08	-0.25	0.05	801.90	-0.03	0.03
In	25.46	-0.76	0.40	29.72	-0.83	0.91	***	***	***
Above	0.70	-0.15	0.01	1.01	-0.28	0.29	***	***	***

Table S2. Input parameters of SBDART model.

MODULES	OPTIONS
Wavelength limits, filter function specification	1. WLINF: Lower wavelength limit
	2. WLSUP: Upper wavelength limit
	3. WLINC: Spectral resolution of the SBDART run
Solar geometry	4. IDAY: Day number of the year
	5. TIME: UTC time in decimal hours
	6. ALAT: Latitude of point on earth's surface
	7. ALON: East longitude of point on earth's surface
	8. SZA: Solar zenith angle
Surface reflectance properties	9. ISALB: Surface albedo feature
	10. ALBCON: A spectrally uniform, surface albedo
Boundary layer aerosols	11. IAER: Boundary layer aerosol type selector
	12. TBAER: Vertical optical depth of boundary layer aerosols nominally at 550 nm 13. WBAER: Single scattering albedo used with IAER=5 14. GBAER: Asymmetry factor used with IAER = 5
	15. ABAER: Angstrom exponents used with IAER = 5
Model atmospheres	16. Atmospheric profile: Atmospheric profile
	17. ZPRES: Surface altitude

References:

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