

Supplement of

Measurement Report: Year-to-year Variability and Influence of Winter Olympics and other Special Events on Air Quality in Urban Beijing during Wintertime

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S1. Division of pollution level

20 The concentrations of air pollutants usually change dramatically with varying pollution levels, and their variation trends with pollution are not also always consistent. Therefore, it is necessary to look into their properties under different pollution levels. Among all the atmospheric parameters, $PM_{2.5}$ is always a representative of pollution, and thus we divided the pollution level based on $PM_{2.5}$ as follows:

- 25 a. Clean condition: $PM_{2.5} \leq 35 \mu\text{g m}^{-3}$.
- b. Moderate-polluted condition: $35 < PM_{2.5} \leq 75 \mu\text{g m}^{-3}$.
- 30 c. Heavy-polluted condition: $75 < PM_{2.5} \leq 150 \mu\text{g m}^{-3}$.
- d. Severe-haze condition: $PM_{2.5} > 150 \mu\text{g m}^{-3}$.

Then, the frequency of different pollution levels during the yearly variation period and the special event period were further analyzed. As shown in **Fig. S2**, during the yearly variation period (1st to 22nd January), the air mass in 2021 winter Beijing was the cleanest with only ~ 6 % heavy-polluted days and no severe-haze days. During the special event period, the Olympic period was the cleanest with almost no heavy-polluted and severe-haze days (< 1 %), while the COVID period suffered from the most severe-haze (~ 18 %) and heavy-polluted (~ 29 %) days.

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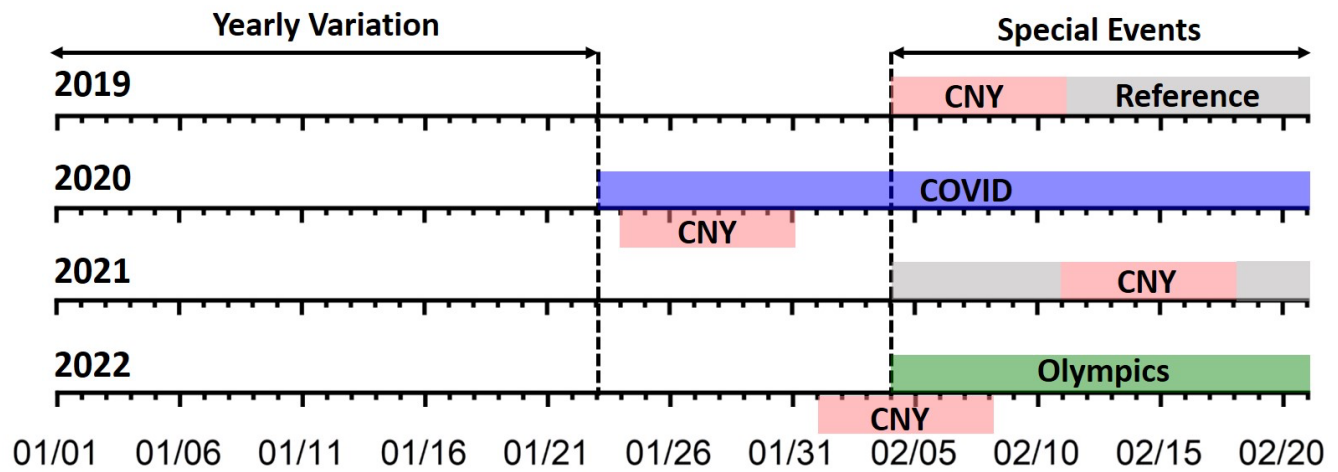
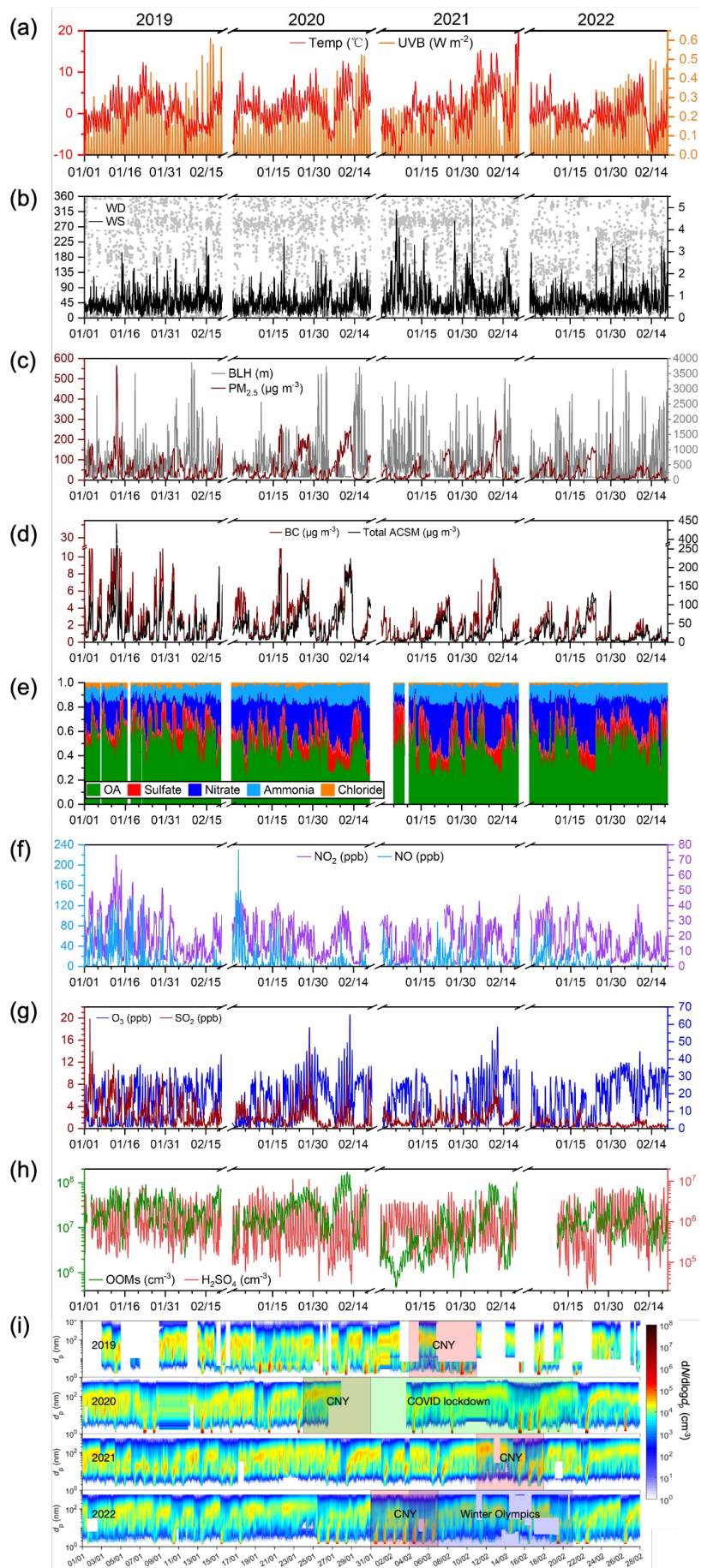


Figure S1. Division of different periods from 2019 to 2022. Gray, blue, green and red regions correspond to Reference, COVID, Chinese New Year period (CNY) and Beijing Winter Olympic periods, respectively. The yearly variation periods are from 1st to 22nd January and last for 22 days when no special event occurred. The special event periods are from 4th to 20th February, during which the COVID, Beijing Winter Olympics and the Chinese New Year happened.

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Figure S2. Time variation of (a) temperature (Temp) and UVB, (b) wind speed (WS) and wind direction (WD), (c) boundary layer height (BLH) and $PM_{2.5}$, (d) black carbon (BC), particulate mass concentration measured by ACSM (total ACSM), (e) fractions of organic aerosol (OA), sulfate, nitrate, ammonia and chloride, mixing ratios of (f) NO_2 and NO , (g) O_3 and SO_2 , (h) number concentration of total OOMs and sulfuric acid (H_2SO_4), (i) aerosol size distributions measured by the DEG SMPS and PSD during 1st, Jan. – 28th, Feb. in 2019–2022. In (i), the contour color represents the aerosol number size function ($dN/d\log dp$). Different special events, including Winter Olympics in 2022, COVID lockdown in 2020 and Chinese New Year (CNY) in each year were shaded with light blue, green and red colors, respectively.

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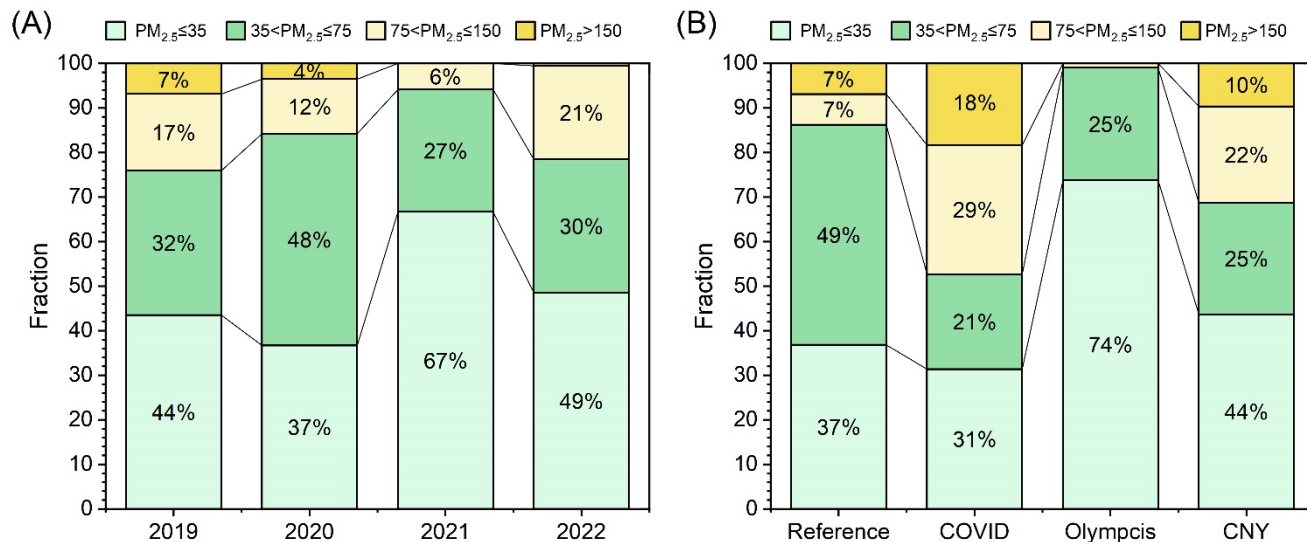


Figure S3. Fraction of different $PM_{2.5}$ levels for (a) different years during yearly variation periods (1st – 22nd January) and (b) reference, COVID, Olympics and CNY periods (4th – 20th February).

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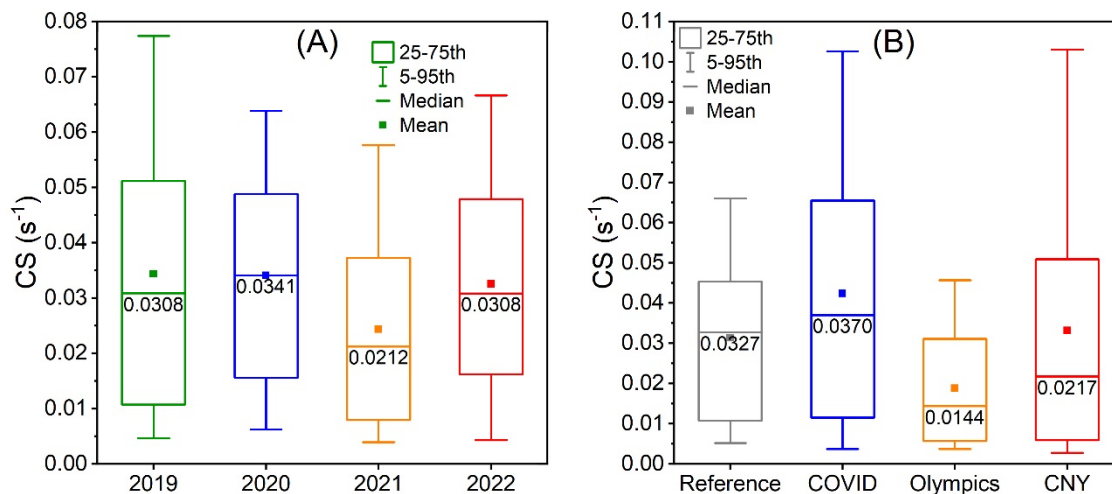


Figure S4. Condensation sink (CS) of sulfuric acid for (a) different years during yearly variation periods (1st – 22nd January) and (b) reference, COVID, Olympics and CNY periods (4th – 20th February). The value inside each box is the median value of corresponding parameter.

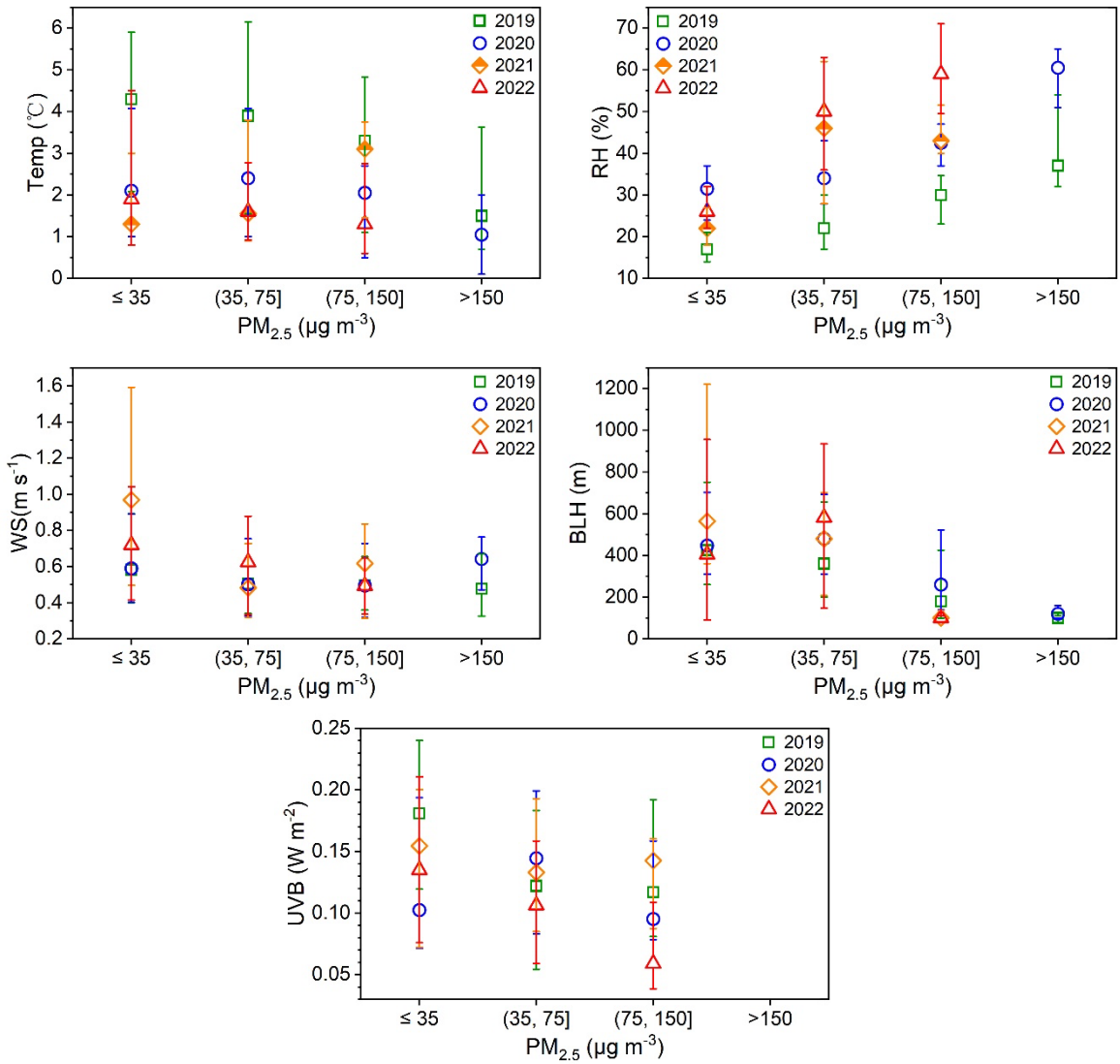


Figure S5. Temperature (Temp), relatively humidity (RH), wind speed (WS), boundary layer height (BLH) and UVB under different $PM_{2.5}$ levels for different years. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively. Please note that for UVB, only daytime (08:00 – 16:00) dataset was used.

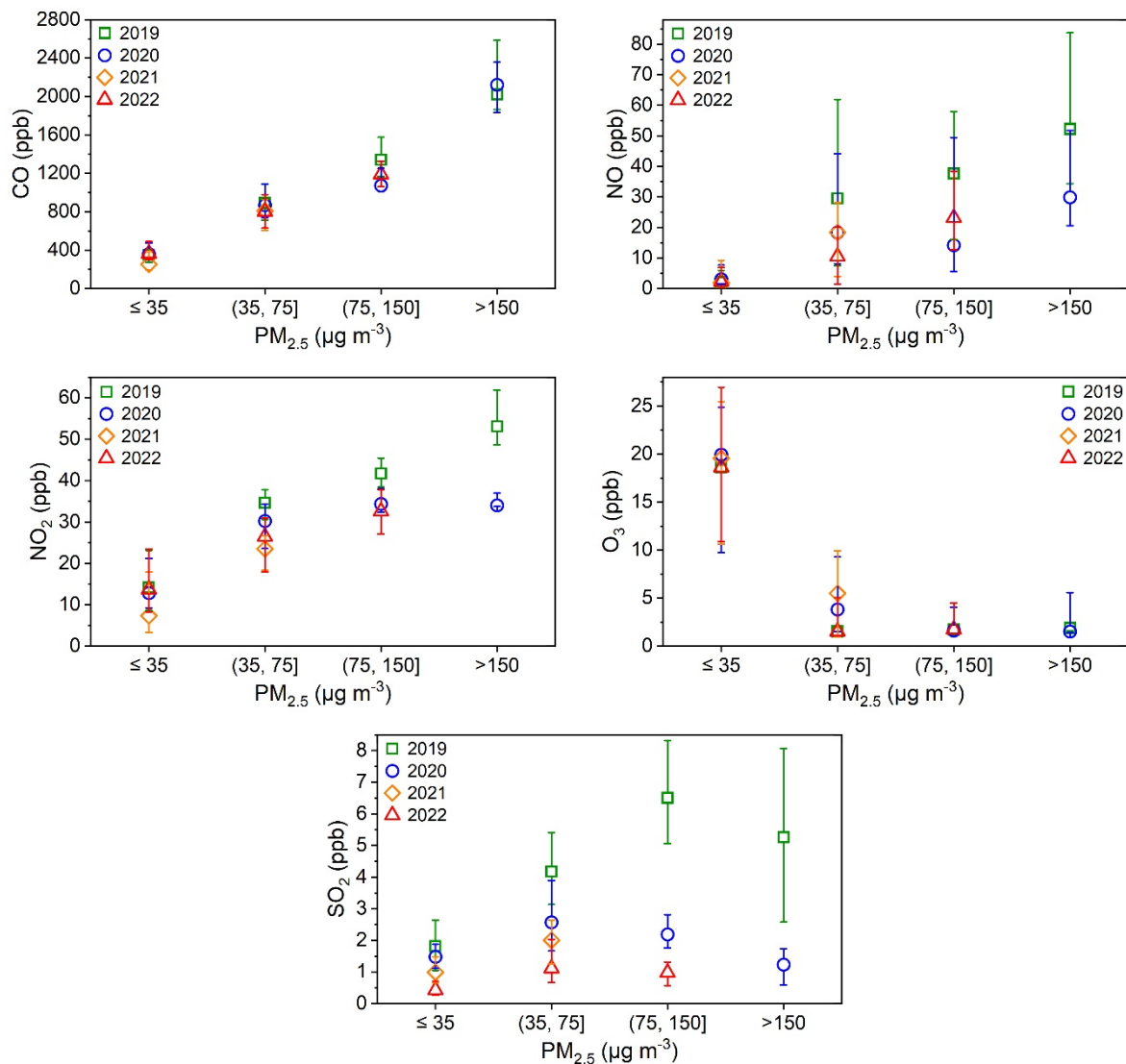
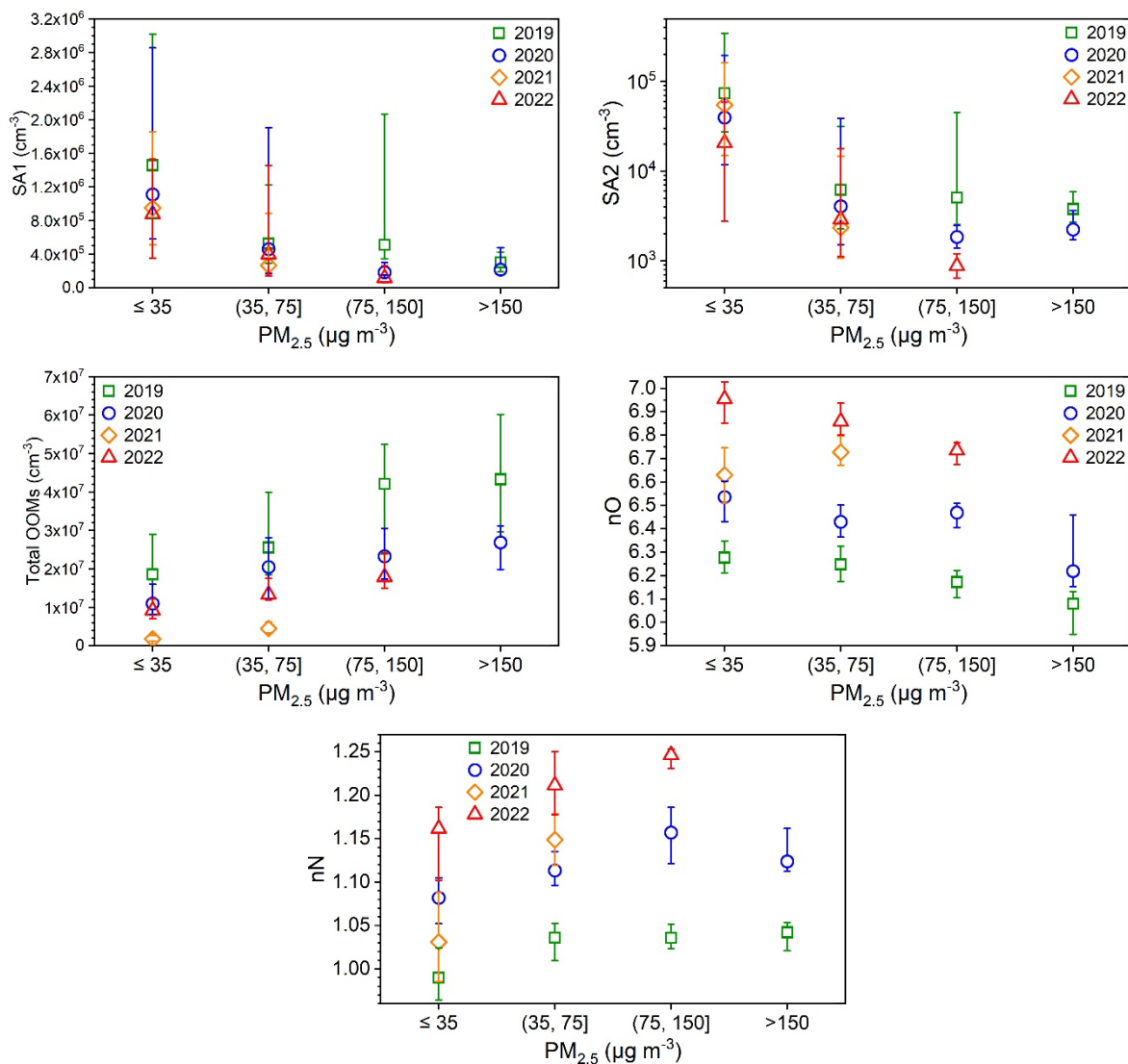
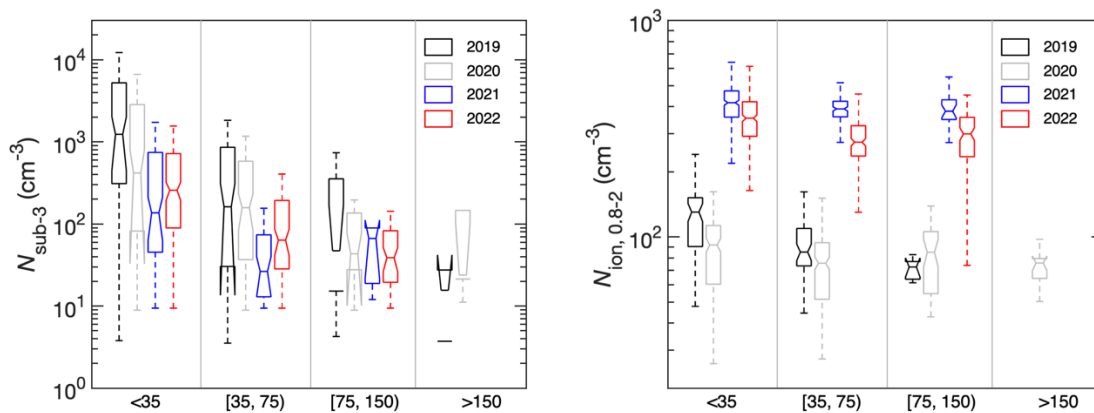


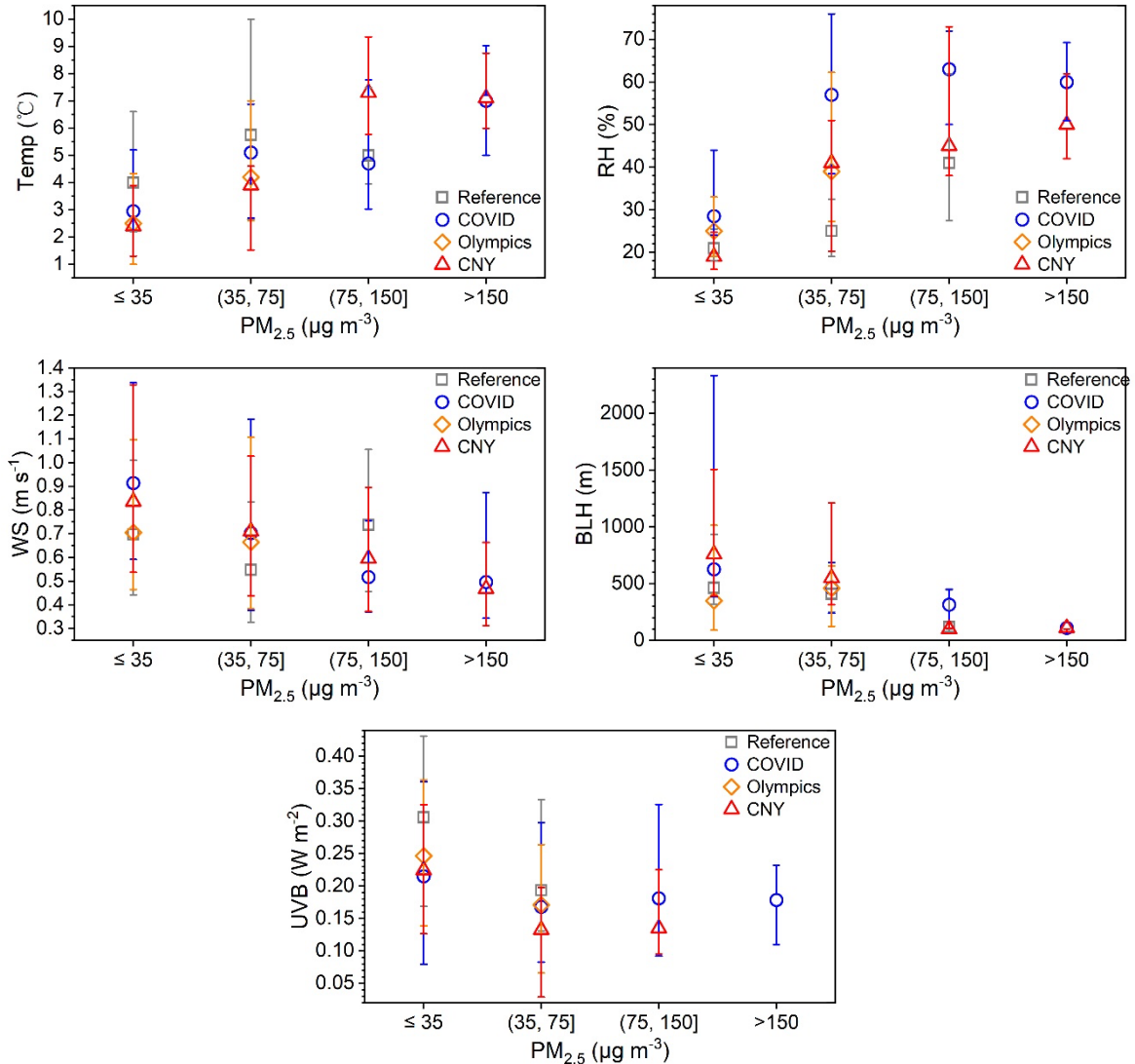
Figure S6. Mixing ratios of CO, NO, NO₂, O₃ and SO₂ under different PM_{2.5} levels for different years. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.



75 **Figure S7.** Concentration of sulfuric acid monomer (SA1), sulfuric acid dimer (SA2) and total OOM concentration, as well as fraction weighted oxygen number (nO) and fraction weighted nitrogen number (nN) of OOMs under different $PM_{2.5}$ levels for different years. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.

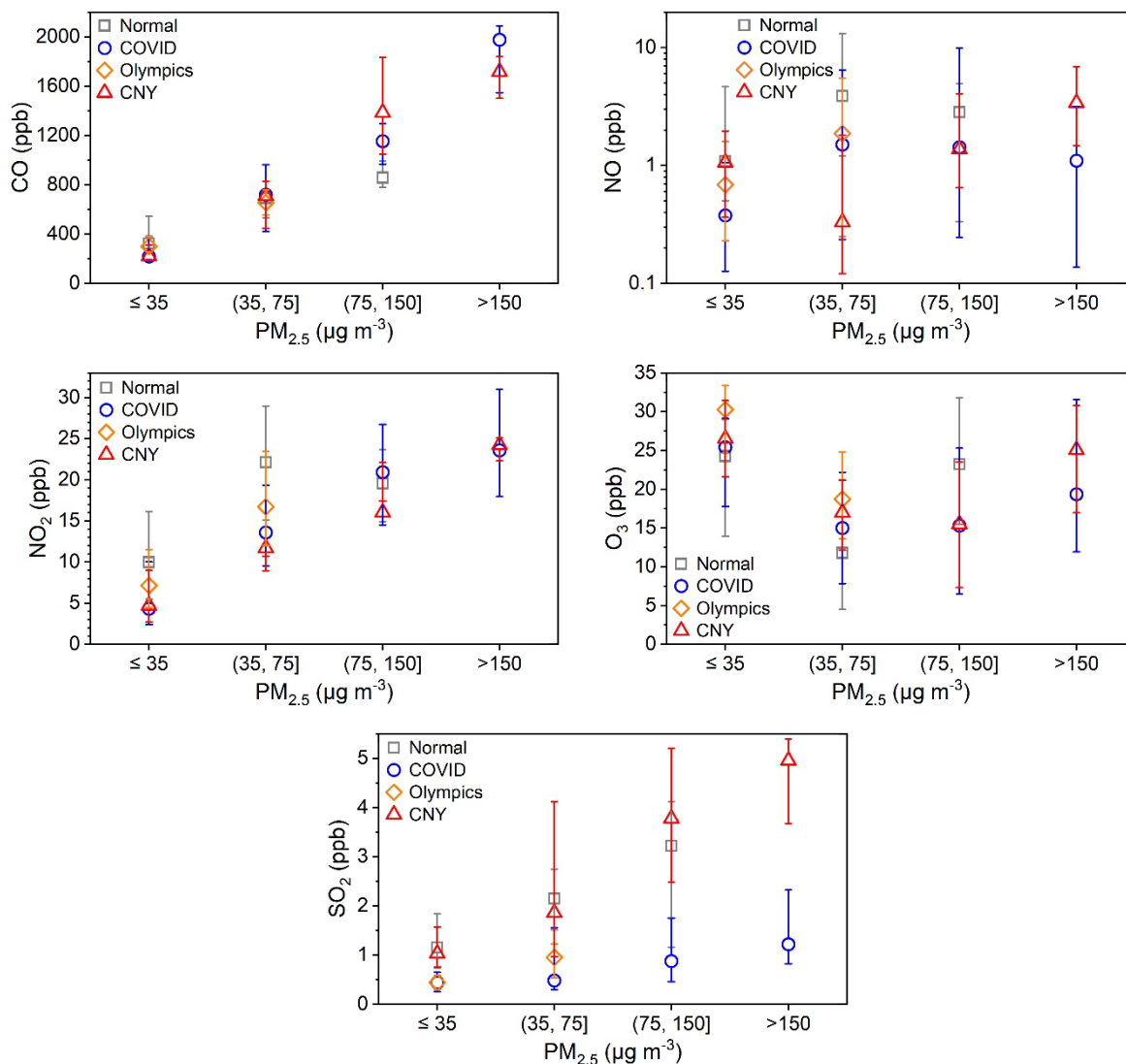


80 **Figure S8.** The particle number concentration in sub-3 nm size range (left panel), and ion concentration in sub-2 nm size range (right panel) under different pollution level during 1st, Jan. – 23rd, Jan. in 2019 – 2022 (without any special events).

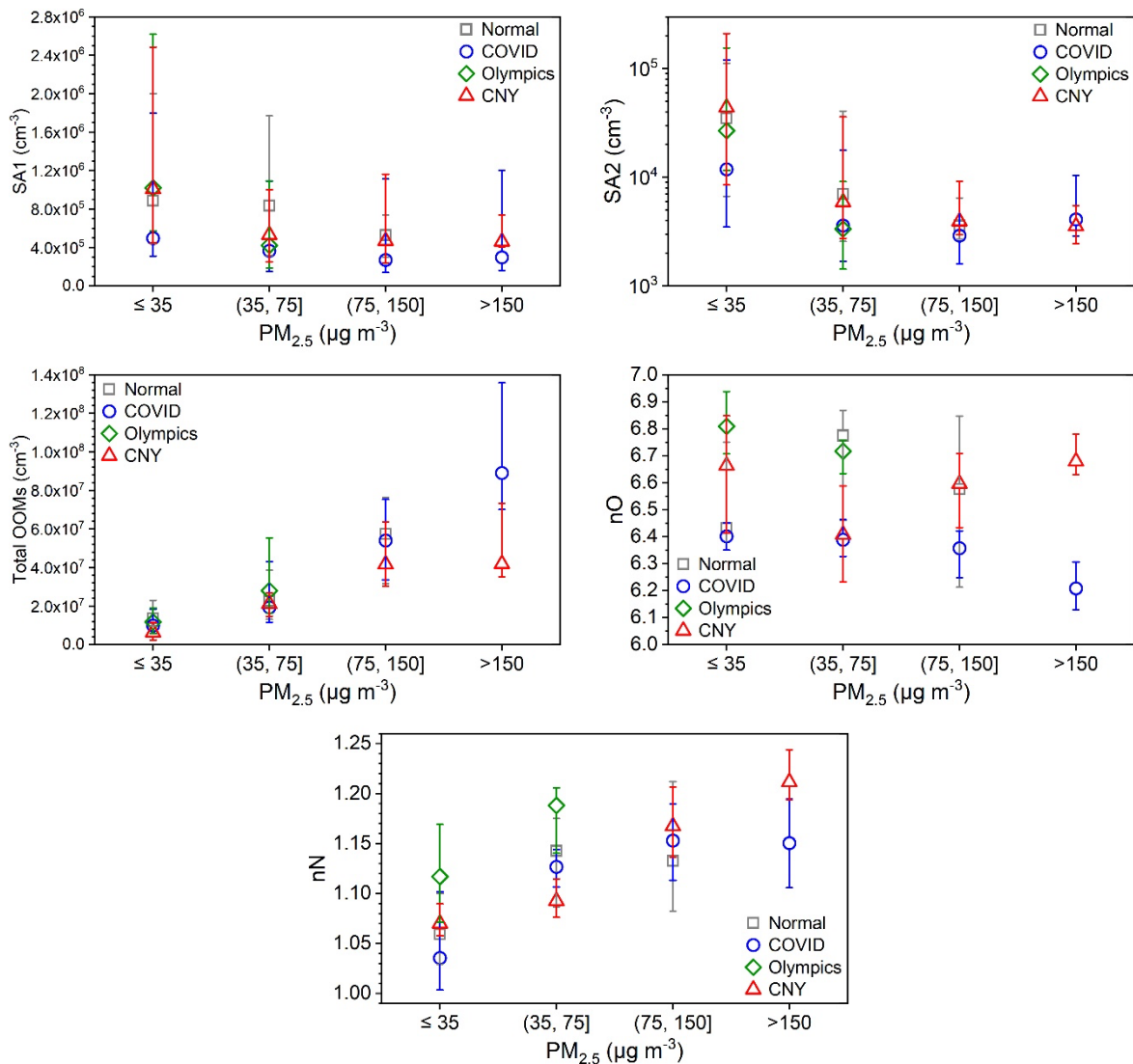


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Figure S9. Temperature (Temp), relative humidity (RH), wind speed (WS), boundary layer height (BLH) and UVB under different PM_{2.5} levels for reference, COVID, Olympics and CNY periods. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively. Please note that for UVB, only daytime (08:00 – 16:00) dataset was used.



95 **Figure S10.** Mixing ratios of CO, NO, NO₂, O₃ and SO₂ under different PM_{2.5} levels for reference, COVID, Olympics and CNY periods. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.



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Figure S11. Concentration of sulfuric acid monomer (SA1), sulfuric acid dimer (SA2) and total OOM concentration, as well as fraction weighted oxygen number (nO) and fraction weighted nitrogen number (nN) of OOMs under different $PM_{2.5}$ levels for reference, COVID, Olympics and CNY periods. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.

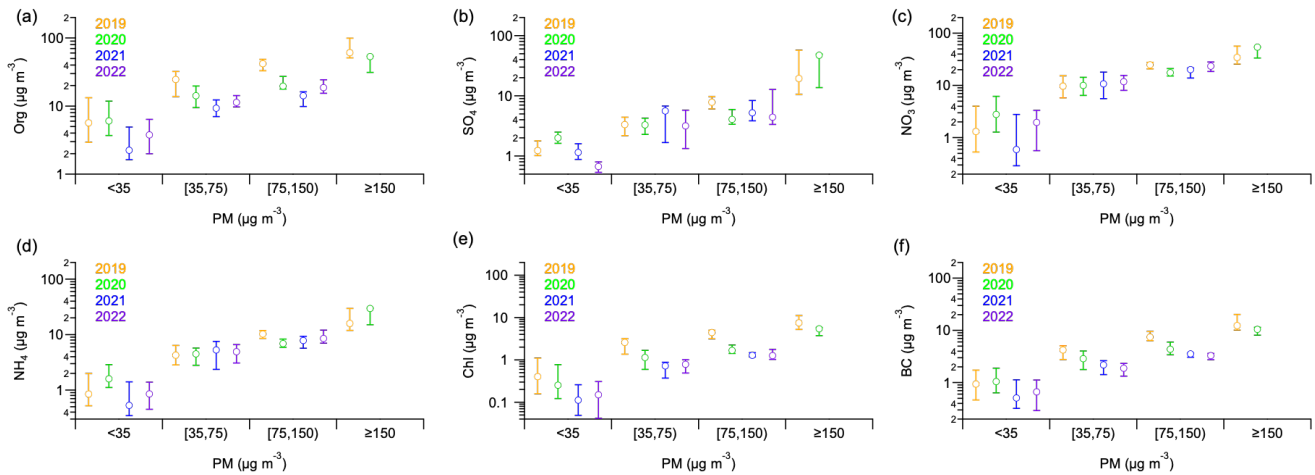


Figure S12. Yearly variations of PM_{2.5} compositions: (a) Org, (b) sulfate, (c) nitrate, (d) ammonia, (e) chloride and (f) BC under different PM_{2.5} levels during normal period from 2019 to 2022. The bottom and top edges indicate the 25th and 75th percentiles, respectively. the circles denote the median values.

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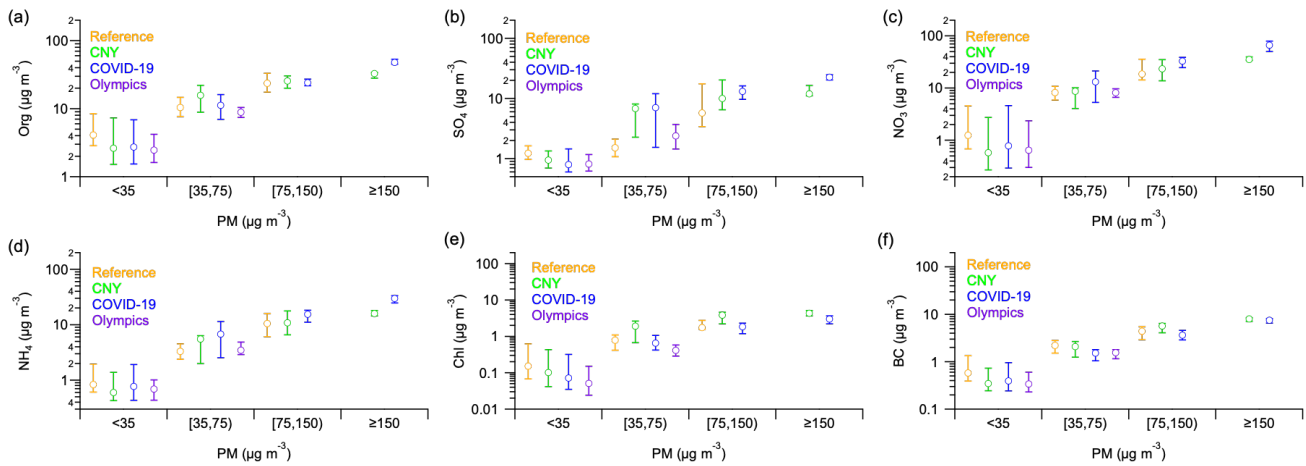


Figure S13. PM_{2.5} compositions during special event periods: (a) Org, (b) sulfate, (c) nitrate, (d) ammonia, (e) chloride and (f) BC under different PM_{2.5} levels. The bottom and top edges indicate the 25th and 75th percentiles, respectively. the circles denote the median values.

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