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Measurement report: The 4-year variability and influence of the Winter Olympics and other special events on air quality in urban Beijing during wintertime

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S1. Division of pollution level

The concentrations of air pollutants usually change dramatically with varing pollution levels, and their variation trends with pollution are not also always consistent. Therefore, it is neceassay 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:

a. Clean condition: $PM_{2.5} \leq 35$ μg m^{-3}.

b. Moderate-polluted condition: $35 < PM_{2.5} \leq 75$ μg m^{-3}.

c. Heavy-polluted condition: $75 < PM_{2.5} \leq 150$ μg m^{-3}.

d. Serve-haze condition: $PM_{2.5} > 150$ μg 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 serve-haze days. During the special event period, the Olympic period was the cleanest with almost no heavy-polluted and serve-haze days (< 1 %), while the COVID period suffered from the most serve-haze (~ 18 %) and heavy-polluted (~ 29 %) days.

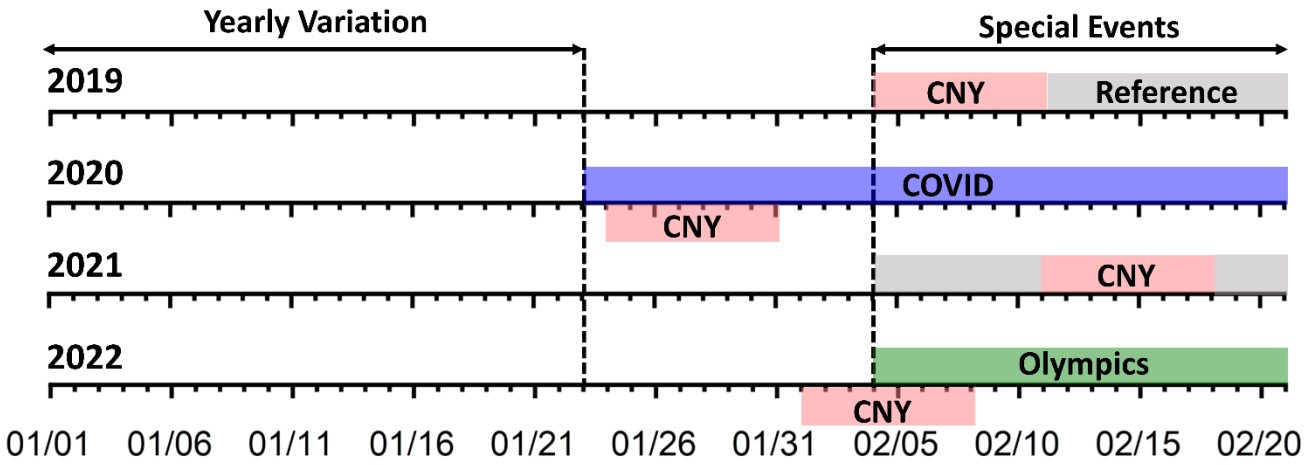

Figure S1. Division of different periods from 2019 to 2022. Gray, blue, green and red regions correspond to Reference, COVID, Chinese New Year period (CNY) and Beijing Winter Olympic periods, respectively. The yearly variation periods are from 1st to 22nd January and last for 22 days when no special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

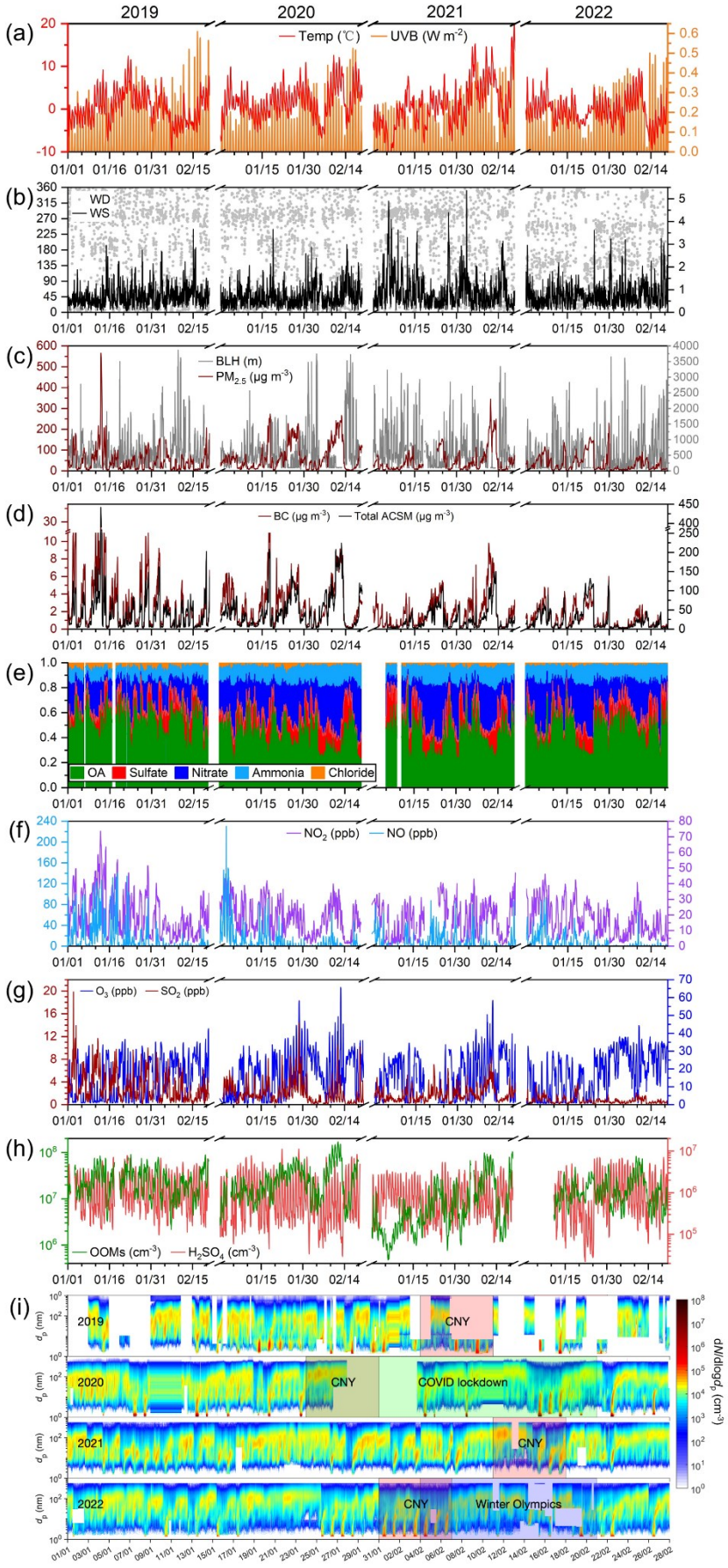
2019
2020
2021
2022
(a)
Temp (℃)
UVB (W m-2)
(b)
WD
WS
(c)
BLH (m)
PM2.5 (μg m-3)
(d)
BC (μg m-3)
Total ACSM (μg m-3)
(e)
OA
Sulfate
Nitrate
Ammonia
Chloride
(f)
NO2 (ppb)
NO (ppb)
(g)
O3 (ppb)
SO2 (ppb)
(h)
OOMs (cm-3)
H2SO4 (cm-3)
(i)
2019
CNY
2020
CNY
COVID lockdown
2021
CNY
2022
CNY
Winter Olympics
dp (nm)
dN/dlogDp (cm-3)
01/01 01/16 01/31 02/15
01/15 01/30 02/14

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, ammonium 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 from 1st January to 28th Feburary in 2019 – 2022. In (i), the contour color represents the aerosol number size function (dN/dlogdp). 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.

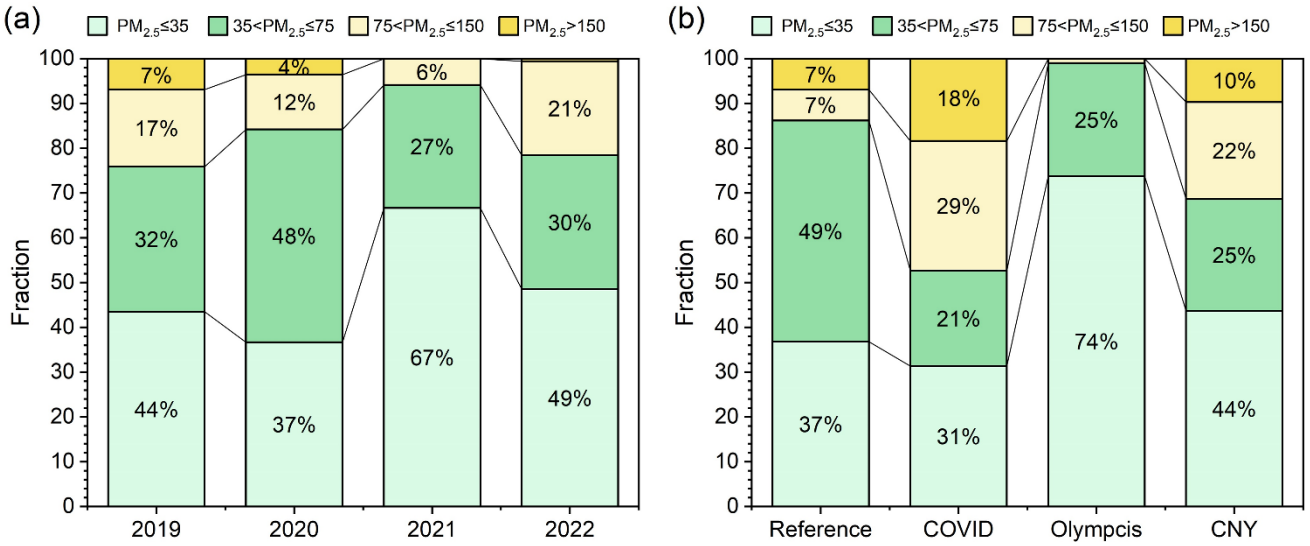

Figure S3. Fraction of different $PM_{2.5}$ levels for (a) different years during yearly variation periods (1st – 22nd January) and (b) Reference, COVID, Olympics and CNY periods (4th – 20th Feburary).

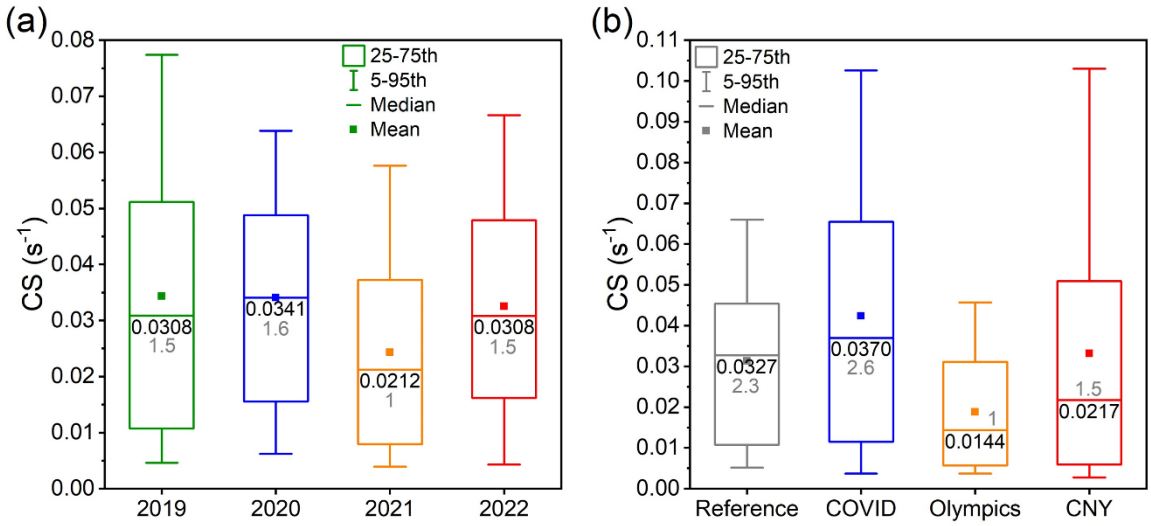

Figure S4. Condensation sink (CS) of sulfuric acid for (a) different years during yearly variation periods (1st – 22nd January) and (b) Reference, COVID, Olympics and CNY periods (4th – 20th Feburary). The value inside each box is the median value of corresponding parameter.

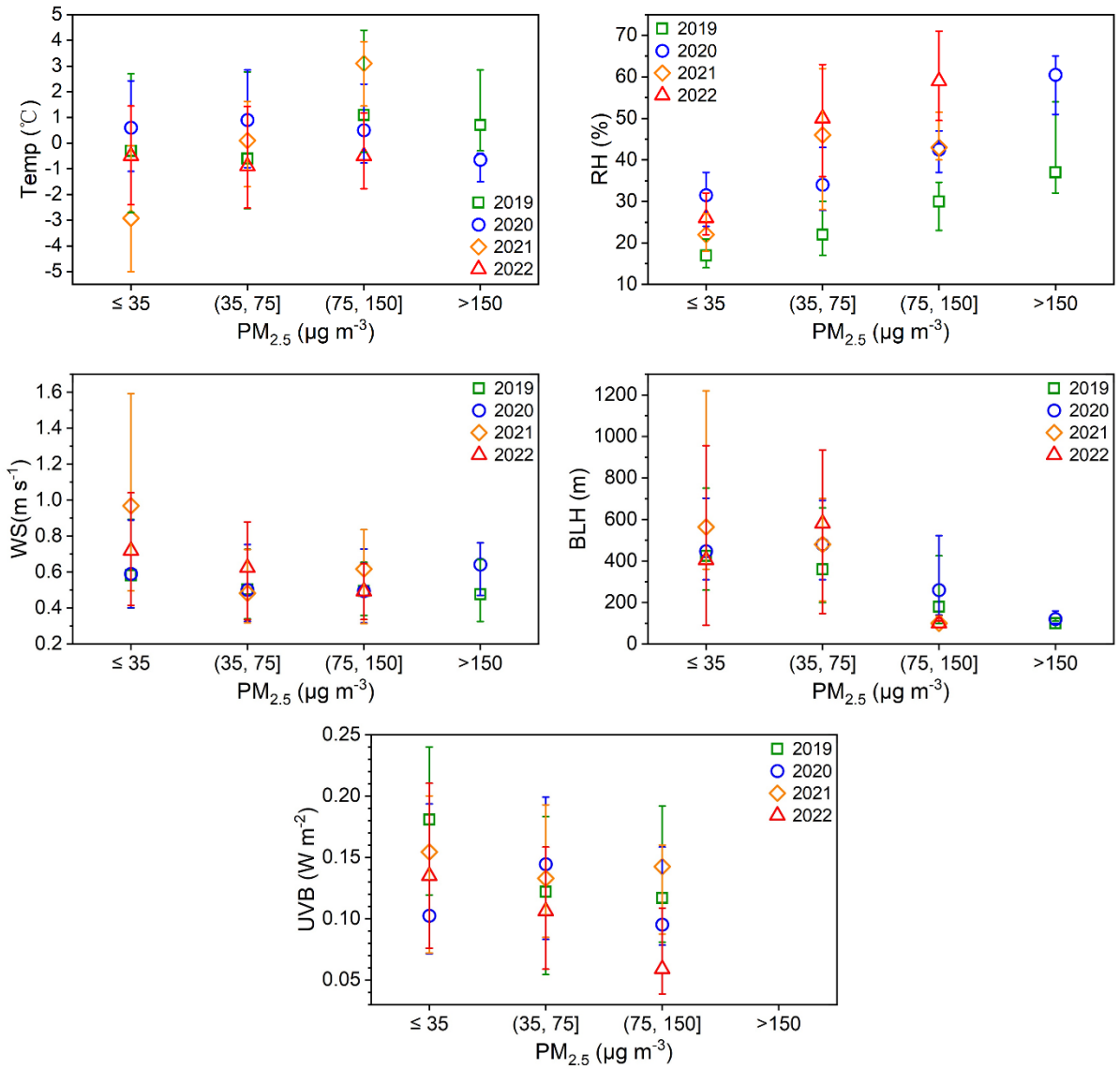

Figure S5. Temperature (Temp), relatively humidity (RH), wind speed (WS), boundary layer height (BLH) and UVB under different $PM_{2.5}$ levels for different years. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively. Please note that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

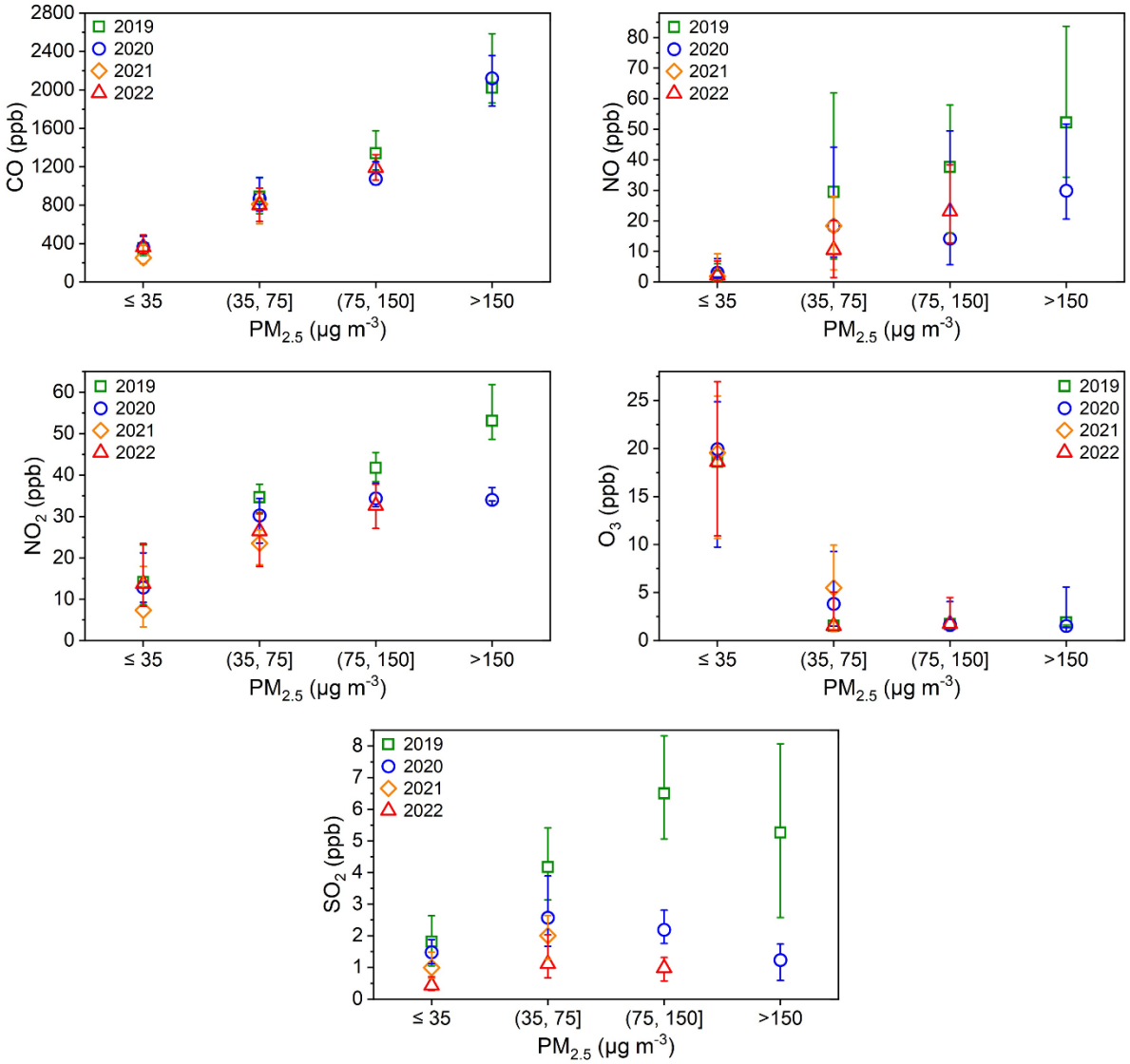

Figure S6. Mixing ratios of CO, NO, NO_2, O_3 and SO_2 under different $PM_{2.5}$ levels for different years. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.

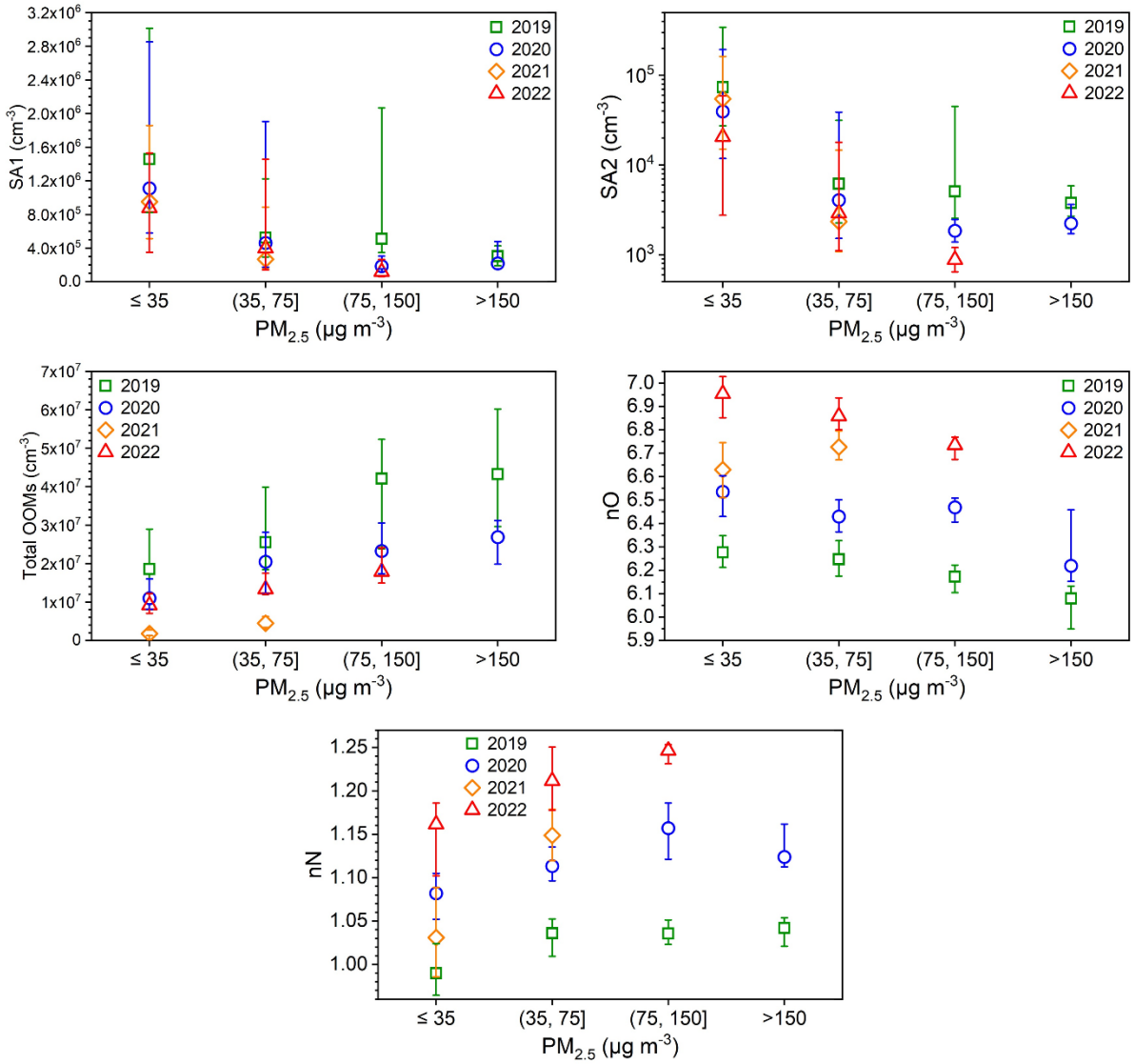

Figure S7. Concentrations of sulfuric acid monomer (SA1), sulfuric acid dimer (SA2) and total OOMs, as well as fraction weighted oxygen number (nO) and fraction weighted nitrogen number (nN) of OOMs under different $PM_{2.5}$ levels for different years. The up lines, middle markers and bottom lines stand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

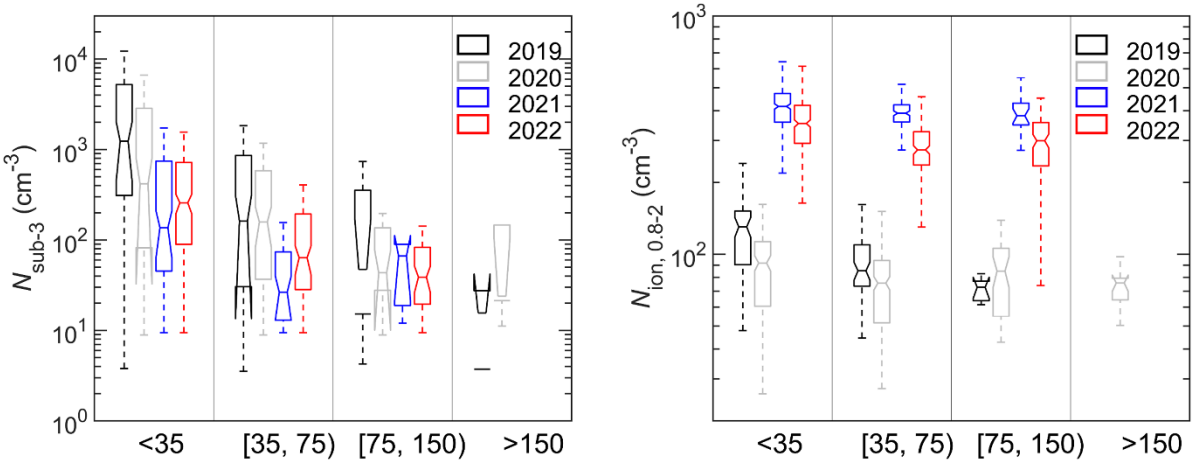

Figure S8. The particle number concentration in sub-3 nm size range (left panel), and ion concentration in sub-2 nm size range (right panel) under different pollution level during 1st, Jan. – 23rd, Jan. in 2019 – 2022 (without any special events).

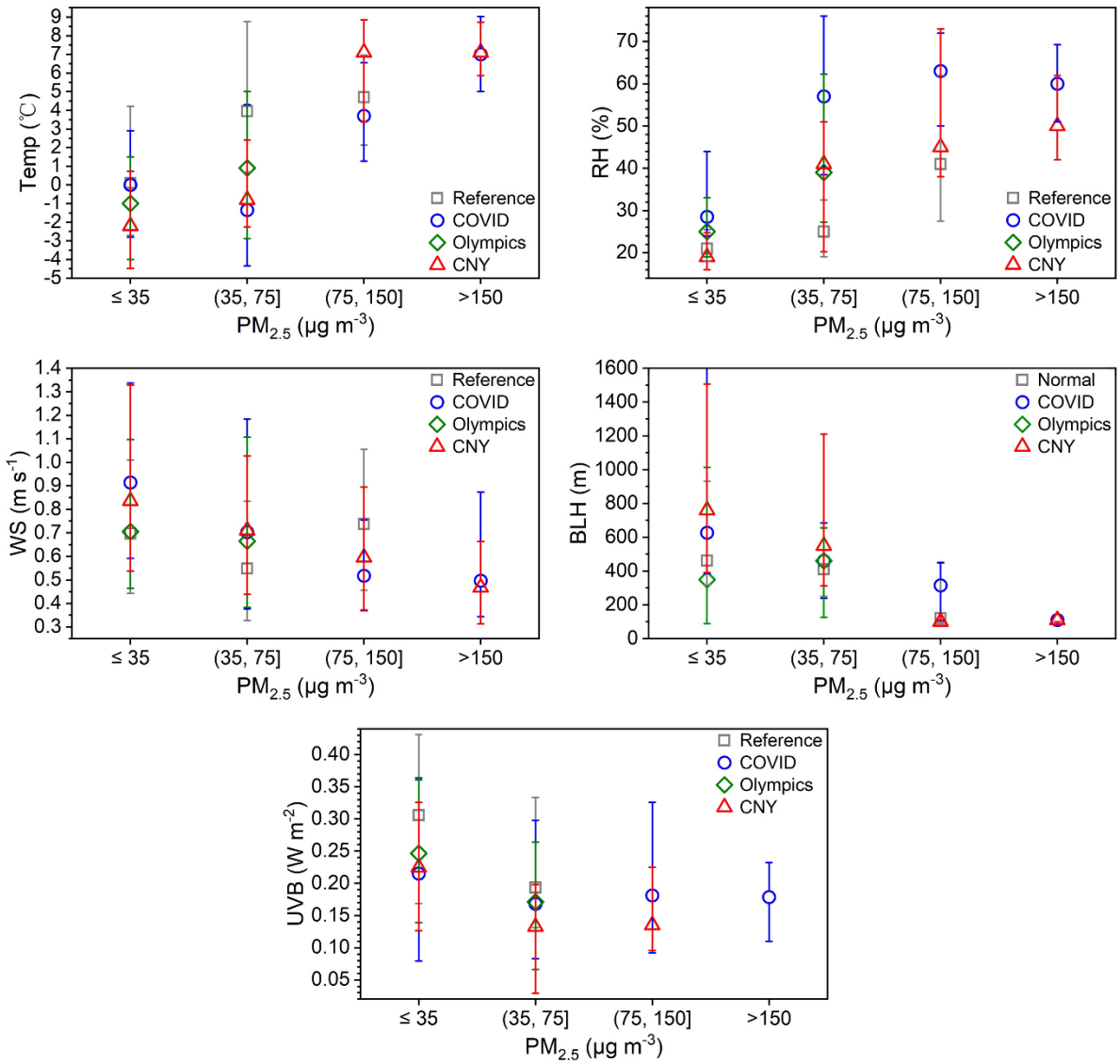

Figure S9. Temperature (Temp), relatively humidity (RH), wind speed (WS), boundary layer height (BLH) and UVB under different $PM_{2.5}$ levels for Reference, COVID, Olympics and CNY periods. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.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

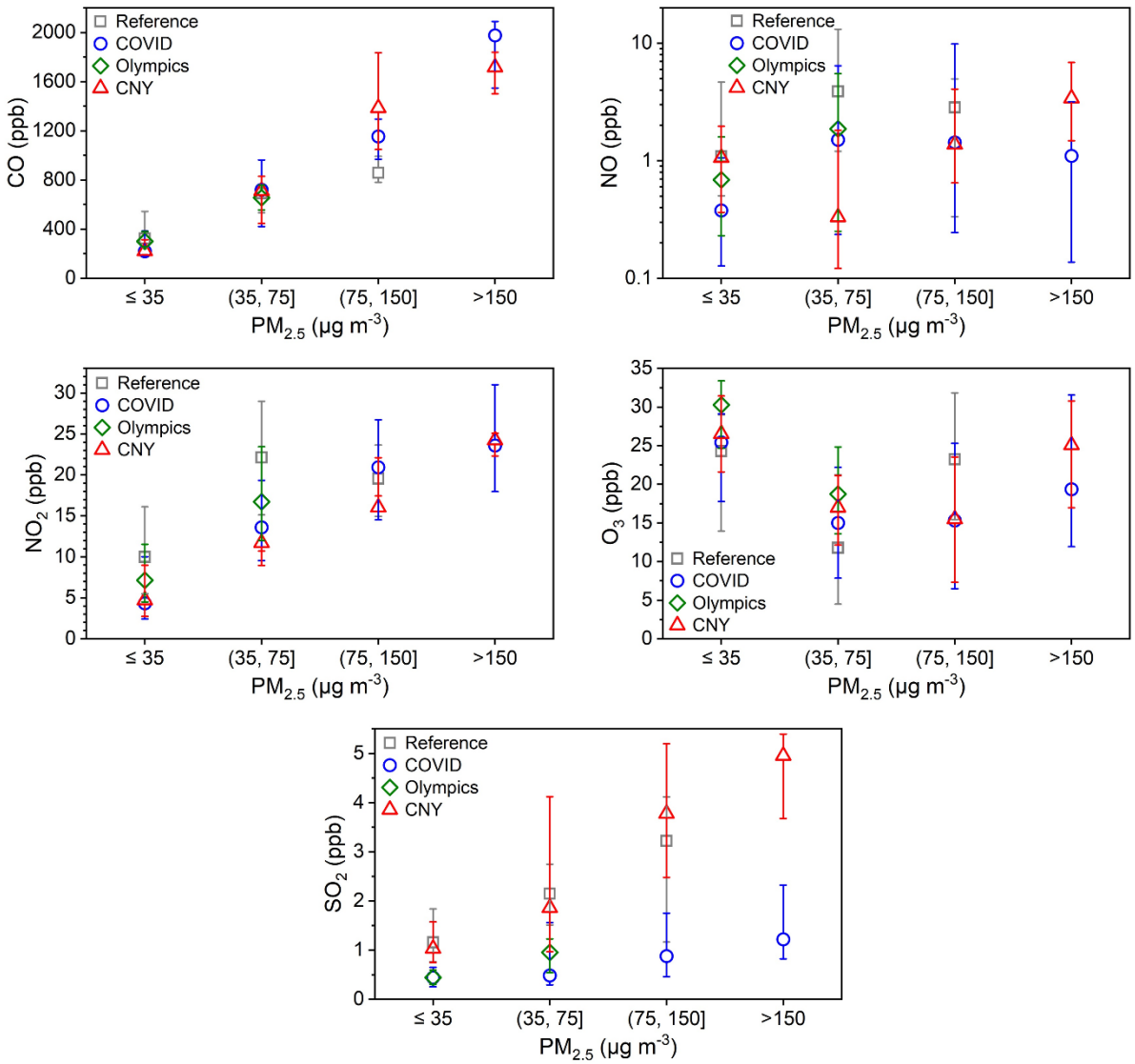

Figure S10. Mixing ratios of CO, NO, NO_2, O_3 and SO_2 under different $PM_{2.5}$ levels for Reference, COVID, Olympics and CNY periods. The up lines, middle markers and bottom lines stand for upper quartile, median and lower quartile values, respectively.

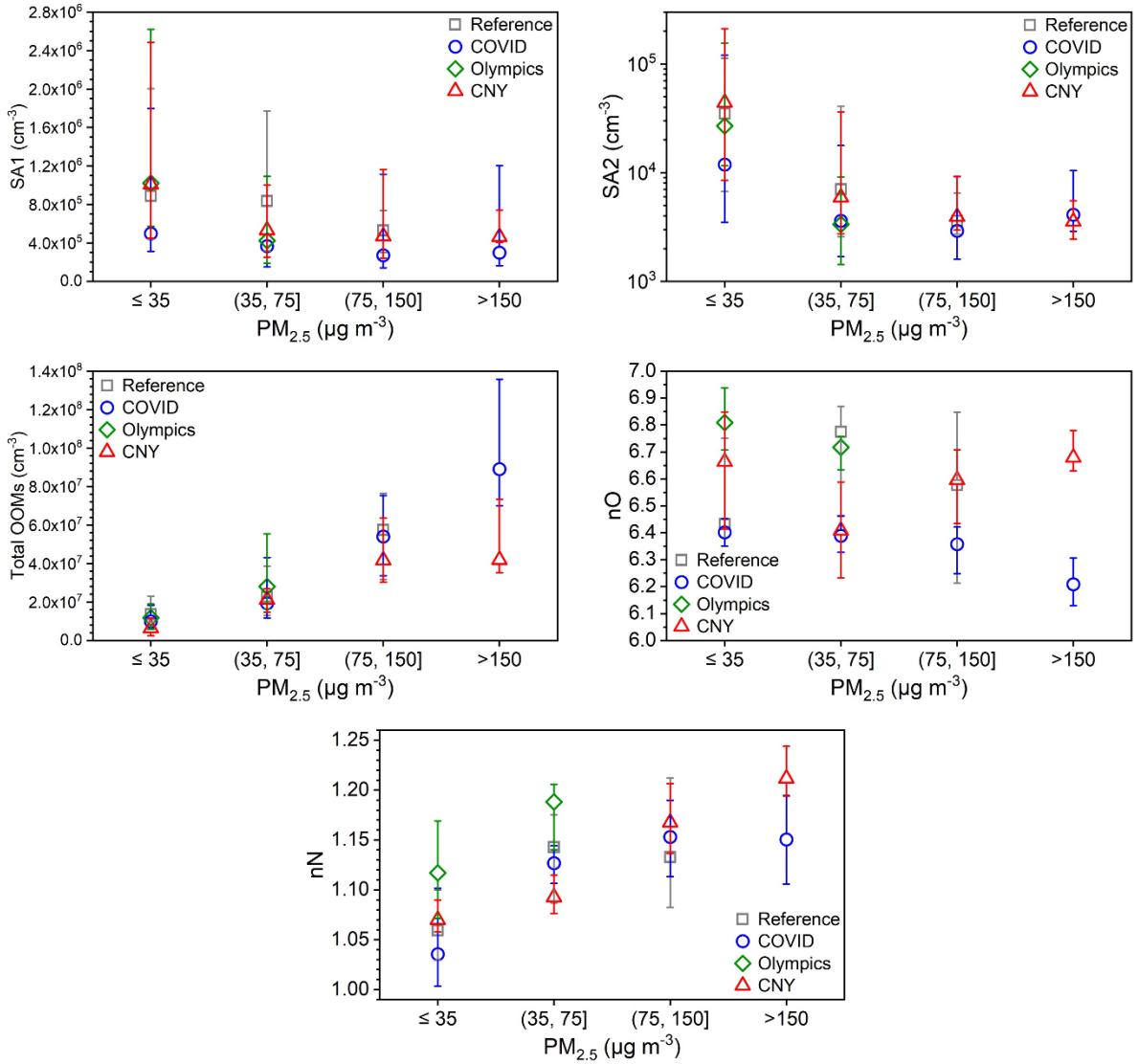

Figure S11. Concentrations of sulfuric acid monomer (SA1), sulfuric acid dimer (SA2) and total OOMs, as well as fraction weighted oxygen number (nO) and fraction weighted nitrogen number (nN) of OOMs under different $PM_{2.5}$ levels for Reference, COVID, Olympics and CNY periods. The up lines, middle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

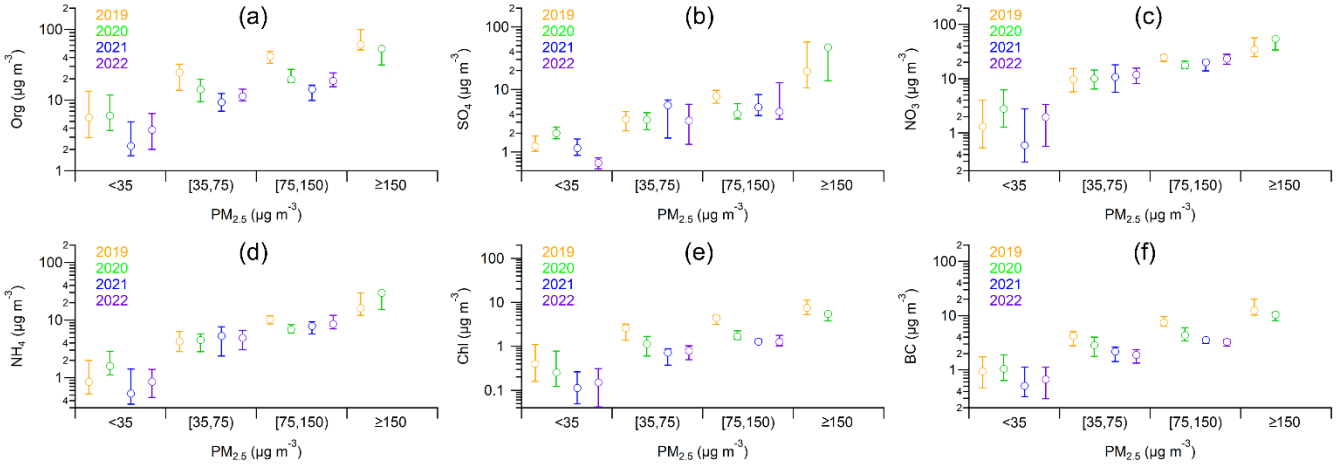

Figure S12. Yearly variations of $PM_{2.5}$ compositions: (a) Org, (b) sulfate, (c) nitrate, (d) ammonia, (e) chloride and (f) BC under different $PM_{2.5}$ levels during normal1 period from 2019 to 2022. The bottom and top edges indicate the 25th and 75th percentiles, respectively. the circles denote the median values.

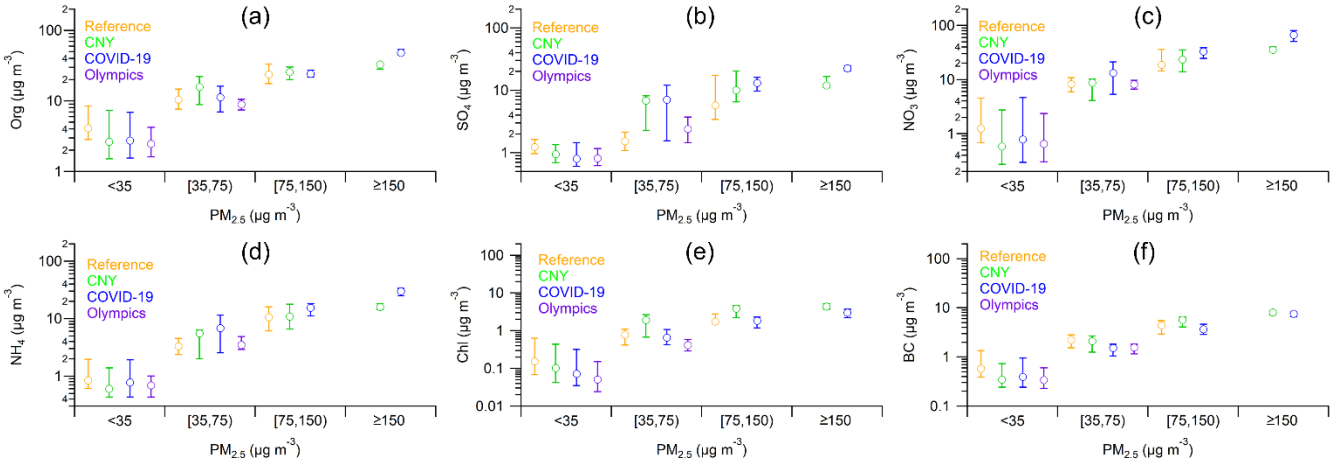

Figure S13. $PM_{2.5}$ compositions during special event periods: (a) Org, (b) sulfate, (c) nitrate, (d) ammonia, (e) chloride and (f) BC under different $PM_{2.5}$ levels. The bottom and top edges indicate the 25th and 75th percentiles, respectively. the circles denote the median values.