国家大气污染防治攻关联合中心
National Joint Research Center for Tackling Key Problems In Air Pollution Control

Study on the Co-control of $PM_{2.5}$ and Ozone Pollution in Beijing, Tianjin, Hebei and Surrounding Region of China

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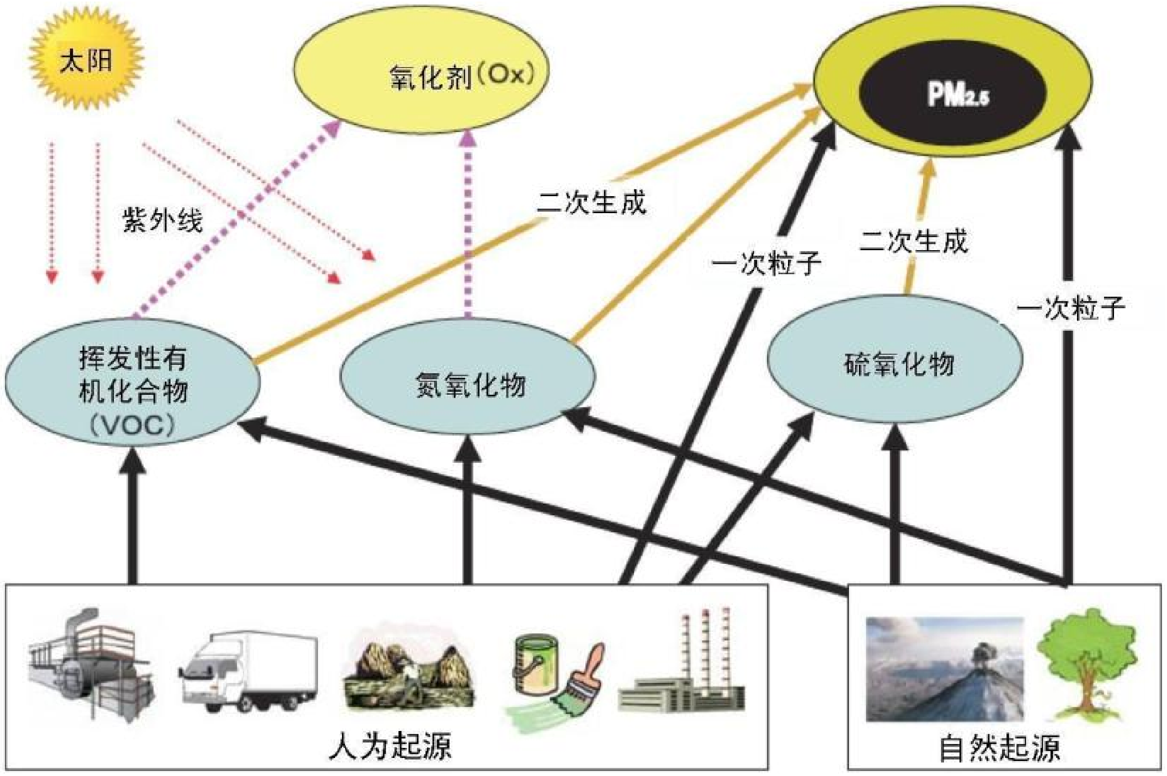
Outline

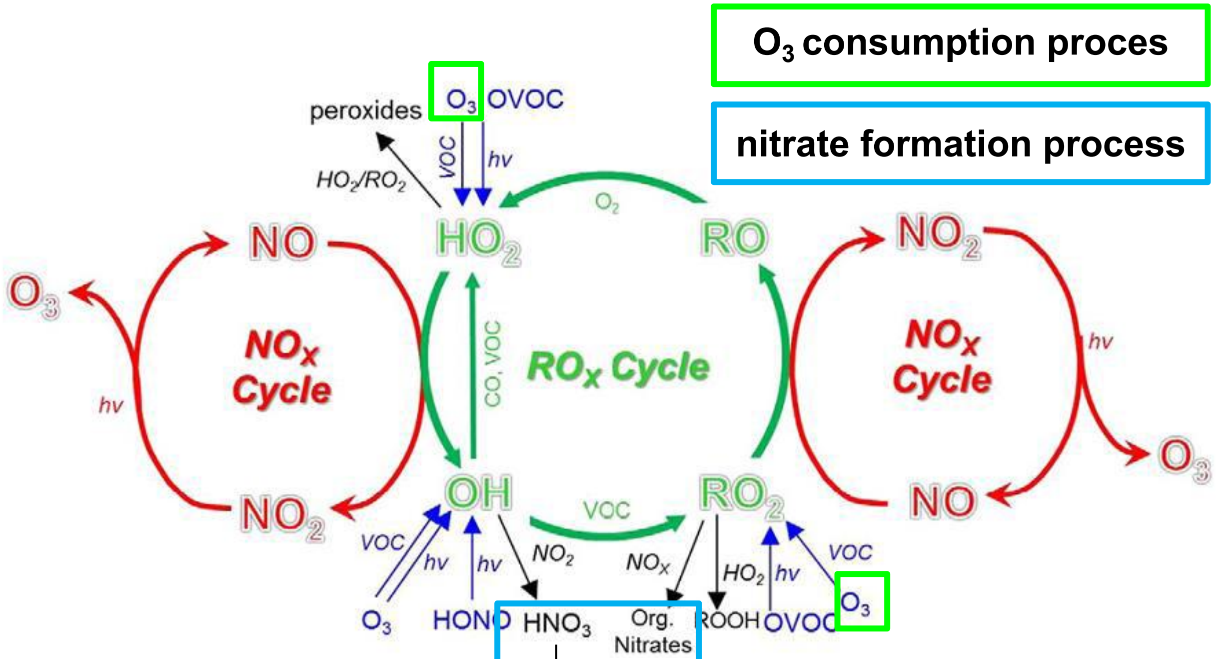
- **$PM_{2.5}$ and O_3 pollution characteristics**
- **Meteorological conditions for $PM_{2.5}$ and O_3 pollution**
- **Pollution causes and control strategy**

PM$_{2.5}$ and O$_3$ formation mechanism

PM$_{2.5}$ formation mechanism



O$_3$ formation mechanism

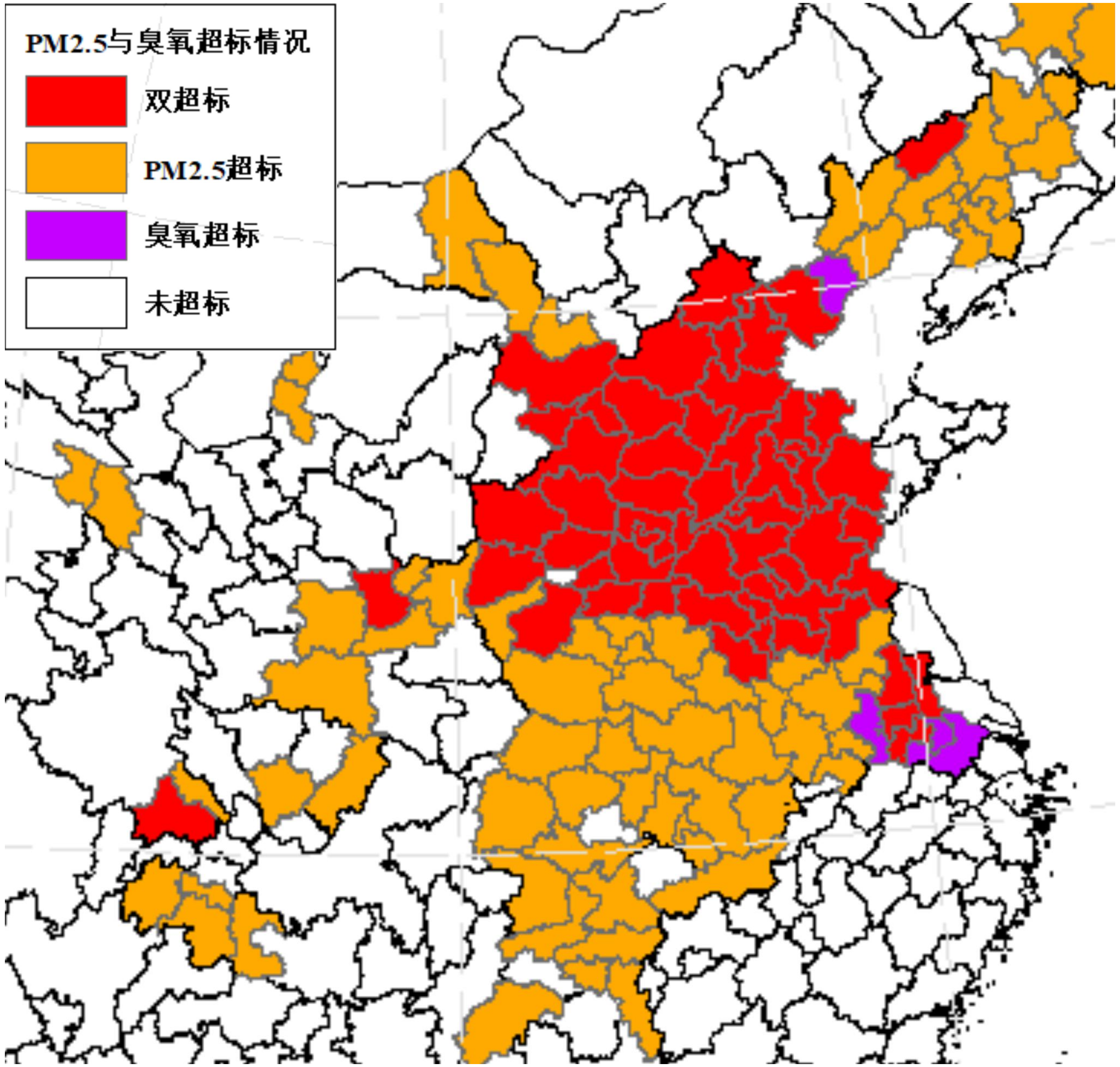


Modified based on Wang et al. 2017

- PM$_{2.5}$ and O$_3$ pollution: having sources and precursors in common, anthropogeic or biogenic, especially VOCs and NOx
- O$_3$ is not only the product of photochemical reaction, but also a very important oxidant to oxidize SO$_2$, NOx and VOCs

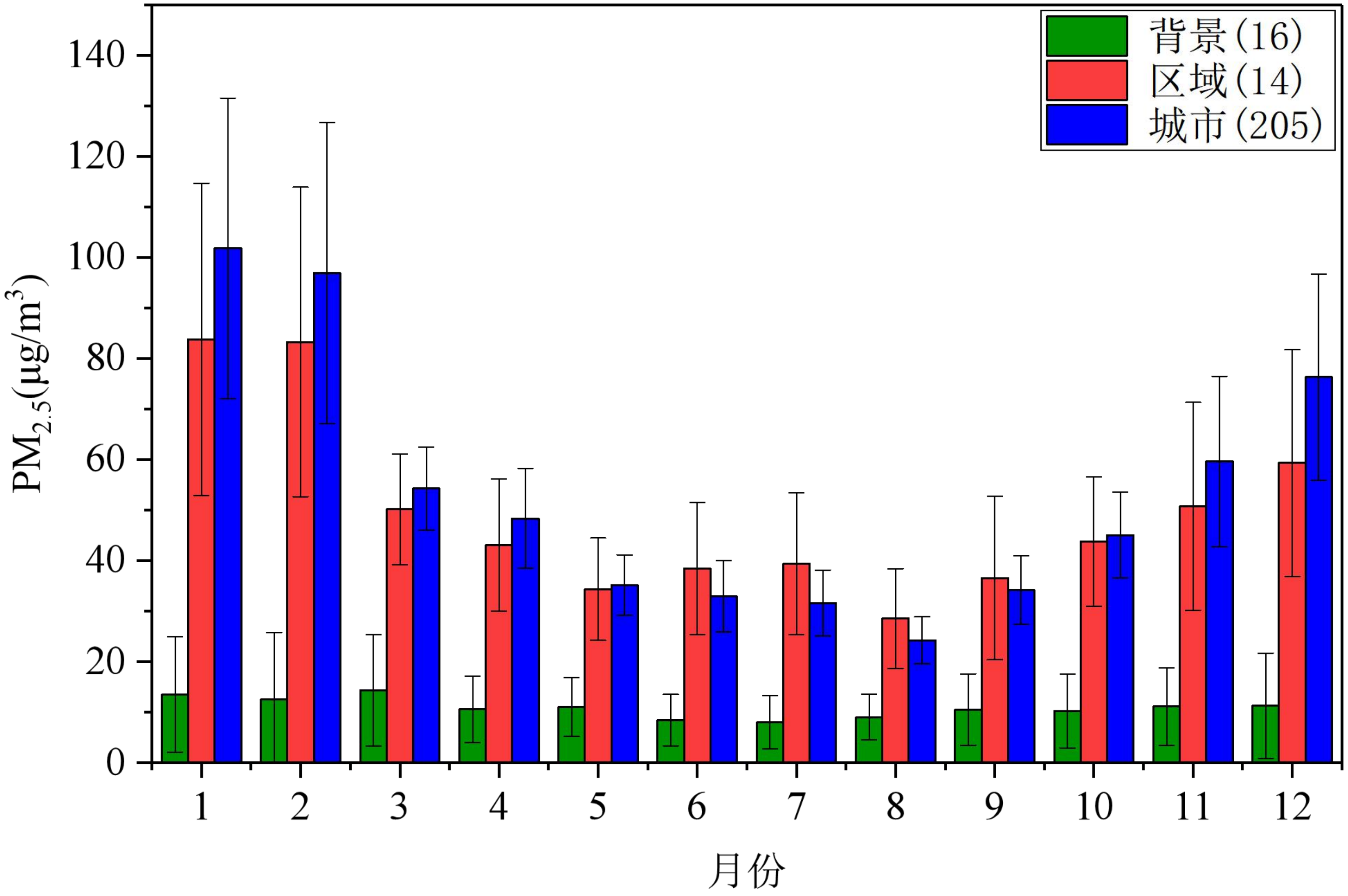
$PM_{2.5}$ and O_3 pollution in east and central China

- In 2020, most of the cities (in red) both exceeding the annual concentration limits of $PM_{2.5}$ (35 ug/m^3) and O_3 (160 ug/m^3 for MDA8-90th) regulated in the National Ambient Air Quality Standards (NAAQS) of China are located in Beijing, Tianjin, Hebei and Surrounding (BTH+) Region
- Other cities (in yellow) only exceeding the annual limit of $PM_{2.5}$ are located in south Henan, central Jiangsu and Anhui, Hubei and north Hunan, Liaoning and central Sichuan, etc.
- Just a few cities (in purple) located in south Jiangsu only exceeded the annual limit of O_3



$PM_{2.5}$ and O_3 pollution in different locations and seasons

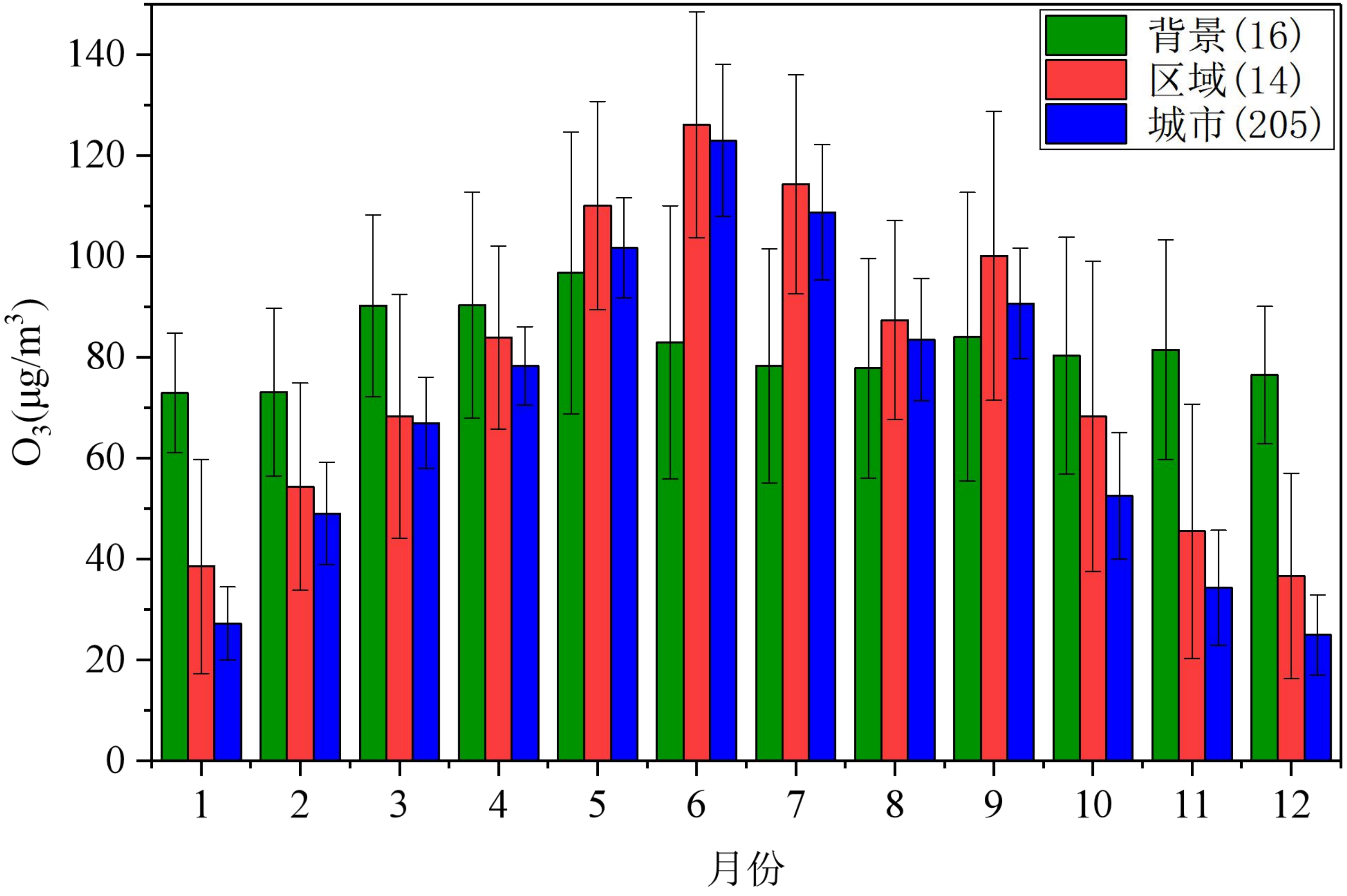
- In 2019, $PM_{2.5}$ background level (green column) could reach ~10 ug/m^3 nationwide, but the concentrations in urban and rural sites (blue and red column) in BTH+ Region are much higher than the background
- In late autumn and winter time, especially from middle Nov. to next Feb., $PM_{2.5}$ pollution are much higher than the warm season



Data source：China National Environmental Monitoring Center. Background values stand for national average.

$PM_{2.5}$ and O_3 pollution in different locations and seasons

- In 2019, O_3 background level (green column) are pretty high (~80 ug/m³) throughout the year, and even a little bit lower in the summer
- Only from May to Sept., higher O_3 concentration were observed in urban and rural monitoring sites (blue and red column), and the difference is not as large as $PM_{2.5}$ concentration

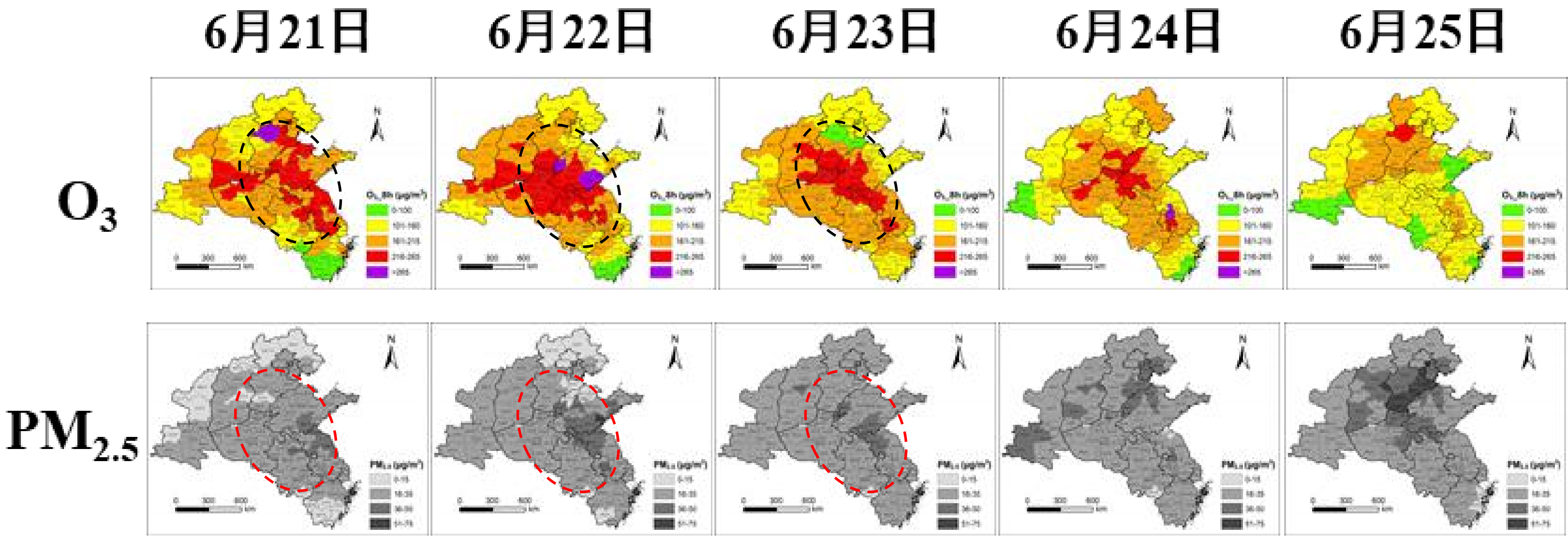


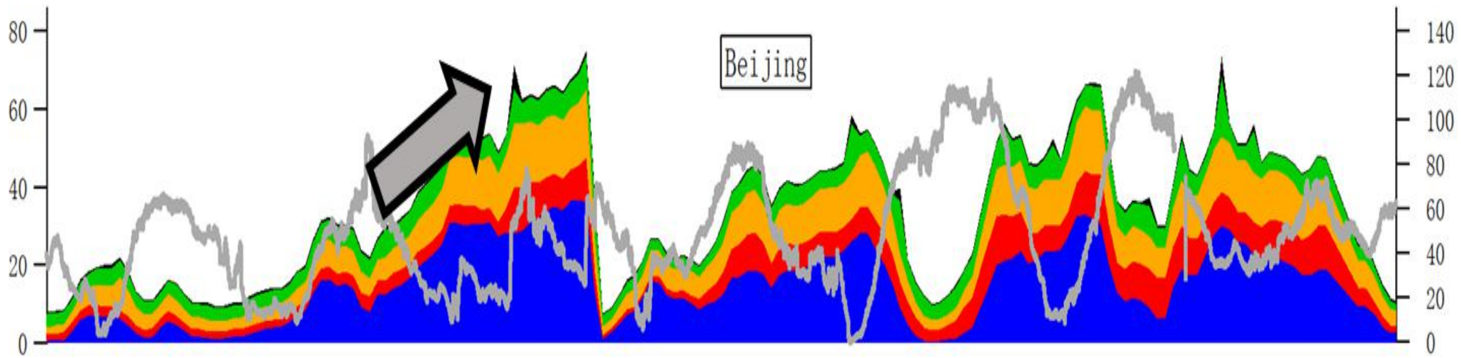
Data source：China National Environmental Monitoring Center. Background values stand for national average.

$PM_{2.5}$ and O_3 during a pollution episode in the summer of BTH+

- In the summer of 2021 and during a typical regional O_3 pollution episode, daily $PM_{2.5}$ concentration increased along with O_3 pollution in the same days and cities

- High concentration of O_3 promoted the production of nitrate, so as to increase the $PM_{2.5}$ concentration, especially during the night





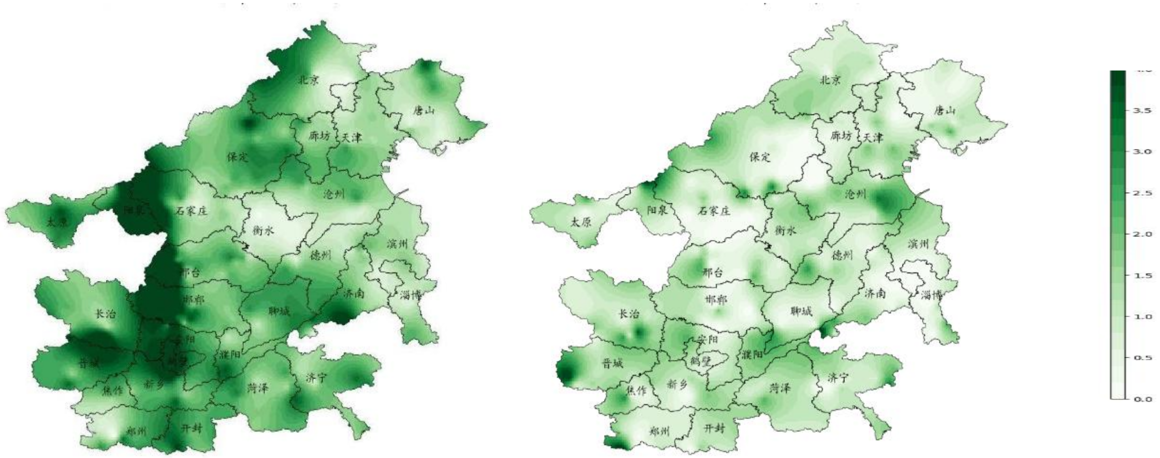
$PM_{2.5}$ composition and O_3 concentration (grey line) in Beijing, 6/21-6/25 2021

Outline

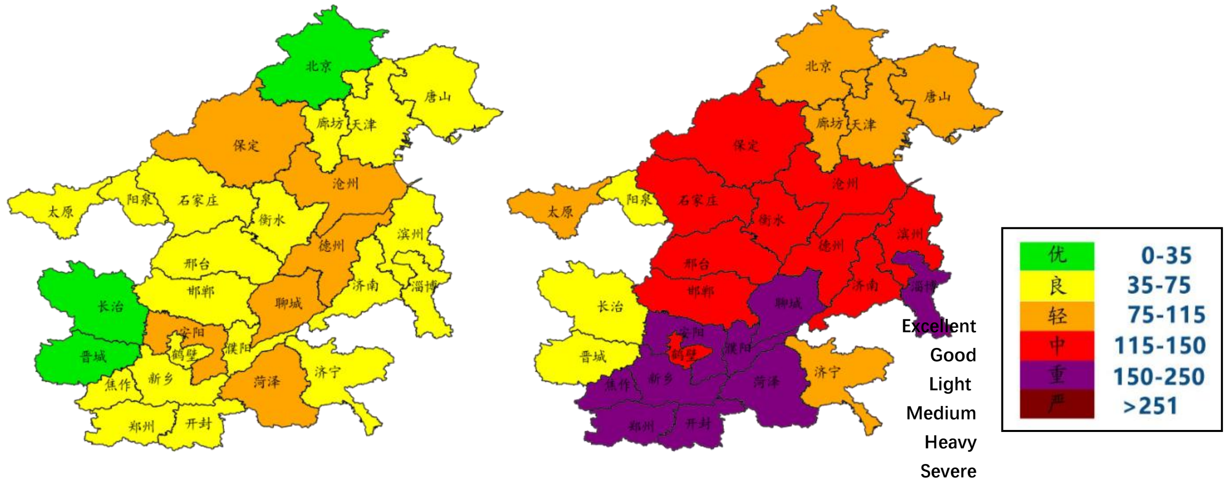
- $PM_{2.5}$ and O_3 pollution characteristics
- Meteorological conditions for $PM_{2.5}$ and O_3 pollution
- Pollution causes and control strategy

Meteorological conditions for $PM_{2.5}$ pollution

- Unfavorable meteorological conditions include: near-surface wind speed less than 2 m/s, relative humidity higher than 60%, near-surface inversion, and boundary layer height less than 500 m
- It is easy to cause accumulation of local primary pollutant and chemical formation of secondary pollutant under the unfavorable meteorological conditions



"2+26" Cities near-surface wind speed



"2+26" Cities daily average concentration of $PM_{2.5}$

Meteorological conditions for O_3 pollution

Major meterological conditions for O_3 pollution include

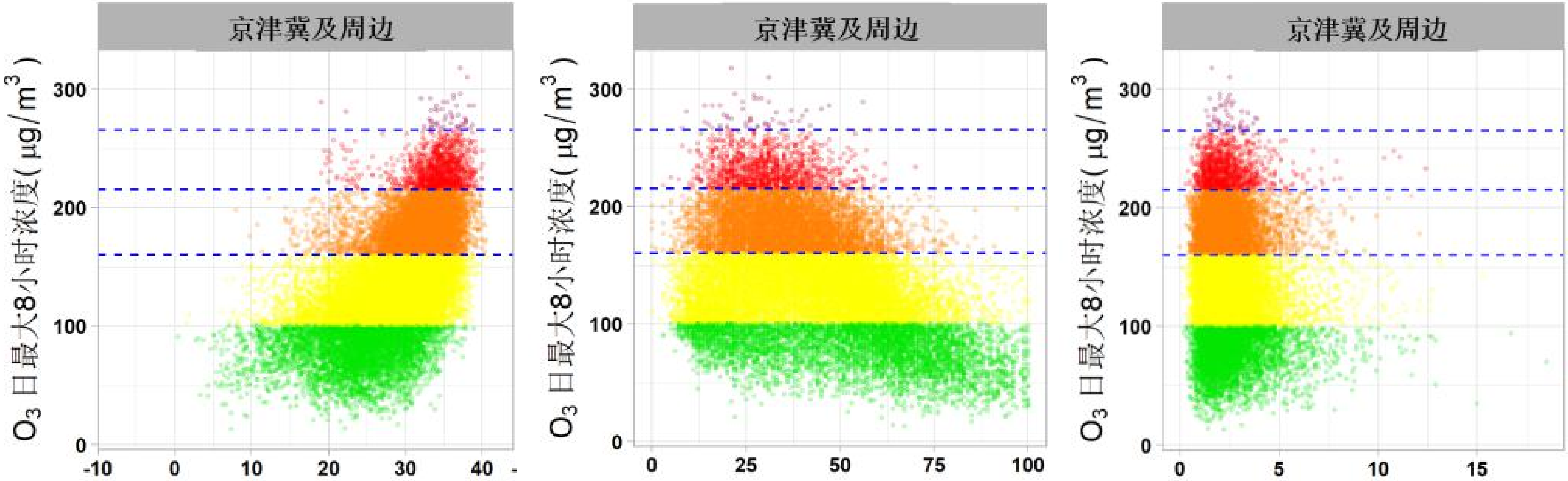
- Max. ambient temperature
- Wind speed and direction
- Relative humidity and rainfall
- Solar radiation and cloud cover
- ......

Variable	Usefulness	Condition for High Ozone[a]
Maximum temperature	Highly correlated with ozone and ozone formation	High
Morning wind speed	Associated with dispersion and dilution of ozone precursor pollutants	Low
Afternoon wind speed	Associated with transport of ozone	-
Cloud cover	Controls solar radiation, which influences photochemistry	Few
Relative humidity	Surrogate for cloud cover	Low
500-mb height	Indicator of the synoptic-scale weather pattern	High
850-mb temperature	Surrogate for vertical mixing	High
Pressure gradients	Causes winds/ventilation	Low
Length of day	Amount of solar radiation	Longer
Day of week	Emissions differences	-
Morning NO_x concentration	Ozone precursor levels	High
Previous day's peak ozone concentration	Persistence, carry-over	High
Aloft wind speed and direction	Transport from upwind region	-

Source：USEPA ozone forecasting guideline

Meteorological conditions for $PM_{2.5}$ pollution

- In BTH+ Region, O_3 pollution is easy to occur under the meteorological conditions including max. ambient temperature > 20 °C, relative humidity < 60% and daily average wind speed < 5 m/s



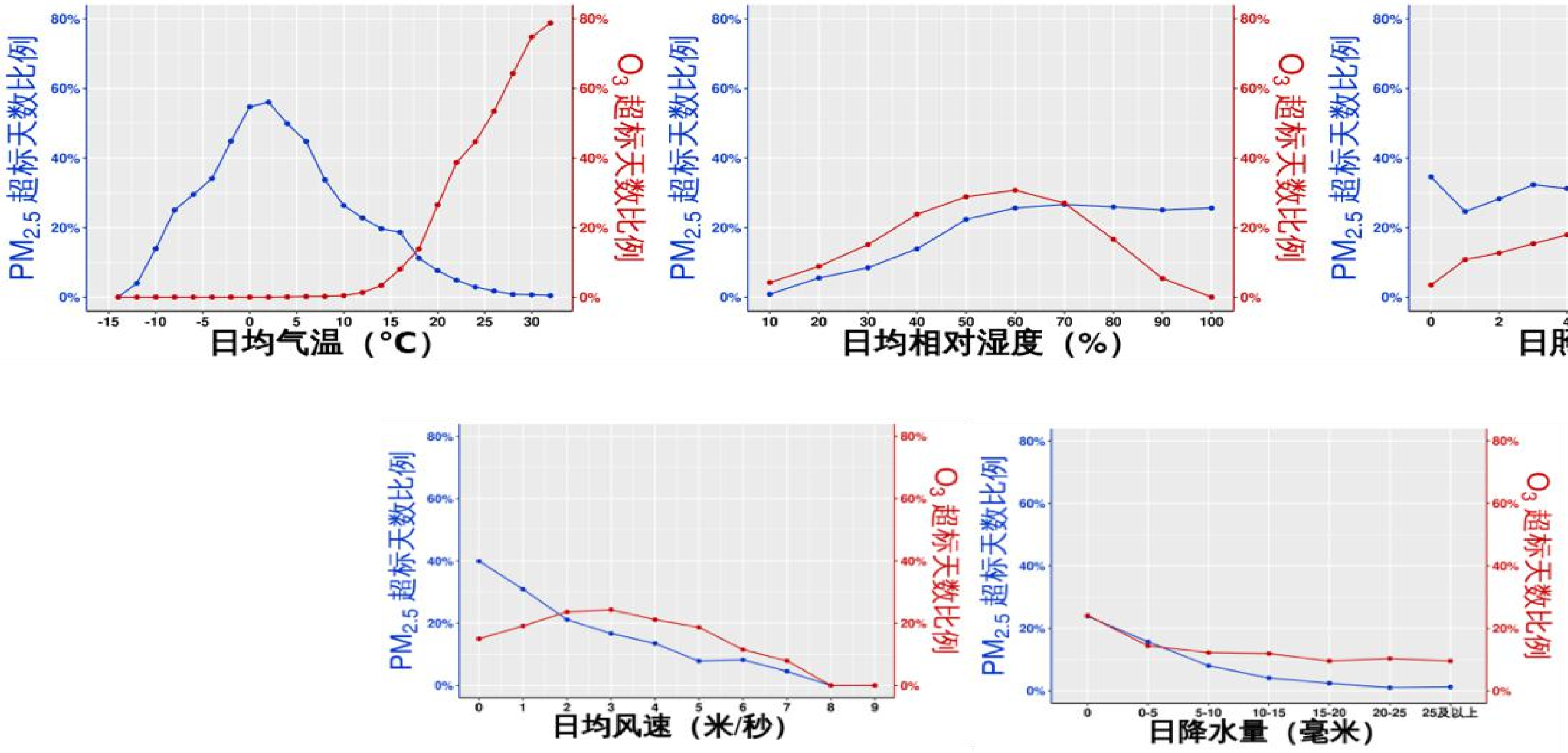
Max. ambient temperature

Relative humidity

Average wind speed

Meteorological conditions for $PM_{2.5}$ and O_3 pollution

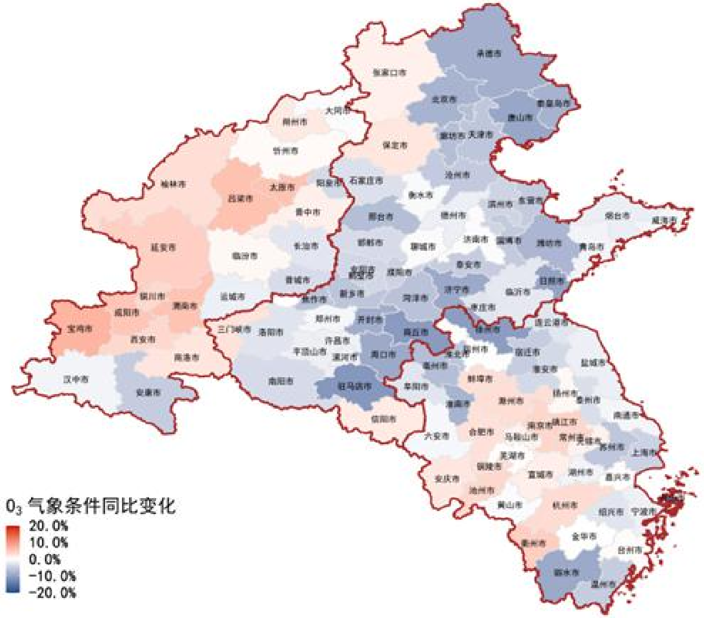
- For both $PM_{2.5}$ and O_3 pollution, daily average wind speed and rainfall have the similar effect, while ambient temperature and relative humidity are different

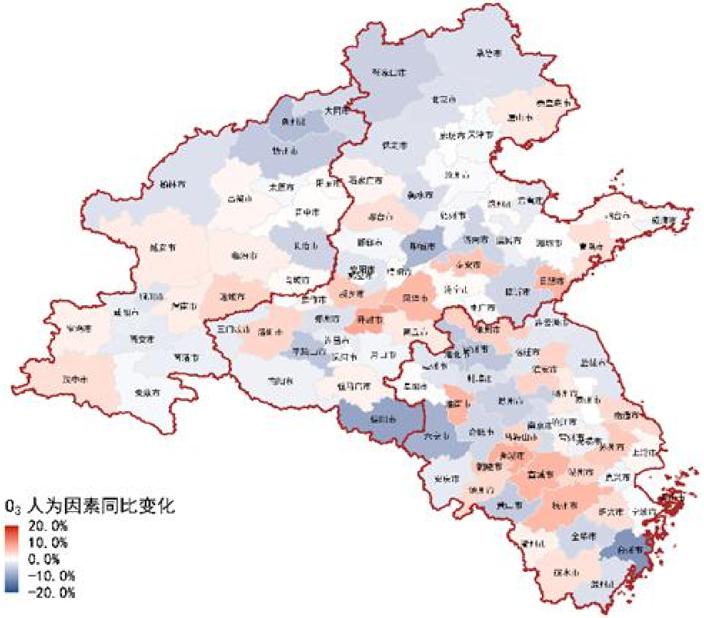


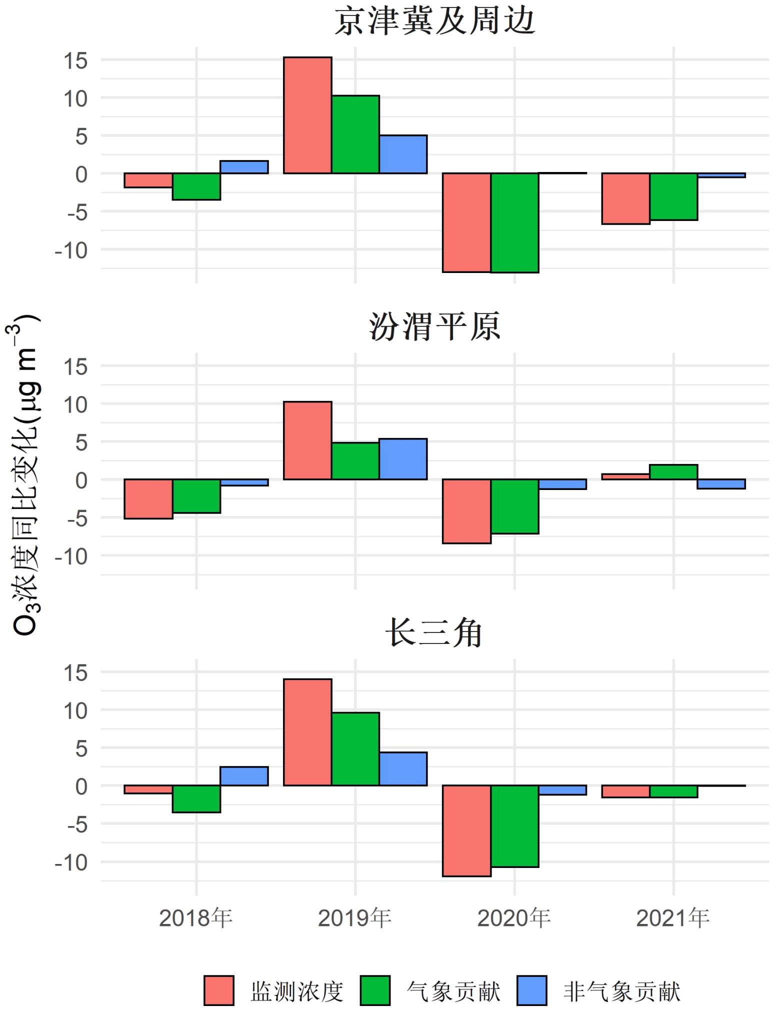
$PM_{2.5}$ and O_3 pollution days vs. different meterological conditions

Meteorological conditions for $PM_{2.5}$ and O_3 pollution

- Assessment shows that the meteorological conditions contributed about 70% of the ozone variation in BTH+ Region inrecent years
- Compared to the anthropogenic emissions, meteorological conditions have greater effect on ozone pollution







Meteorological effect on ozone concentration in key regions during the summer of 2018~2021 (May–Sept.)

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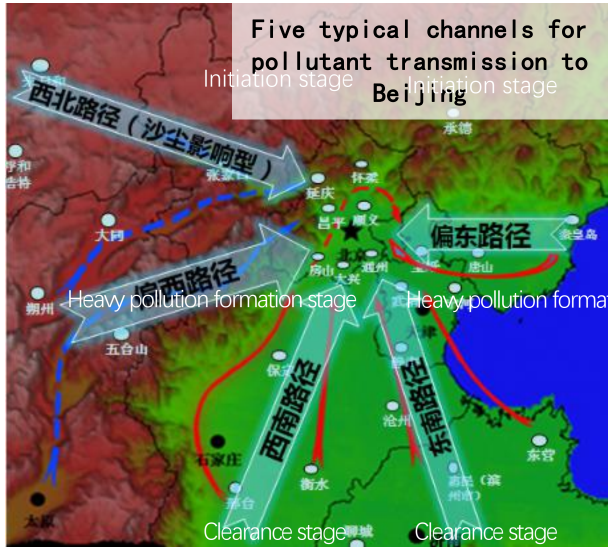
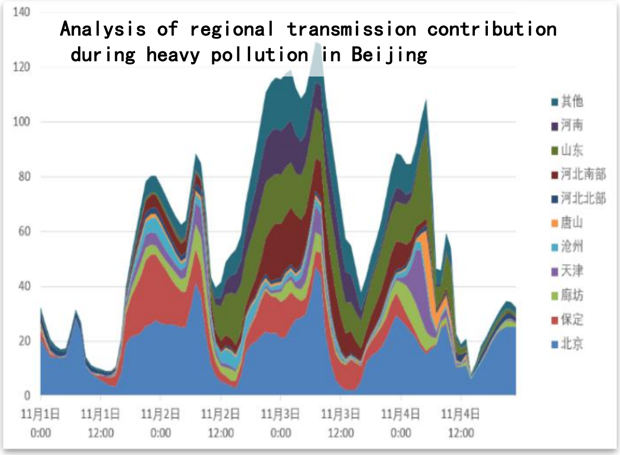
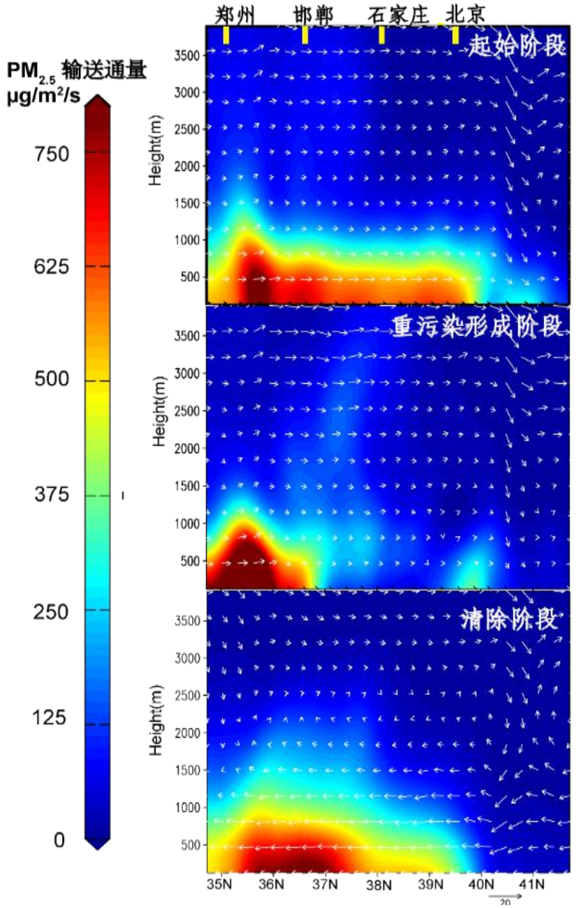
Transport of regional $PM_{2.5}$ pollution

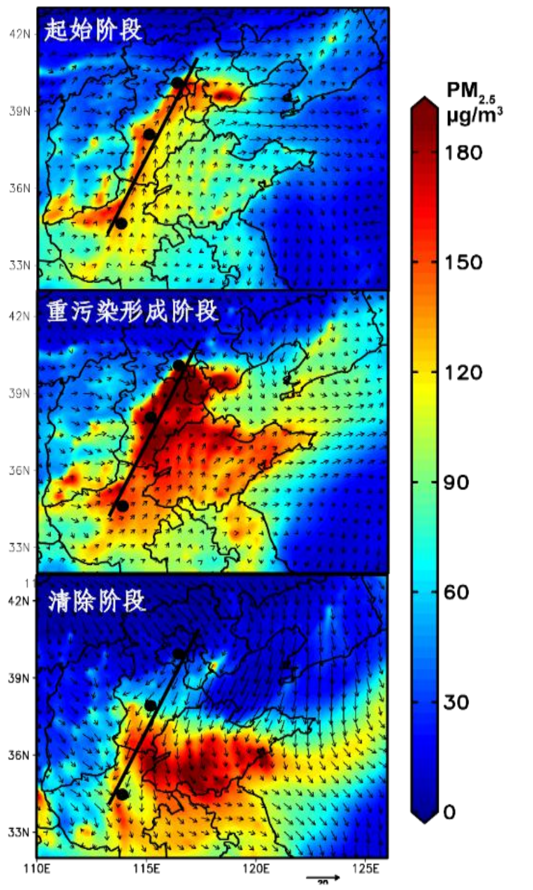
- BTH+ cities are affected by regional transport, with an average annual contribution of around 20-30%
- During the heavy pollution period, the regional transport impact will increase by about 15-20%, and Beijing can reach 60-70%







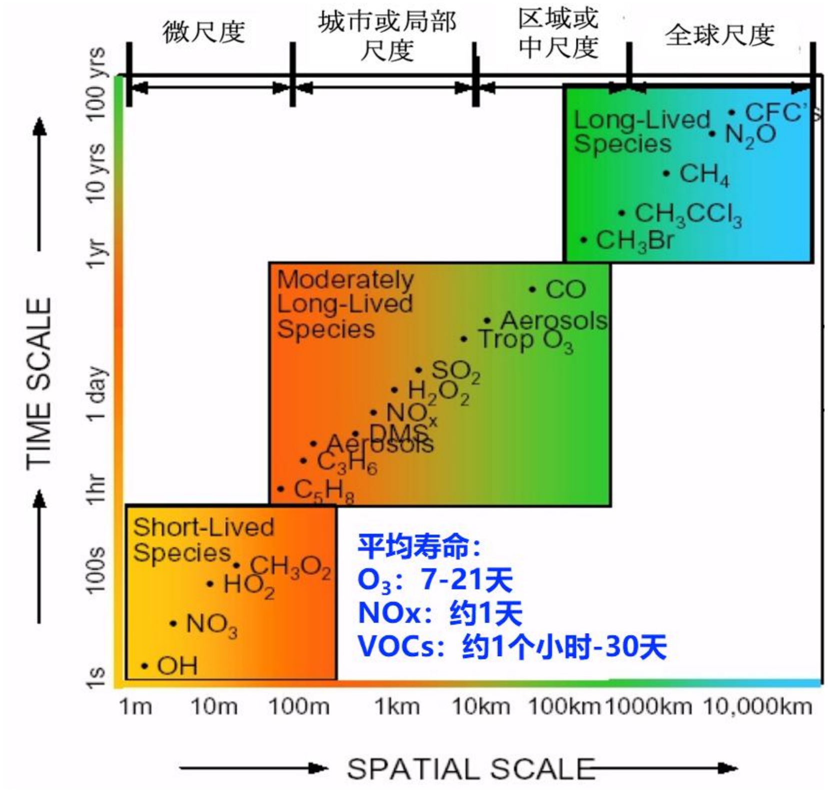
Transport flux and wind fields



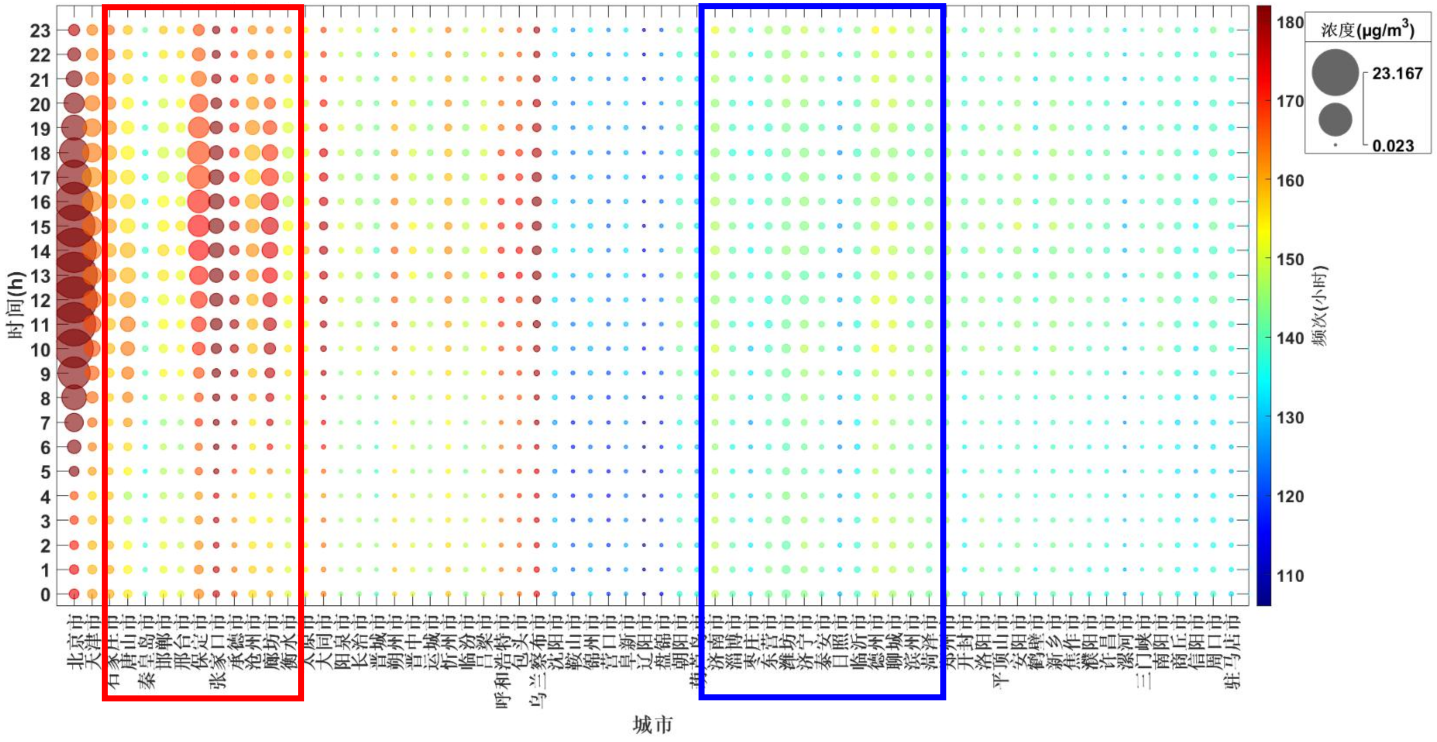
$PM_{2.5}$ and wind fields

Transport of regional O_3 pollution

- O_3 lifetime last for one or two weeks, much longer than NOx (about 1 day) and high reactive VOCs



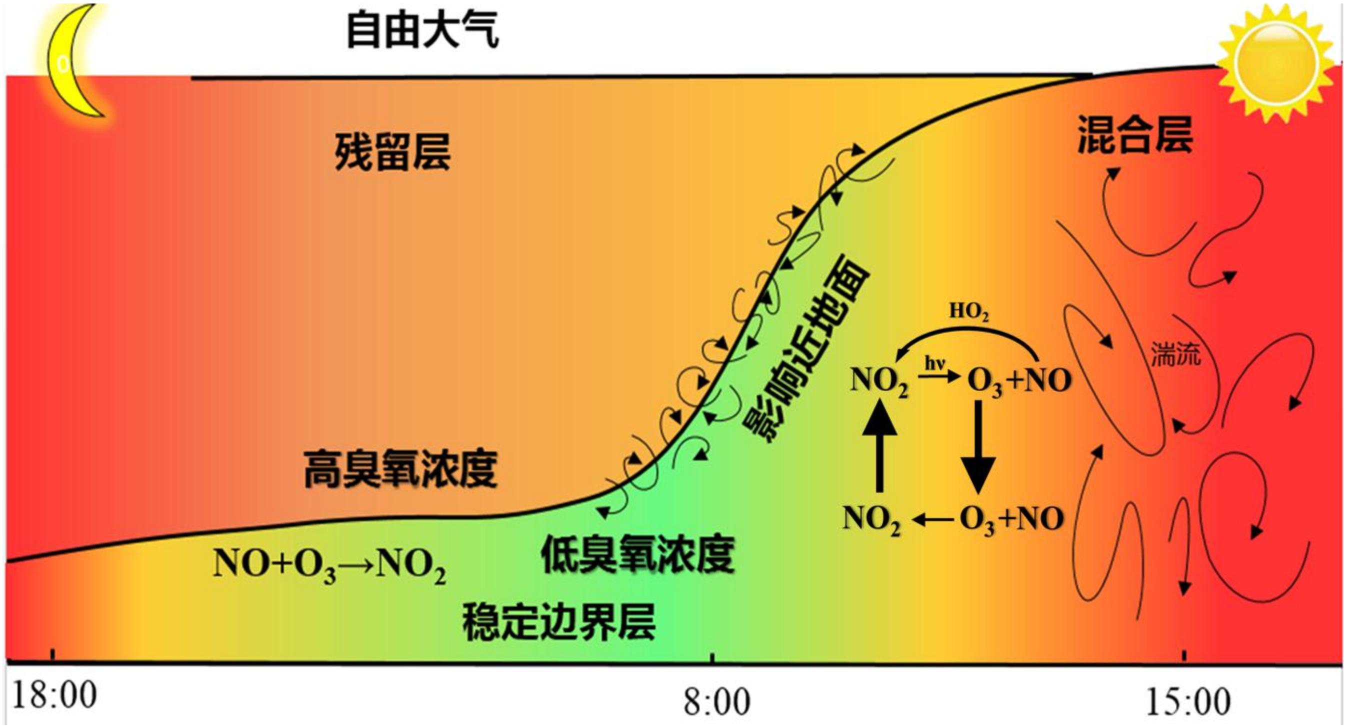
- O_3 pollution transport to Beijing mostly occurred from 7am to 20pm
- Hebei and Shandong provinces are the largest two contributors of O_3 pollution transport to Beijing



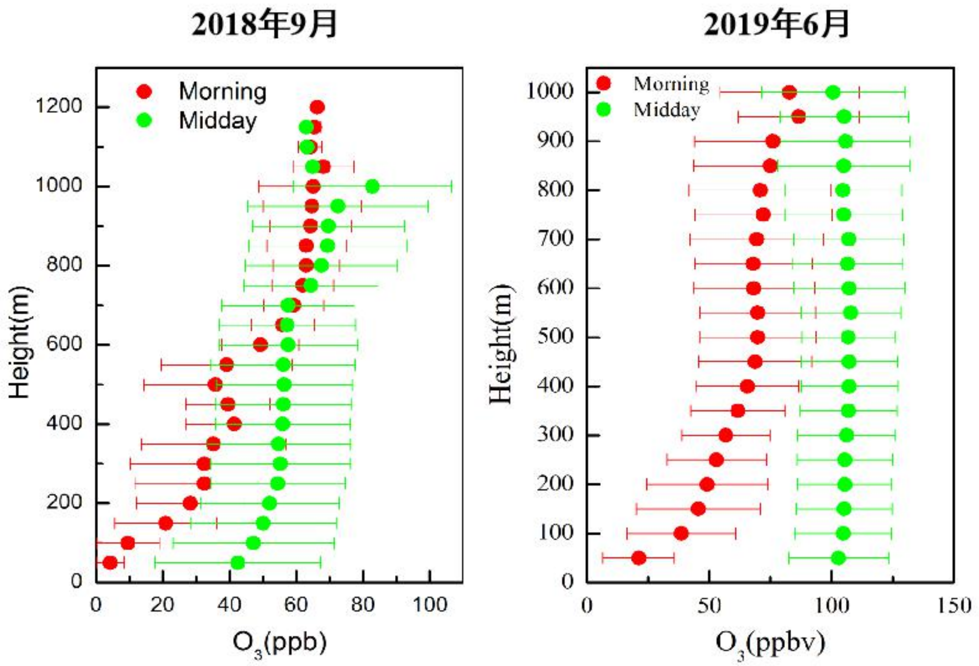
O_3 transport from BTH+ Region to Beijing (May to June, 2018-2020)

Vertical transport of O_3 pollution

- Current studies reveals that vertical transport (under the boundary layer) contribute about 20%~50% of the surface O_3, but how to quantify the contribution is still a challenge
- The diurnal variation of O_3 concentration at different height is totally different



Zhao et al., JES, 2019;Tang et al., AR, 2021; Tang et al., STETON, 2021

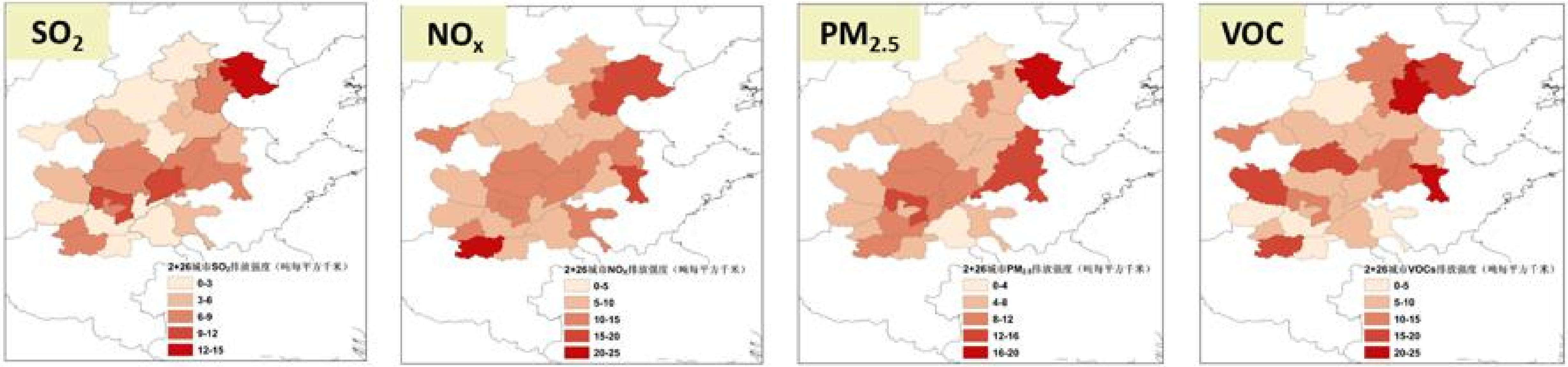


石家庄市夏秋季O_3浓度垂直演变

Source: Tang et al., IAP CAS

Anthropogenic emissions in BTH+ Region

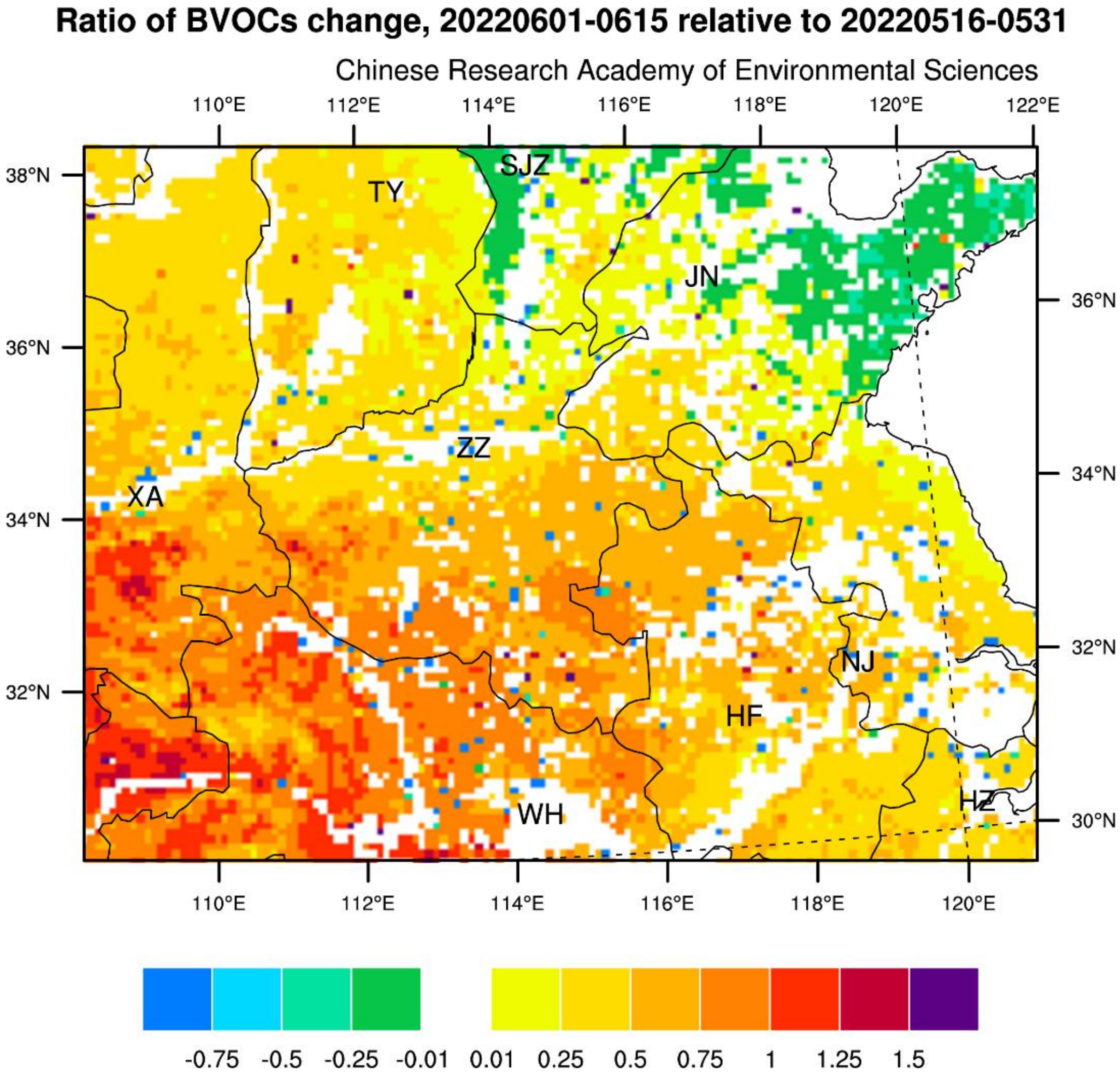
- The emissions in BTH+ Region are large, and the emission intensity is 2-5 times of the national average for different pollutants
- Higher VOCs and NOx emission intensity (per unit area) are observed in Tianjin City, Tangshan City in Hebei Prov., Jinan City in Shandong Prov. and Zhengzhou City in Henan Prov., etc.



Main pollutants emission intensity in “2+26” cities (emission per unit area)

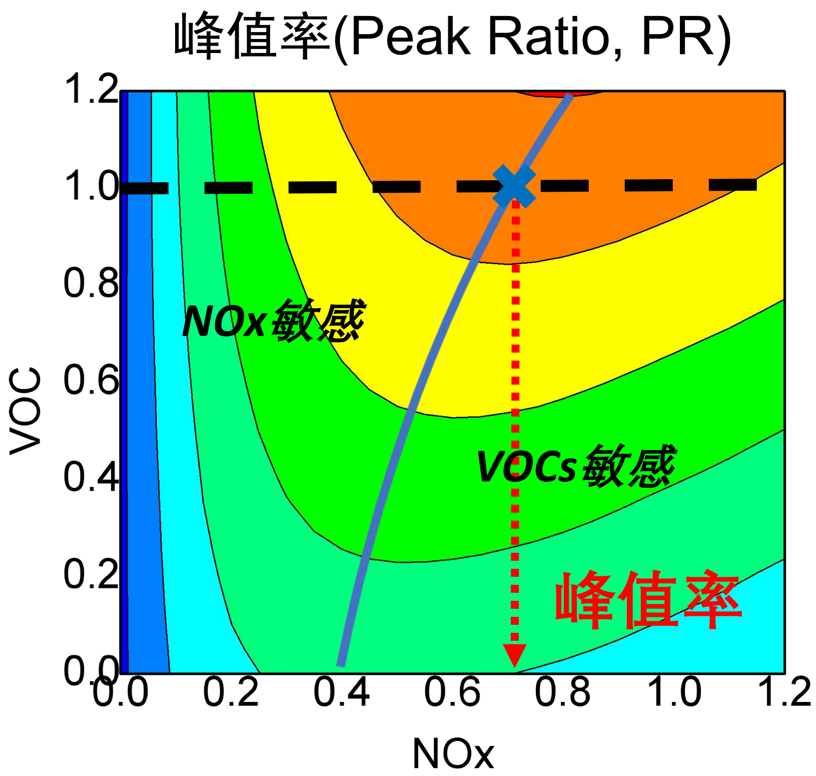
Biogenic emissions in BTH+ Region

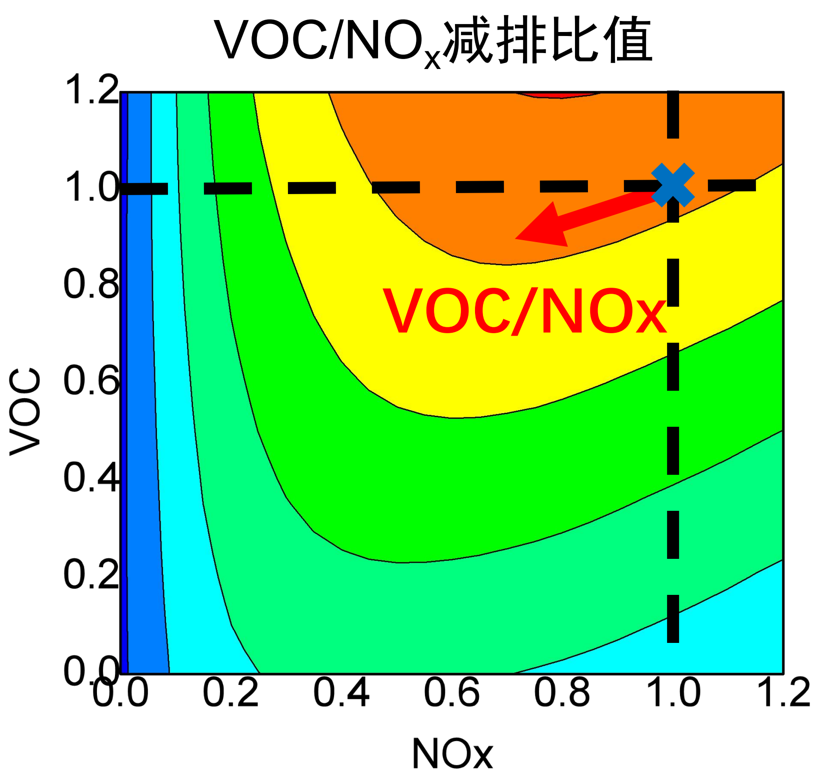
- Larger VOCs emissions from the vegitation are observed in the summer time, especially in the hot days with high solar radiation (cloudless days)
- In June of 2022, simulation shows larger biogenic emissions in BTH+ Region compared to that in May, which also contributed to higher O_3 pollution

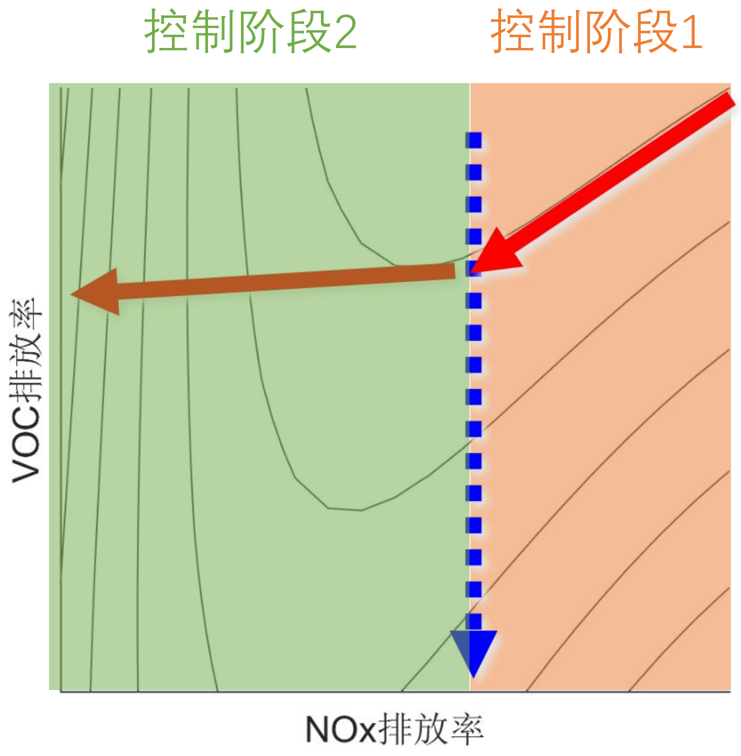


Control Strategy for Regional $PM_{2.5}$ and O_3

- Modelling simulation indicate that VOCs emissions along with NOx are the two key pollutants to control for the BTH+ Region in this decade, and further NOx emission reduction is expected for the next step







Source: Wang et al., Tsinghua University

Thank you for your attention!