



复旦大学环境科学与工程系

Department of Environmental Science and Engineering

NATIONAL  
ACADEMIES

Sciences  
Engineering  
Medicine

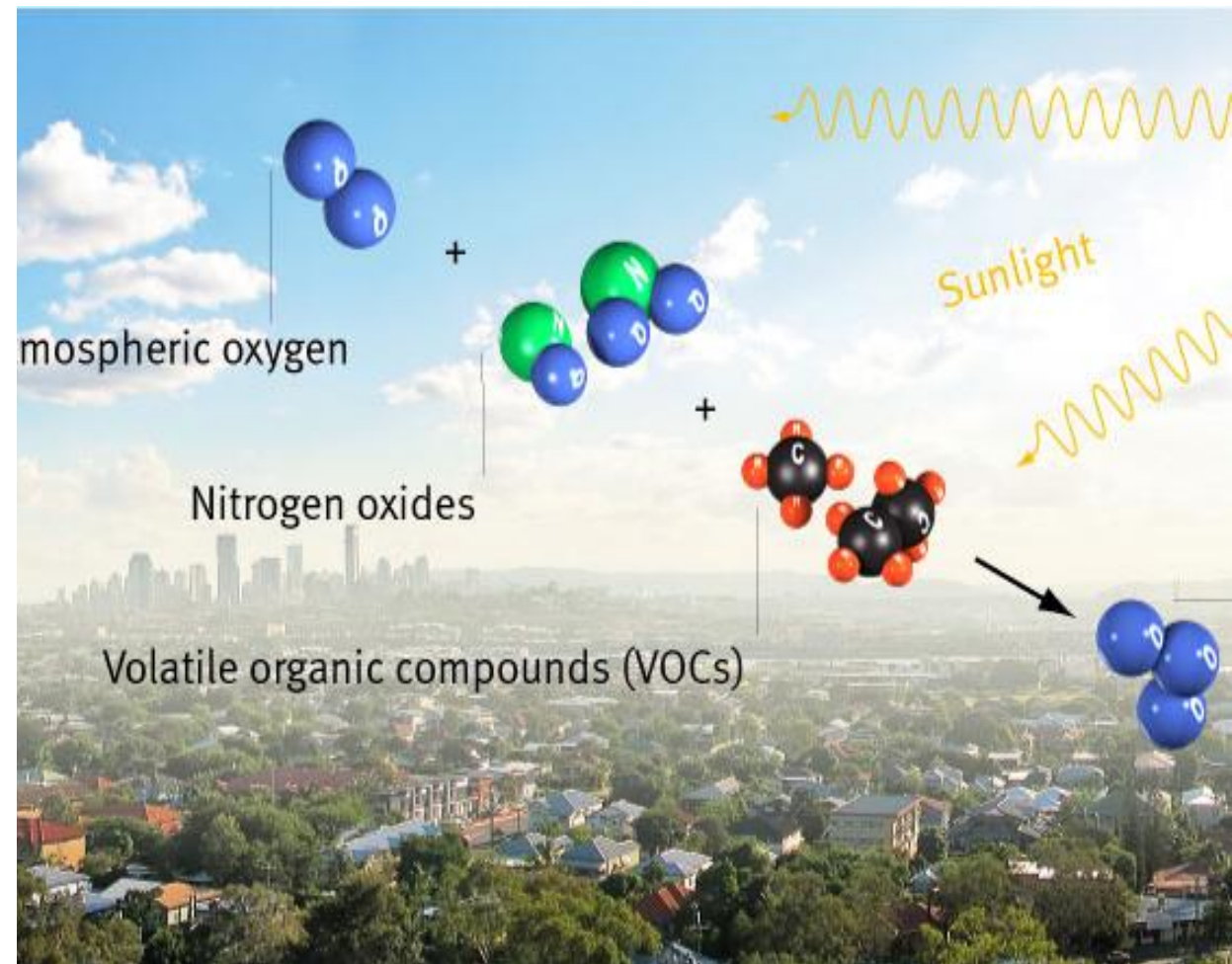
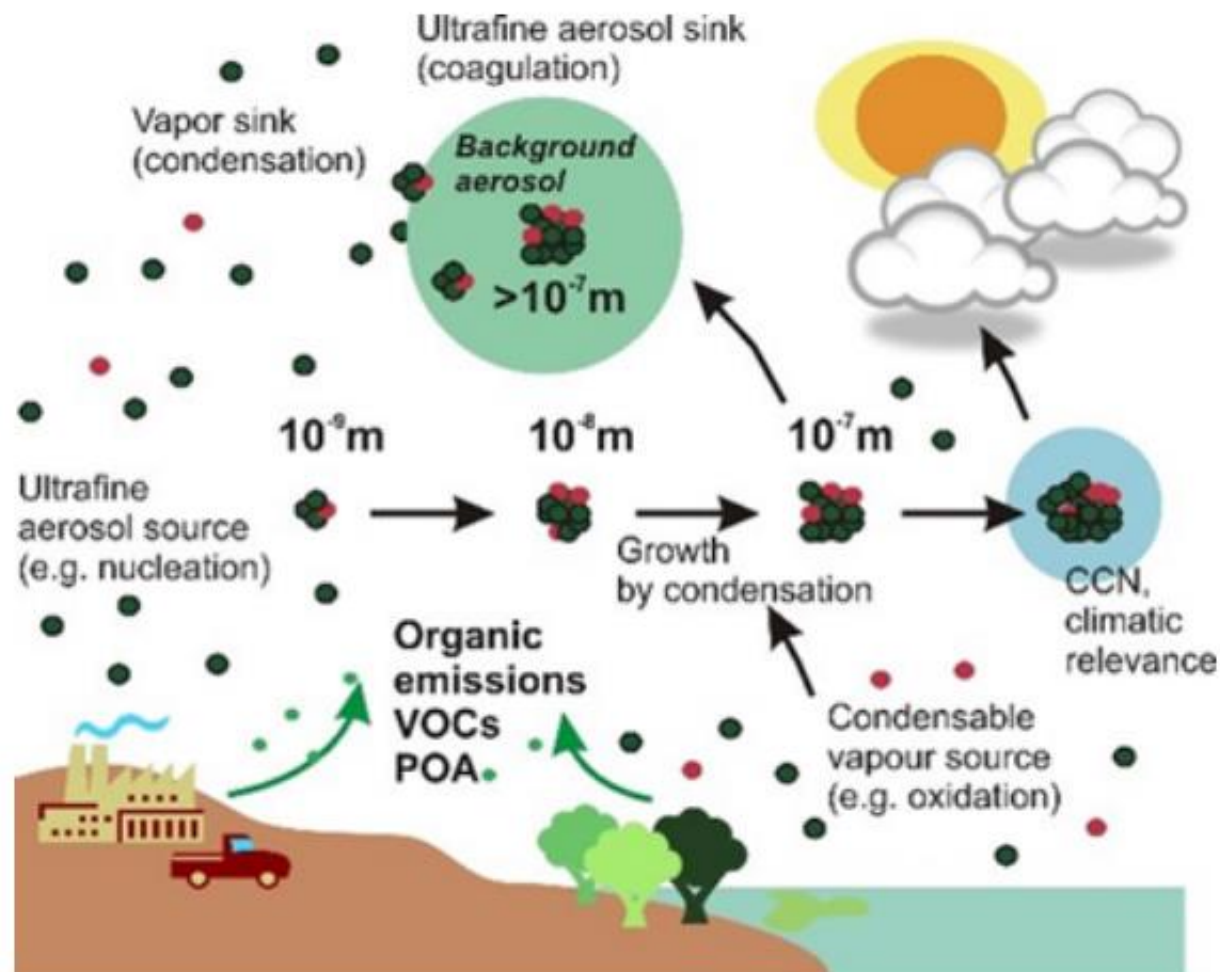
China-U.S. Scientific Engagement on Sustainability: A Workshop Series  
Workshop II: Sustainability and Planetary Health: Key Issues and Possible Solutions

# Natural originated emissions threaten future air quality goals

Hongliang Zhang

Fudan University  
June 20, 2023

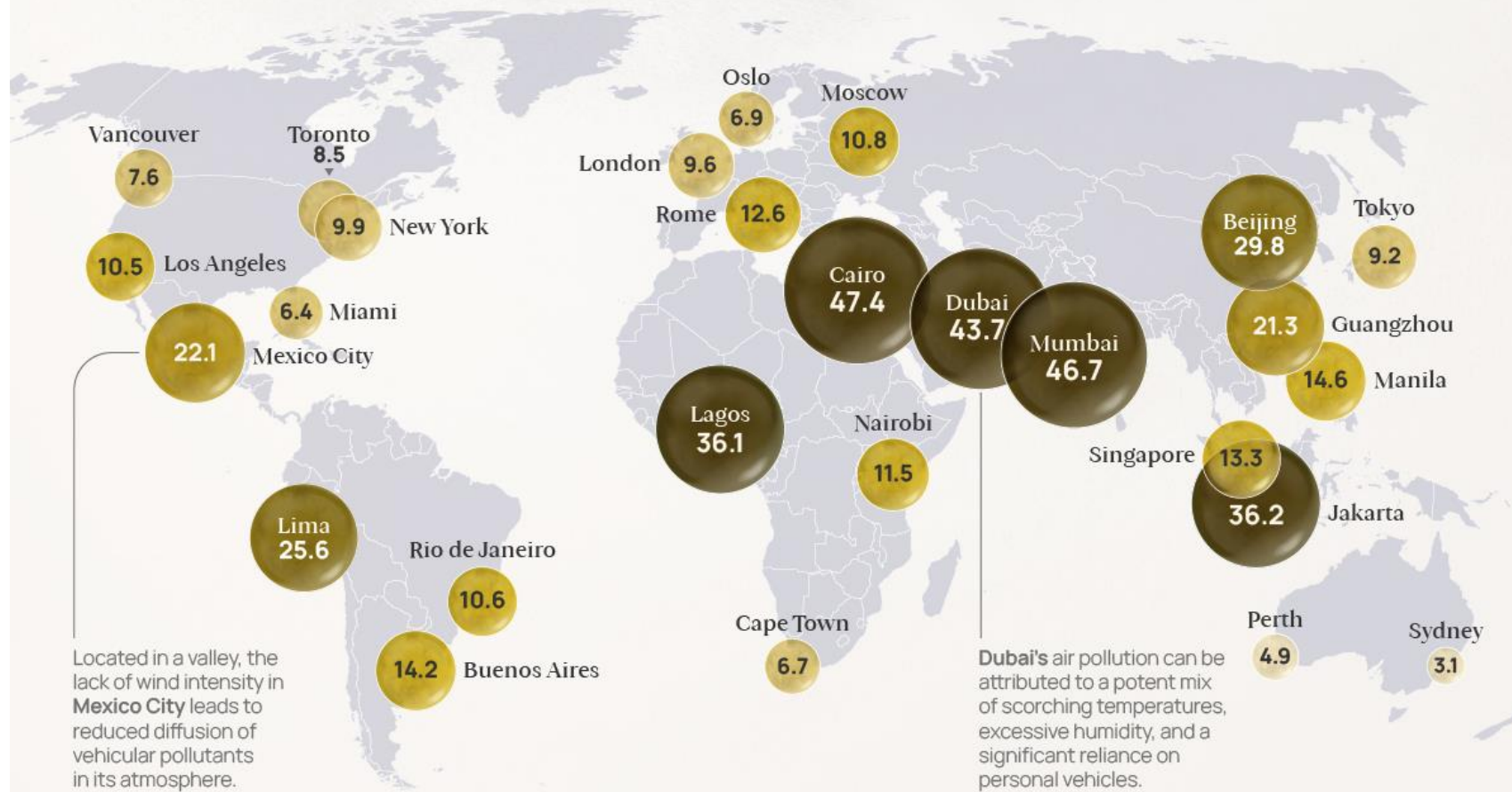
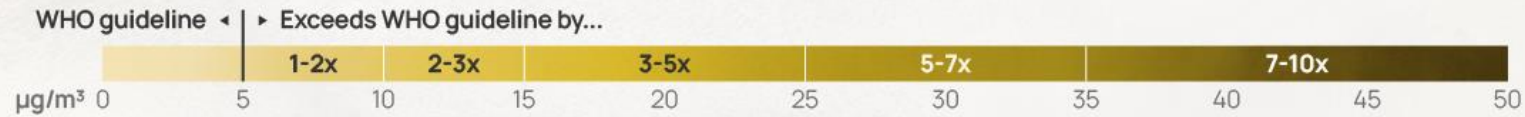
# Formation of particulate matter and ozone



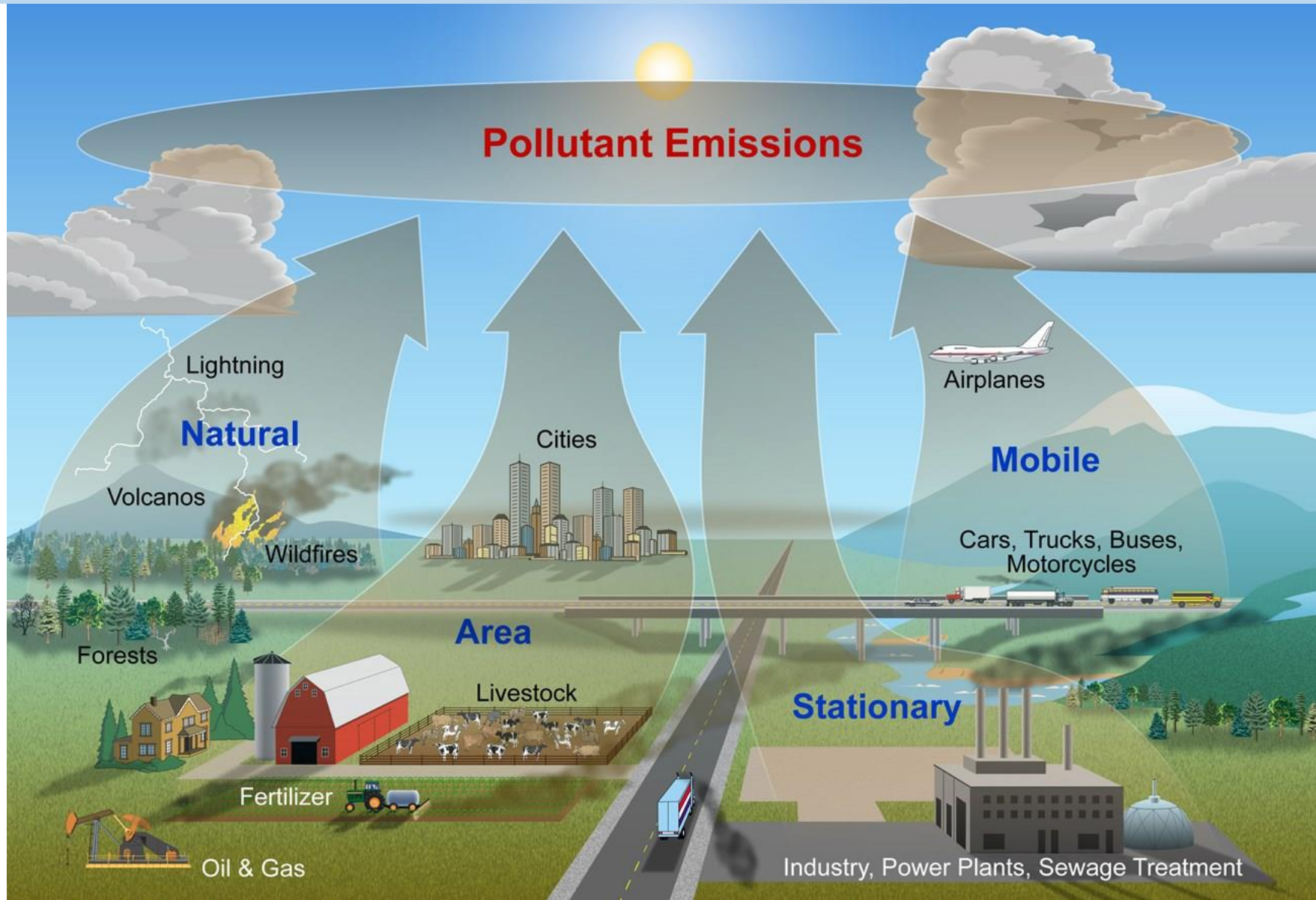
# Air pollution is severe worldwide

## 2022 Average PM2.5 Concentration in Select Major Cities

Micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ )



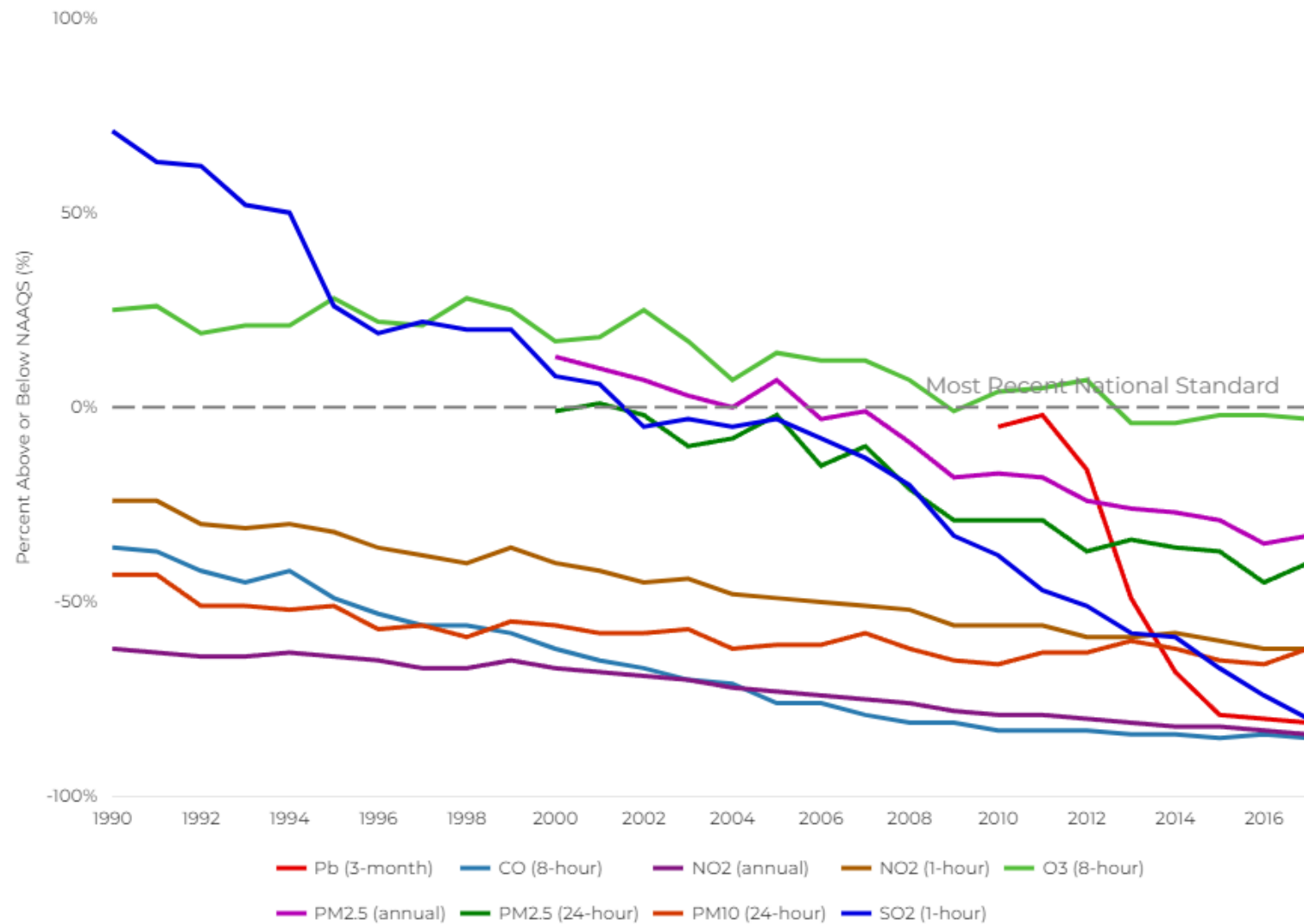
# Natural and anthropogenic sources



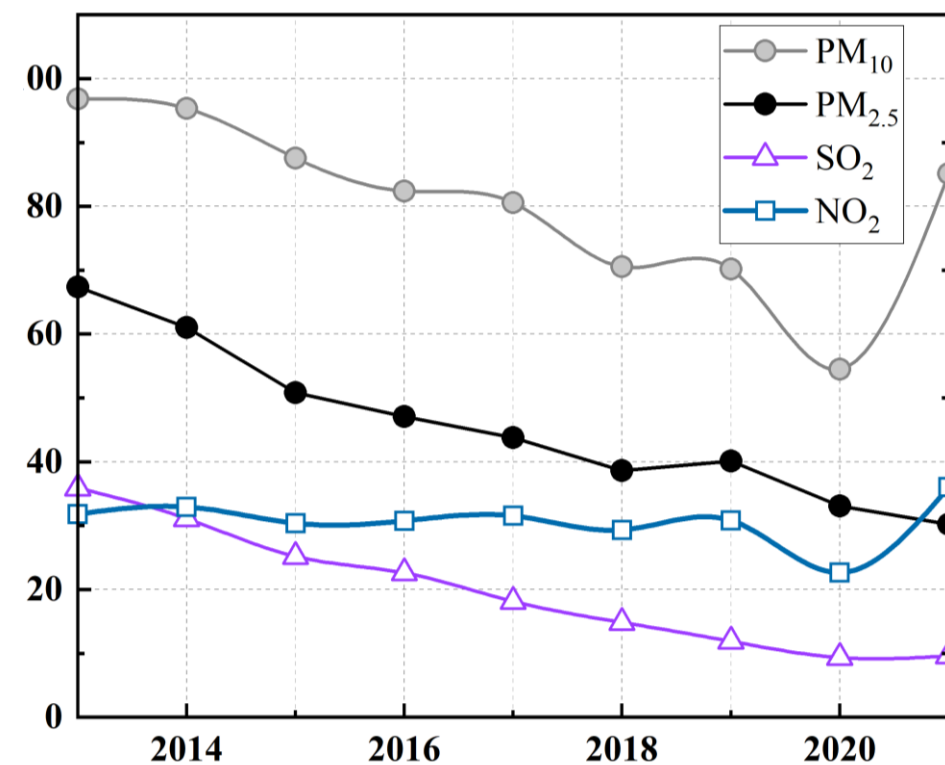
# US and China made progresses

Declining National Air Pollutant Concentration Averages

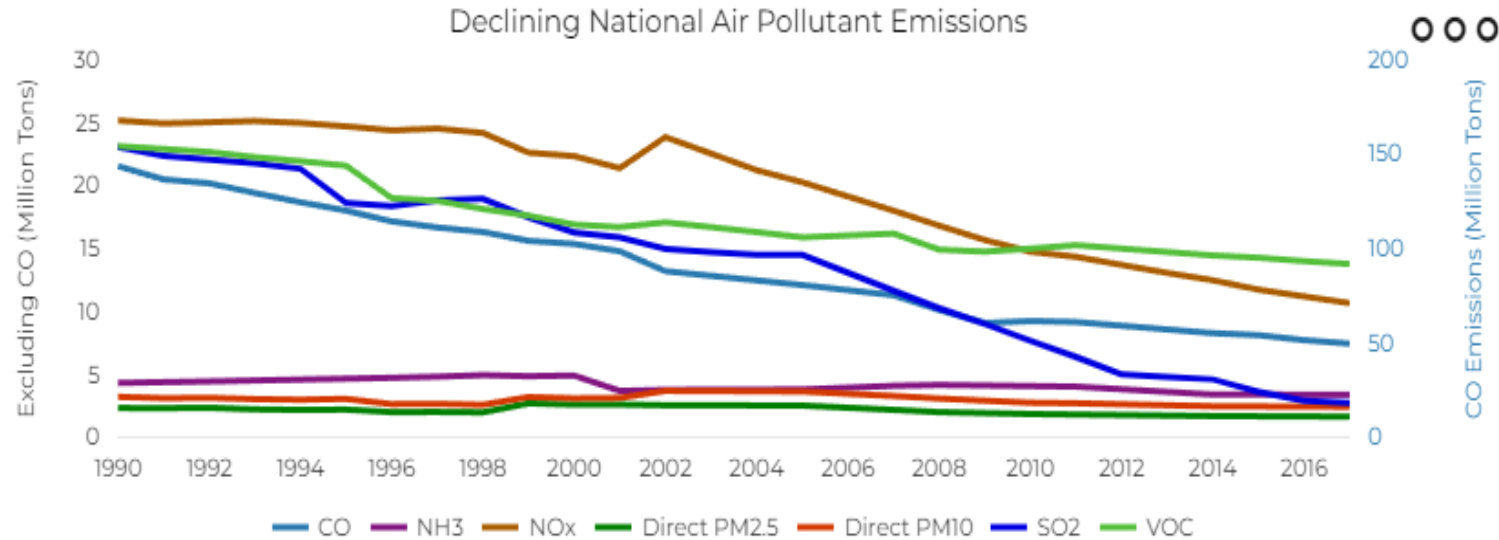
ooo



Source: U.S. EPA Air Quality System



# By controlling anthropogenic emissions



|                                               |                     |                                                                                        |                                                                |      |      |      |
|-----------------------------------------------|---------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------|------|------|------|
| Strengthen industrial emission standards      | Coal-fired power    | 99% and 92% equipped with de-S and de-N devices                                        | 71% meet "ultralow emission" standard                          |      |      |      |
|                                               | Iron and steel      | 88% steel sintering machine equipped with de-S devices                                 | 80% with high efficiency de-S devices                          |      |      |      |
|                                               | Cement              | 92% equipped with de-N devices                                                         | 87% with high efficiency de-N devices                          |      |      |      |
|                                               | Flat glass          | 33% & 19% equipped with de-S and de-N devices (0 before 2013)                          |                                                                |      |      |      |
| Phase out small and polluting factories       | Small factories     | 62,000 "small and polluting" enterprises were phased out or rectified                  |                                                                |      |      |      |
|                                               |                     |                                                                                        |                                                                |      |      |      |
| Phase out outdated industrial capacities      | Coal-fired power    | 25 GW of coal-fired power generation capacity were phased out                          |                                                                |      |      |      |
|                                               | Iron and steel      | Eliminated 130 million ton outdated capacity                                           | Eliminated 70 million ton capacity                             |      |      |      |
|                                               | Cement              | Eliminated 250 million ton outdated capacity                                           |                                                                |      |      |      |
|                                               | Flat glass          | Eliminated 86 million weight boxes outdated capacity                                   | Eliminated 24 million weight boxes capacity                    |      |      |      |
| Upgrades on industrial boilers                | Emission standard   | Tightened emission standard; half of operating capacity meet the new emission standard |                                                                |      |      |      |
|                                               | Eliminate boiler    | Phased out 115 thousand small boilers                                                  | Phased out 85 thousand small boilers                           |      |      |      |
|                                               |                     |                                                                                        |                                                                |      |      |      |
| Promote clean fuels in the residential sector | Upgrade stove       | Upgraded to clean stoves                                                               | Coal substituted by NG and electricity in 6 million households |      |      |      |
|                                               | Energy substitution | Applied washed clean coal                                                              |                                                                |      |      |      |
|                                               |                     |                                                                                        |                                                                |      |      |      |
| Strengthen vehicle emission standards         | Emission standard   | "China 4" standard applied nationally<br>"China 5" standard applied in key regions     | "China 5" standard applied nationally                          |      |      |      |
|                                               | Old cars            | Eliminated 15 million old vehicles                                                     |                                                                |      |      |      |
|                                               |                     | Eliminated 5 million old vehicles                                                      |                                                                |      |      |      |
|                                               |                     | 2013                                                                                   | 2014                                                           | 2015 | 2016 | 2017 |

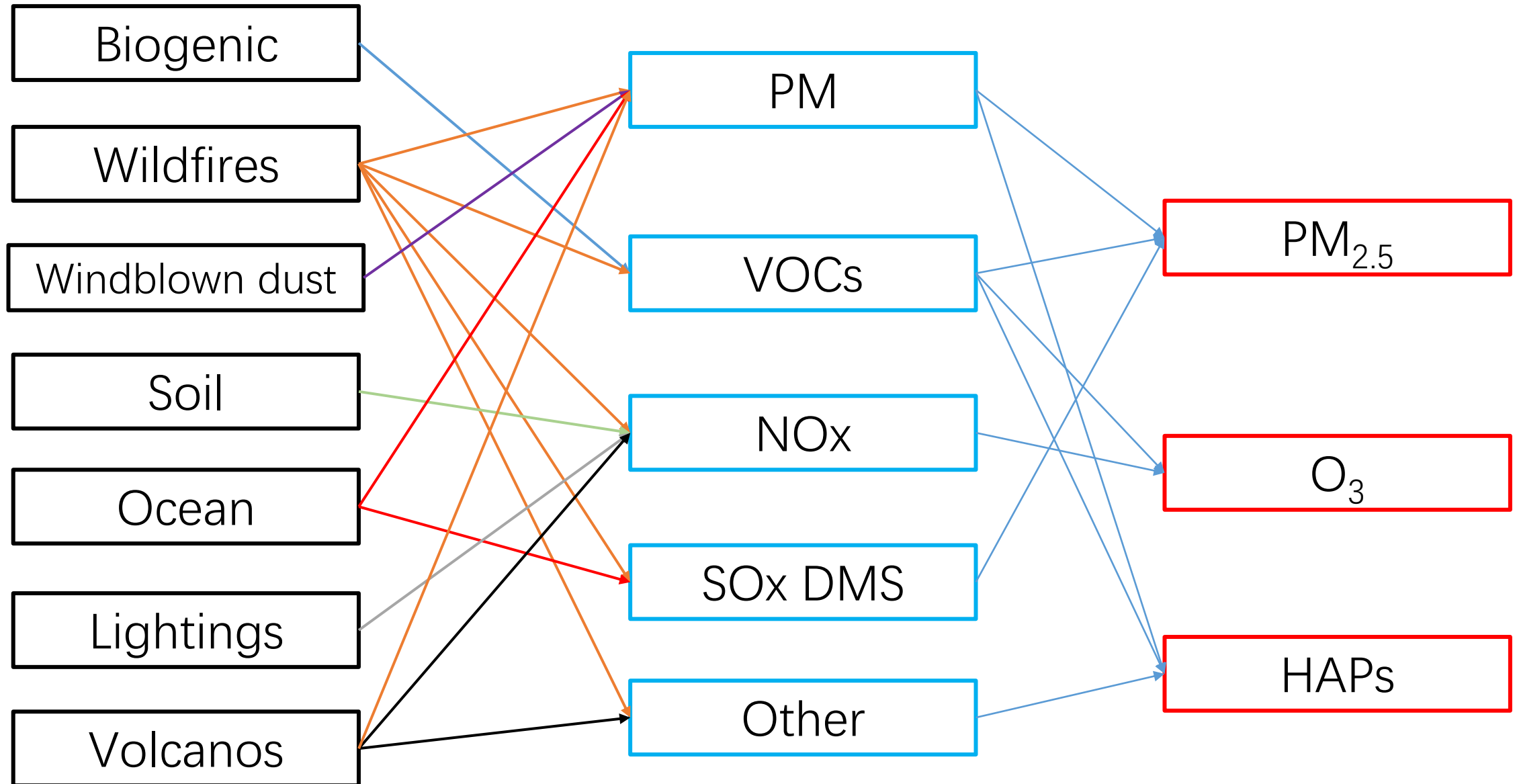
| Emission sector | Emission source                  | Policy type                | 2018                                                                               | 2019 | 2020 |
|-----------------|----------------------------------|----------------------------|------------------------------------------------------------------------------------|------|------|
| Power           | Coal-fired power plants          | End-of-pipe control        |                                                                                    |      |      |
|                 |                                  | Power plant fleet turnover | capacities <sup>3,4</sup>                                                          |      |      |
|                 | Other thermal power plants       | End-of-pipe control        |                                                                                    |      |      |
| Industry        | Coal-fired boilers               | End-of-pipe control        |                                                                                    |      |      |
|                 |                                  | Technology turnover        |                                                                                    |      |      |
|                 | Sinter/Iron/Steel/Coke           | End-of-pipe control        | Special emission limits <sup>5</sup>                                               |      | F    |
|                 |                                  | Technology turnover        | Phase out outdated iron/steel capacities by 0.17 billion tonnes <sup>4</sup>       |      |      |
|                 | Nonferrous metal                 | End-of-pipe control        |                                                                                    |      |      |
|                 | Cement plants                    | End-of-pipe control        |                                                                                    |      |      |
|                 |                                  | Cement kiln turnover       | Phase out outdated cement/clinker capacities by 0.19 billion tonnes <sup>4</sup>   |      |      |
|                 | Flat glass                       | End-of-pipe control        |                                                                                    |      |      |
|                 |                                  | Technology turnover        | Phase out outdated flat glass capacities by 0.02 billion weight cases <sup>4</sup> |      |      |
|                 | Brick/ lime and other industries | End-of-pipe control        |                                                                                    |      |      |

| Emission sector | Emission source             | Policy type                  | 2018                                                       | 2019                   | 2020  |
|-----------------|-----------------------------|------------------------------|------------------------------------------------------------|------------------------|-------|
| Transportation  | Light-duty gasoline vehicle | End-of-pipe control          | a 5 <sup>27</sup>                                          | China 6a <sup>28</sup> |       |
|                 | Heavy-duty gasoline vehicle | End-of-pipe control          |                                                            |                        | China |
|                 | Light-duty diesel vehicle   | End-of-pipe control          | China V <sup>30</sup>                                      |                        |       |
|                 | Heavy-duty diesel vehicle   | End-of-pipe control          | China V <sup>30</sup>                                      |                        |       |
|                 | Off-road                    | End-of-pipe control          | a III <sup>33</sup>                                        |                        |       |
|                 | All                         | Mobile fleet turnover        | Phase out 5.5 million old vehicles <sup>4</sup>            |                        |       |
| Residential     | All                         | End-of-pipe control          | Cleaner coals and stoves <sup>4</sup>                      |                        |       |
|                 |                             | Residential fuel transitions | Eliminate bulk coal by 9.2 million households <sup>4</sup> |                        |       |
| Solvent use     | All                         | End-of-pipe control          | lower the VOCs content <sup>4</sup>                        |                        |       |
| Agriculture     | All                         | End-of-pipe control          | Promote the use of organic fertilizer <sup>4</sup>         |                        |       |

# New WHO guidelines

| Pollutant               |                                 | Time        | 2005 levels | New 2021 levels |
|-------------------------|---------------------------------|-------------|-------------|-----------------|
| <b>PM<sub>2.5</sub></b> | Particulate matter <2,5 microns | Annual      | 10          | 5               |
|                         |                                 | 24-hour     | 25          | 15              |
| <b>PM<sub>10</sub></b>  | Particulate matter <10 microns  | Annual      | 20          | 15              |
|                         |                                 | 24-hour     | 50          | 45              |
| <b>O<sub>3</sub></b>    | Ozone                           | Peak season | -           | 60              |
|                         |                                 | 8-hour      | 100         | 100             |
| <b>NO<sub>2</sub></b>   | Nitrogen dioxide                | Annual      | 40          | 10              |
|                         |                                 | 24-hour     | -           | 25              |
| <b>SO<sub>2</sub></b>   | Sulfur dioxide                  | 24-hour     | 20          | 40              |
| <b>CO</b>               | Carbon monoxide                 | 24-hour     | -           | 4               |

# Natural sources and contributions to air pollutants



# Natural sources and contributions to air pollutants

- Biogenic VOCs (90% global budget)
- Wildfires / biomass burning (23%  $\text{PM}_{2.5}$  in US 2020, 3720 exceedances NAAQS during 2020 summer)
- Windblown dust (dust storms; 3-5% to  $\text{PM}_{2.5}$  in US)
- Soil NO (15% global budget)
- Ocean (8% to PM in coastal areas; DMS 3-5% to marine  $\text{SO}_2$  and sulfate)
- Lightnings (1-5%)
- Volcanos (1991 Mt. Pinatubo in the Philippines, 2022 Hunga-Tonga)

# Wildfire and biomass burning



California 2020



China before 2017



New York 2022

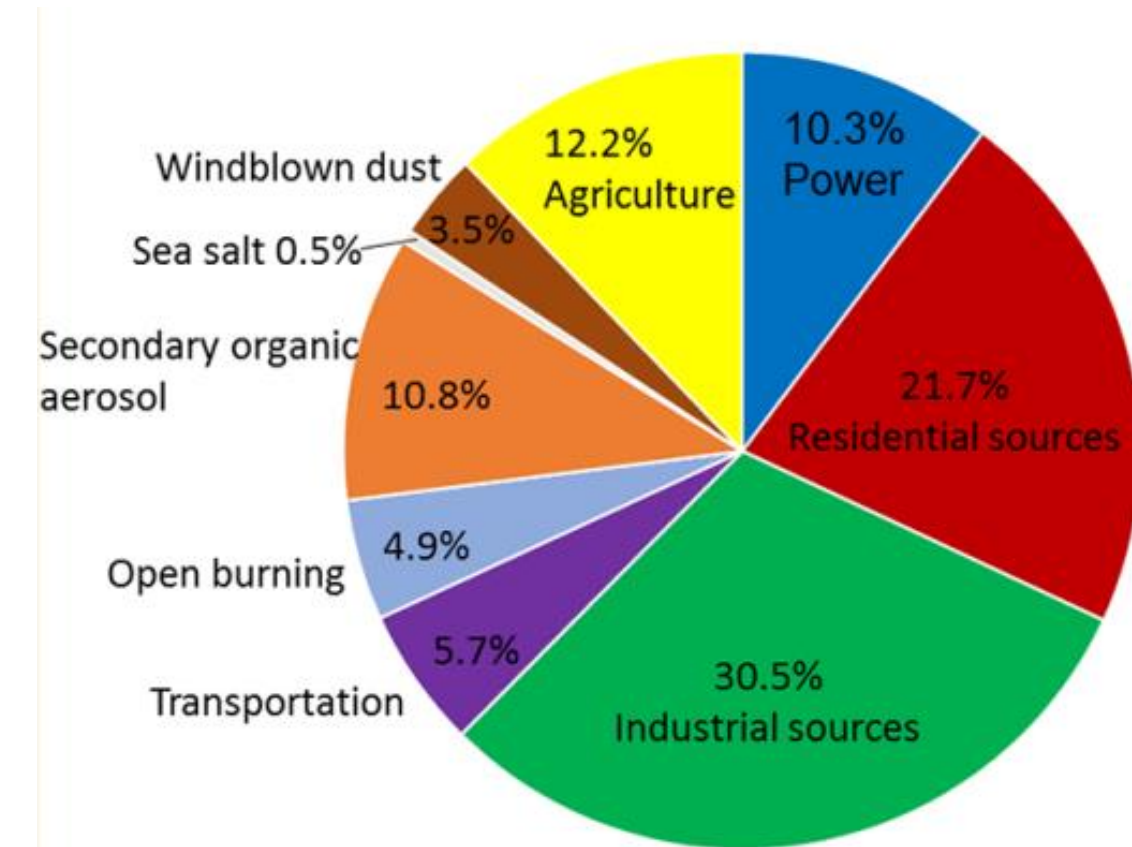


India twice each year

# Natural sources and contributions to air pollutants

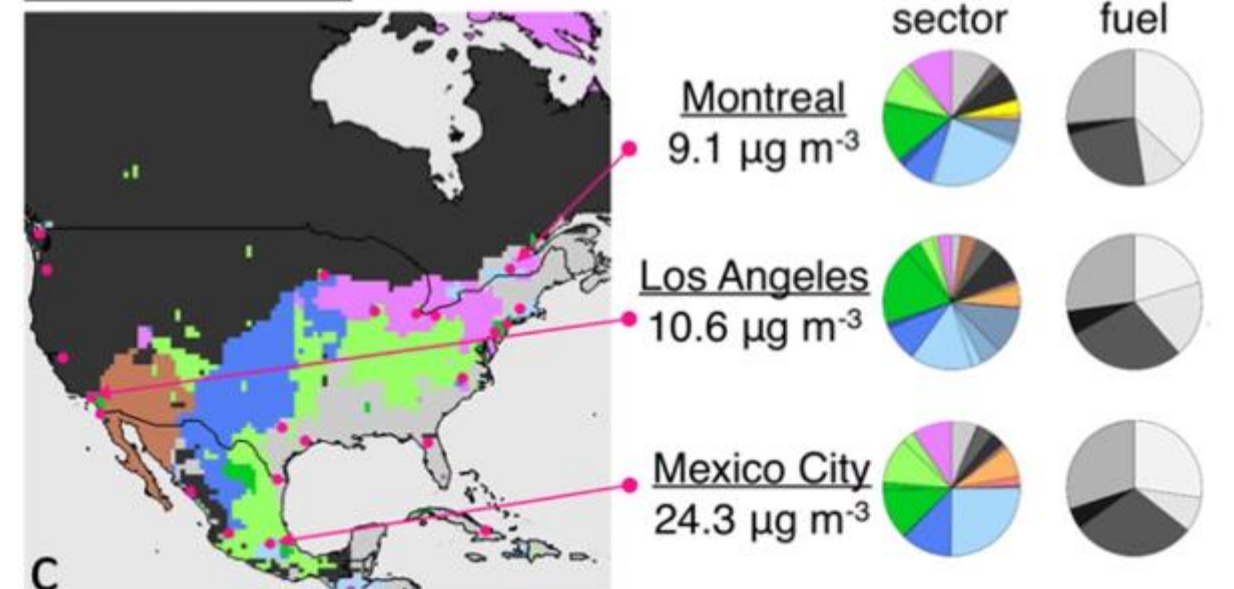
- 2013 China  $\text{PM}_{2.5}$   $62 \mu\text{g m}^{-3}$
- Natural sources ~20%

- 2017 North American  $\text{PM}_{2.5}$   $7.8 \mu\text{g m}^{-3}$
- Natural sources ~25-30%



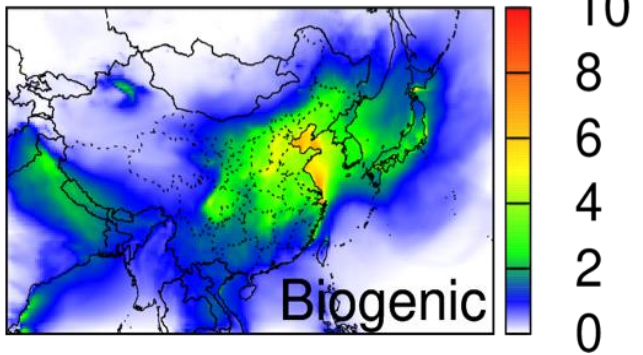
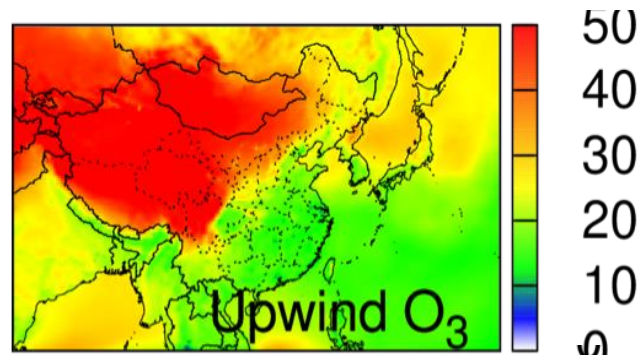
Hu et al, EST, 2017

## North America



McDuffie et al., NC, 2021

# Natural sources and contributions to air pollutants

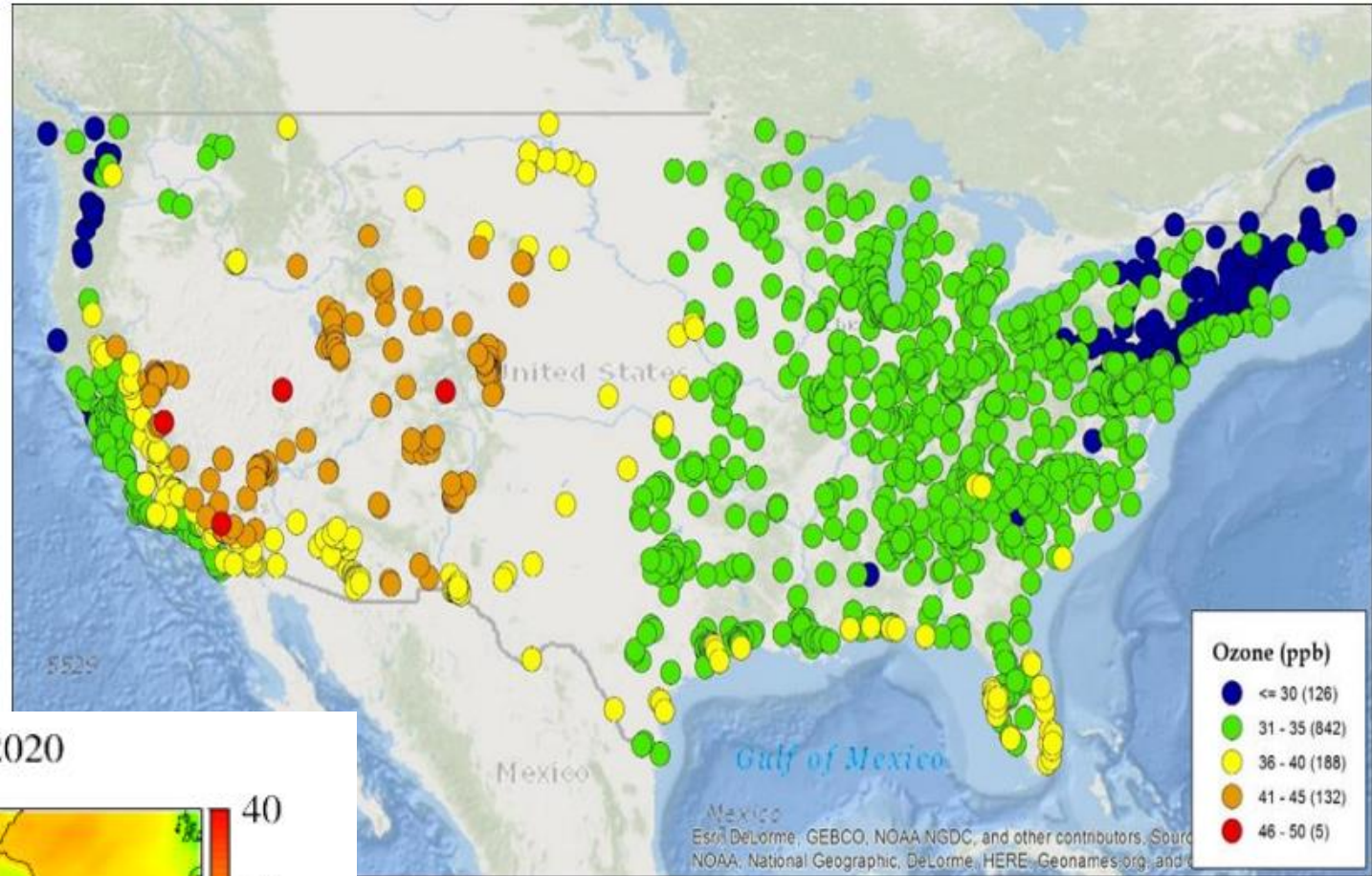
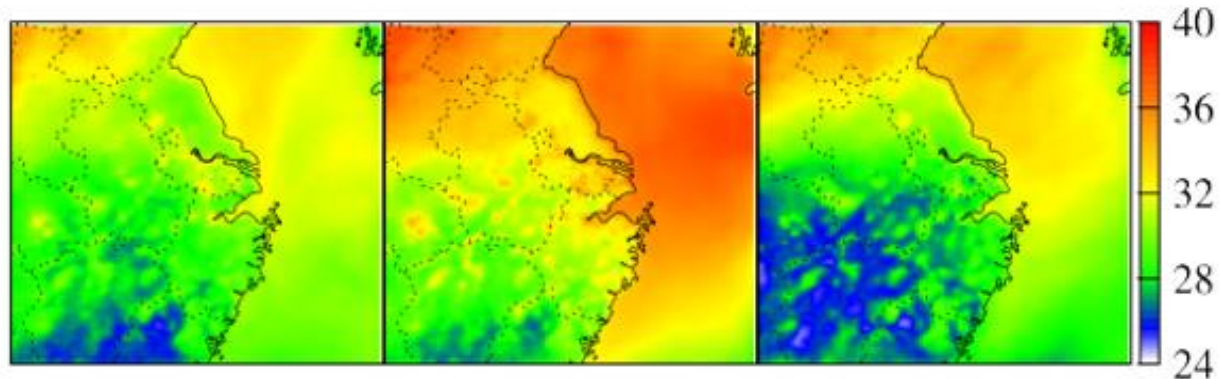


2018

2019

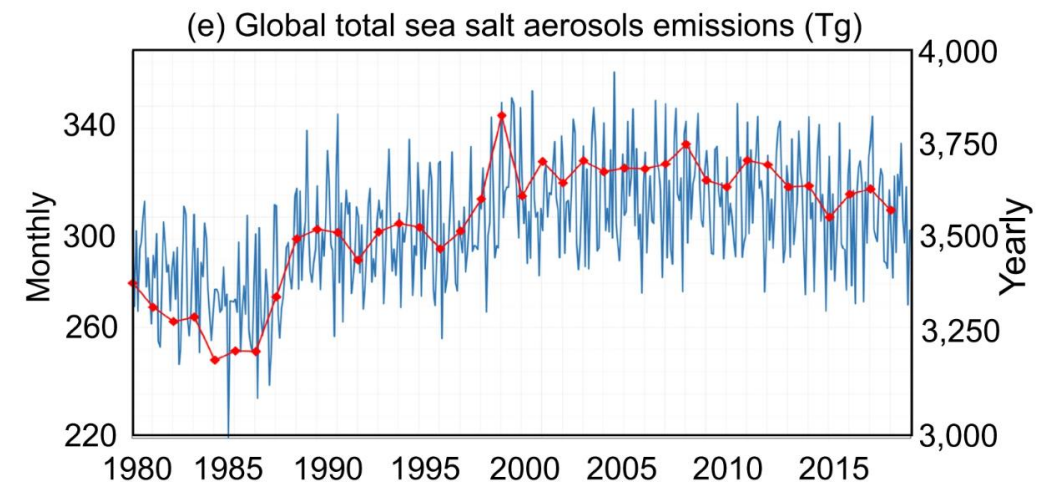
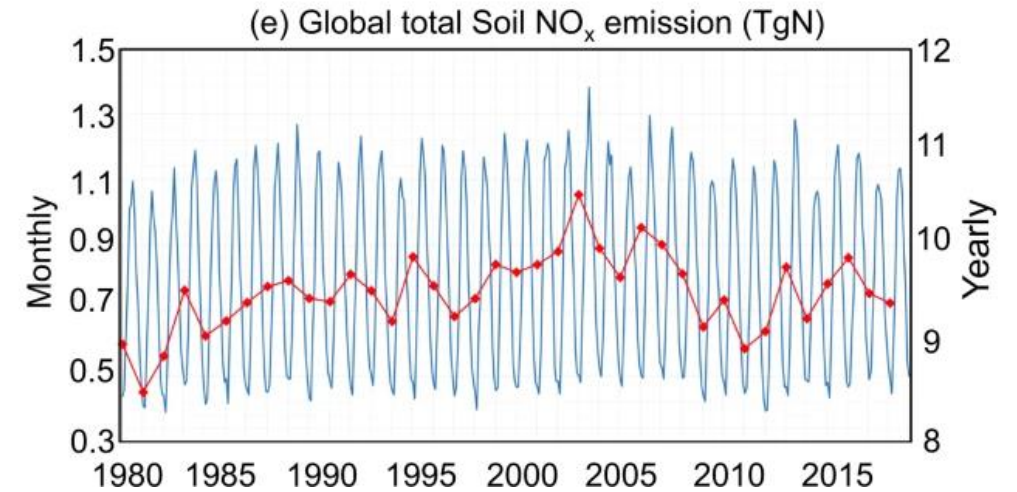
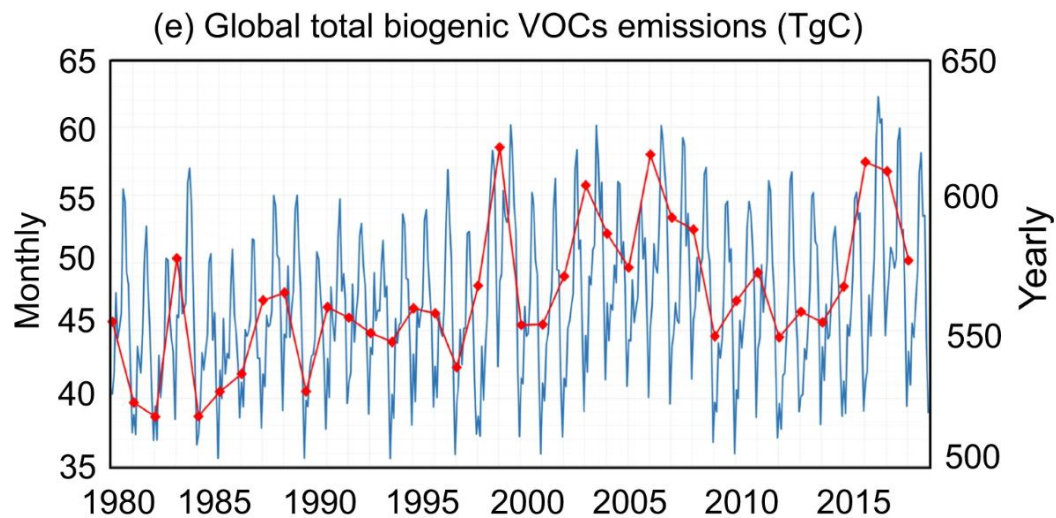
2020

(a) Background

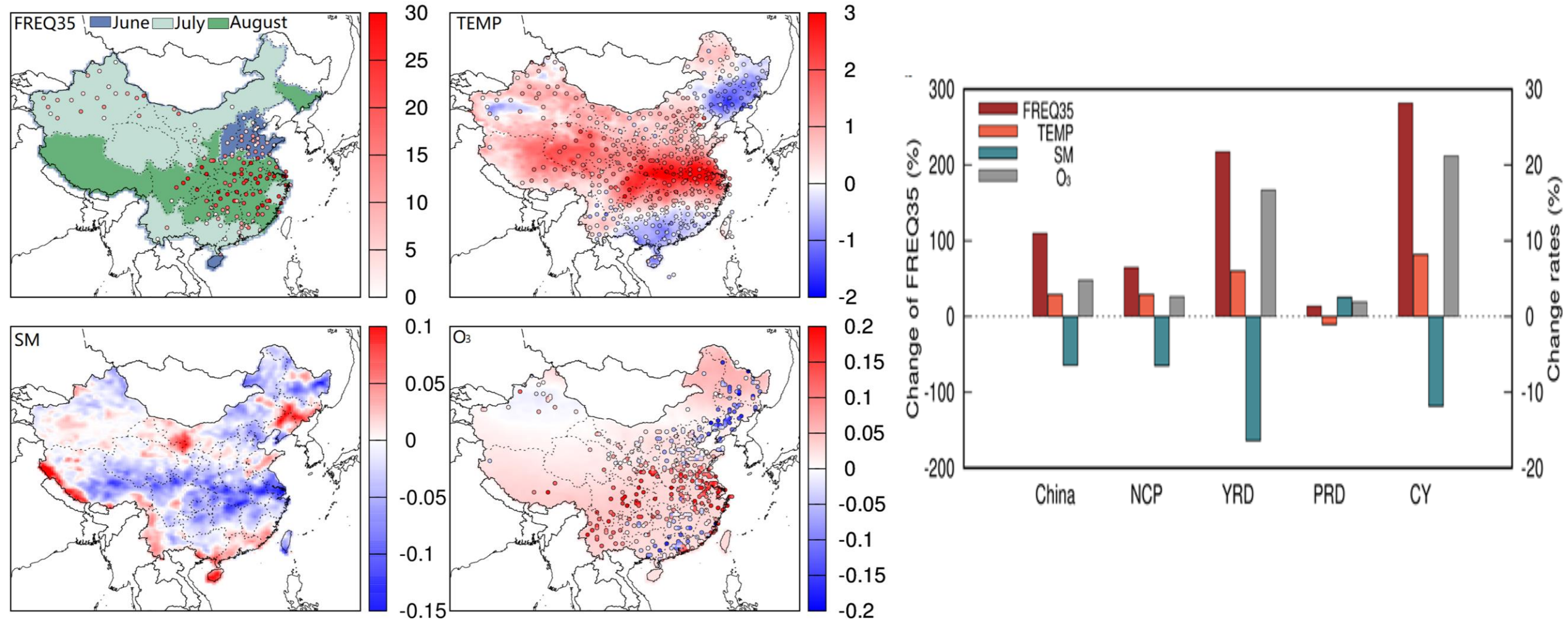


# Natural sources change in changing climate

- Higher temperatures
- Less wind speed
- Humidity/droughts
- Land-cover changes
- Stronger lightnings
- Lower boundary layer height

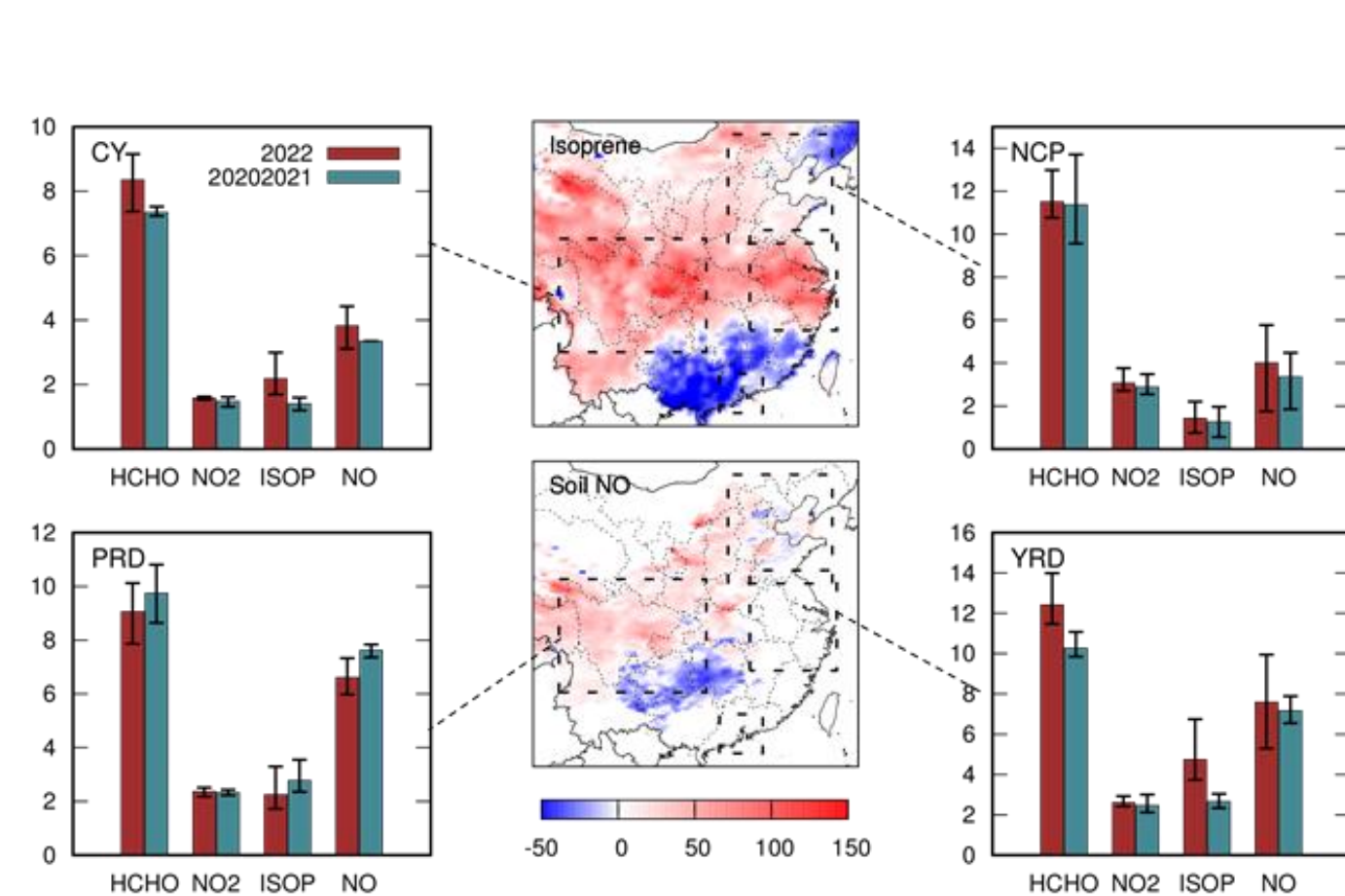


# Example: extreme high temperature with O<sub>3</sub>

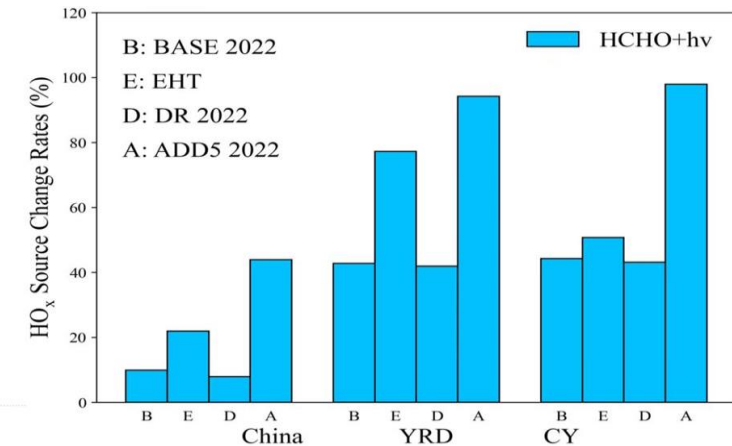
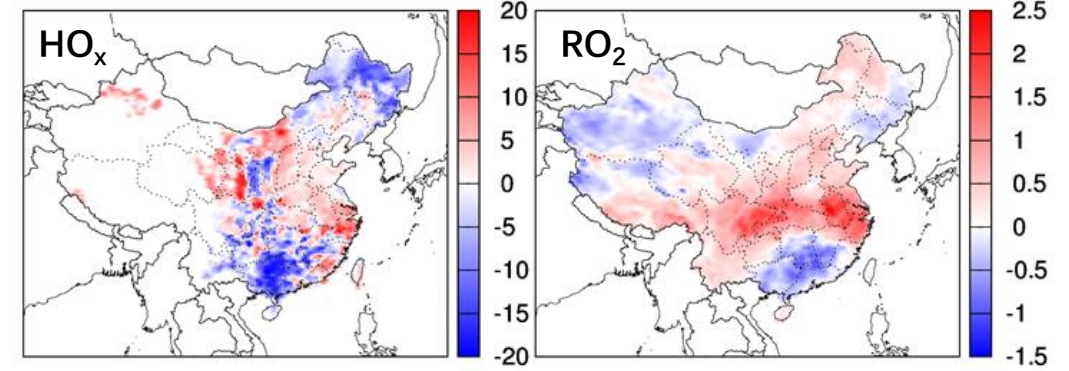
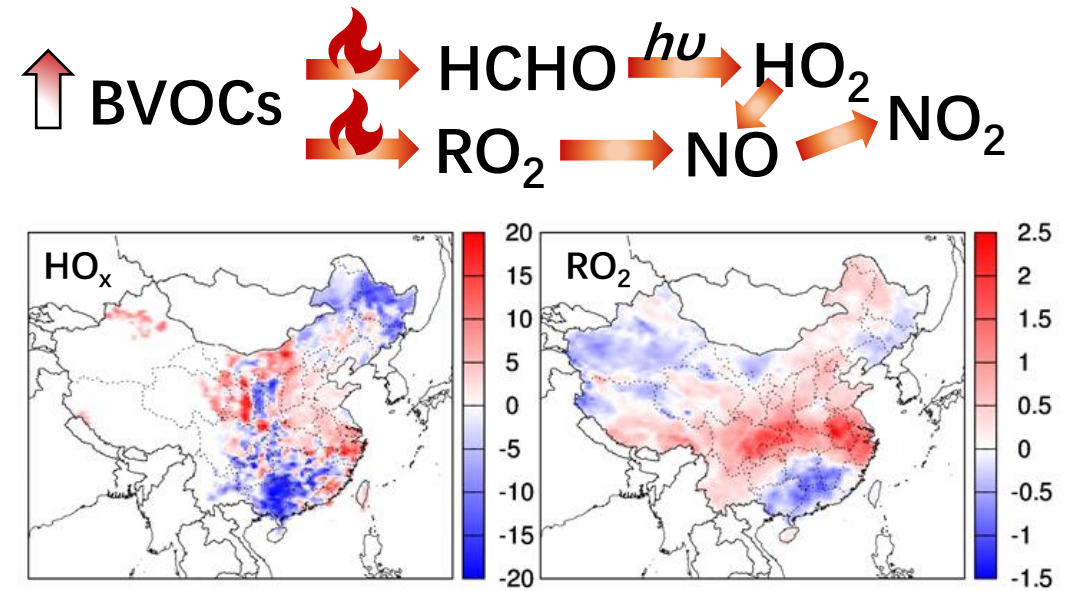


Extreme high temperature events accompanied with elevated O<sub>3</sub> concentration along the Yangtze River Basin.

# Synergetic impacts of BVOCs and soil NO



High temperatures lead to increases in BVOCs and soil NO emissions



Rising BVOCs increase the AOC (HCHO photolysis), converting soil NO to NO<sub>2</sub>

# What should we do?

- Pay attention
  - Blowing the whistler
  - Informing the public
  - Scientific researches
  - Formulating strategies
- Working together
  - Leading US and China
  - Attending all countries



# Thanks!