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

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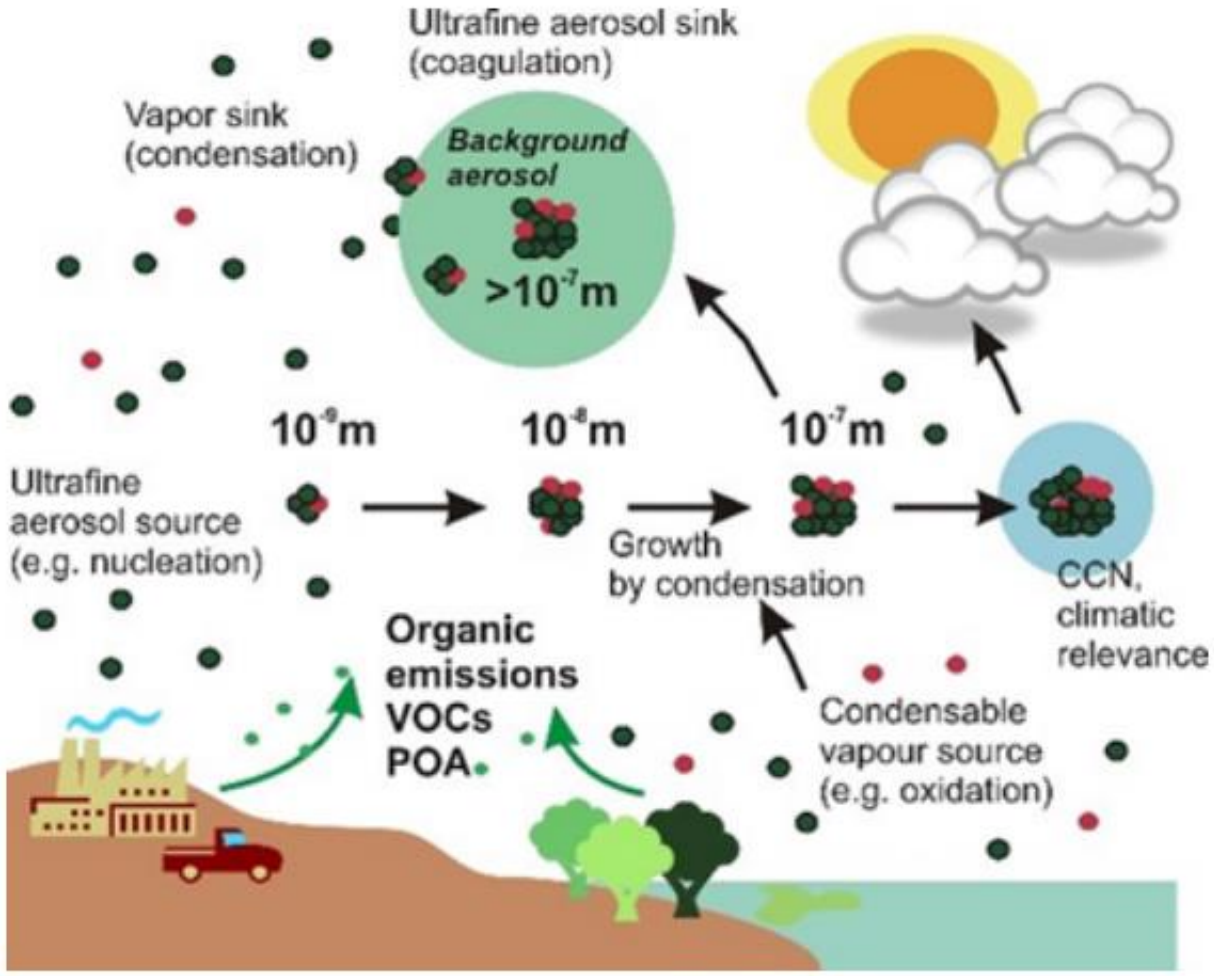
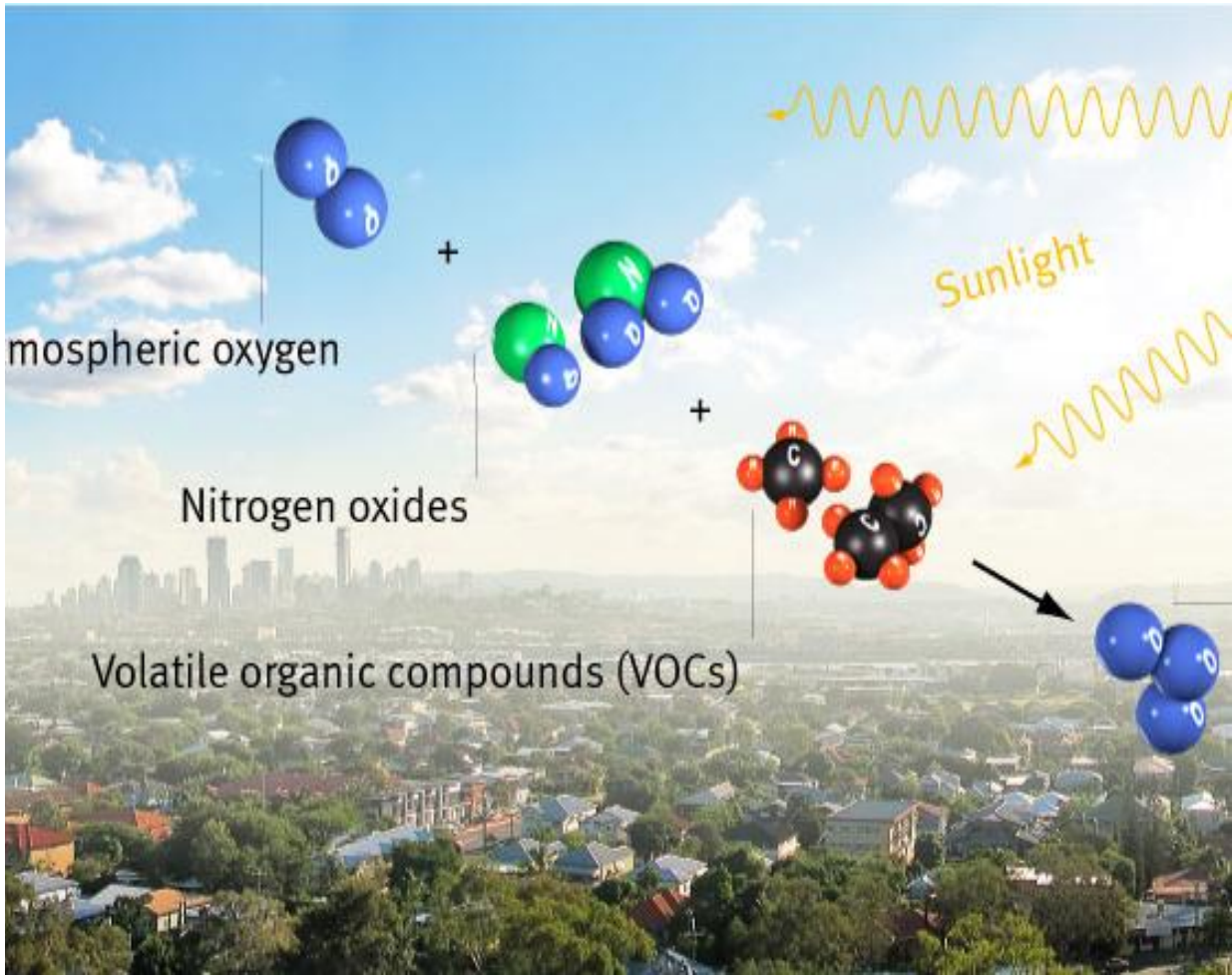
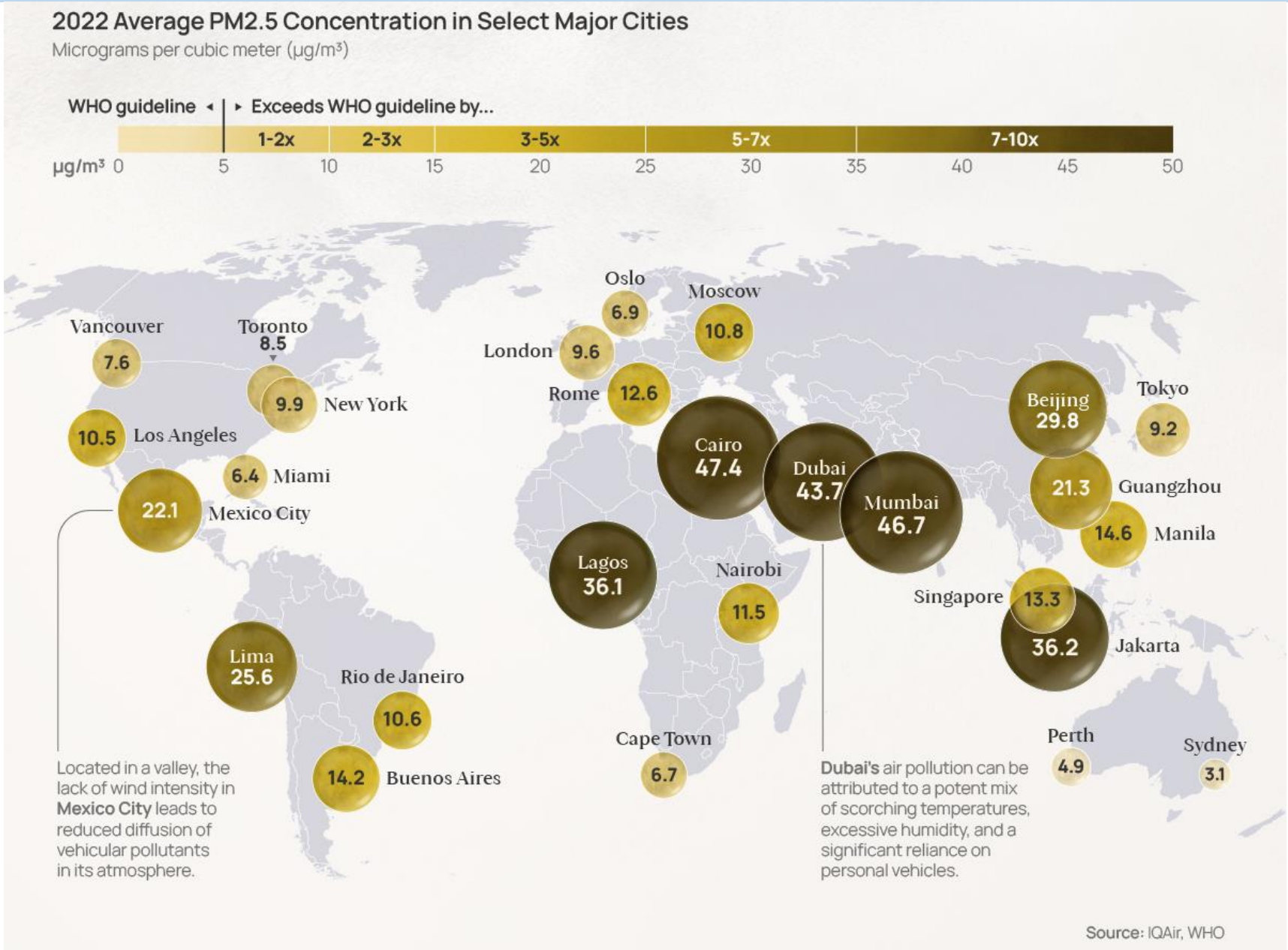
Formation of particulate matter and ozone



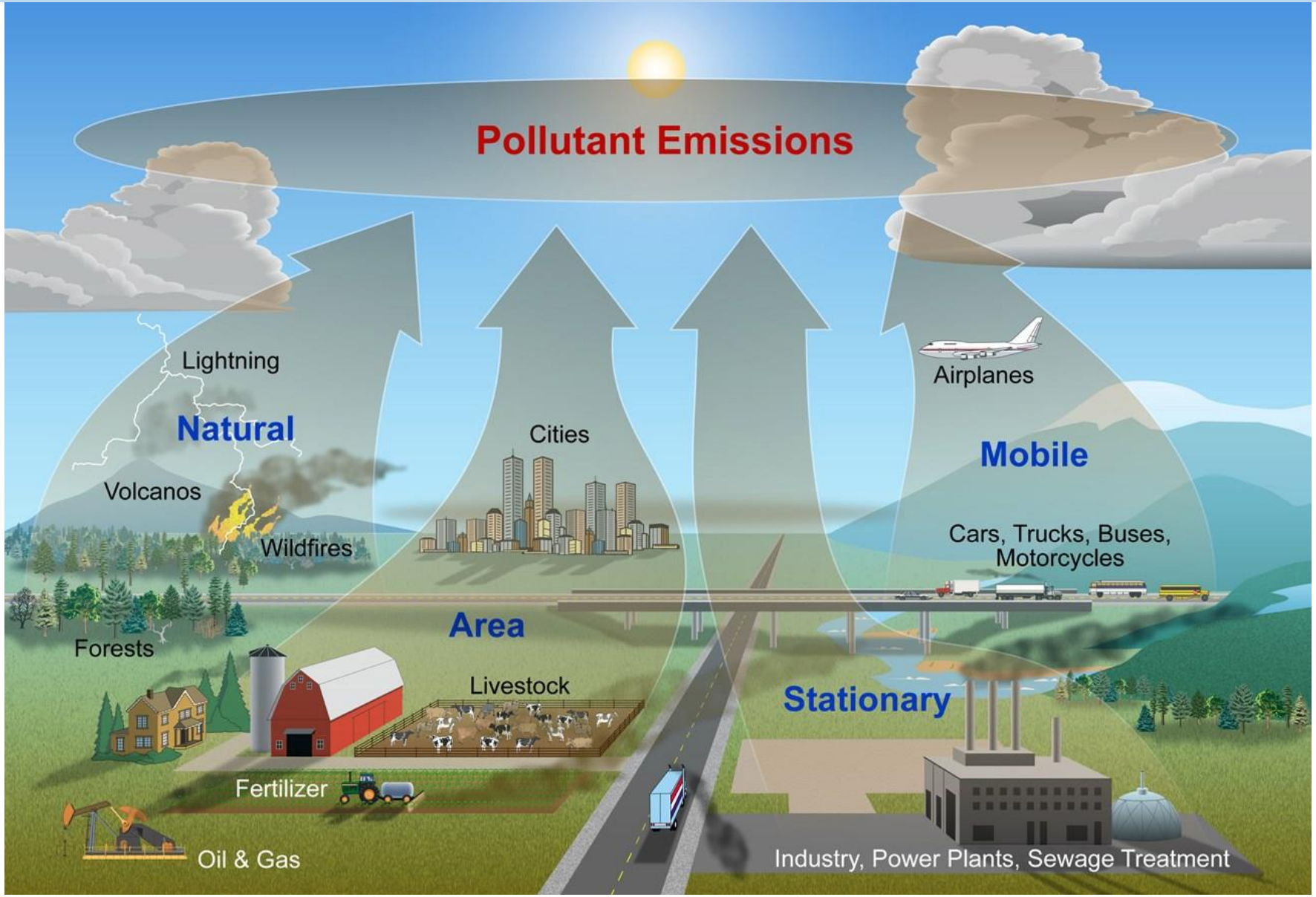


Fuzzi et al., ACP 2015

Air pollution is severe worldwide

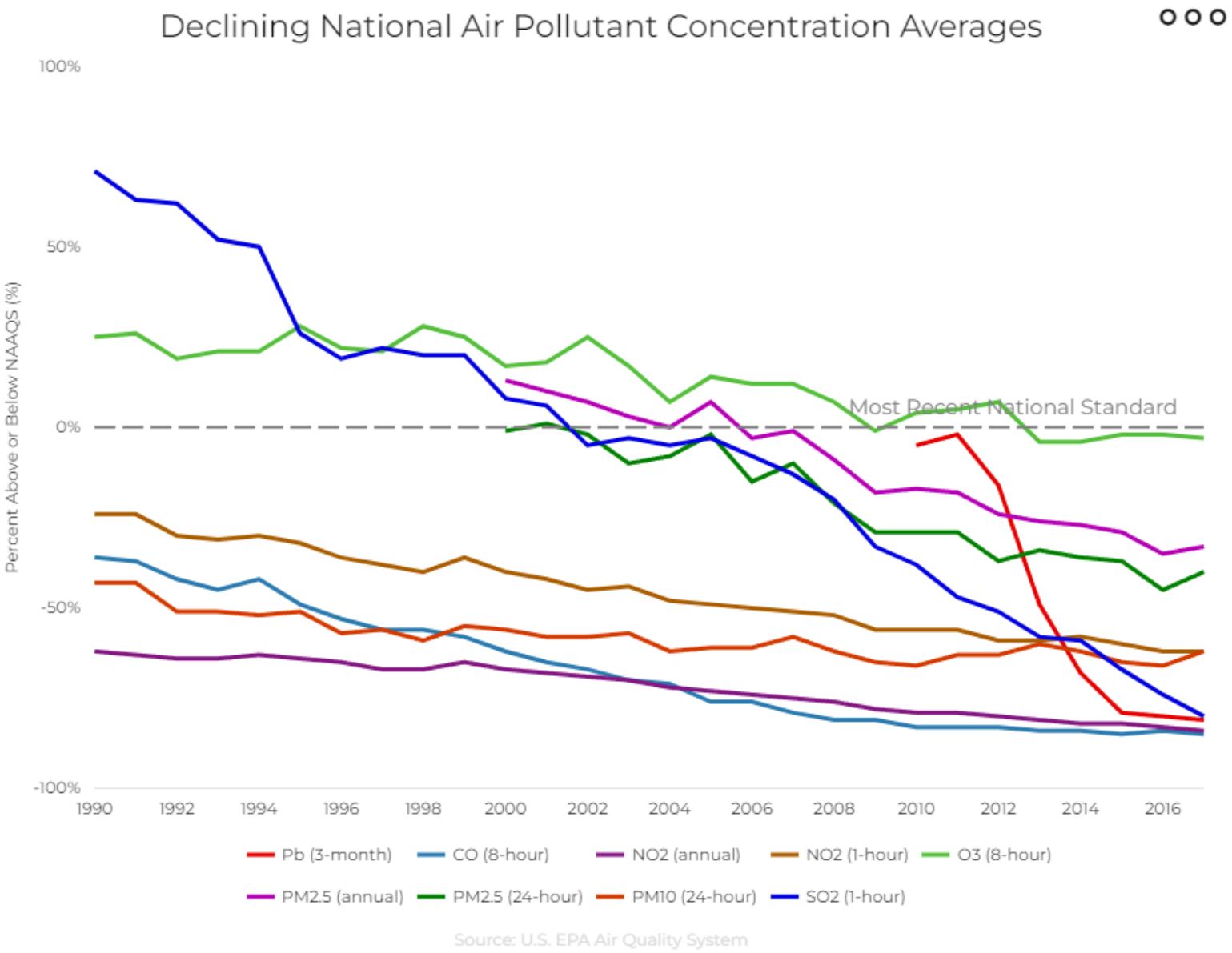


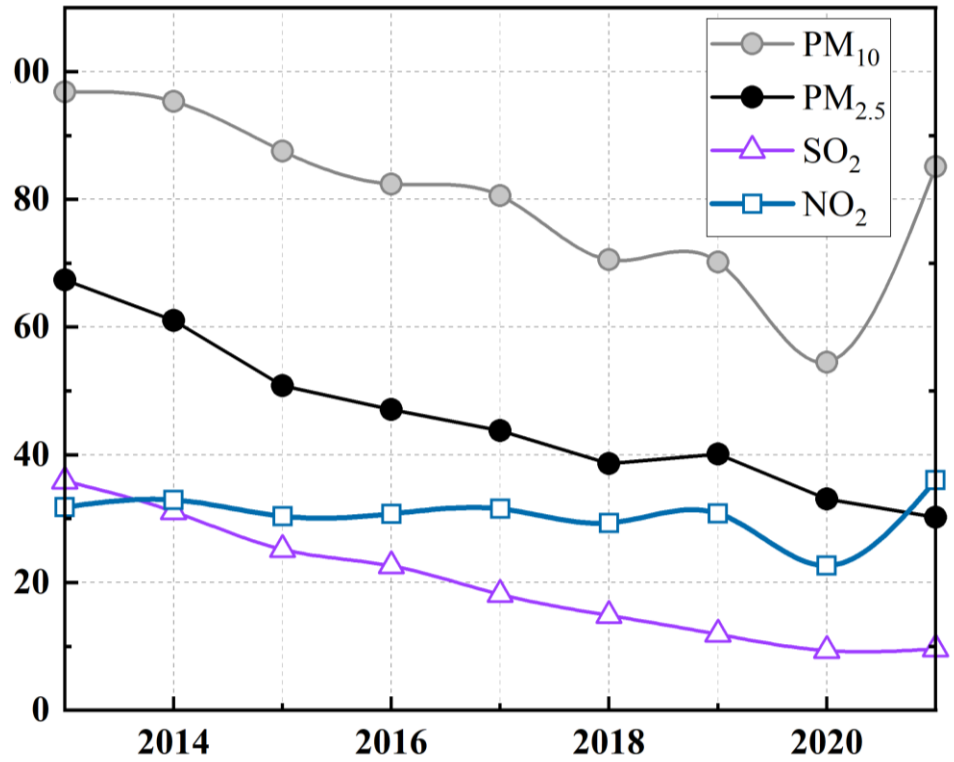
Natural and anthropogenic sources



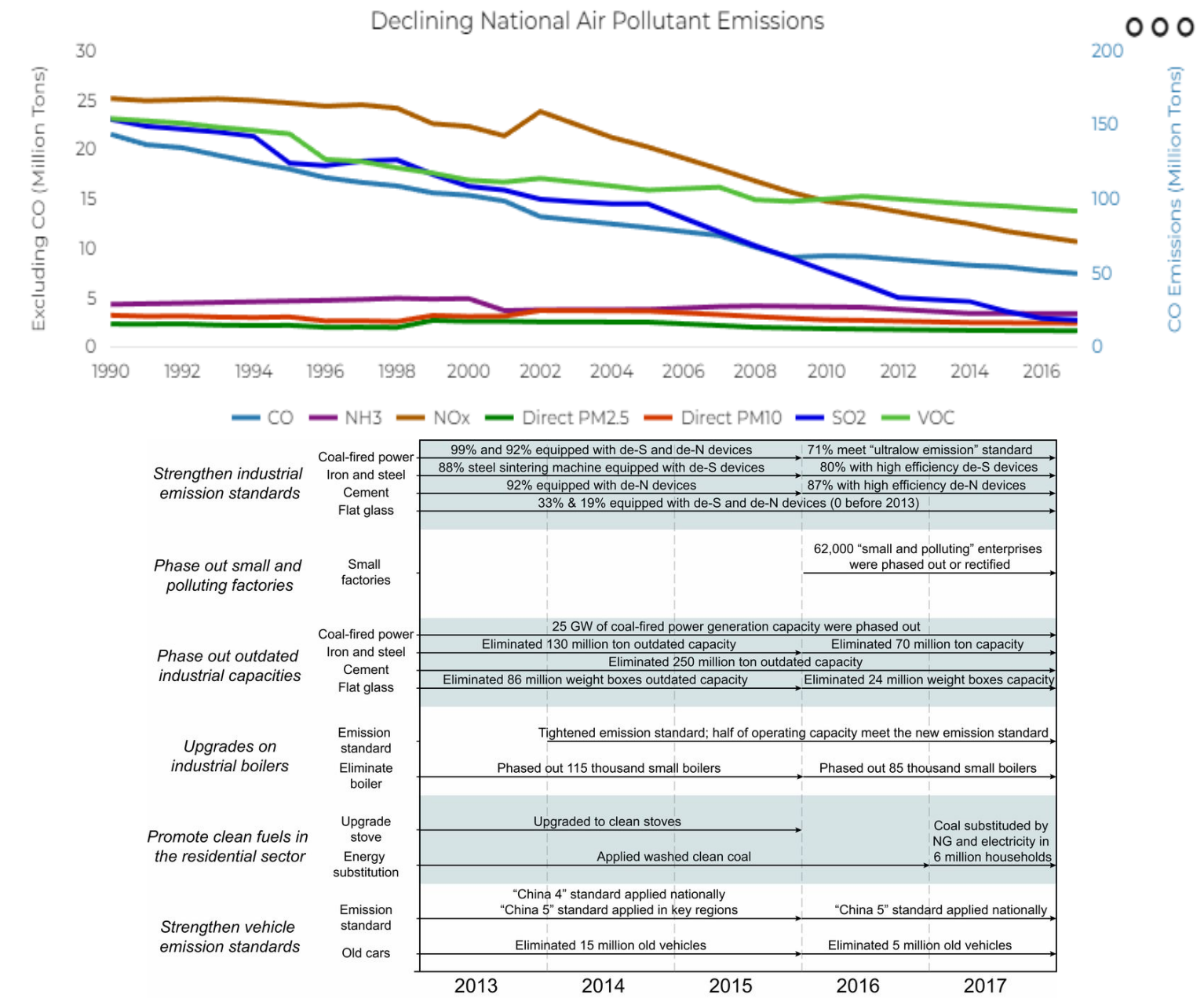
https://www.nps.gov/subjects/air/sources.htm

US and China made progresses





By controlling anthropogenic emissions



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

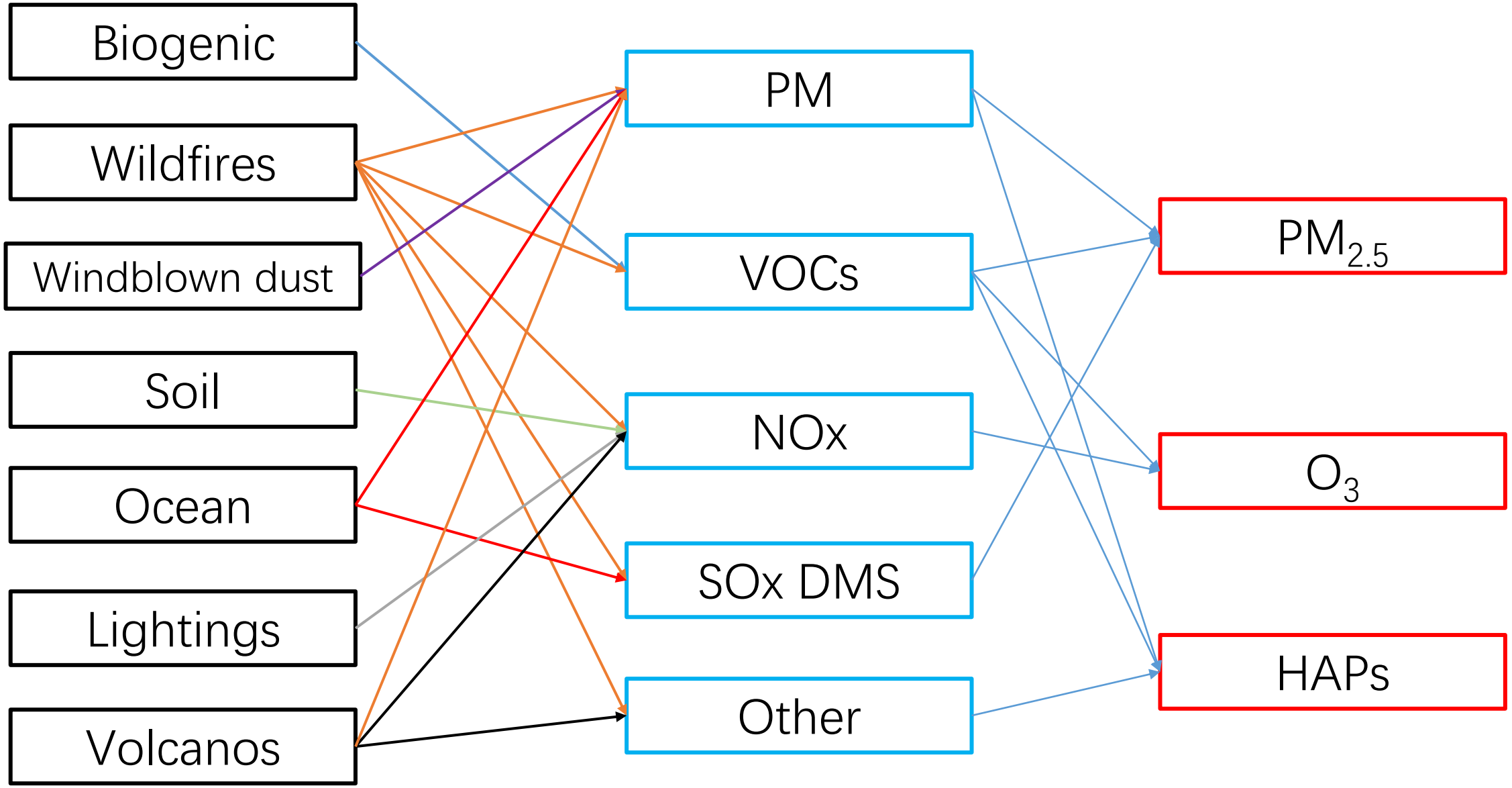
Emission sector	Emission source	Policy type	2018	2019	2020
Transportation	Light-duty gasoline vehicle	End-of-pipe control	a 5[27]	China 6a[28]	
	Heavy-duty gasoline vehicle	End-of-pipe control			China
	Light-duty diesel vehicle	End-of-pipe control	China V[30]		
	Heavy-duty diesel vehicle	End-of-pipe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

New WHO guidelines

Pollutant		Time	2005 levels	New 2021 levels
$PM_{2.5}$	Particulate matter <2,5 microns	Annual	10	5
		24-hour	25	15
PM_{10}	Particulate matter <10 microns	Annual	20	15
		24-hour	50	45
O_3	Ozone	Peak season	-	60
		8-hour	100	100
NO_2	Nitrogen dioxide	Annual	40	10
		24-hour	-	25
SO_2	Sulfur dioxide	24-hour	20	40
CO	Carbon monoxide	24-hour	-	4

https://www.drishtiias.com/

Natural sources and contributions to air pollutants



Natural sources and contributions to air pollutants

- Biogenic VOCs (90% global budget)
- Wildfires / biomass burning (23% $PM_{2.5}$ in US 2020, 3720 exceedances NAAQS during 2020 summer)
- Windblown dust (dust storms; 3-5% to $PM_{2.5}$ in US)
- Soil NO (15% global budget)
- Ocean (8% to PM in coastal areas; DMS 3-5% to marine SO_2 and sulfate)
- Lightings (1-5%)
- Volcanos (1991 Mt. Pinatubo in the Philippines, 2022 Hunga-Tonga)

Wildfire and biomass burning

California 2020

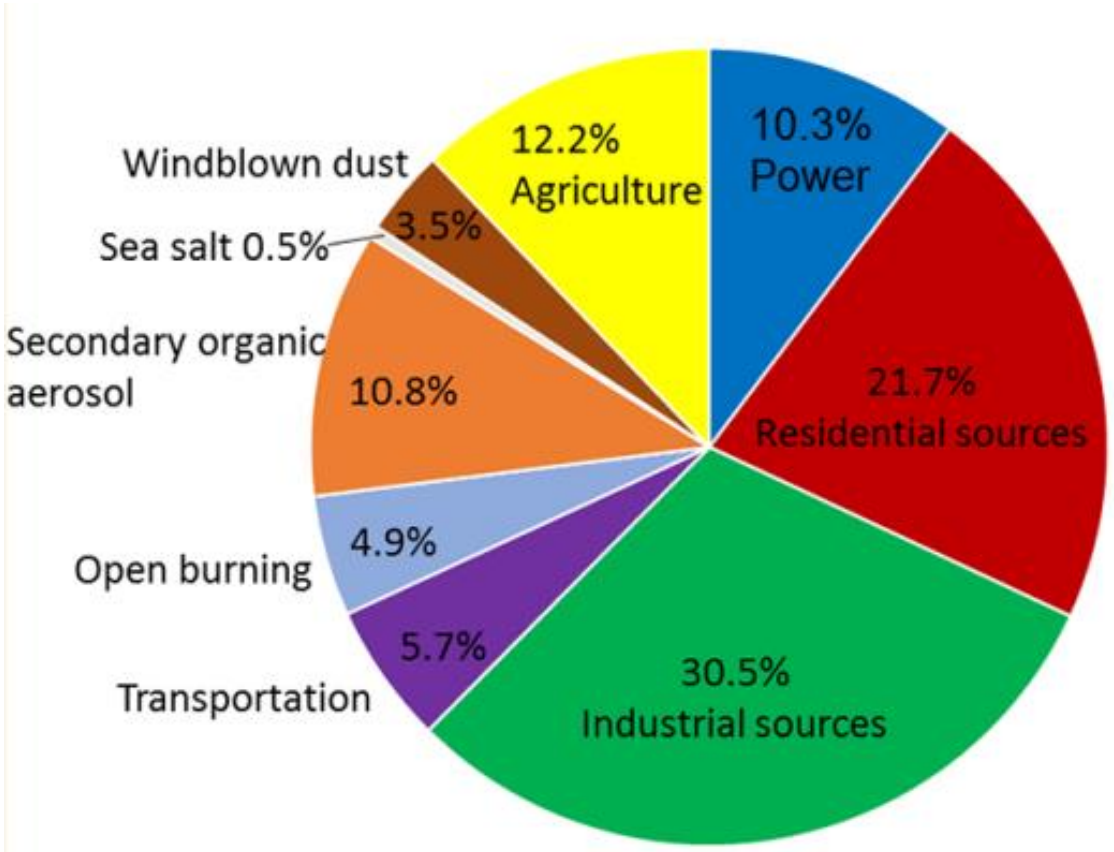
China before 2017

New York 2022

India twice each year

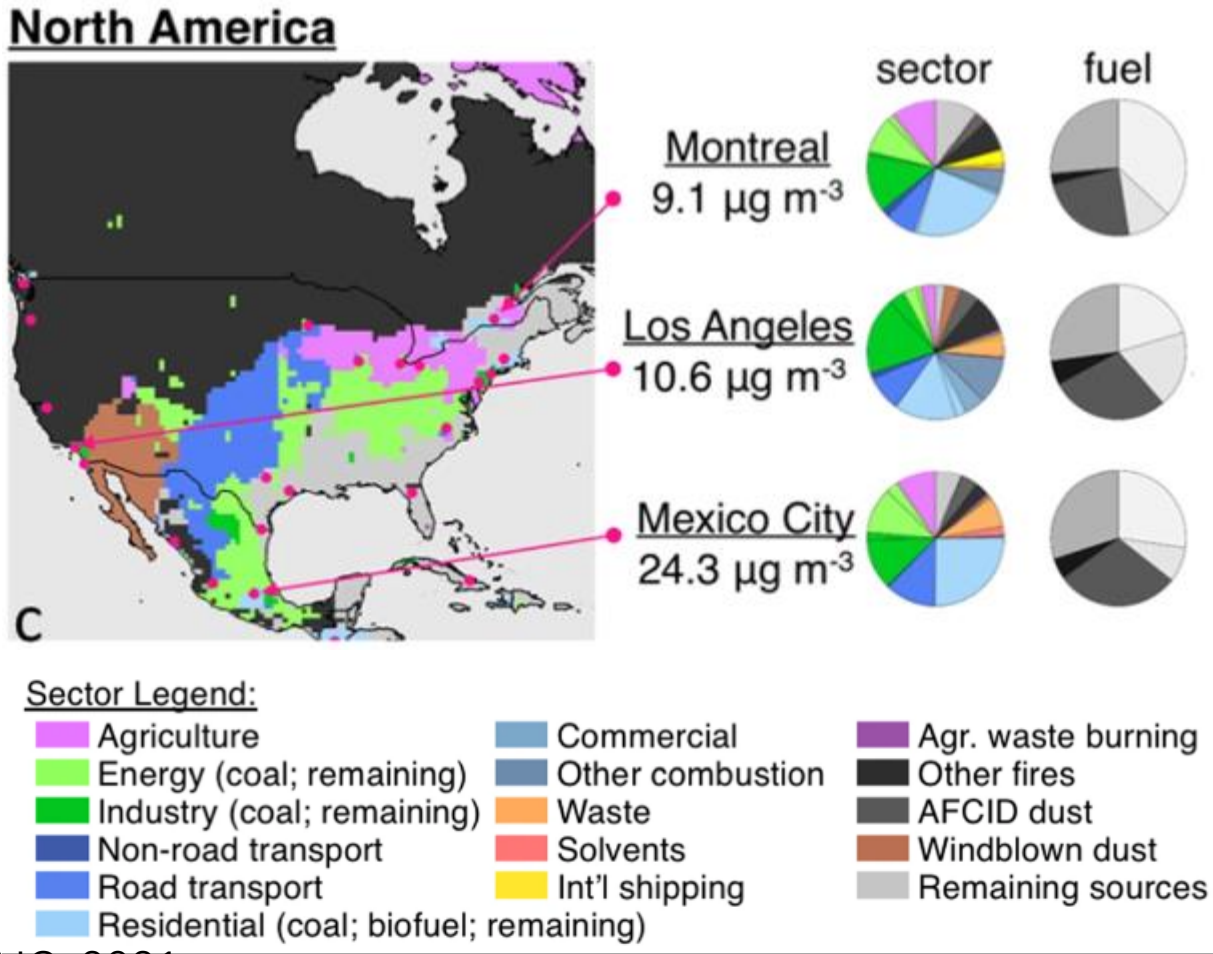
Natural sources and contributions to air pollutants

- 2013 China $PM_{2.5}$ 62 μg m^{-3}
- Natural sources ~20%



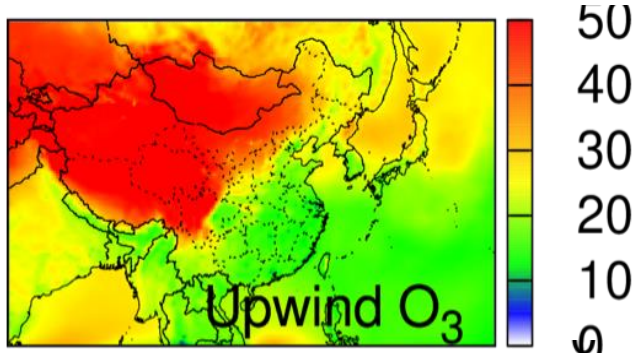
Hu et al, EST, 2017

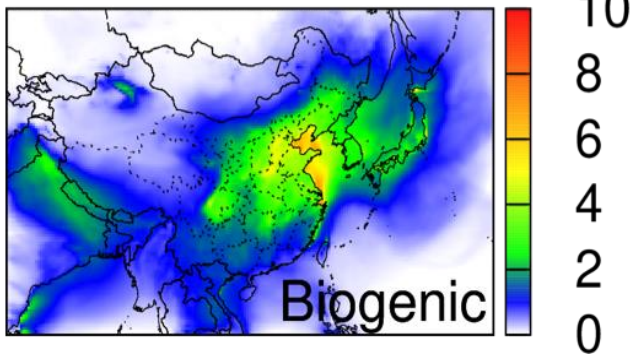
- 2017 North American $PM_{2.5}$ 7.8 μg m^{-3}
- Natural sources ~25-30%

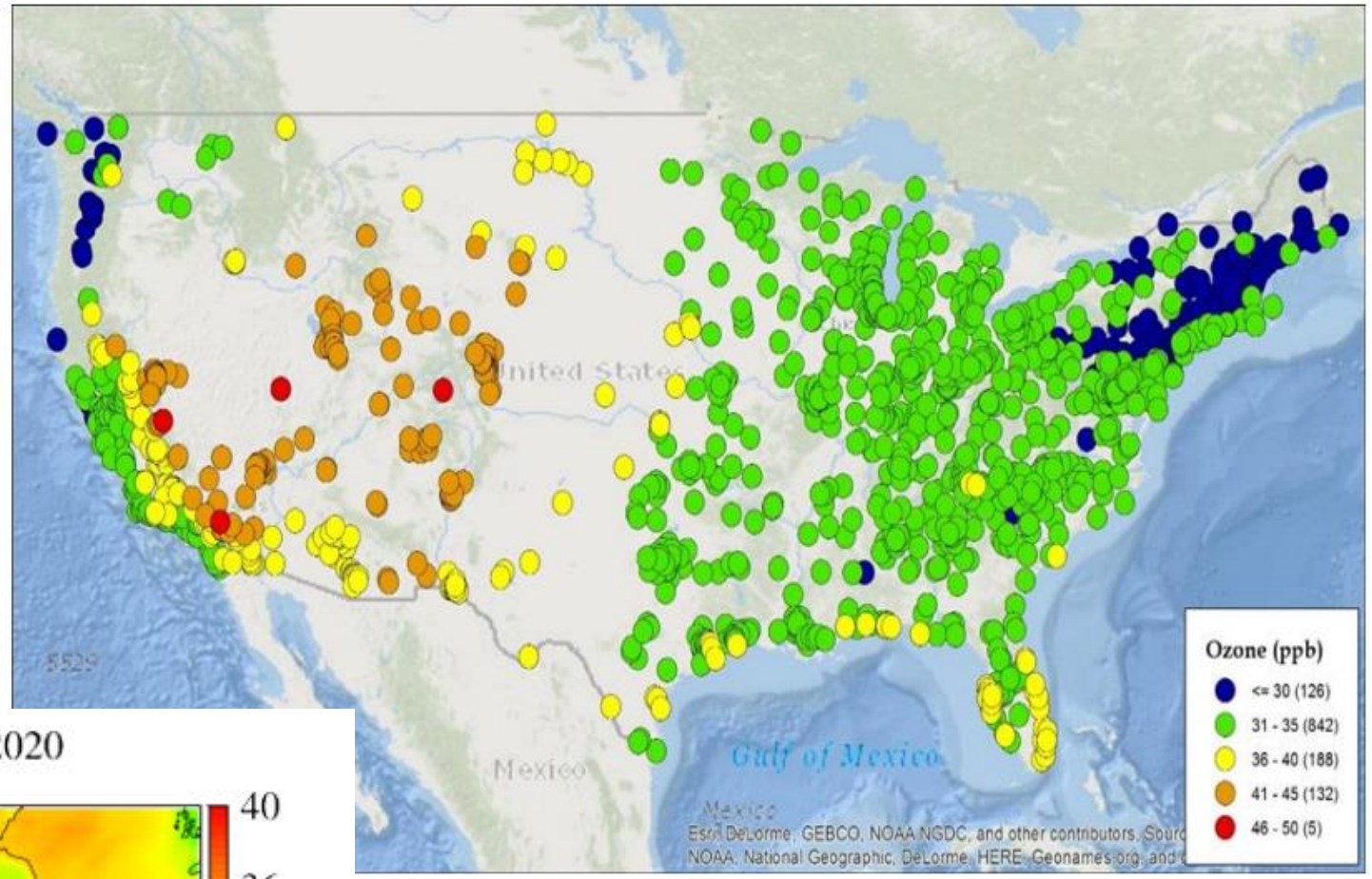


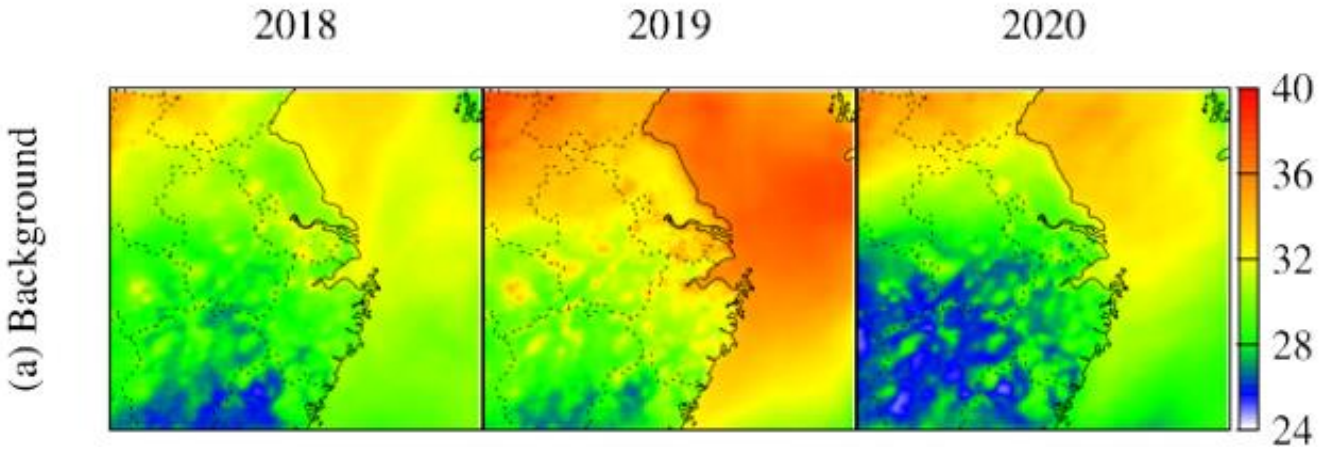
McDuffie et al., NC, 2021

Natural sources and contributions to air pollutants



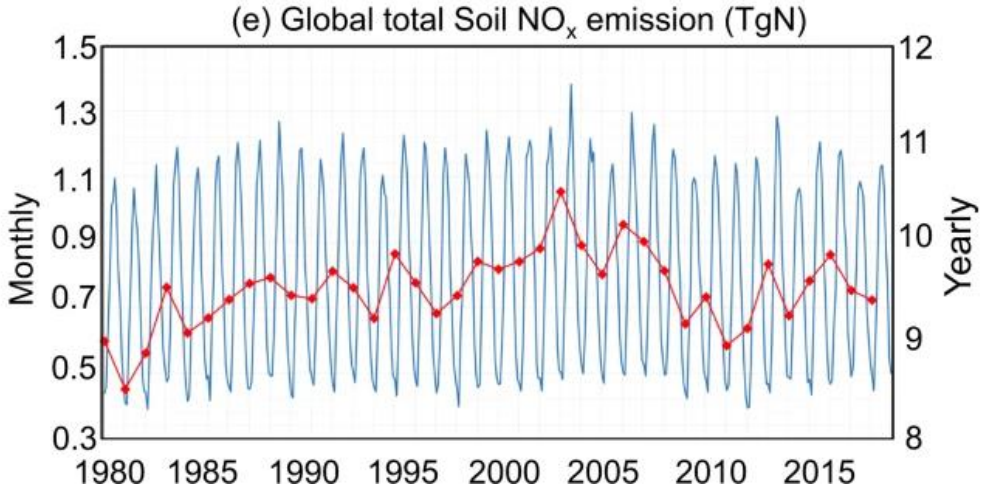


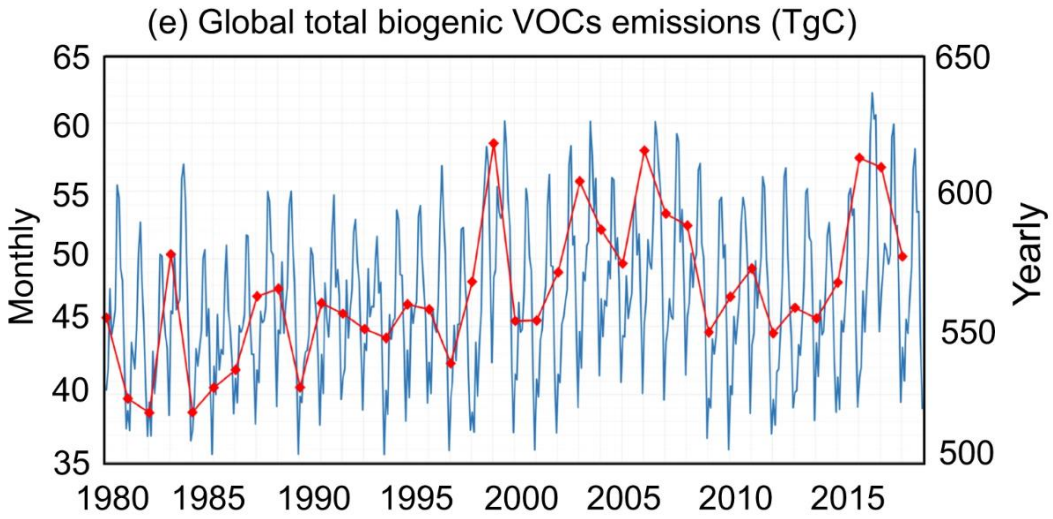


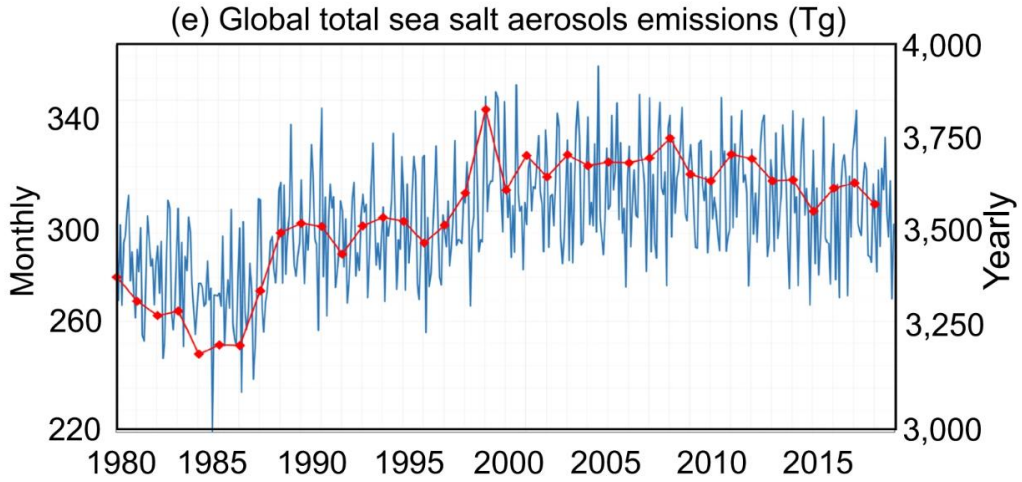


Natural sources change in changing climate

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

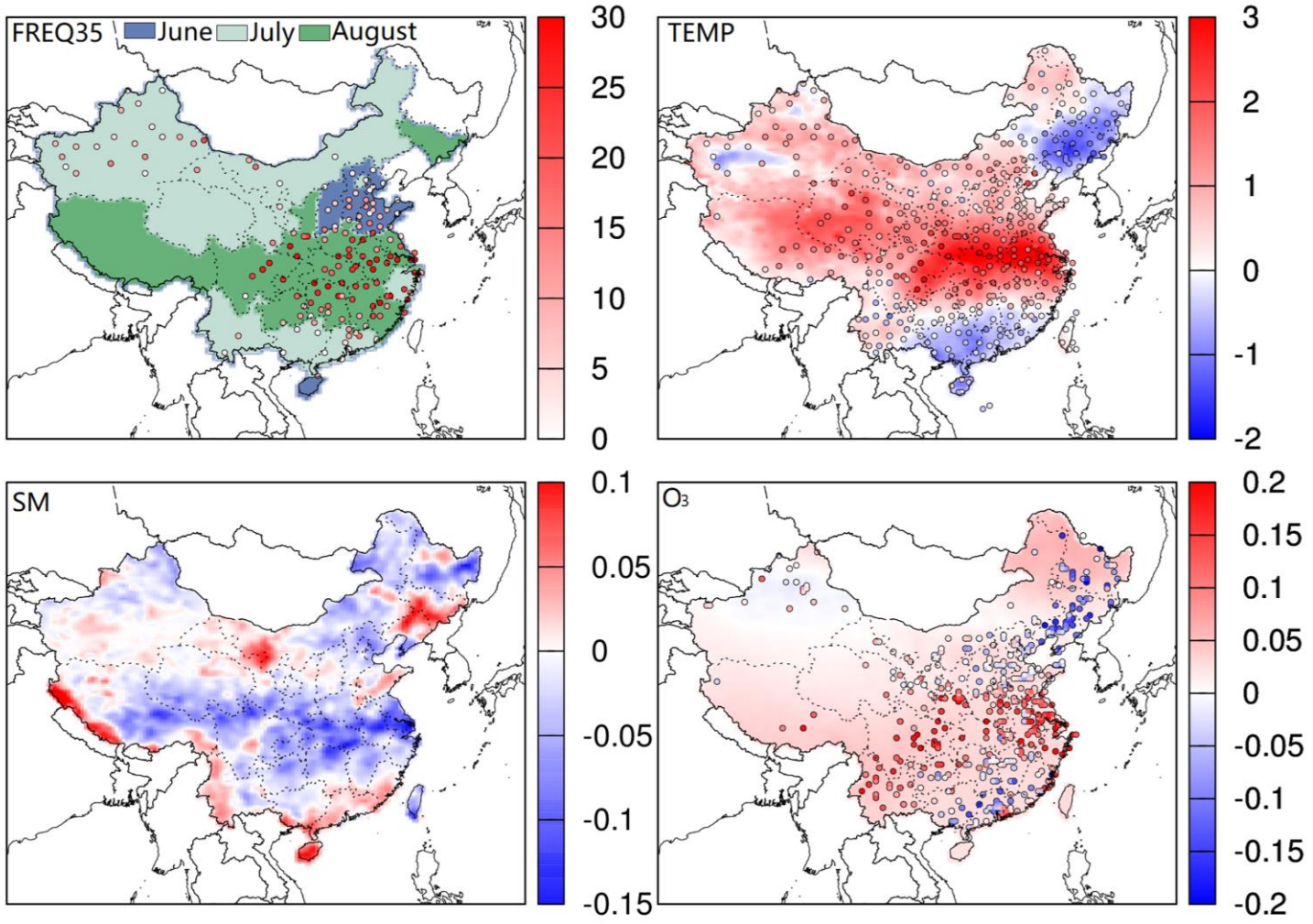


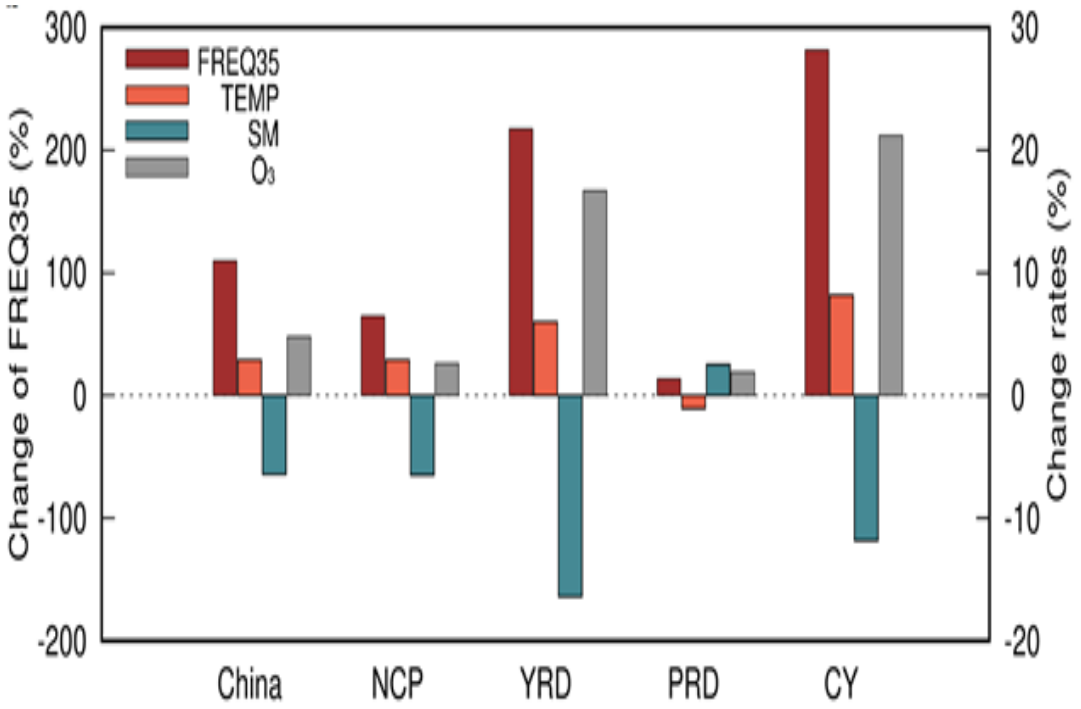




Weng et al., Scientific Data, 2020

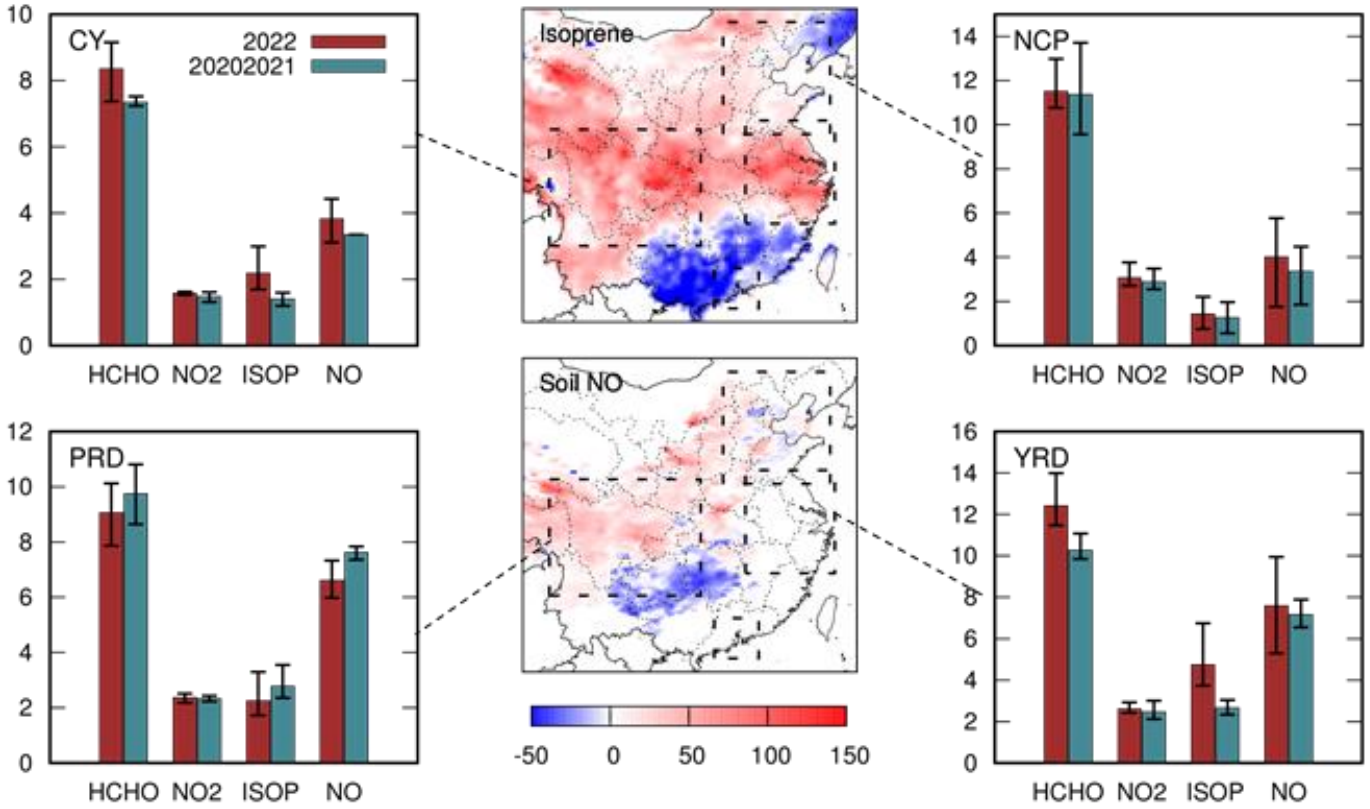
Example: extreme high temperature with O_3



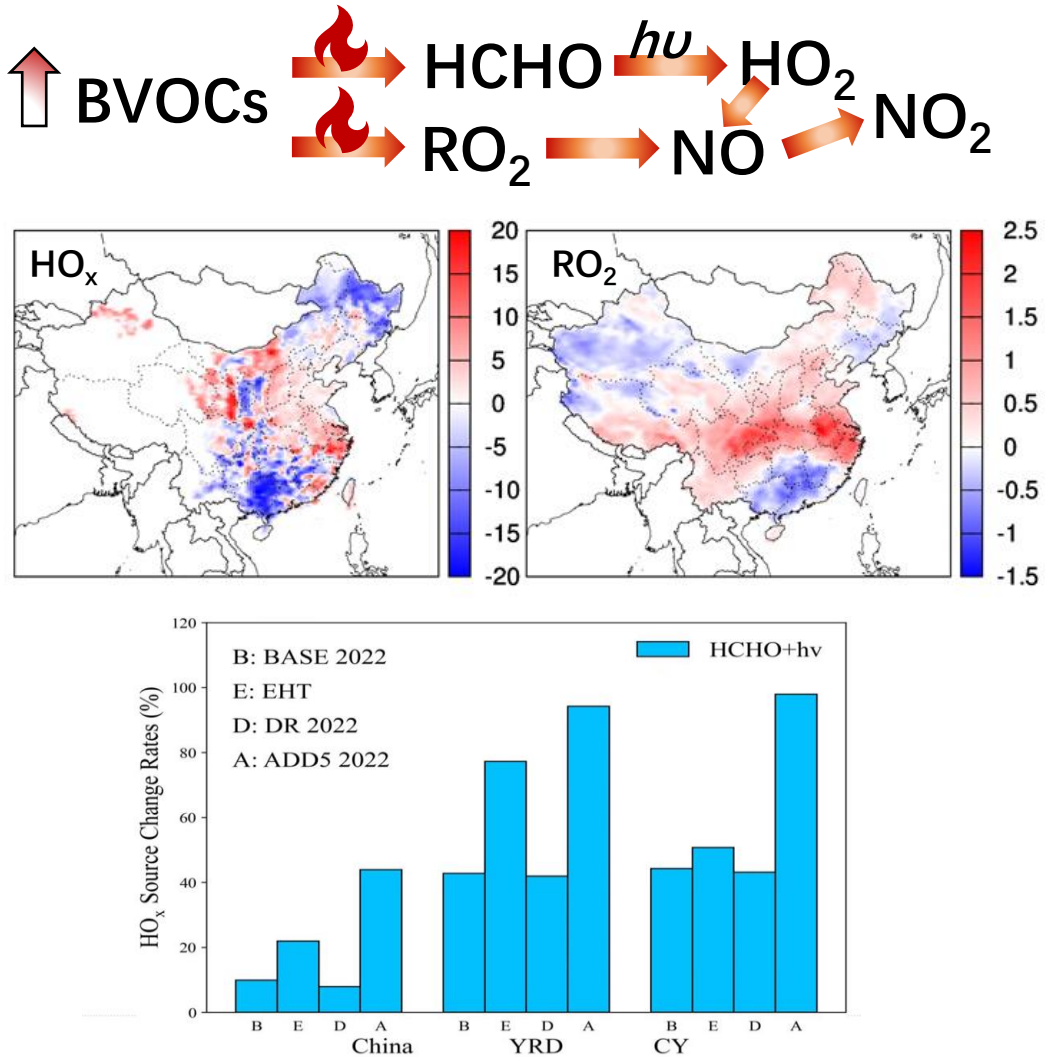


Extreme high temperature events accompanied with elevated O_3 concentration along the Yangtze River Basin.

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_2

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!