Innovative Approaches to improve Air Quality: Implications from PRC's Journey

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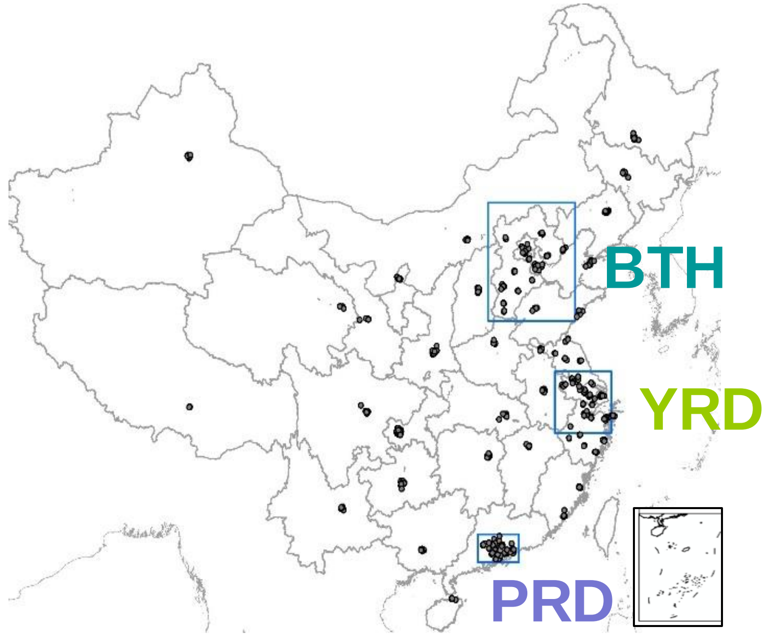
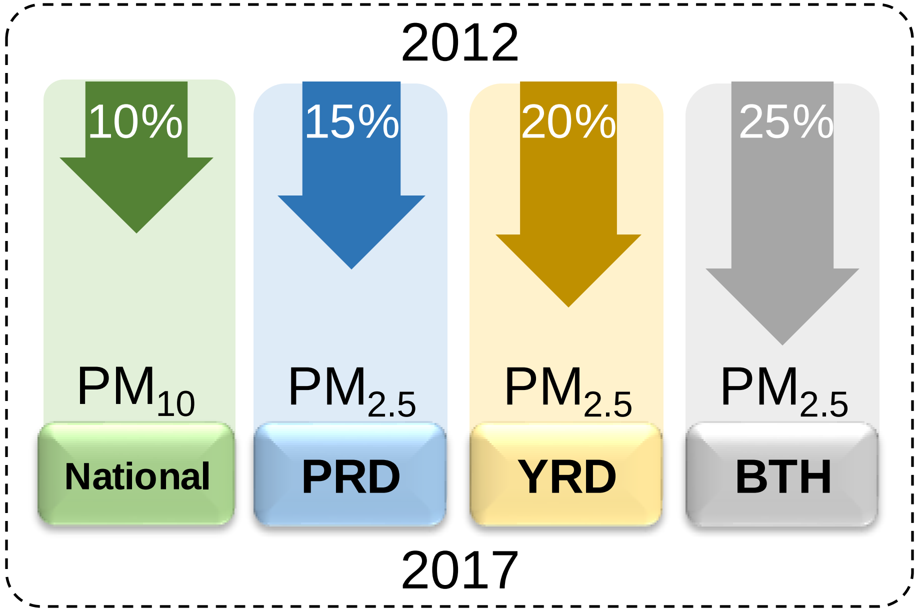
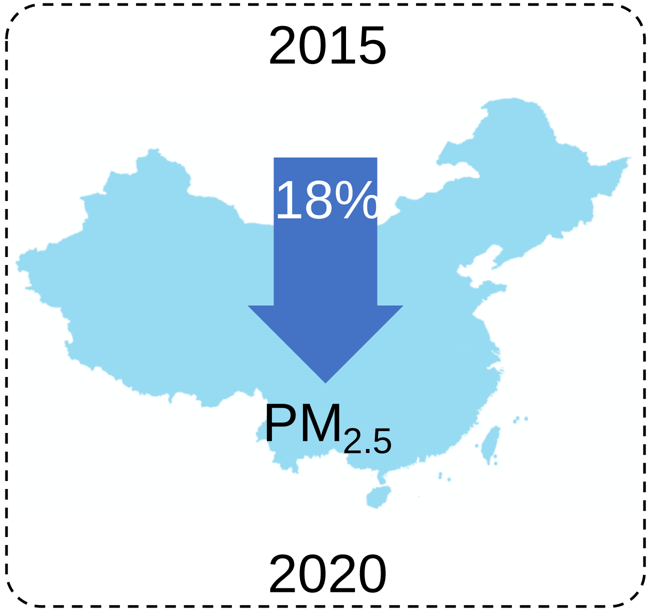
PRC has promulgated a series of stringent policies since 2013

Goals of policies Emission amount → Ambient concentrations





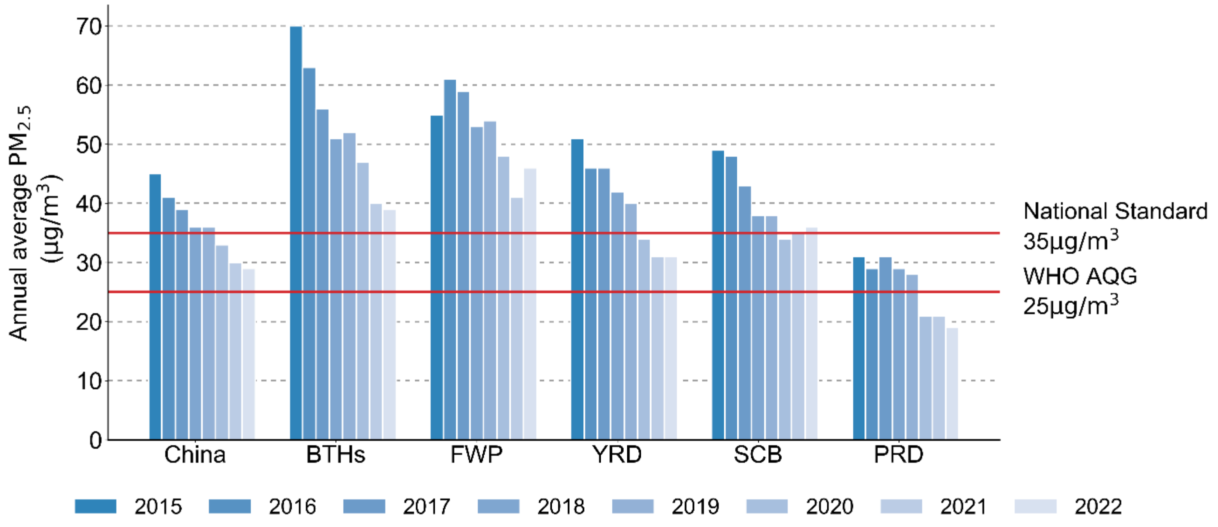
Air Pollution Prevention and Control Action Plan (2013–2017)



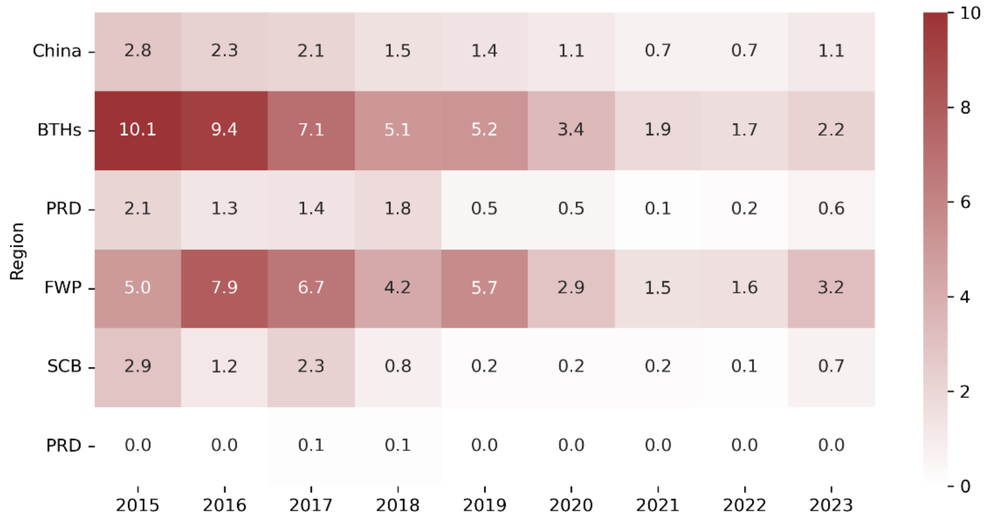
Three-Year Action Plan for Cleaner Air (2018–2020)

Significant air quality improvements in China and its key regions

The annual $PM_{2.5}$ concentrations in China and key regions from 2015 to 2022



Proportion of days with severe $PM_{2.5}$ pollution and above in China and key regions from 2015 to 2022.



- With the effective advancement of China' s air pollution control activities, the air quality has demonstrated significant improvement. Major air pollutants, particularly $PM_{2.5}$, have exhibited consistent year-on-year reductions, accompanied by a marked decrease in heavy pollution episodes both nationwide and in key regions.

CCAPP., 2023.

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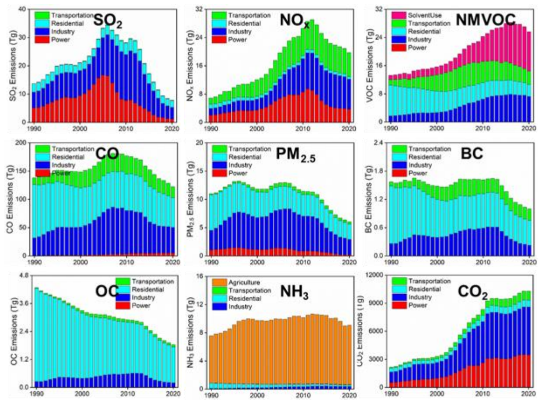
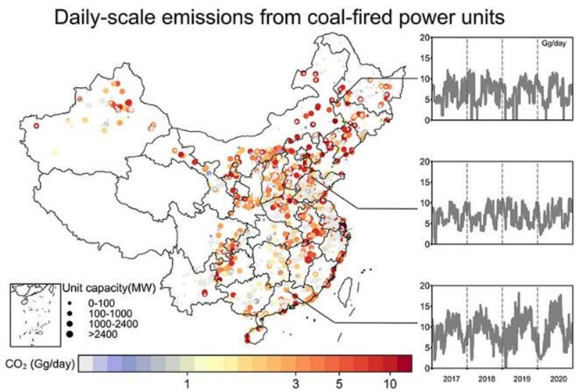
Scientific supports serves as a critical foundation for policy making

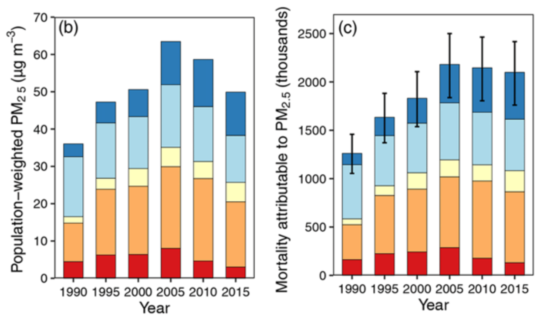
Accurate emission characterization



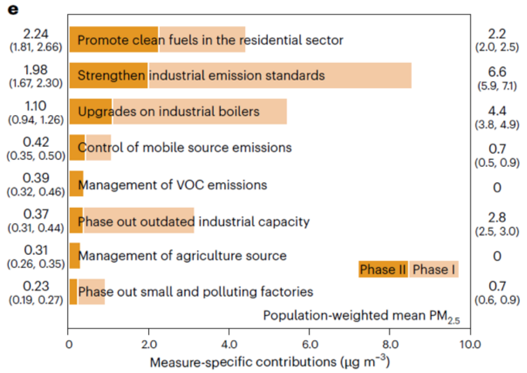
Dynamic pollution monitoring



Pollution source appointment



Control policy assessment



Policy making

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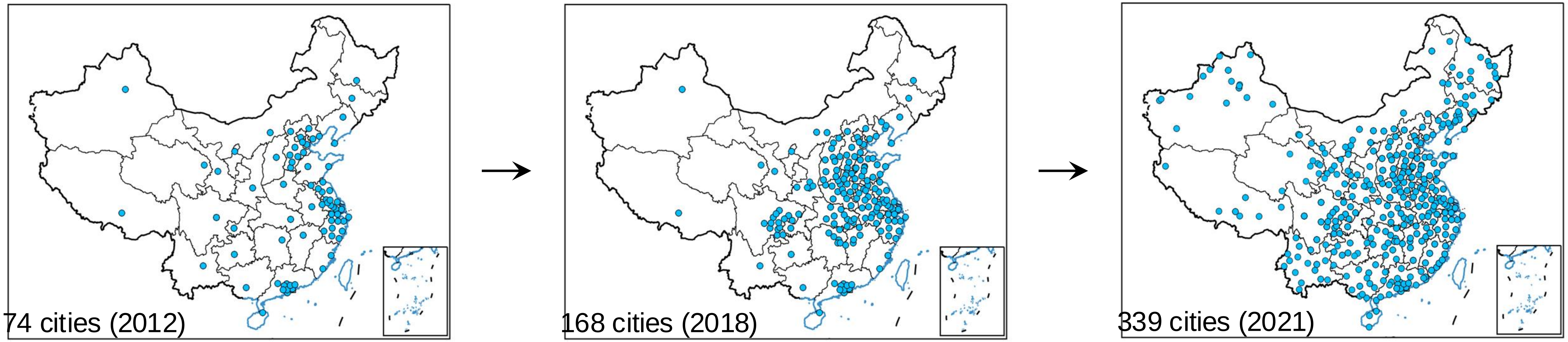
Air quality and emission data support achieving the policy goals

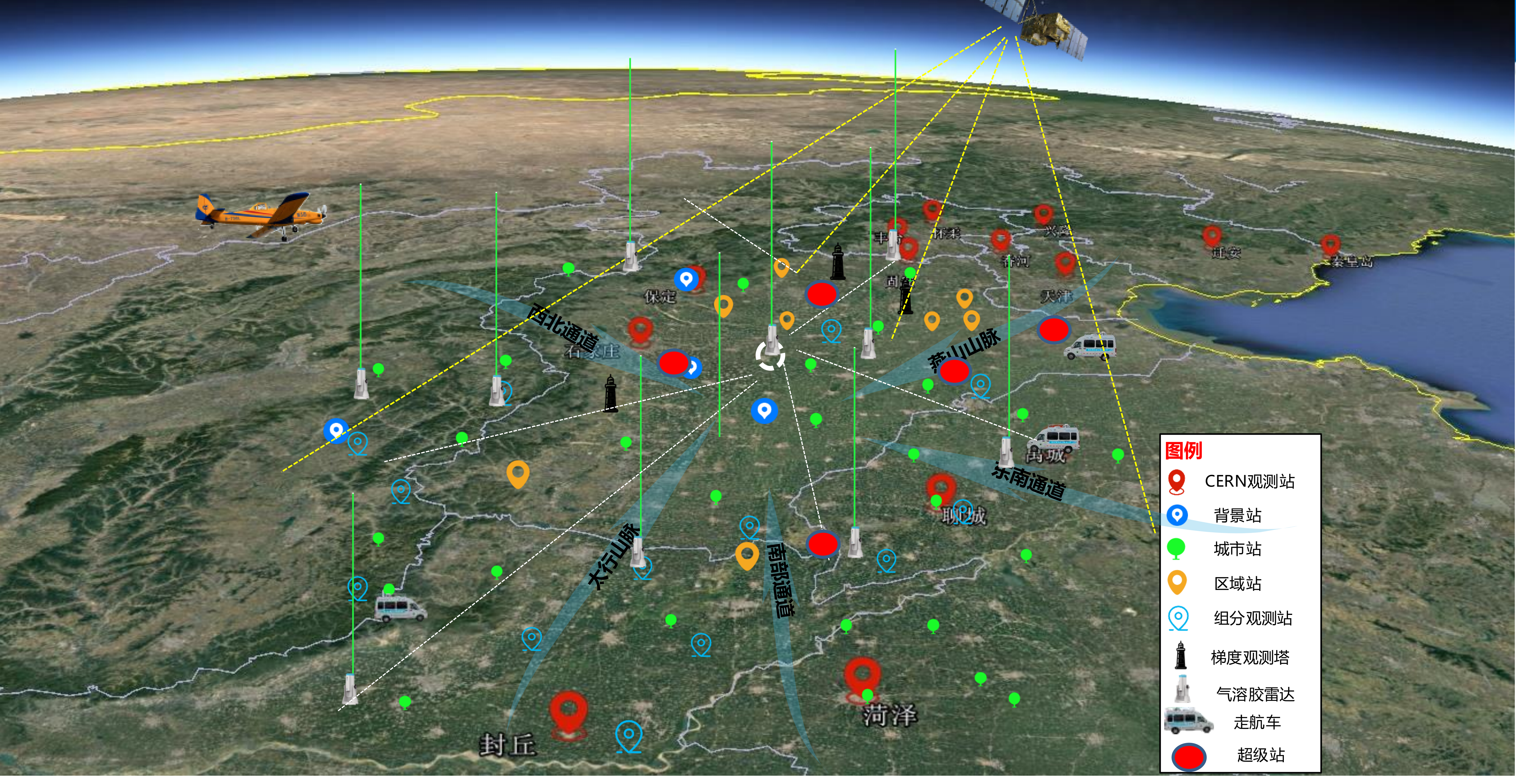
Air quality monitoring network development



Monitored air pollutants updates

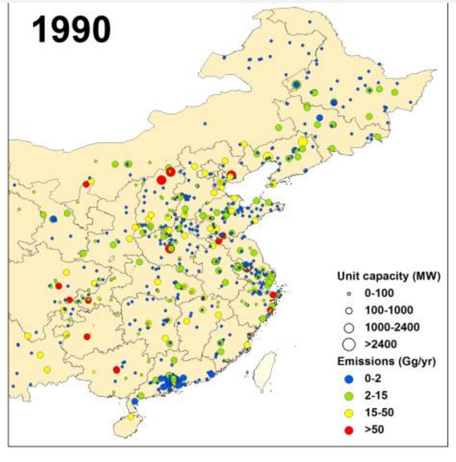
API index & Primary air pollutants	2012 →	Air pollutant concentrations
PM_{10} SO_2 NO_2		PM_{10} $PM_{2.5}$ O_3 SO_2 NO_2 CO

Advanced Monitoring & Observation Systems



Establishment of emission characterization framework: MEIC

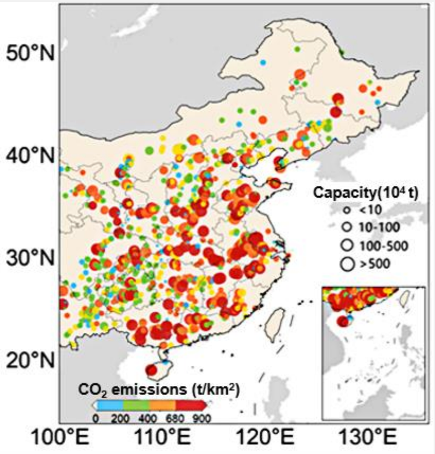
Delicate Emission Model for Power Sector



Resolution Improvement

Provincial Level → Single Facility

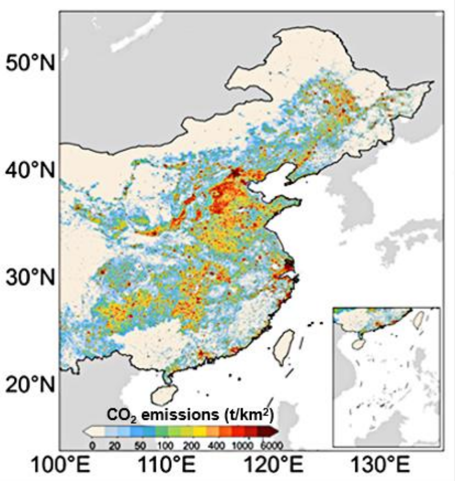
Delicate Emission Model for Industrial Sub-Sectors



Resolution Improvement

Provincial Level → Single Facility

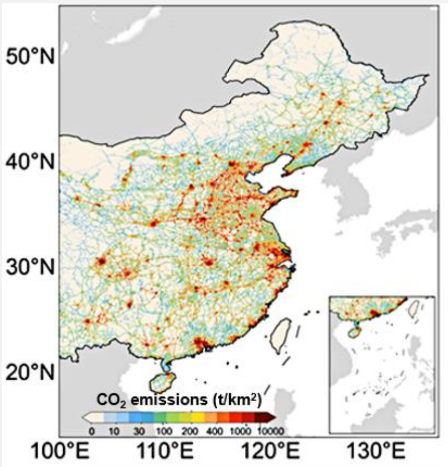
Emission Model for Residential Sector



Resolution Improvement

Provincial Level → Grid Level

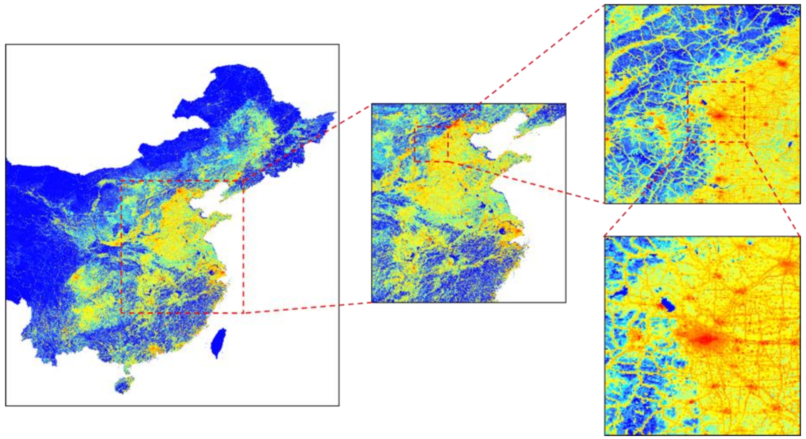
Emission Model for Transportation Sector



Resolution Improvement

City Level → Travel trajectory

Multi-resolution Temporal and Spatial Grid Emissions for Multiple Species



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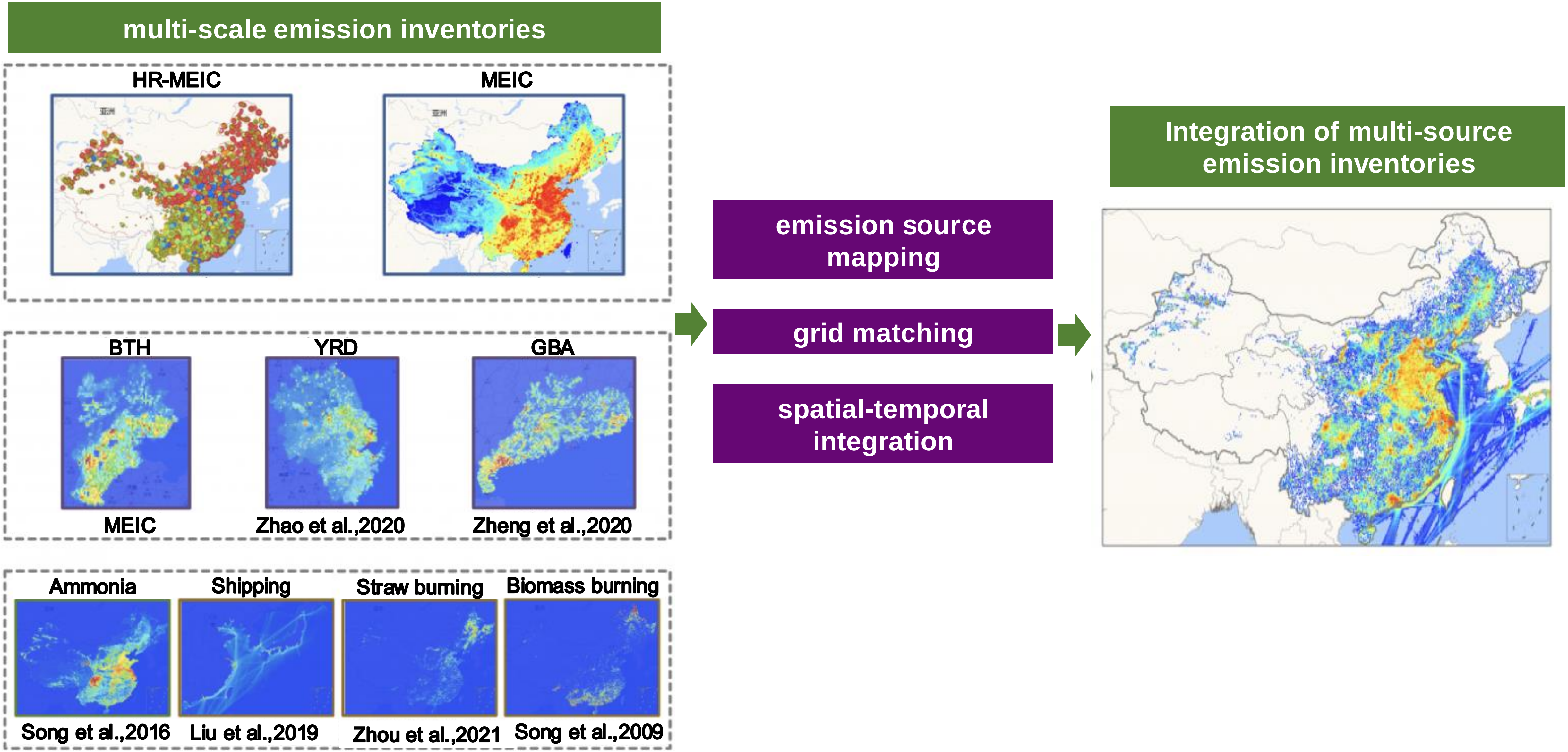
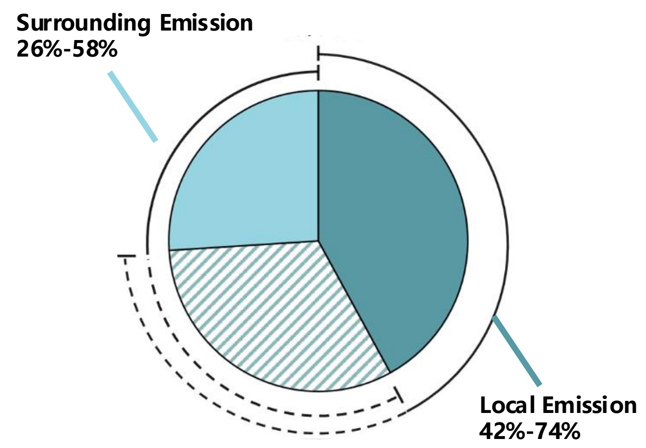
Air quality and emission data support achieving the policy goals

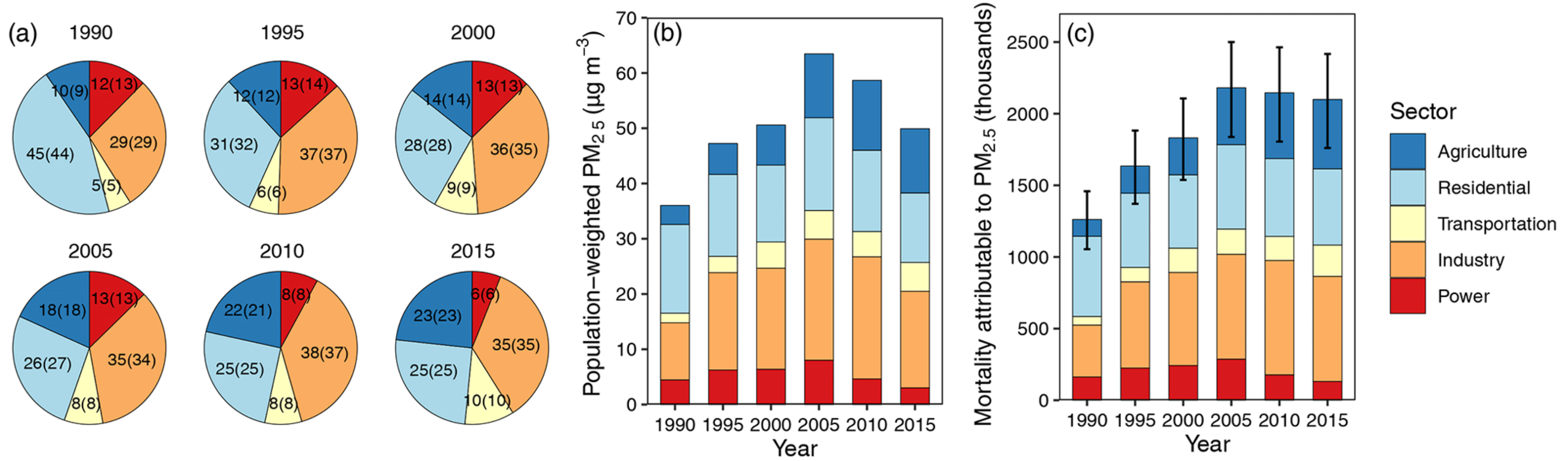


Source apportionment of major pollutants help set the direction for prioritized control strategies

Source appointment of current $PM_{2.5}$ in Beijing



Relative and absolute source contributions to national population-weighted $PM_{2.5}$ concentrations



- In key cities such as Beijing, regional transport is a significant source of pollutants in addition to local emissions. At the current stage, 42-74% of $PM_{2.5}$ in Beijing originates from local emissions, while 26-58% stems from surrounding areas.
- Source apportionment can further quantify emissions from various anthropogenic sectors. In China, $PM_{2.5}$ emissions primarily emanate from residential and industrial sectors, with the proportion from the agricultural sector rising in recent years which requires close attention in the future.

Liu et al., ACP, 2020.

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Dynamic pollution monitoring frameworks：TAP

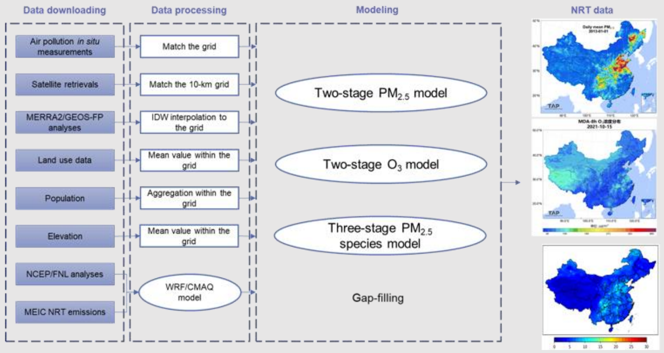
The methodology framework of Tracking Air Pollution in China（TAP）

http://tapdata.org.cn/

Operational multi-source data preprocessing module

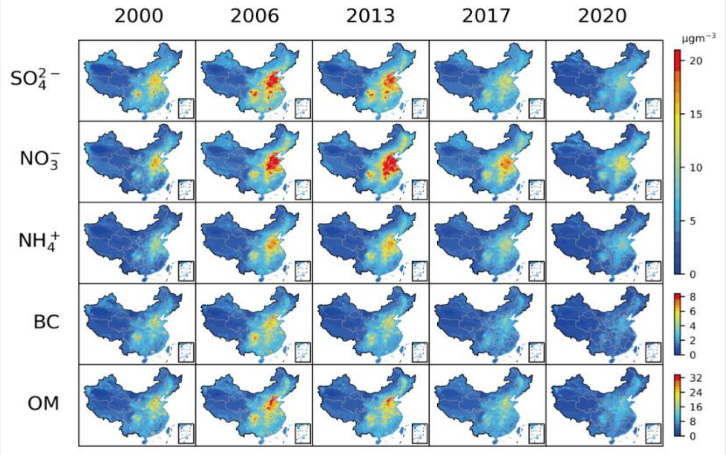
Multi-source data downloading and preprocessing

Dynamic emission inventory → Near-real-time numerical simulation

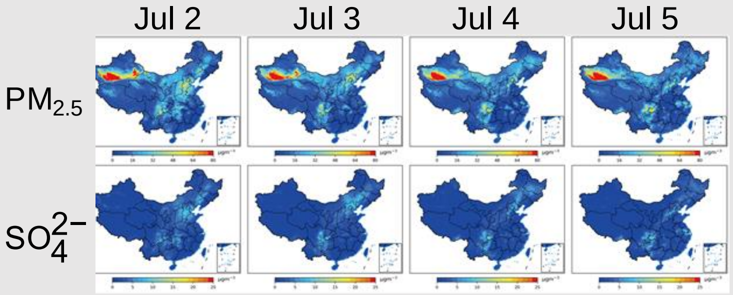


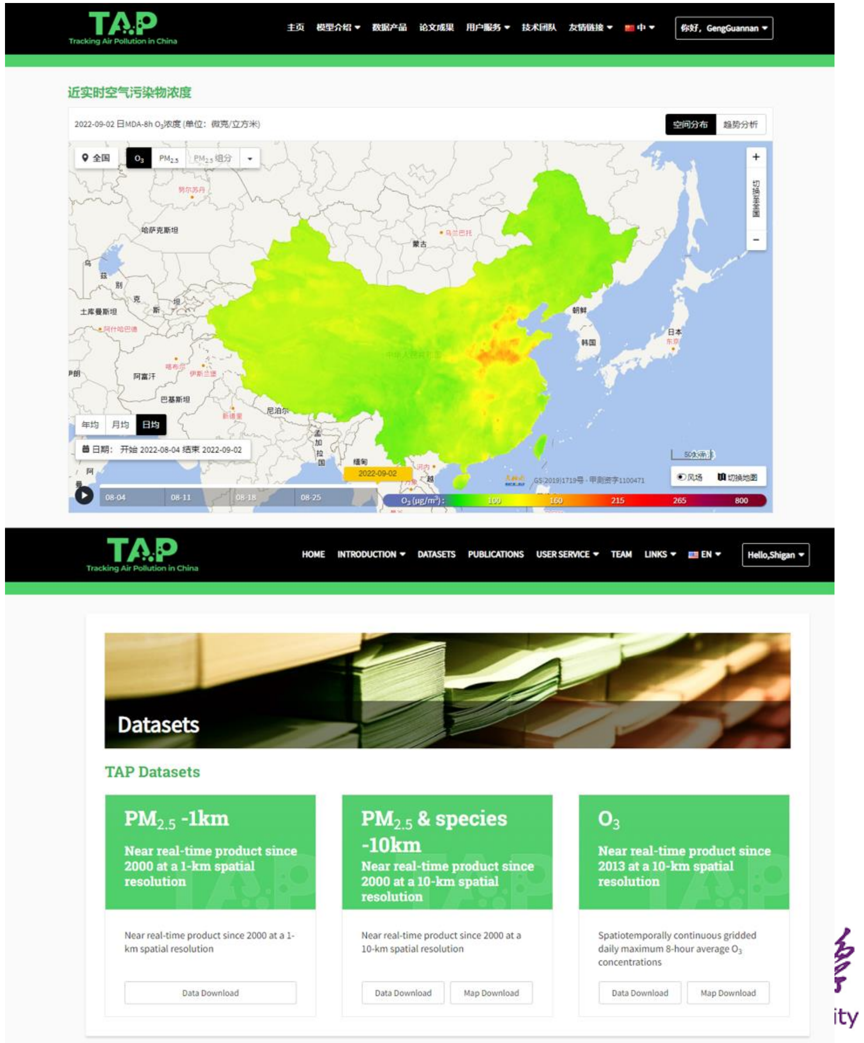
Inversion methods for atmospheric composition

Long-term spatiotemporal continuous data



Daily scale near-real-time update

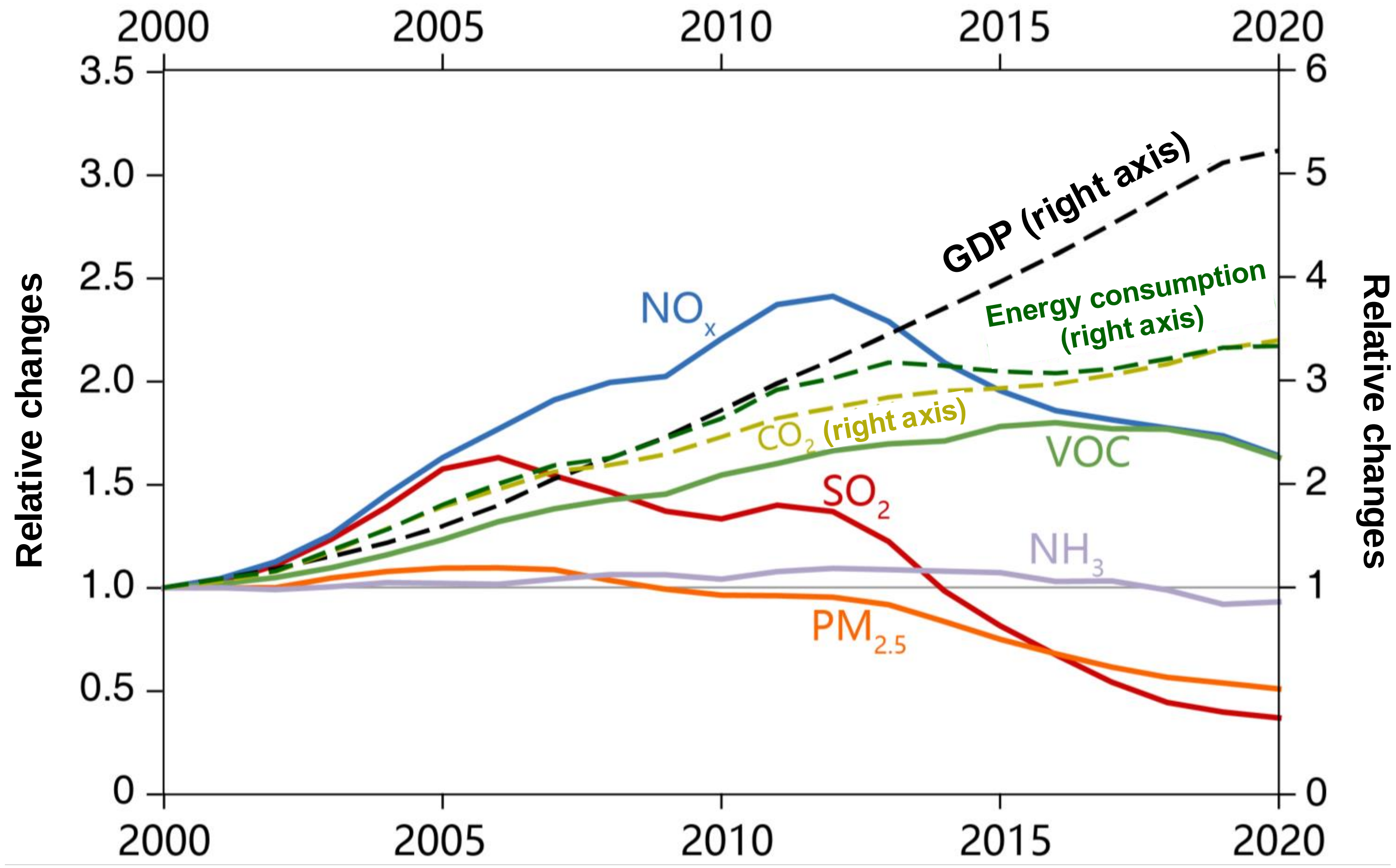




Major clean air actions implemented 2013-2020

Action	2013–2015	2016–2017	2018–2020
Ultra-low emission retrofits of coal-fired power plants	Deadline governance for desulfurization, denitrification and dust removal in the power industry	71% completed ultra-low emission retrofits	88% completed ultra-low emission retrofits
In-depth governance of non-power industries	Deadline governance for desulfurization, denitrification and dust removal in the steel, cement and flat glass industries		620 million tons of crude steel capacity started ultra-low emission retrofits
VOCs integrated control	Completed more than 50,000 VOCs control projects		
Integrated control of coal-fired boilers	Phased out more than 200,000 small coal-fired boilers		Phased out more than 110,000 coal-fire boilers Basically eliminated coal-fired boilers
Clean heating in rural areas			Launched a pilot program for clean heating in winter in the northern region Completed the bulk coal substitution in 25
Mobile source emission control	Fully implemented National IV standard (National V Standard in key areas)	Fully implemented National V standard	Fully implemented National VI Standard for light vehicles
	National VI Standard vehicle gasoline and diesel were fully supplied, and more than 27 million yellow-label and old vehicles were phased out		
Integrated control of agriculture	The application area of soil testing and formulated fertilization technology reached 133 million hectares, and the open burning of straw was effetively controlled		
Integrated control of fugitive dust	More than 230,000 cases of construction related fugitive dust were controlled nationwide; the machine sweeping rate of urban roads in key areas exceeded 90%; more than 30,000 hectares of mine land were restored; more than 10 million hectares of green land were newly created		

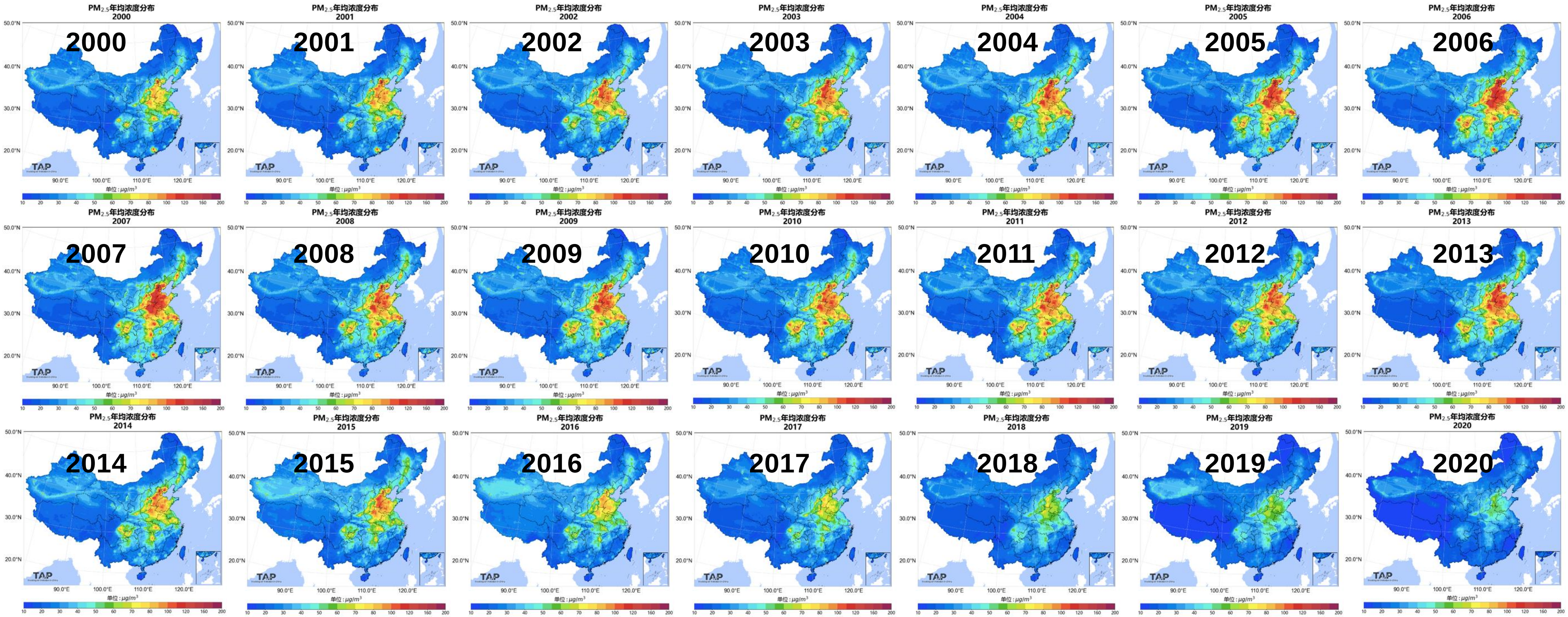
PRC's emissions of major air pollutants have been Suppressed



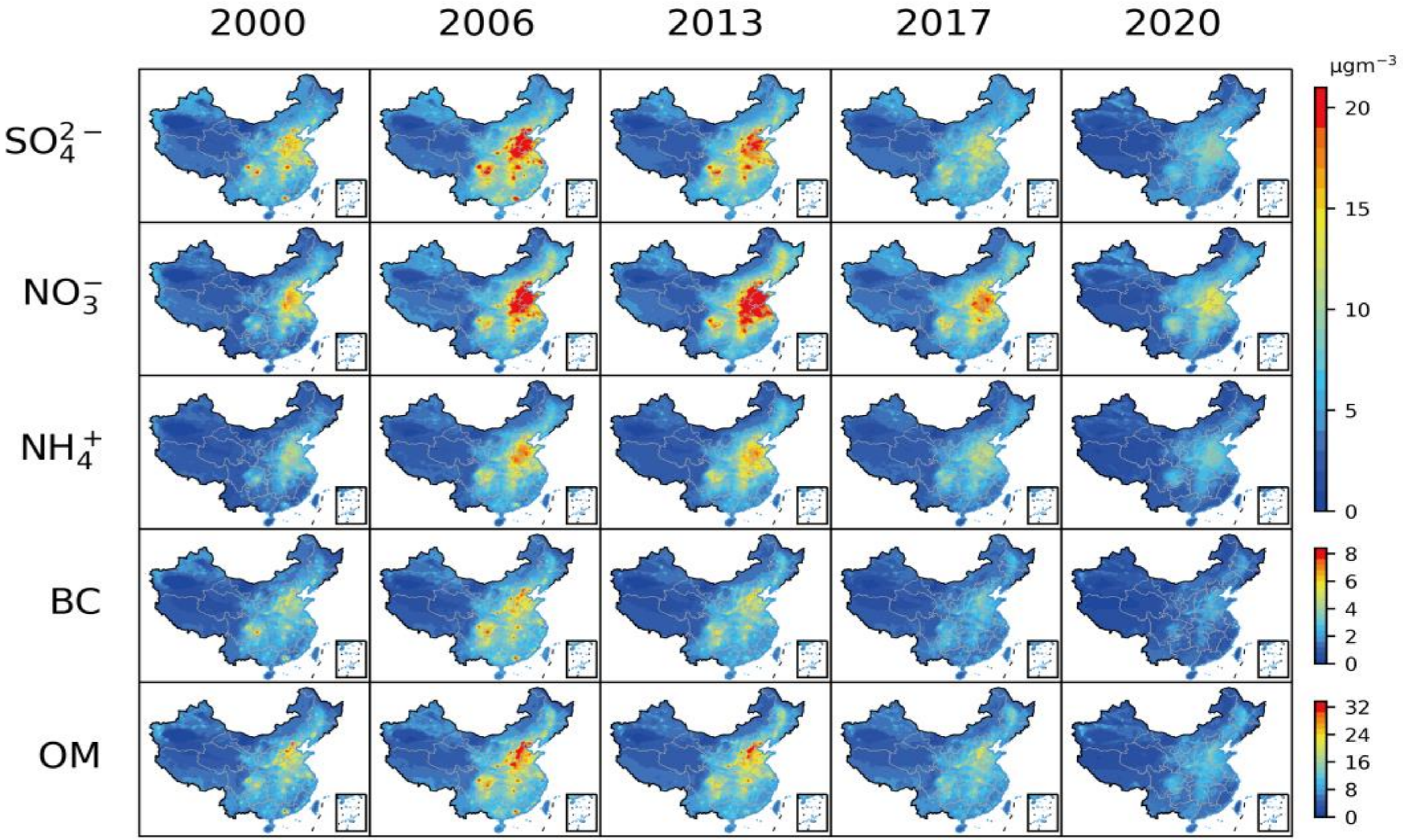
- SO_2, NO_x and primary $PM_{2.5}$ emissions have peaked in 2006, 2012, and 2006 respectively. Emissions in 2020 have decreased by 77%, 32%, and 53% respectively compared to the peak.

- The VOCs and NH_3 emissions have been high for a long time. The first inflection point of VOCs and NH_3 emissions occurred in 2017, but the reductions are small.

$PM_{2.5}$ concentrations in China since 2000

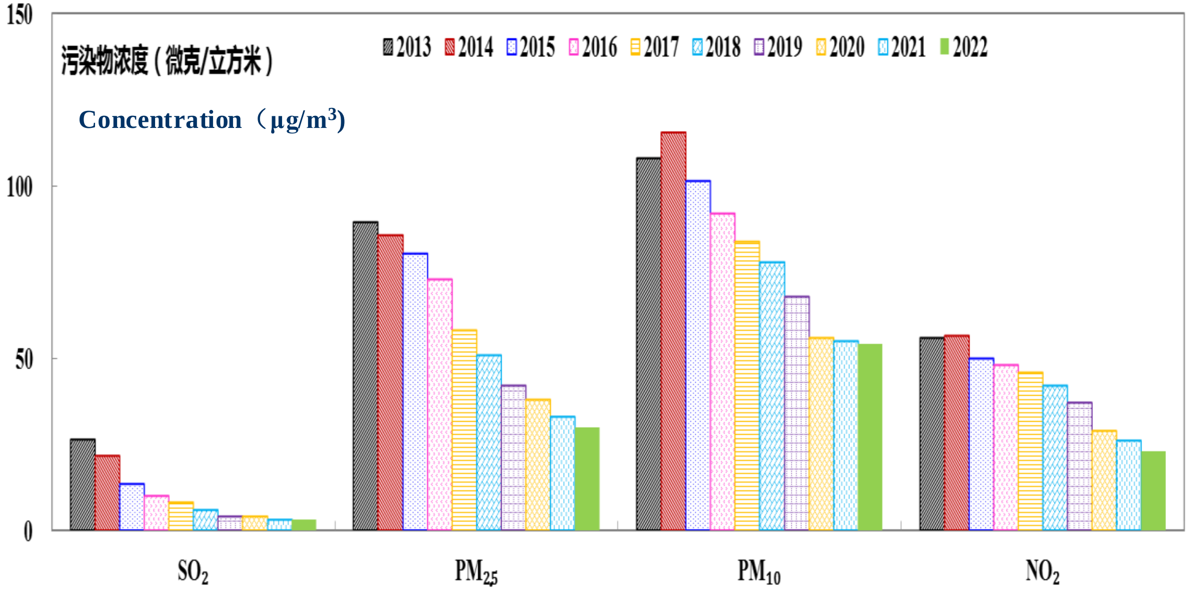


Geng et al., ES&T, 2021, Xiao et al., ACP, 2022


2000
2006
2013
2017
2020
SO_4^{2-}
NO_3^-
NH_4^+
BC
OM
$\mu g m^{-3}$
0
5
10
15
20
0
2
4
6
8
0
8
16
24
32

In the past decade， air quality of Beijing met an overall and significant improvement

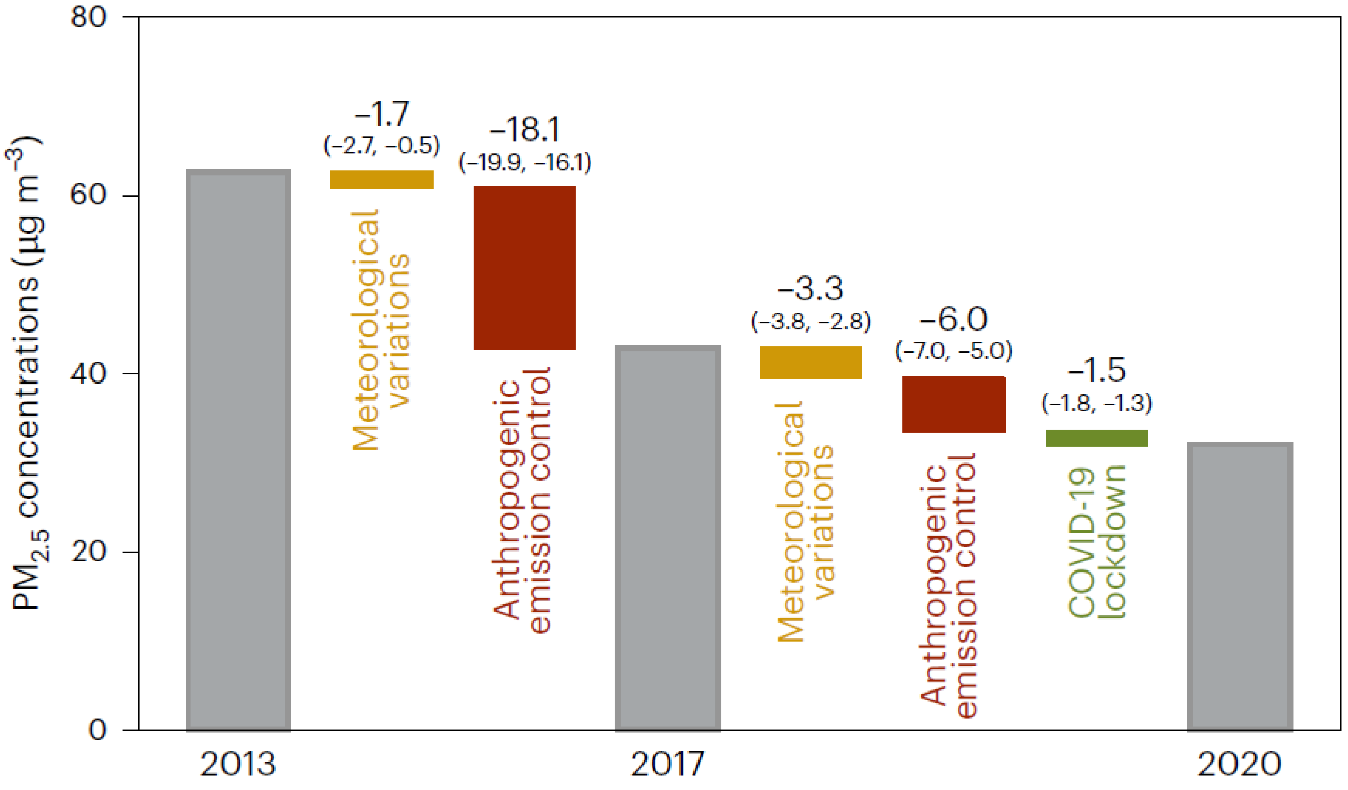
Over the past decade



Compared with 2013, in 2022, the annual average concentrations of Beijing’s $PM_{2.5}$, PM_{10}, NO_2, SO_2 decreased by 66.5%, 50.0%, 58.9% and 88.7%

Assessment of air pollution control policies

Main drivers to the $PM_{2.5}$ reductions from 2013 to 2020



- During 2013-2017, the ***Anthropogenic emission control*** is the main driver for the decrease of $PM_{2.5}$ concentration.
- During 2017-2020, the ***Meteorological variations*** benefits the improvement of $PM_{2.5}$ and the contribution is 30%; the ***COVID-19 lockdown*** contributes 14%; and the impact of ***Anthropogenic emission control*** has a share of 56%.

Zhang et al., PNAS, 2019; Geng et al., Nature Geoscience, 2024

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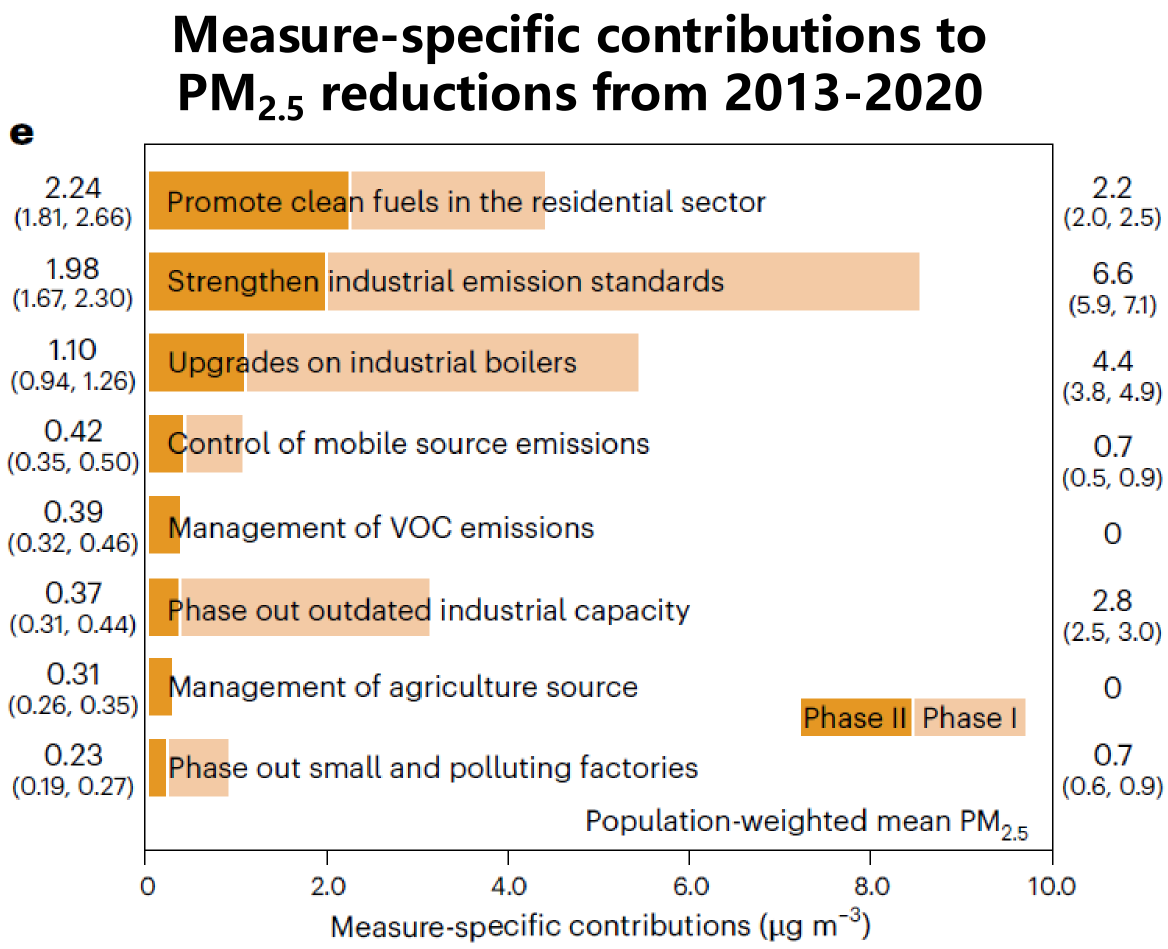
Assessment of air pollution control policies



- The benefits of strengthening industrial emission standards, upgrades on industrial boilers, phasing out outdated industrial capacity, and phasing out small and polluting factories were lower in Phase II (2018-2020) than in Phase I (2013-2017).

- The benefits of promoting clean fuels in the residential sector, controlling of mobile source emissions, managing of VOC emissions, and managing of agriculture source were comparable or even better between Phase I (2013-2017) and Phase II (2018-2020).

Geng et al., Nature Geoscience, 2024

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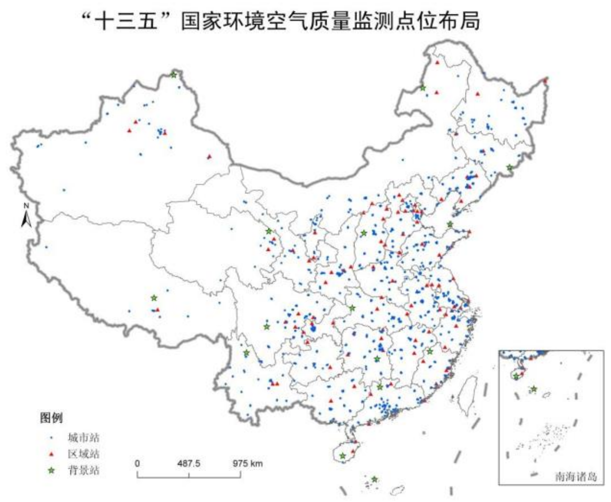
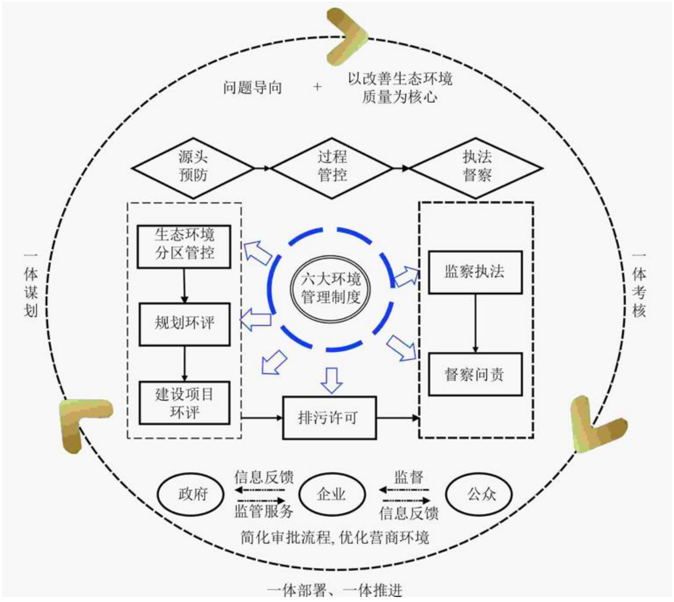
Outlook for future project design

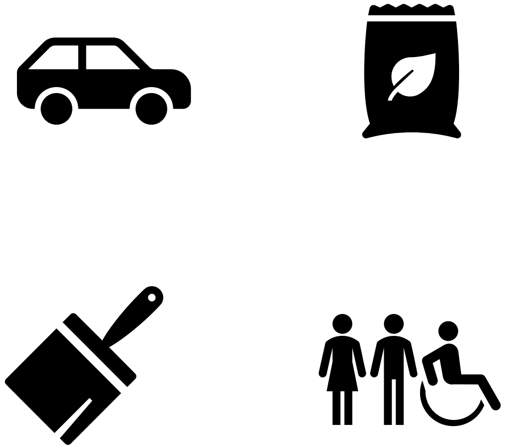
Fundamental Capacity Building for Atmospheric Environment



Enhance the Regulatory Framework for Atmospheric Environment Management



Management of Key Emission Sources



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Thanks！