Mapping China’s Mercury Emissions (1978-2021) by Integrating Point Sources

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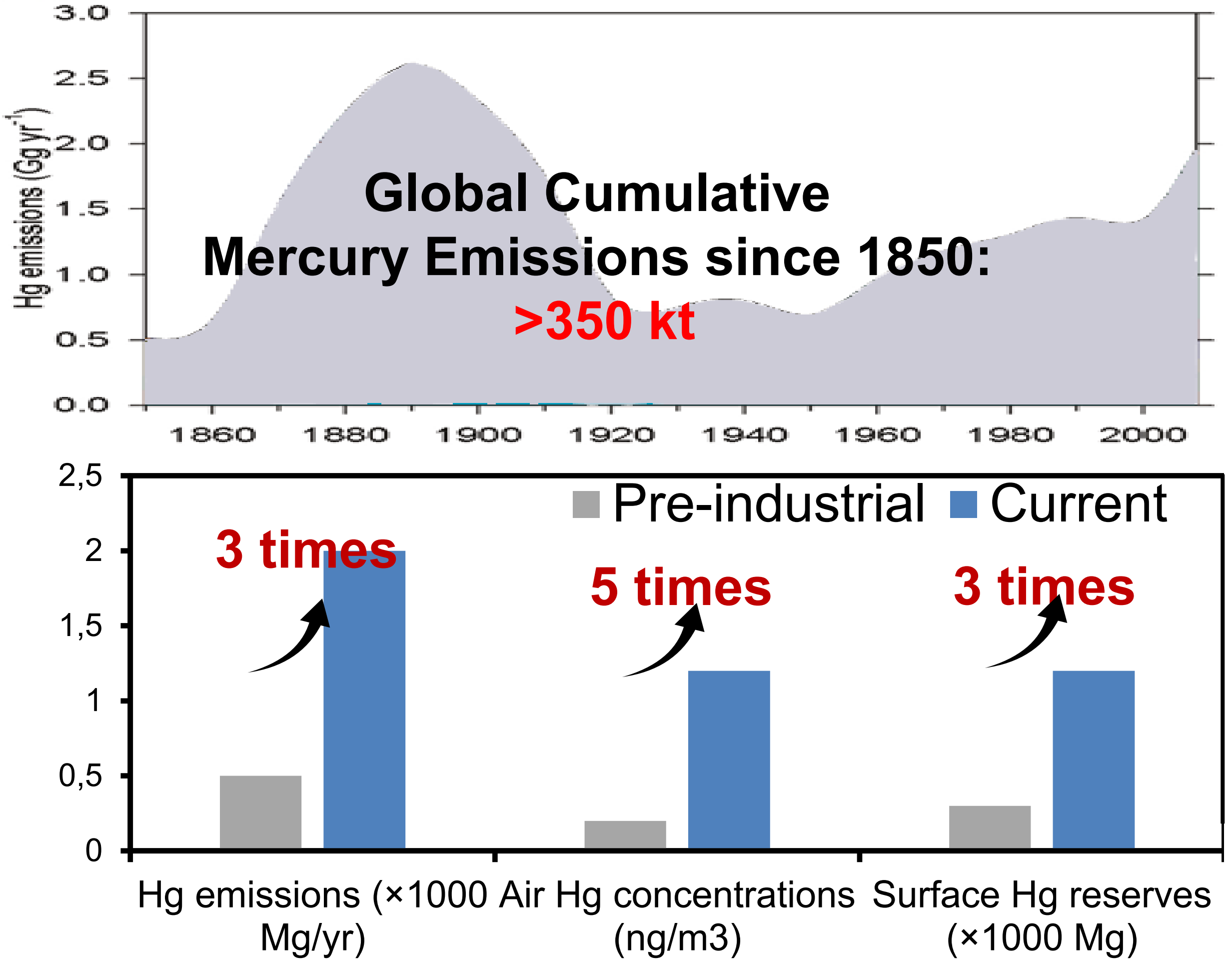
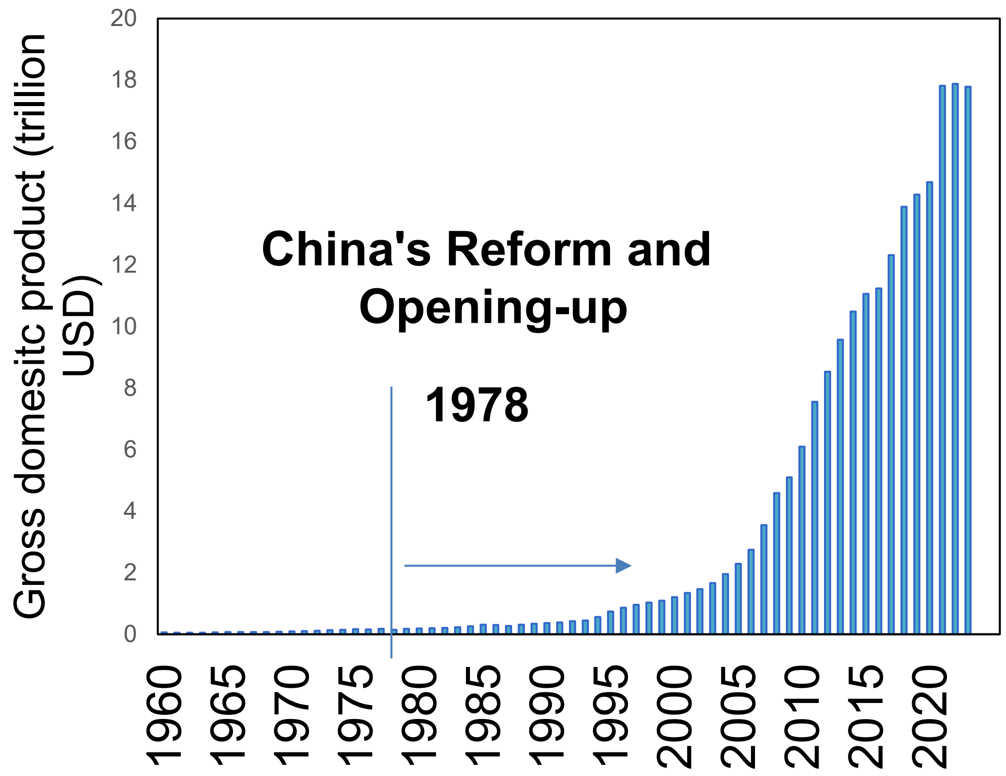
Background

- **Quantifying historical emissions are essential to understand present Hg pollution.**

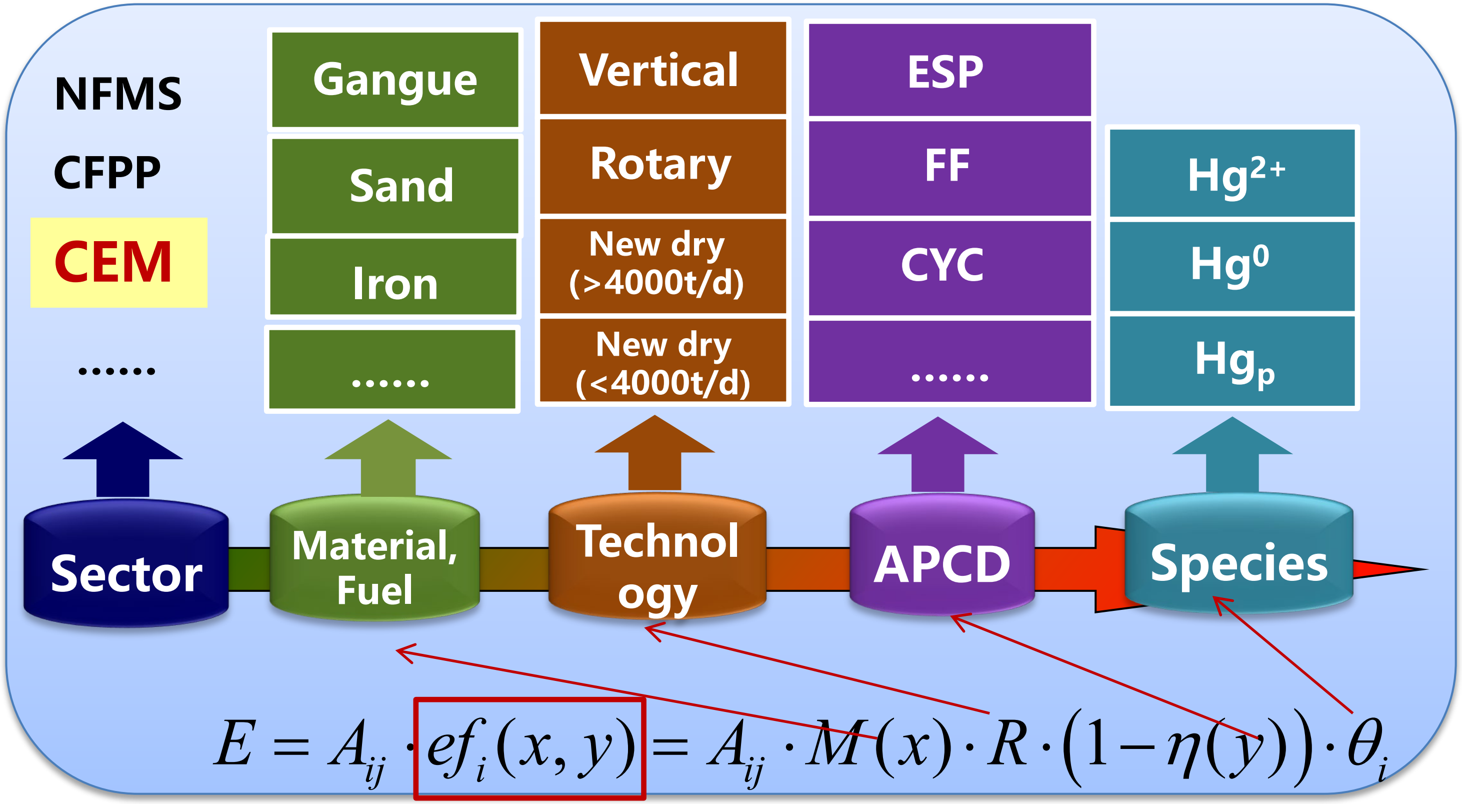


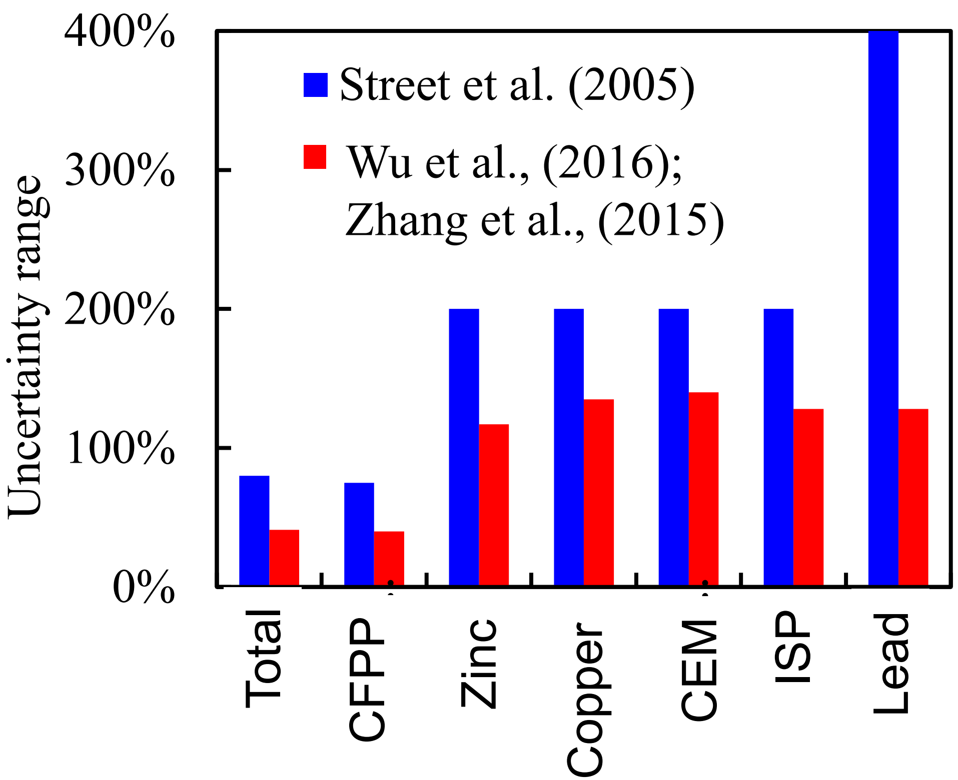


AMAP/UN Environment, 2019, Streets et al. (2019), Amos et al. (2015), World bank 2024

Progress of national emission inventories in China

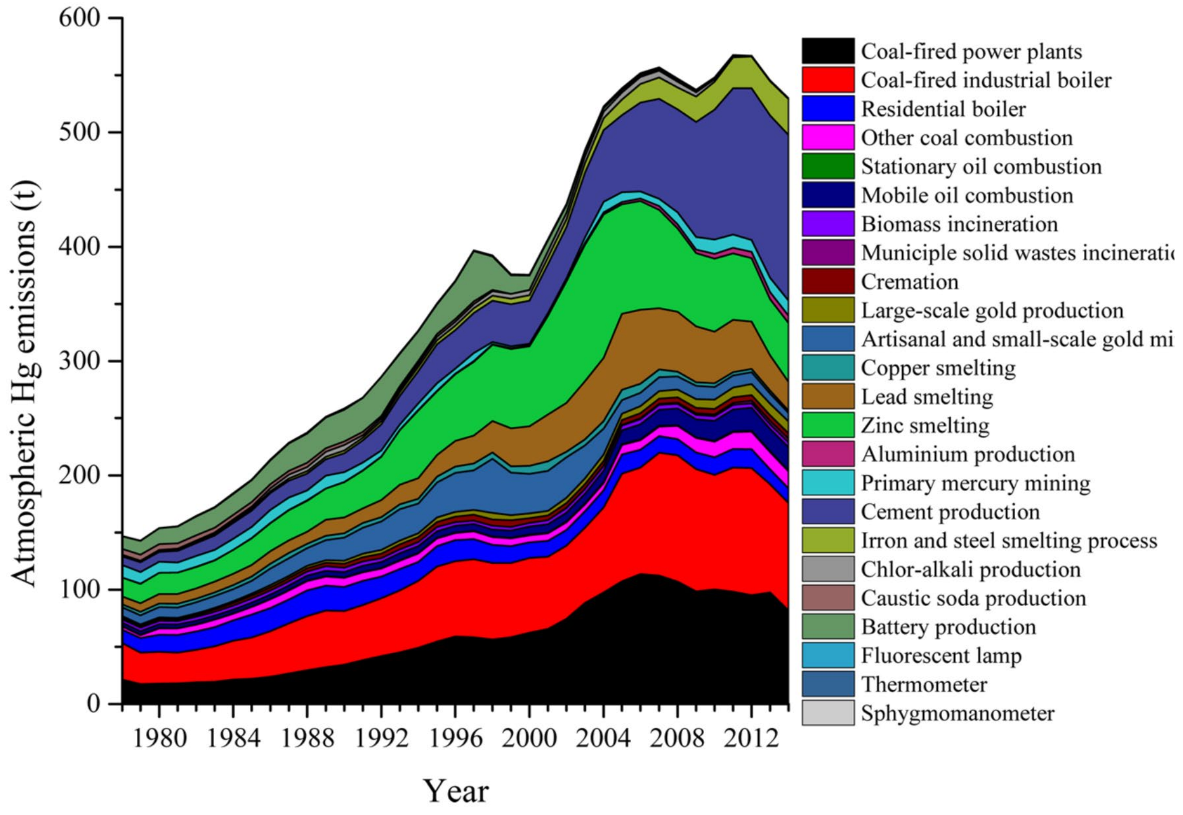
- **Uncertainty of emission factors have been reduced due to widely on-site experiments, as well as survey of Hg content in raw materials and fuels.**

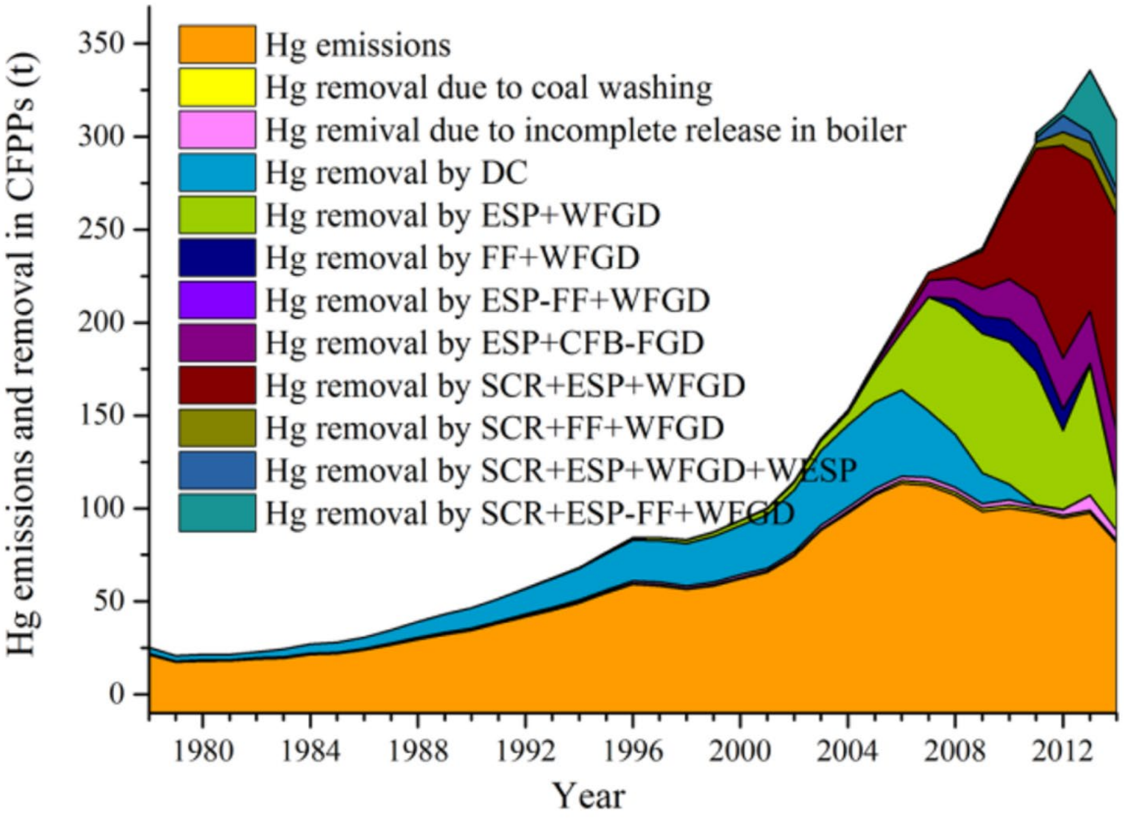




Progress of national emission inventories in China

- **Emission trends and the impact of technology revolution on emission mitigation become clear.**





Wu et al., ES&T, 2016

Progress of national emission inventories in China

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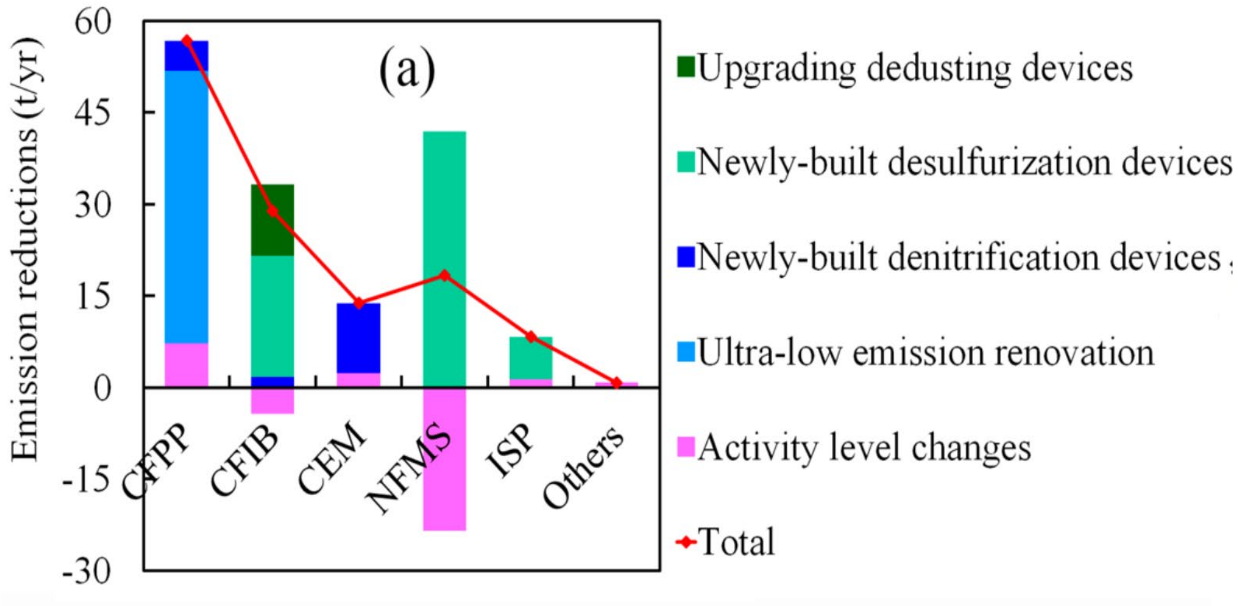
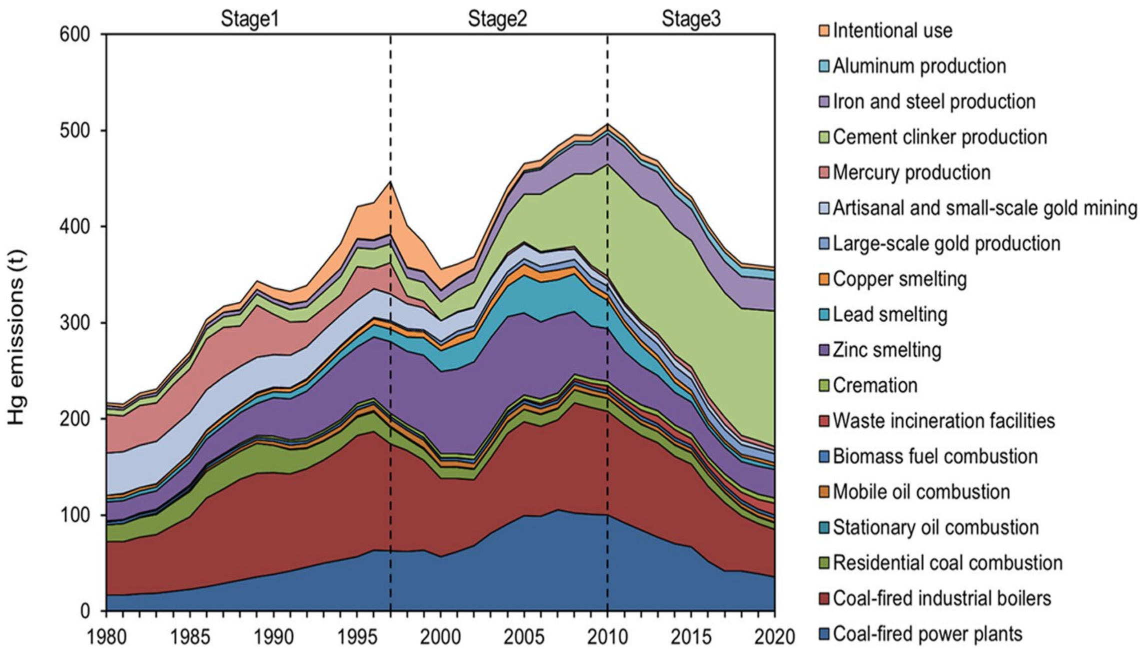


Emission reduction of Hg sources during 2013-2017

Liu et al. ES&T, 2019



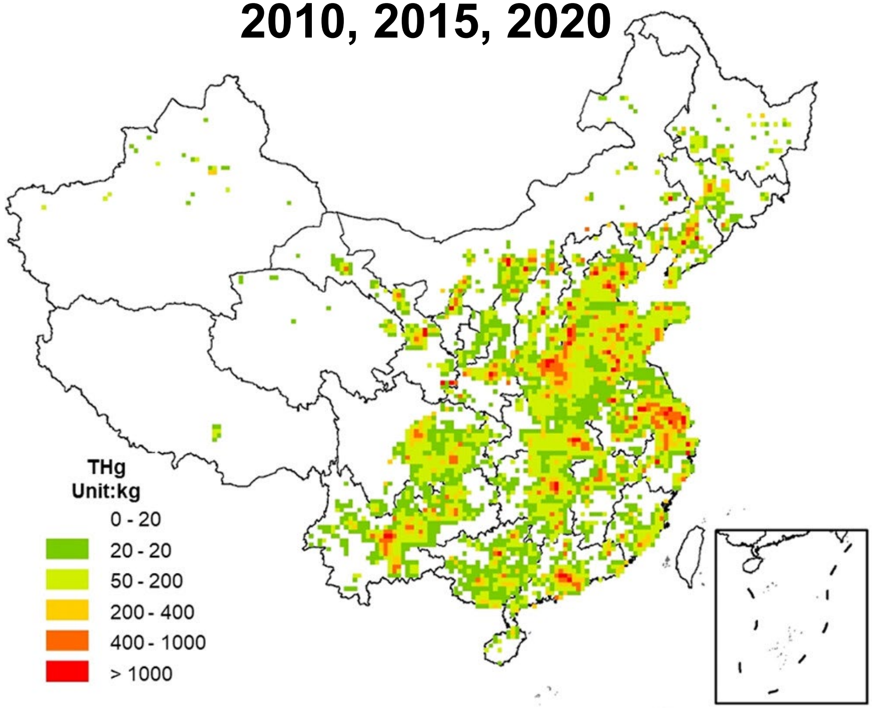
Emission trends during 1980-2020

Zhang et al. ES&T, 2023

Progress of national emission inventories in China

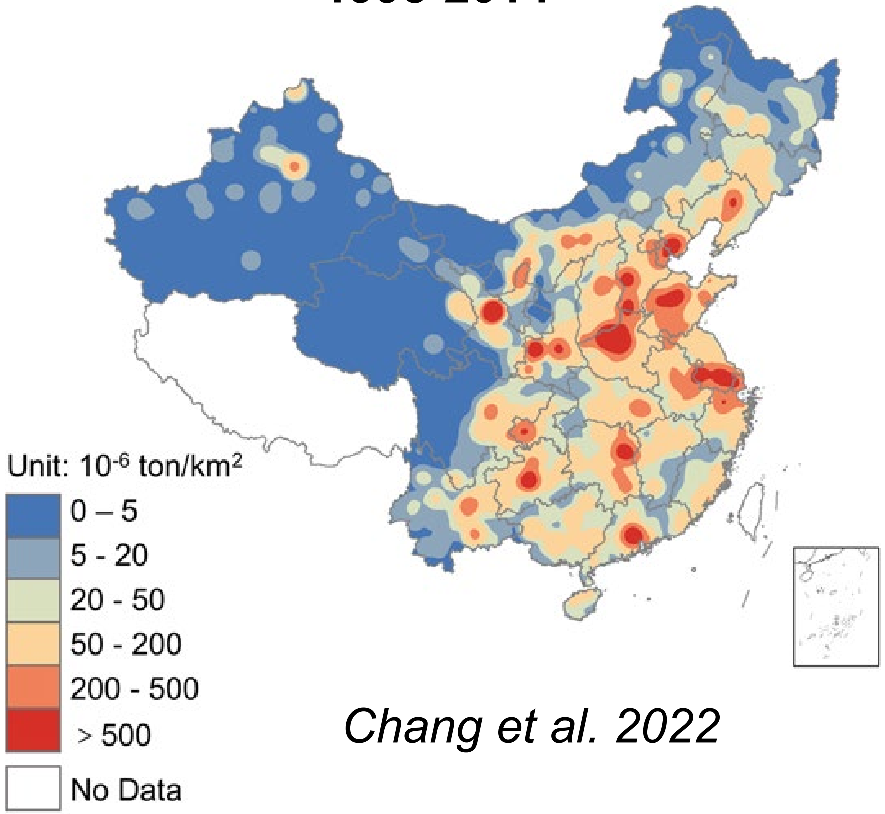
- **Existing gridded emission datasets are typically focused on specific years or early stage, and the gridded methods are not comparable.**

2010, 2015, 2020



Zhang et al. 2023

1998-2014



Chang et al. 2022

Objective

Using enterprise big data and sector-specific proxy parameters to generate a Hg emission dataset for China (P-CAME, 1978-2021) with a continuous time series and refined spatial resolution.

Sector Categories

Category	Sectors	Methods
Category 1	Coal-fired power plant, Lead smelting, Zinc smelting, Copper smelting, Large-scale gold production, Cement and clinker production, Municipal waste disposal， Coal-fired industrial boiler, Primary mercury mining, Iron and steel production	**Point source emissions (accounting for 62%~85%)**
Category 2	Mobile oil combustion	Road map from open street map
Category 3	Open biomass burning	Remote sensing
Category 4	Residential coal/oil/gas/biomass combustion	POI (Point of interest) Population
Category 5	Chlor-alkali production, Caustic soda production, Thermometer production, Sphygmomanometer, Fluorescent lamp production, Battery production, Stationary oil combustion, Artisanal gold mining, opening waste burning, Cremation	GDP+Population / Population

Point source emissions

■ **Determining the point emissions based on multivariate data fusion method**

Data Sources → **Statistical indicators** → **Data calibration**

Data Sources:
- Environ. statistics
- Industry association
- Census on the sources of pollution
- Pollutant Discharge Permit Management
- Expert Consultation
- Environ. monitoring
- Remote sensing
- Energy Information Administration Bulletin

GIS

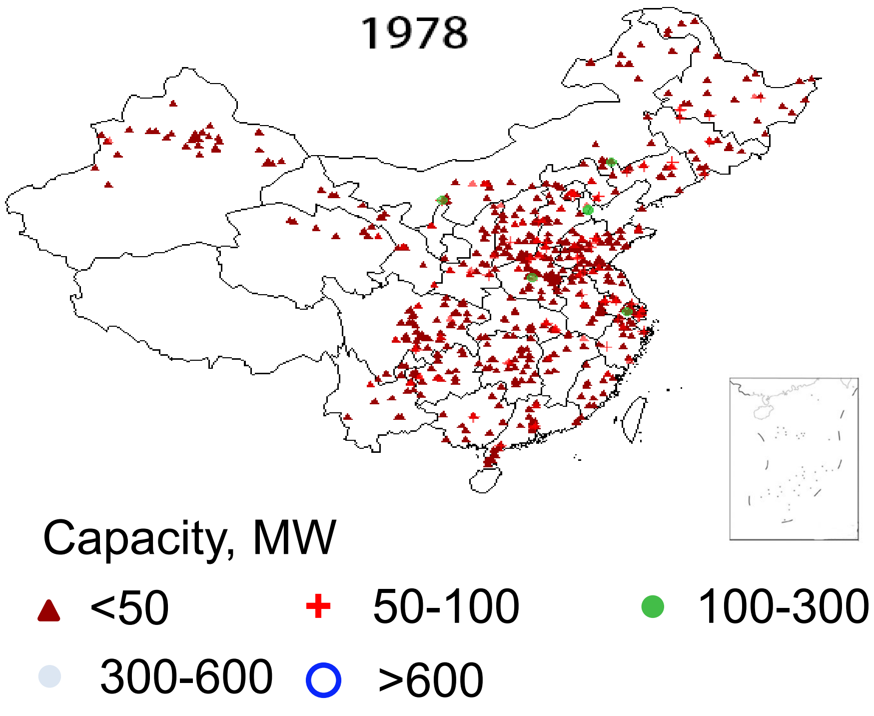
Statistical indicators:
- Activity level of point source
- APCDs types
- Temporal distribution

Enterprise credit code

Data calibration:
- China Statistical Yearbook
- China Energy Statistical Yearbook
- Industry Statistical Yearbook
- China Environmental Statistical Yearbook
- National Policy Objectives
- Industry Policy Objectives
- Regional Policy Objectives

➢ **Activity level bias <±10%**

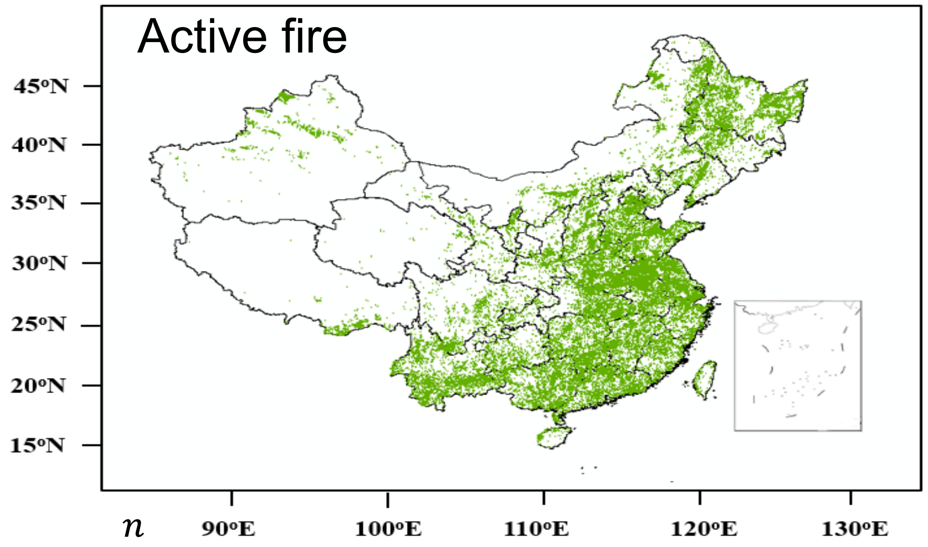
➢ **APCDs application bias <±10%**



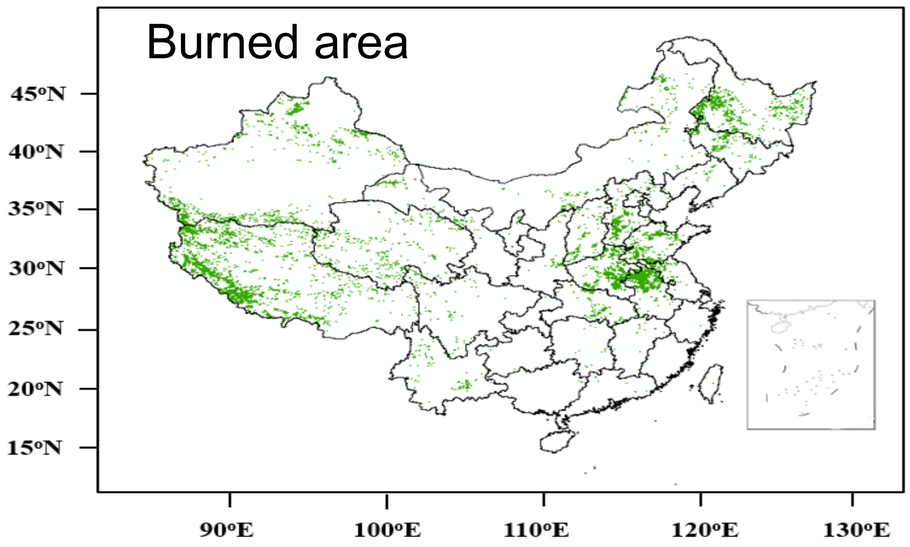
Remote sensing

- **Using multi-satellite technology to solve the spatiotemporal distribution problem of the open biomass emission inventory**

MODIS Active Fire Product MCD14ML



MODIS Burned Area Product MCD45A1



$$E_i = \sum_{j=1}^{n} BA_{x,t} \times BL_x \times FB \times EF_{i,j}$$

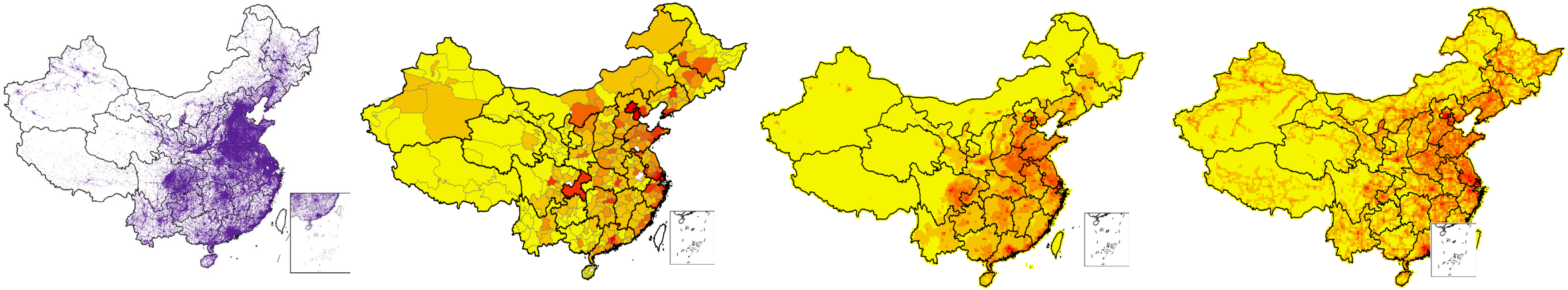
Burned area **Biomass amount** **Burned efficiency** **Emission factor**

$$BA_{sf}(i,t,v) = FC_{out}(i,t.v) \times \alpha_{r,s,v} \times \gamma_{r,s,v}$$

Number of fire points from MCD14ML that fall outside the burned area **Burned area of each fired point** **Coefficient of variation in fire point area**

Other proxies

- Proxies such as Point of interest, GDP, Population and Roadmap database are used to identify spatial distribution.



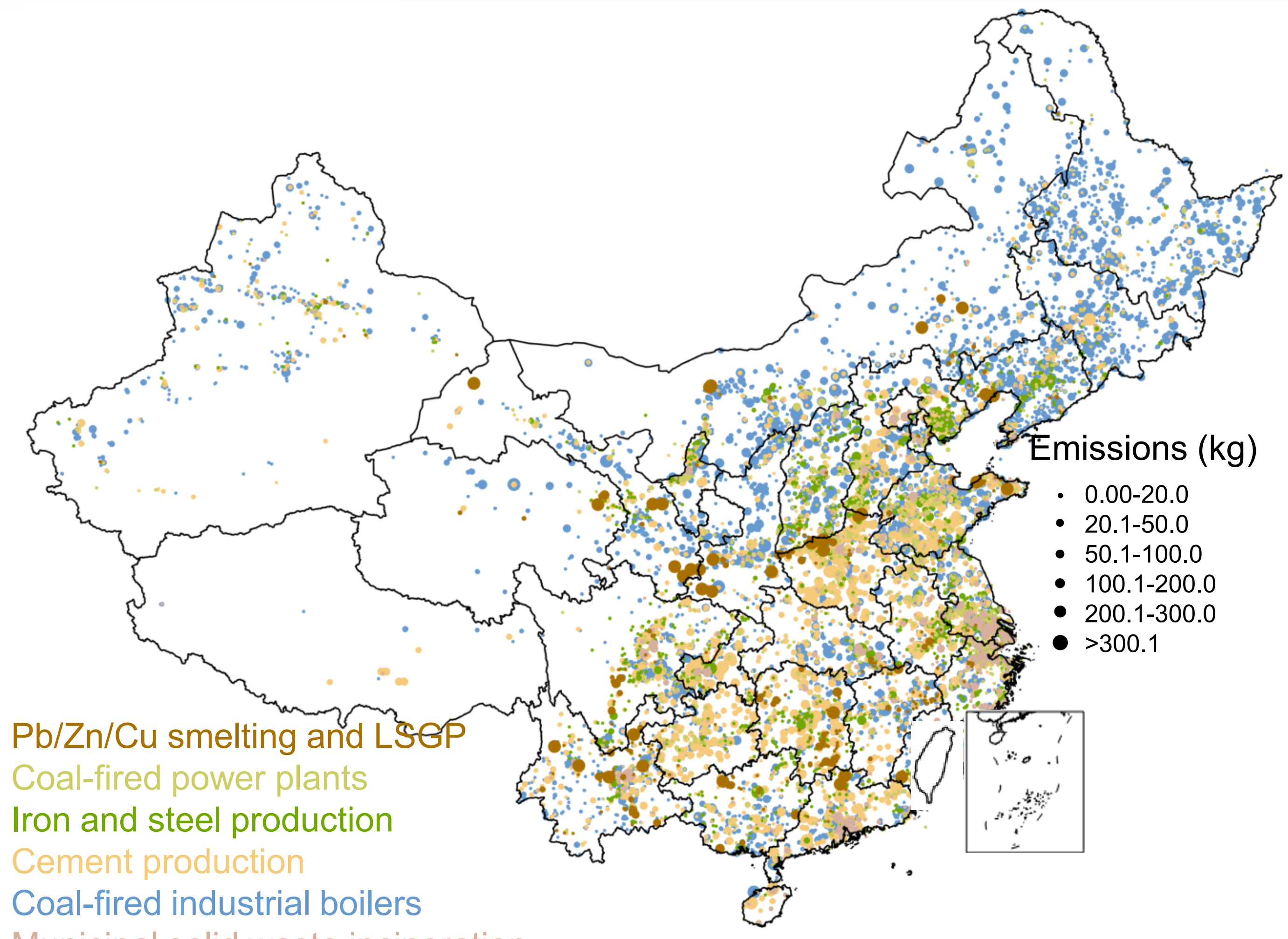
Proxy of interest GDP Population Road

Provincial emission

$$E_{i,j} = [E_{pro}]_i \times \frac{GDP_{\mathrm{m}}}{\sum_{pro} GDP_m} \times \frac{(POP/Road)_j}{\sum_{city}(POP/Road)_j}$$

Grid Sector City/State

Point source emissions in 2021



*The data of Hong Kong, Macau, and Taiwan are not available
LSGP, Large-scale golden production

The inventory includes over 26,000 industrial facilities, accounted for over 85% of emissions at 2021.

- **Spatial distribution:**
  Primarily concentrated in Eastern and Southern China.
- **Emissions magnitude:**
  About 90% of the total emissions were from the top one third large point sources.
  Among the top one third large point sources, 68% were cement clinker production (CEM) facilities.

Gridded emissions during 1978-2021

Phase1: Growth

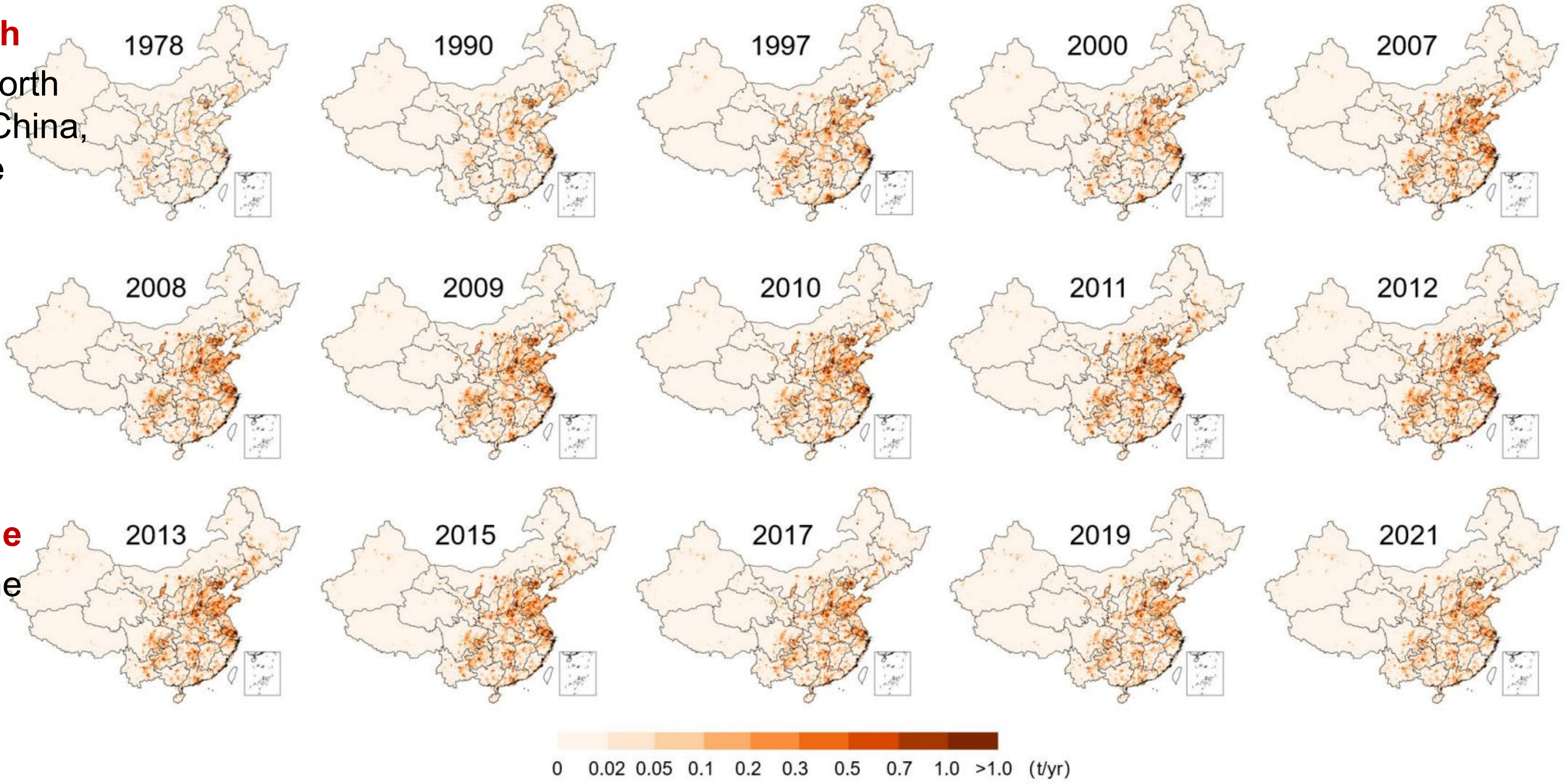
Particularly in North China, Central China, and the Yangtze River Delta

Phase2:

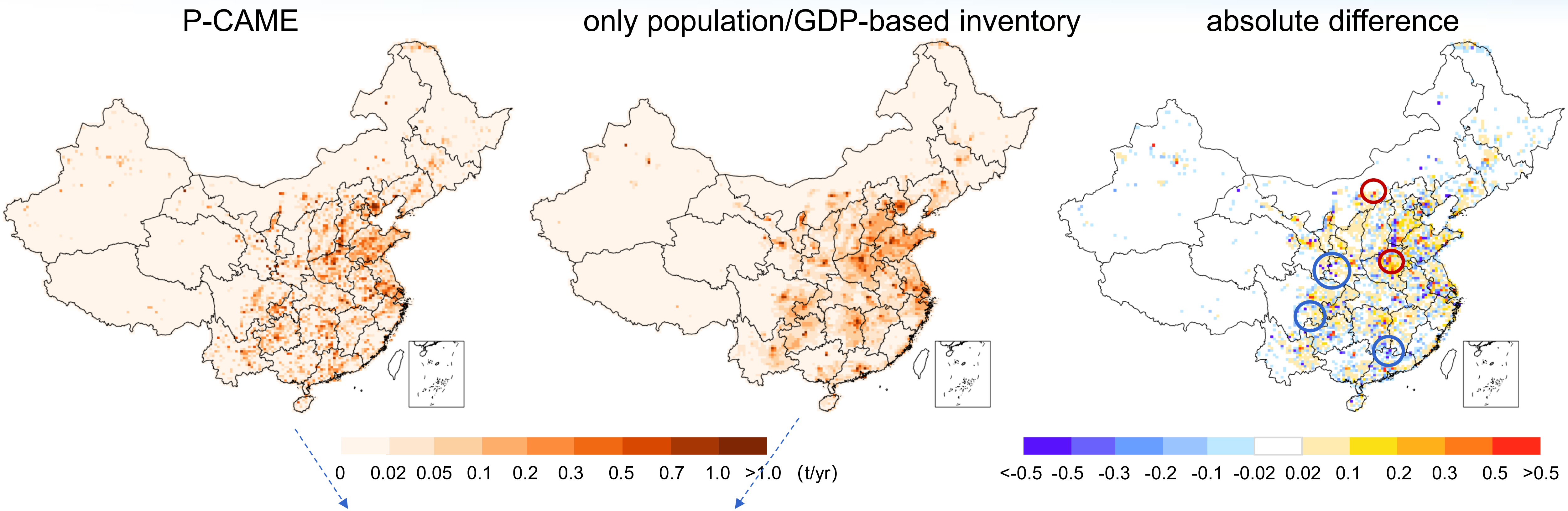
Stabilization

Phase3: Decline

Particularly in the areas similar to phase 1



Improved spatial accuracy

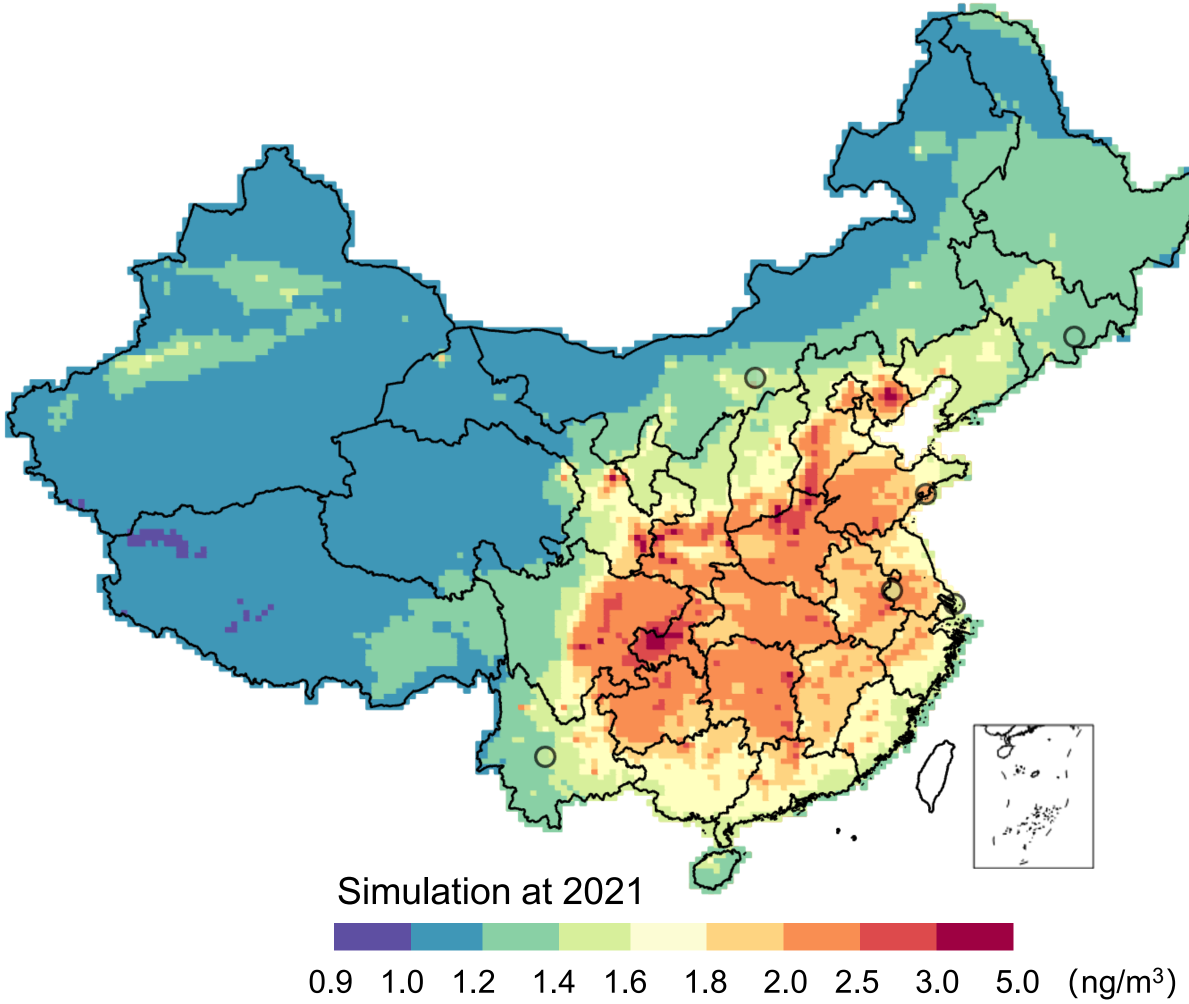


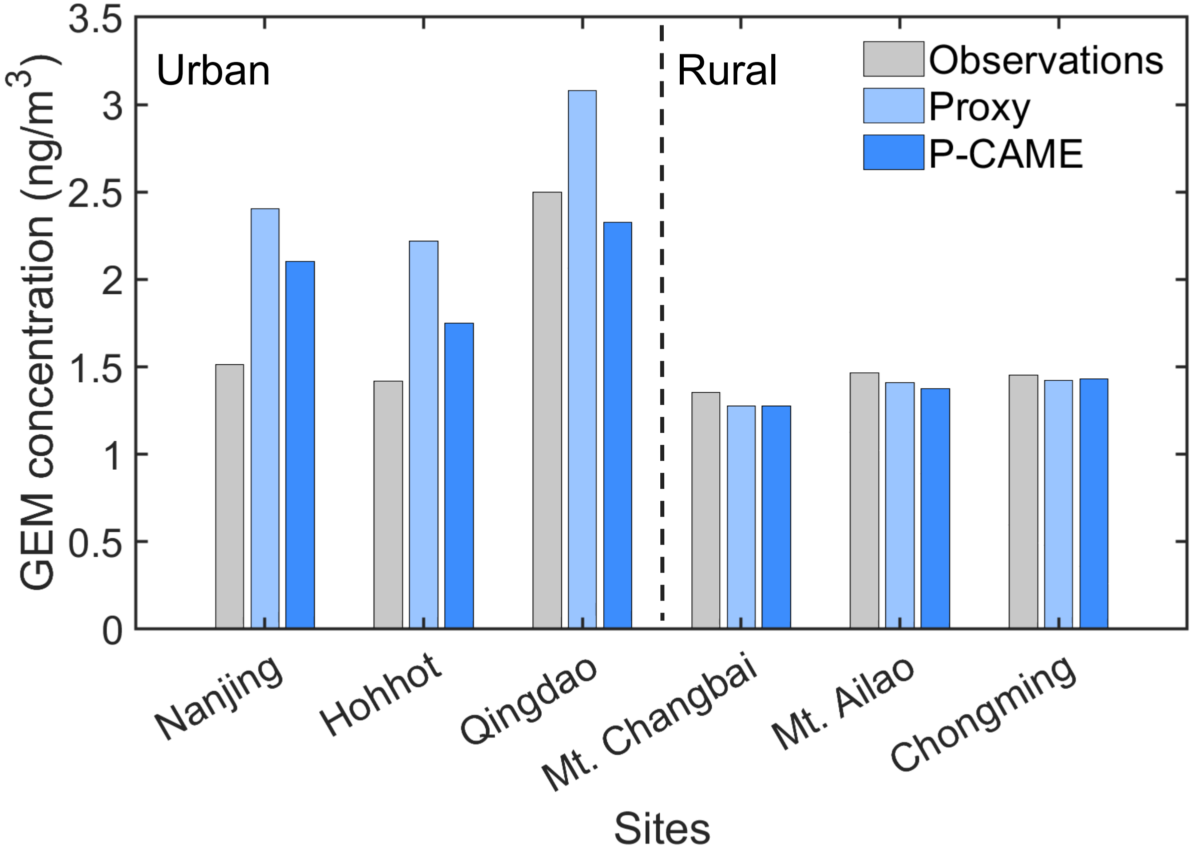
Normalized mean error: 108% ——Proxy methods tend to exhibit distribution bias

- **Overestimate emissions in densely populated areas**, notably in capital cities such as Lanzhou, Xi’an, Kunming, Guizhou and Guangzhou
- **Underestimated emissions in industrial clusters** like Jiaozuo, Baoji, Handan, Tangshan and Chenzhou

Impacts on the simulation of atmospheric Hg

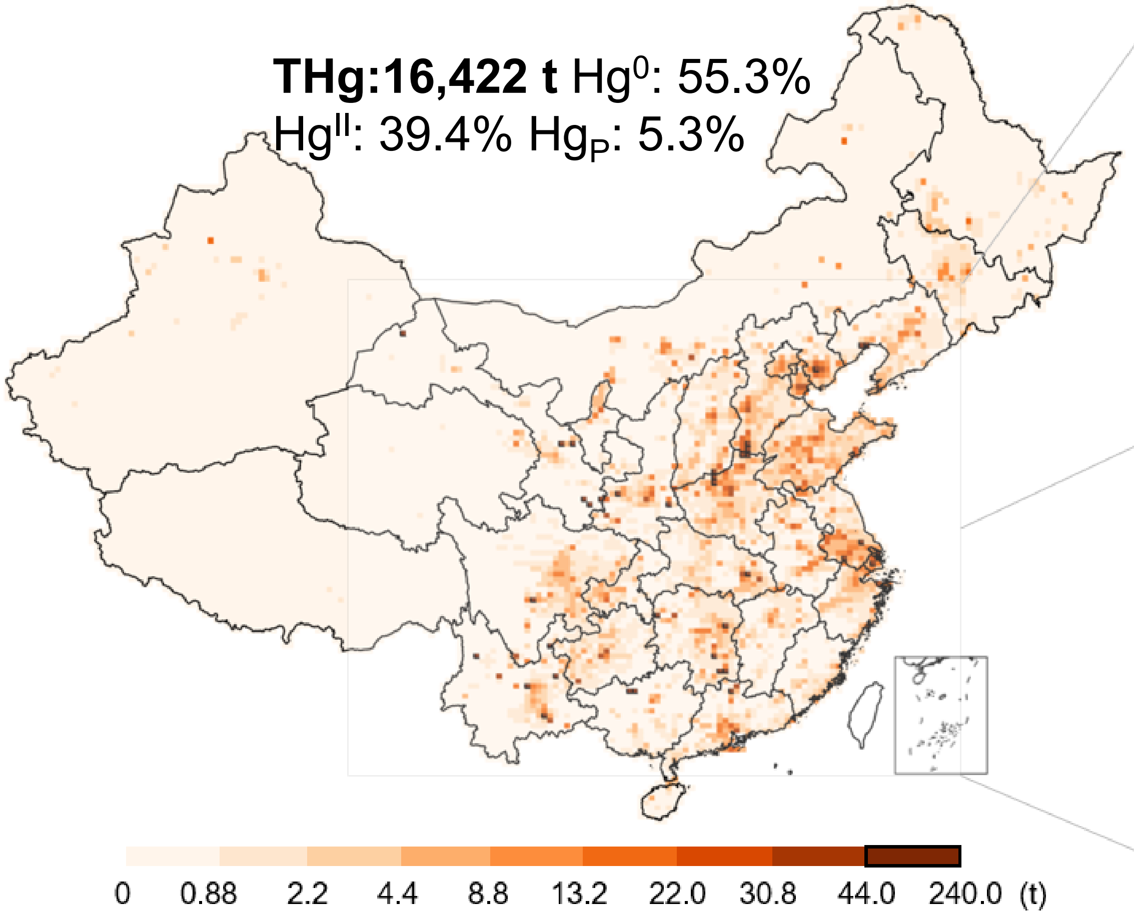
■ P-CAME inventory enhanced the simulation of Hg concentration in urban areas



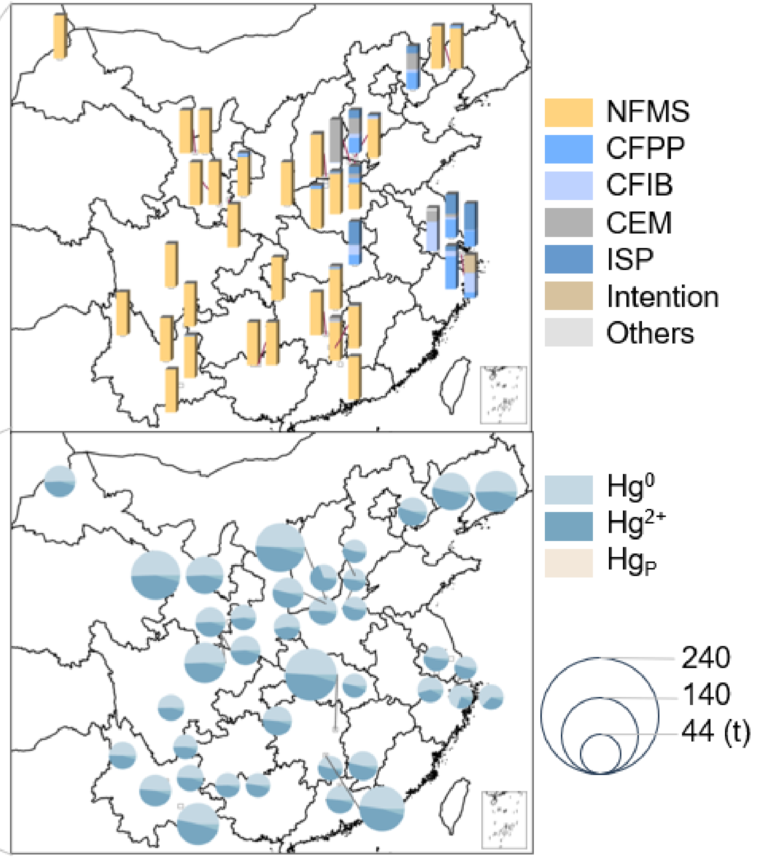


Identifying cumulative emission hotspots

- **Approximately 20% of the total cumulative emissions were from 0.3% of grid**



Spatial distribution of cumulative Hg emissions



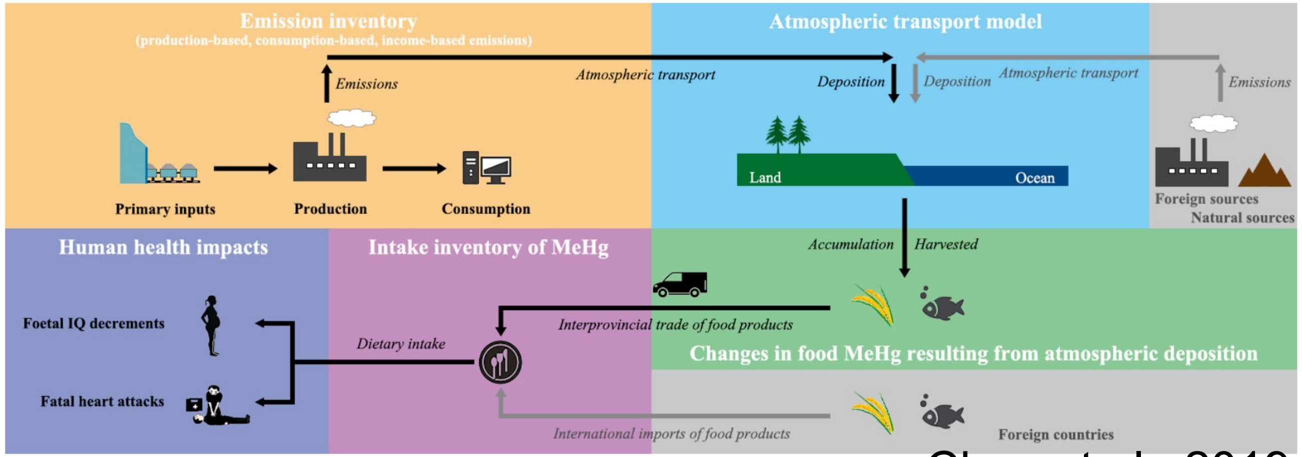
Area with high Hg cumulative emissions was dominated by NFMS. 76% of the total.

These areas also exhibited a significant presence of Hg^{II} and Hg_P, averaging 51%.

May cause severe cross-media mercury pollution

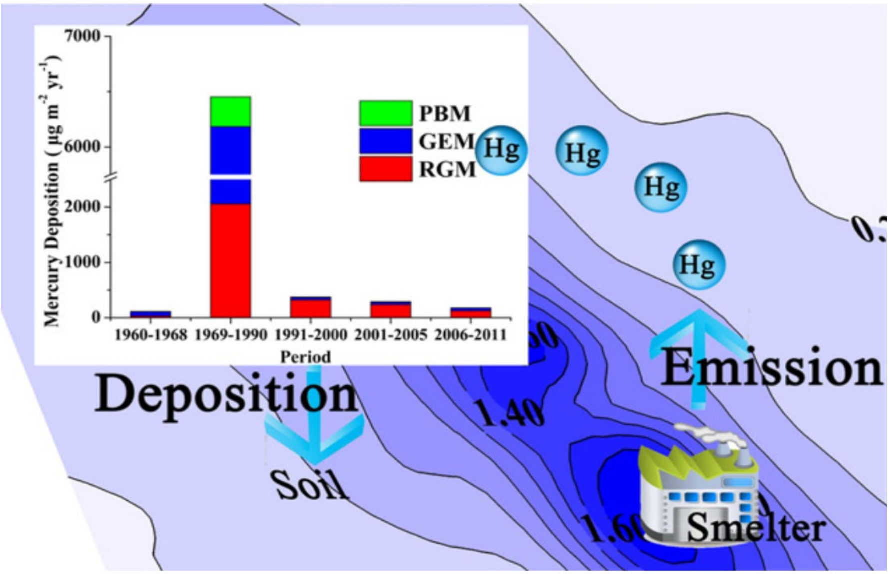
Future application

1. Emission + Earth system model or attribution model



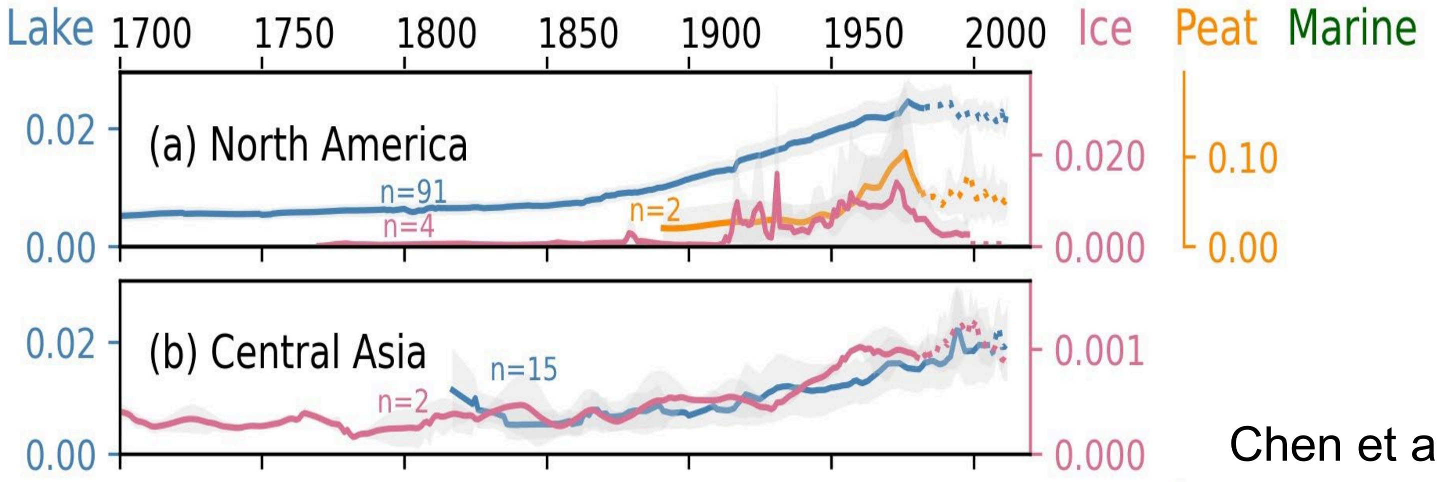
Chen et al., 2019

2. Insight into local cross-media pollution and control



Wu et al., 2014

3. Emission + Environmental Archive + ML/DL



Chen et al., (under review)

Thank you for your attention!

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