Multi-resolution Emission Inventory for China (MEIC):

Introduction and recent improvement

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  What is MEIC?

  How does it work?

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Introduction: Purpose of MEIC model

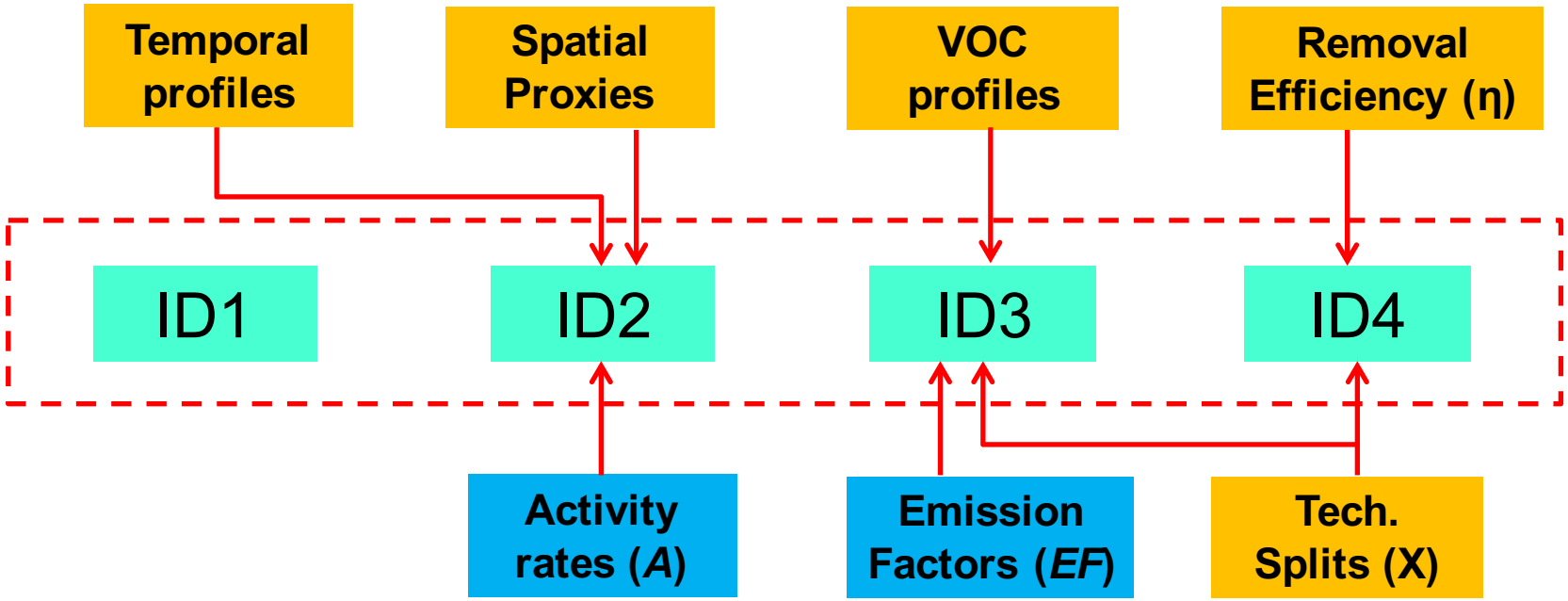
- **Understand magnitudes, trends, and driving forces of anthropogenic emissions in China**
- **Speed up the development process and update inventories timely**
- **Provide an online emissions dataset to the community with constant methodology and underlying data**
- **Support climate and air quality modeling at different spatial resolution and time scale**

Introduction: Emissions data in MEIC database

- Years: 1990-
- Spatial domain: Mainland China
- Categories/Sectors: ~800 anthropogenic sources, aggregated to four sectors (Power, Industry, Residential, Transportation)
- Species: SO2, NOx, CO, NMVOC, NH3, BC, OC, PM2.5, PM10, and CO2
- VOC speciation: ~600 individual species, lumped to five mechanisms (SAPRC99, SAPRC07, CB05, CBIV, and RADM2)
- Spatial resolution: user defined

Work in progress!

Introduction: *Model Framework*



ID1: sectors

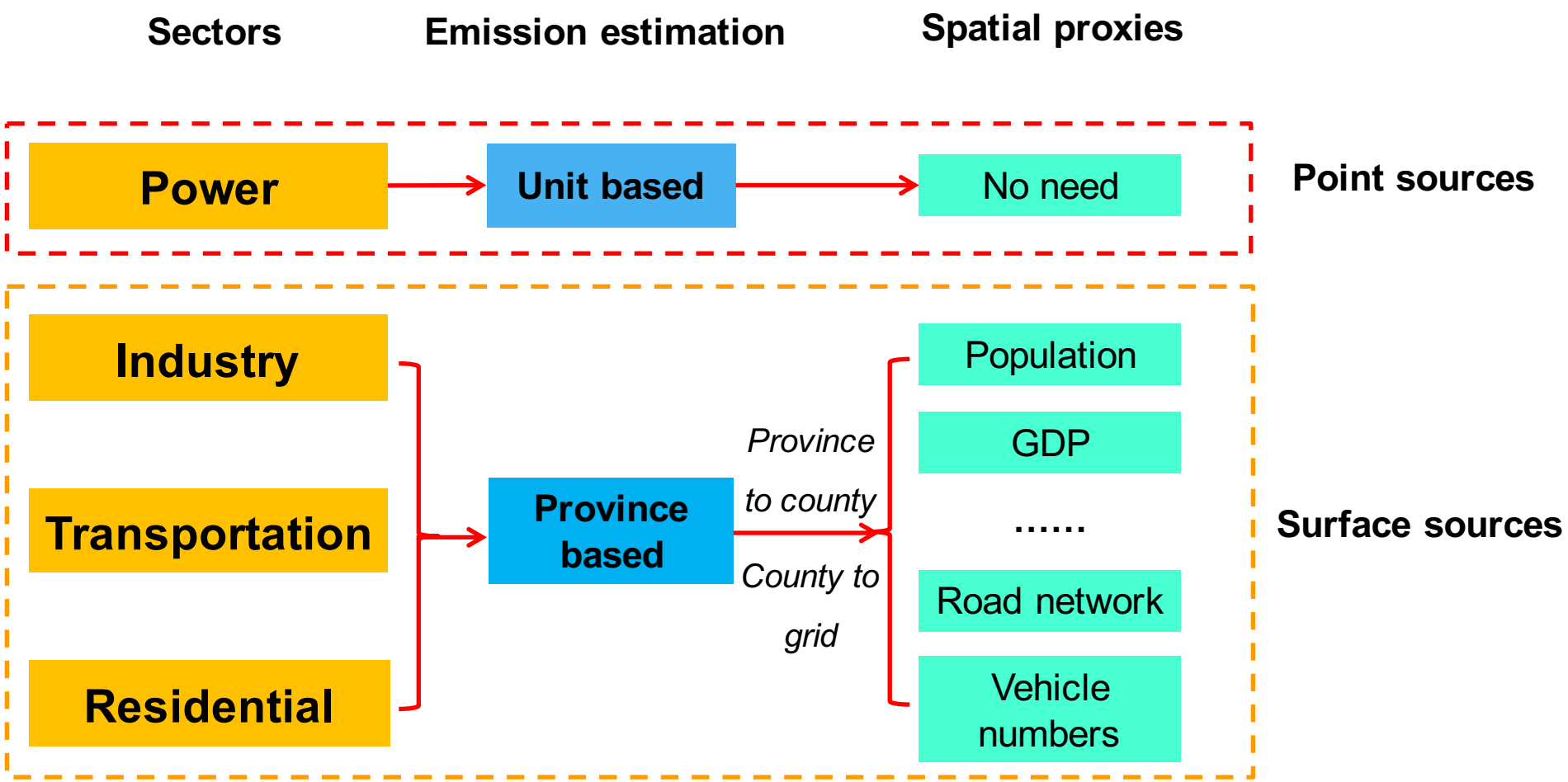
ID2: fuel/product

ID3: technology

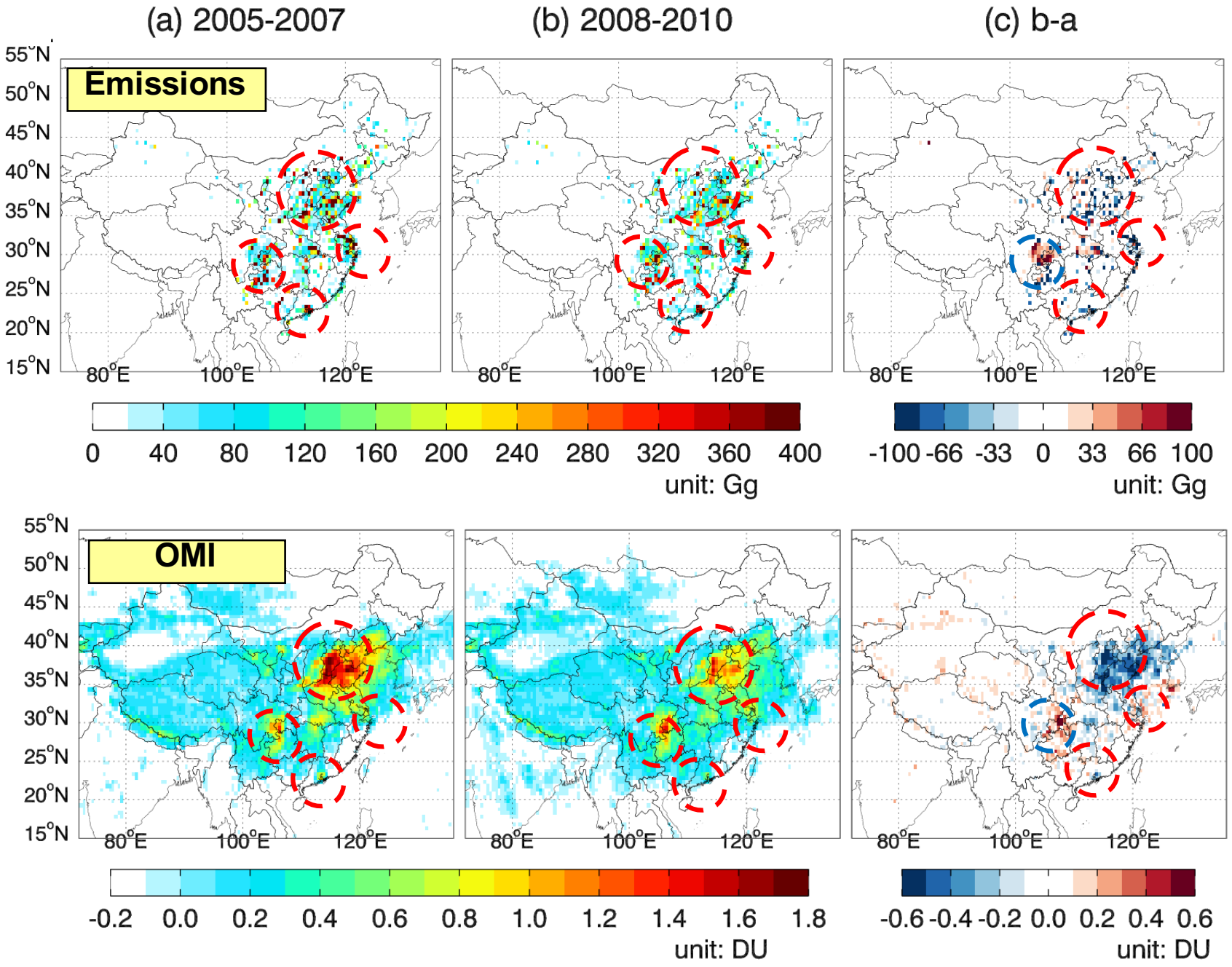
ID4: emission control

$$\text{Emissions} = A \times X \times EF \times (1-\eta)$$

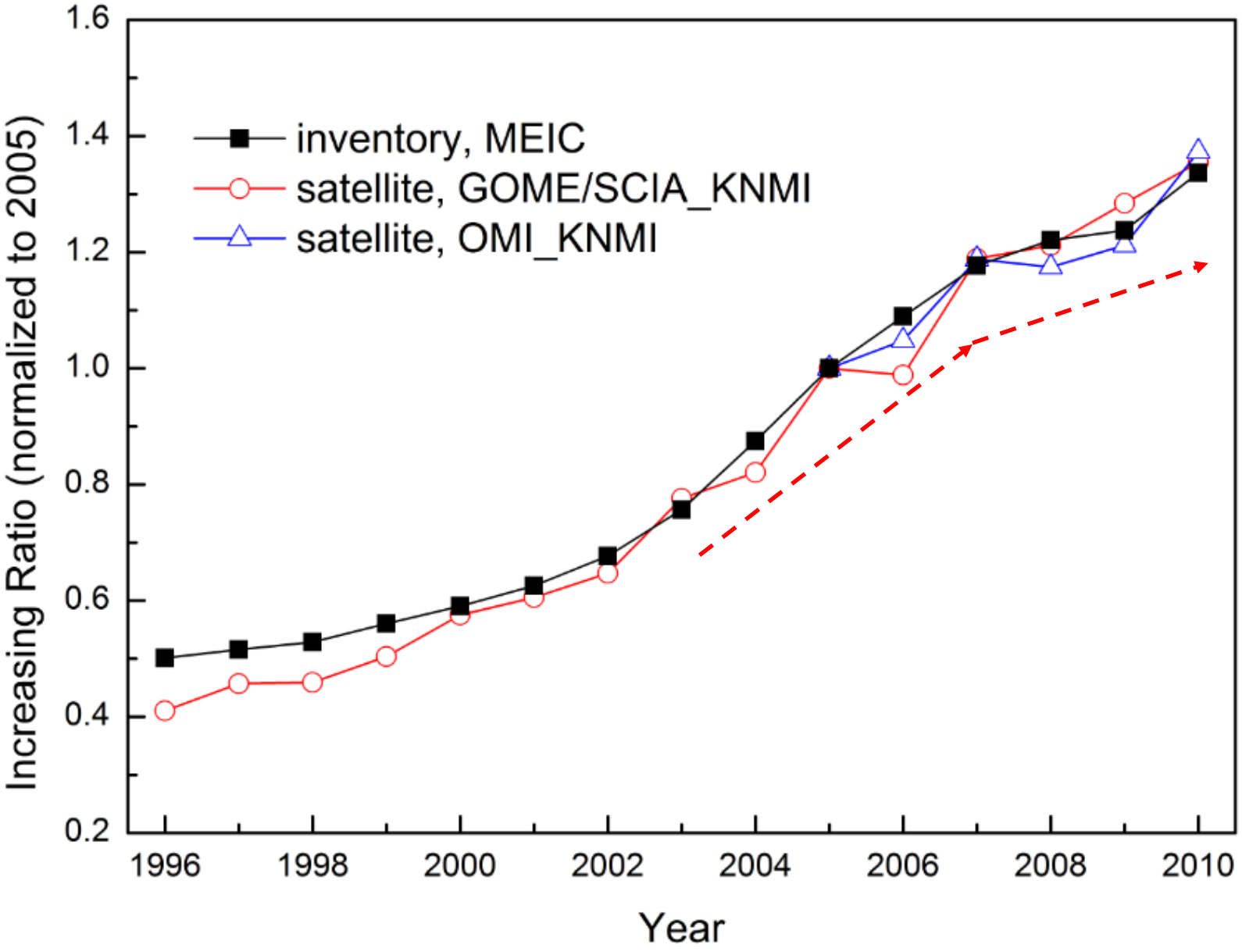
Introduction: Emission estimation & Spatial proxies



OMI proved the decreases of SO_2 over Central Eastern China after 2007

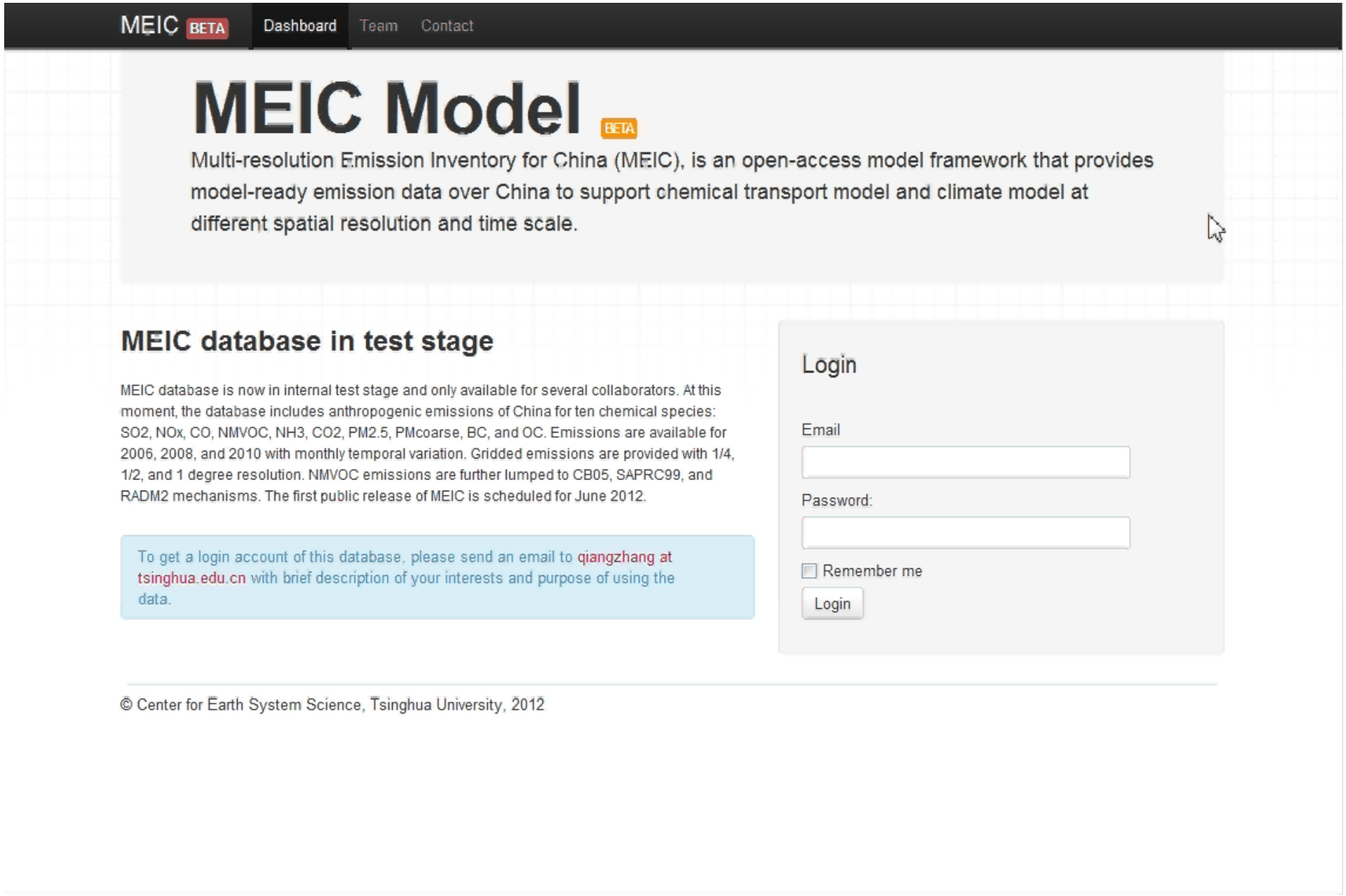


Trend in NO_x emissions from MEIC and NO_2 columns from satellite



Emissions data processed and delivered through an online system

http://www.meicmodel.org



Review: Spatial proxies used in China

- **Review of the spatial proxies used in regional bottom-up emission inventories covering China**

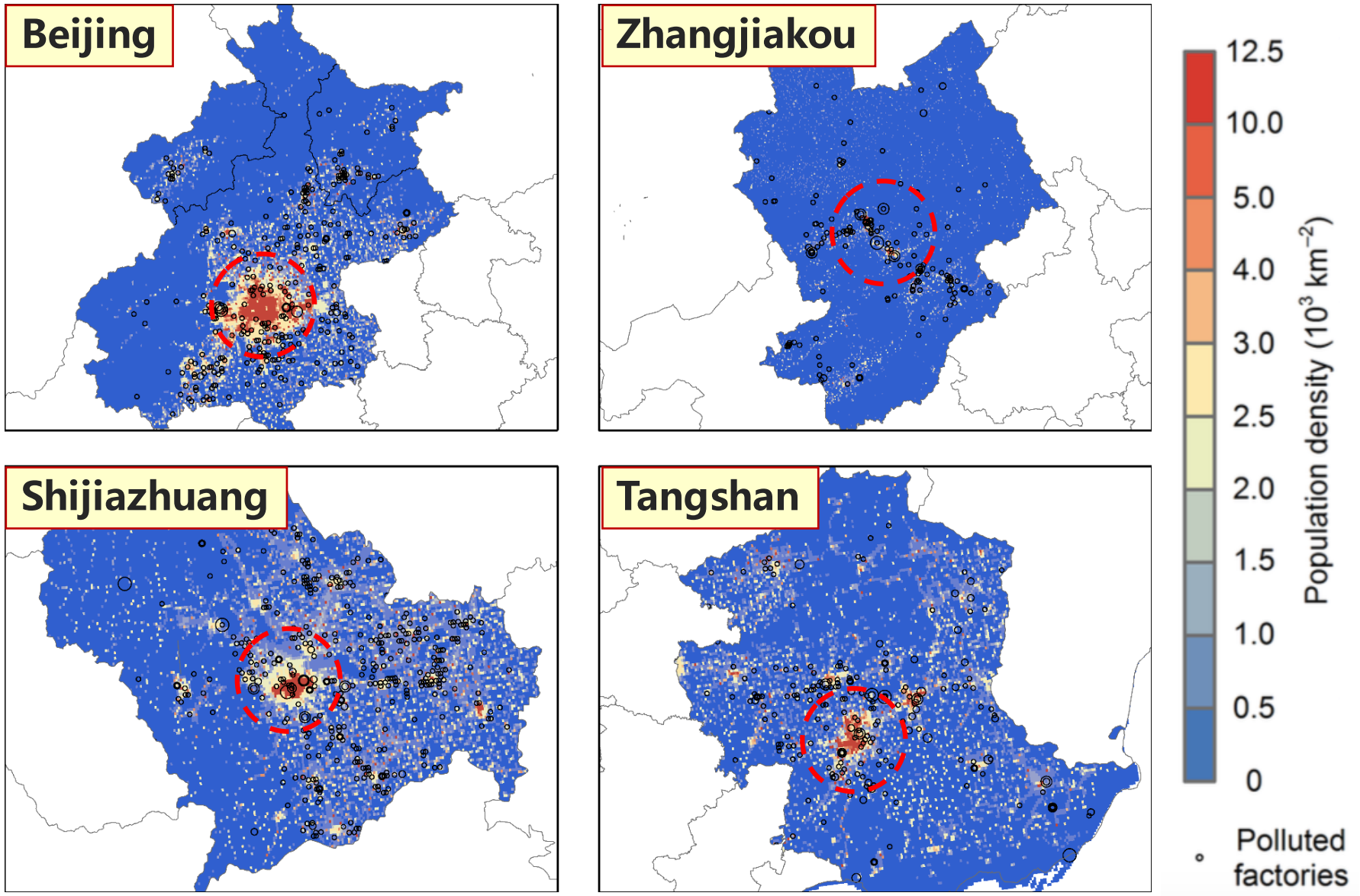
Inventories	Sectors	Spatial proxies	Data sources
TRACE-P (Streets et al., 2003)	Large power plants	Location	RAINS-Asia (Shah et al., 2000) and GEIA inventory (Graedel et al., 1993)
	Small power plants	Total population	LandScan[1]
	Industrial combustion	Total population	LandScan
	Residential fossil fuel	Total population	LandScan
	Residential biofuel	Rural population	LandScan
	On-road transport	Road networks	DCW[2]
	Off-road transport	Total population	LandScan
REAS v.1.1 (Ohara et al., 2007)	Large power plants	Location	China State Grid Company
	Small power plants	Total population	LandScan
	Industrial combustion	Total population	LandScan
	Residential fossil fuel	Total population	LandScan
	Residential biofuel	Rural population	LandScan
	On-road transport	Road networks	DCW
	Off-road transport	Total population	LandScan
REAS v.2 (Kurokawa et al., 2013)	Large power plants	Location	CARMA (Wheeler and Ummel, 2008)
	Small power plants	Total population	GPWv3[3]
	Industrial combustion	Total population	GPWv3
	Residential fossil fuel	Total population	GPWv3
	Residential biofuel	Rural population	GPWv3 and GRUMPv1[4]
	On-road transport	Road networks	DCW
	Off-road transport	Total population	GPWv3
INTEX-B (Zhang et al., 2009)	Large power plants	Location	Ministry of Environmental Protection
	Small power plants	Total population	LandScan
	Industrial combustion	Urban–rural population	LandScan
	Residential fossil fuel	Total population	LandScan
	Residential biofuel	Rural population	LandScan
	On-road transport	Road networks	DCW
	Off-road transport	Total population	LandScan

- **Population (especially total population) is most widely used proxies.**

[1] LandScan Global Population database (ORNL, 1999, 2001, 2006).
[2] DCW, Digital Chart of the World (DMA, 1993).
[3] GPWv3, Gridded Population on the World (CIESIN et al., 2005, 2011).
[4] GRUMPv1, Global Rural-Urban Mapping Project (CIESIN et al., 2005, 2011).

Review: Spatial proxies used in China

- **Population density←→polluted factories distribution: opposite!**



Review: Spatial proxies used in China

- **Spatial proxies used in MEIC**

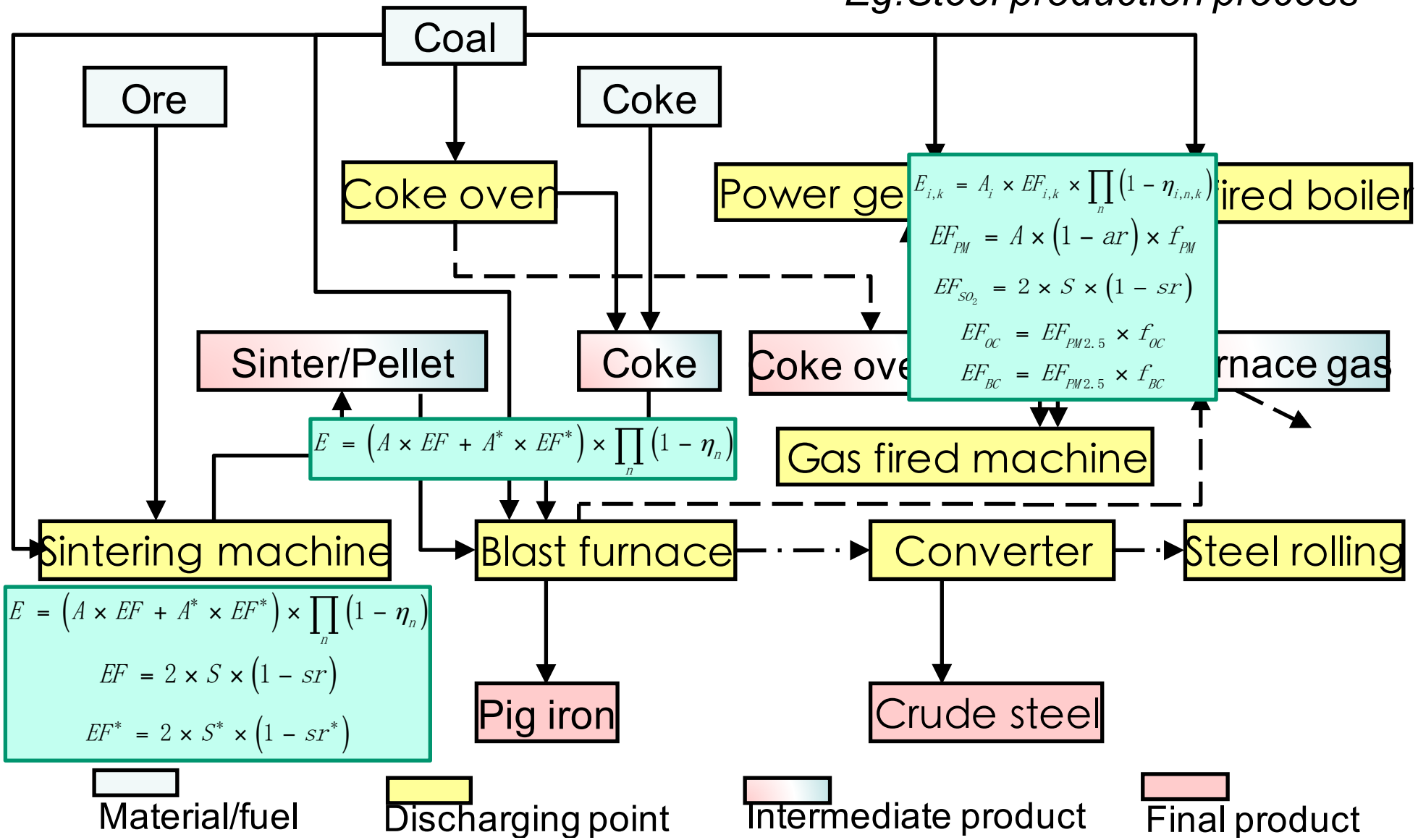
Sector	Subsector	MEIC	
		Province to county	County to grid
Power		Point source	
Industry		Industrial GDP[b]	Urban population[d]
Residential	Urban	Urban population[b]	Urban population[d]
	Rural	Rural population[b]	Rural population[d]
Transportation	On-road[e]	Vehicle numbers	Road network; traffic flow data
	Non-road: agriculture	Machine power[b]	Rural population[d]
	Non-road: construction	Total GDP[b]	Urban population[d]
	Non-road: other source	Total population[b]	Total population[d]
Agriculture	Fertilizer	Fertilizer use[b]	Rural population[d]
	Livestock	Meat consumption[b]	Rural population[d]

[a] The proxies in bold are used in HB-EI and are different from those used in MEIC.
[b] Data source: National Bureau of Statistics (2014).
[c] Data source: statistics from local agencies.
[d] Data source: population data (Oak Ridge National Laboratory, 2013), urban or rural extents (Schneider et al., 2009).
[e] Data source: Zheng et al. (2014).

Recent Improvement: High resolution inventories

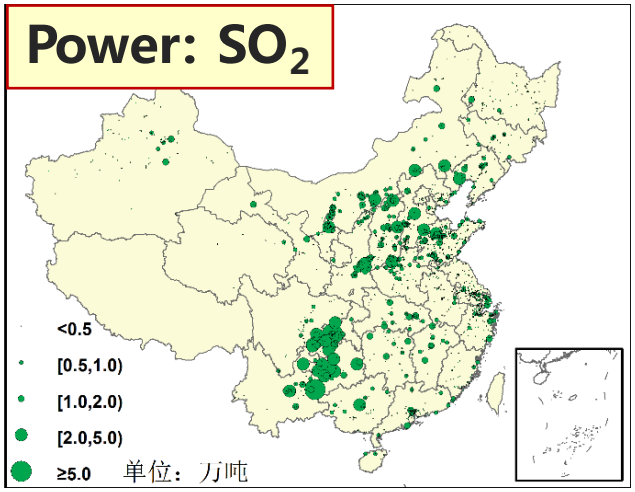
- **Emissions of main sub-sectors in industry sector are estimated based on facility. More point sources!**

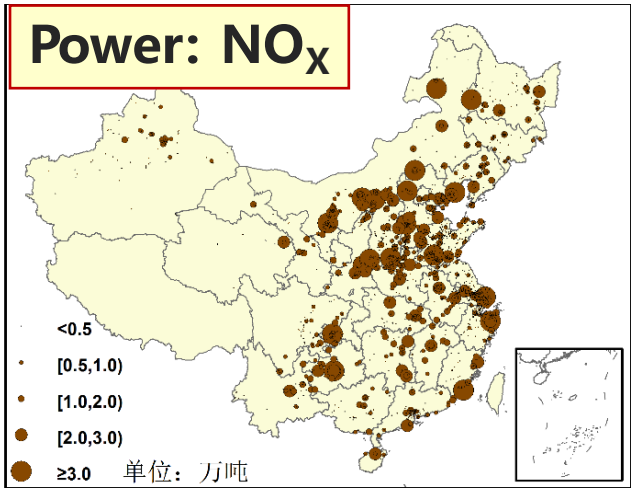
Eg.Steel production process

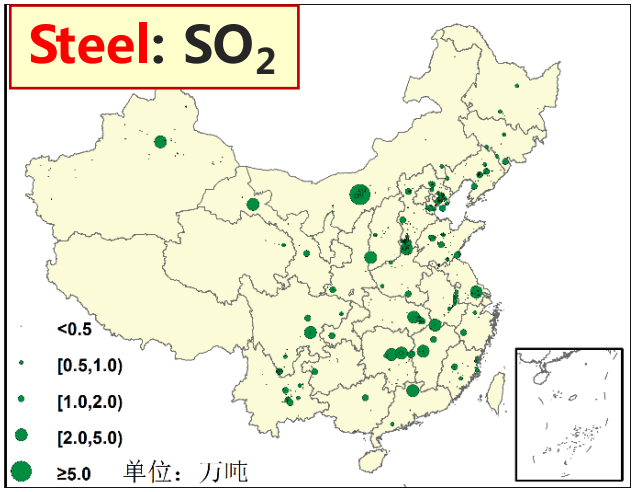


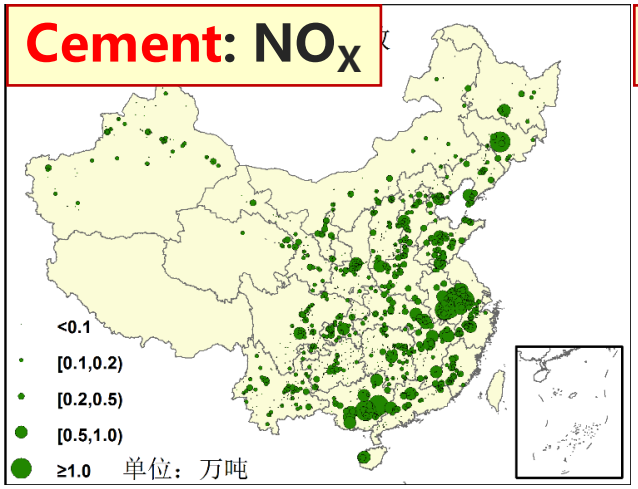
Recent Improvement: High resolution inventories

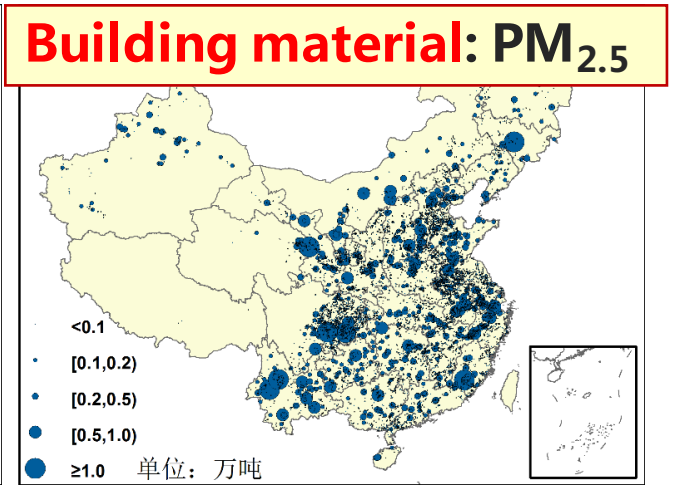
- **Emissions of main sub-sectors in industry sector are estimated based on facility. More point sources!**

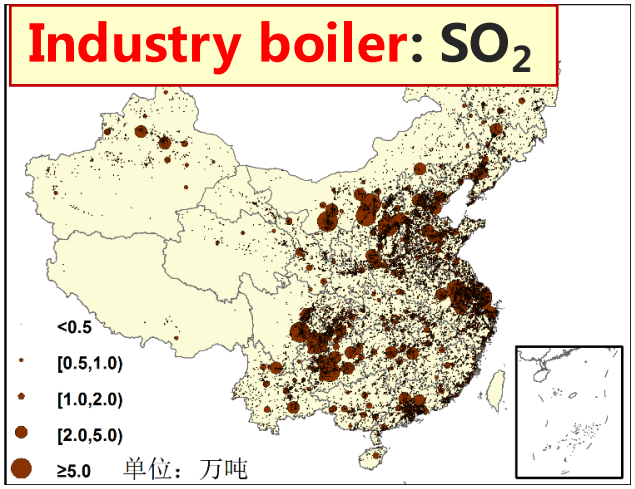








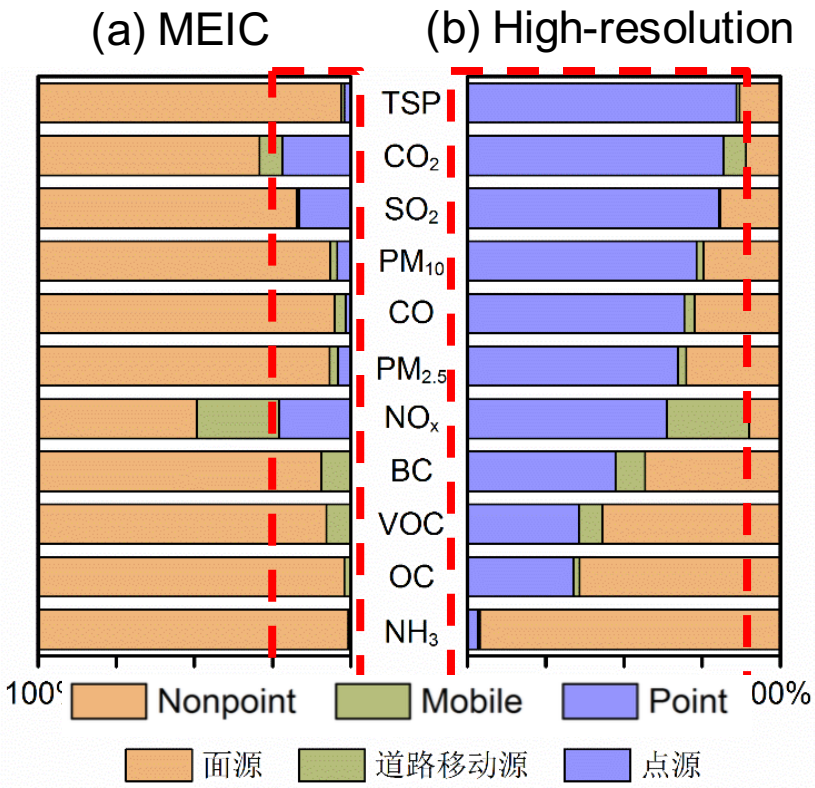




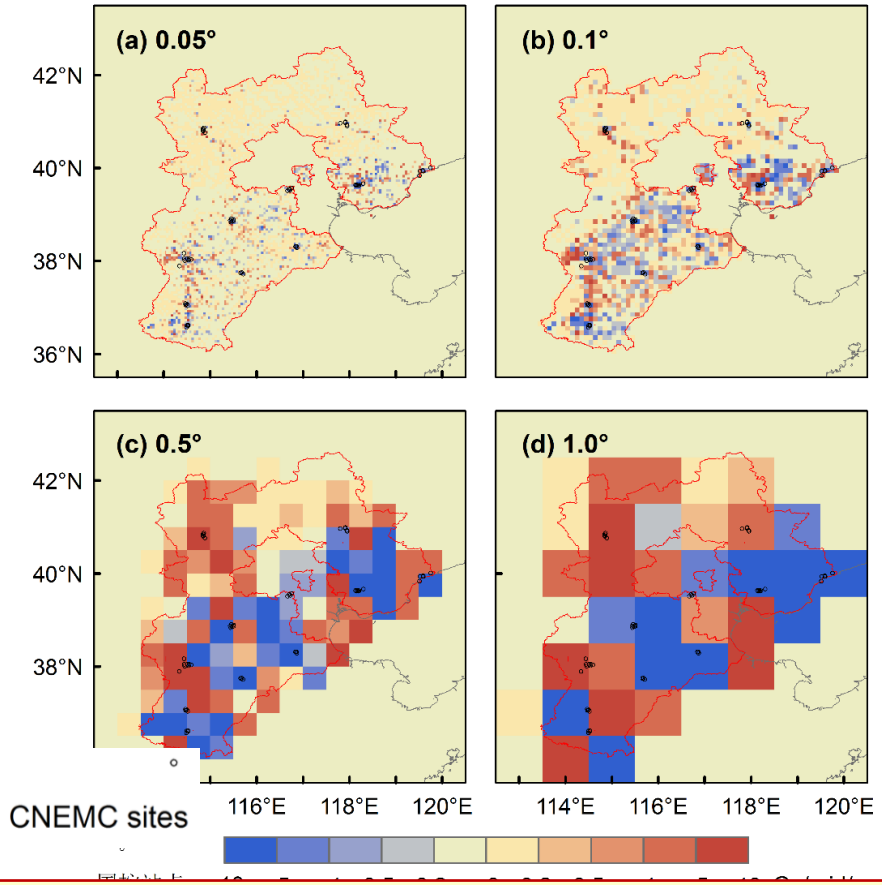
Recent Improvement: High resolution inventories

- **Emissions of main sub-sectors in industry sector are estimated based on facility. More point sources!**

Emission estimation



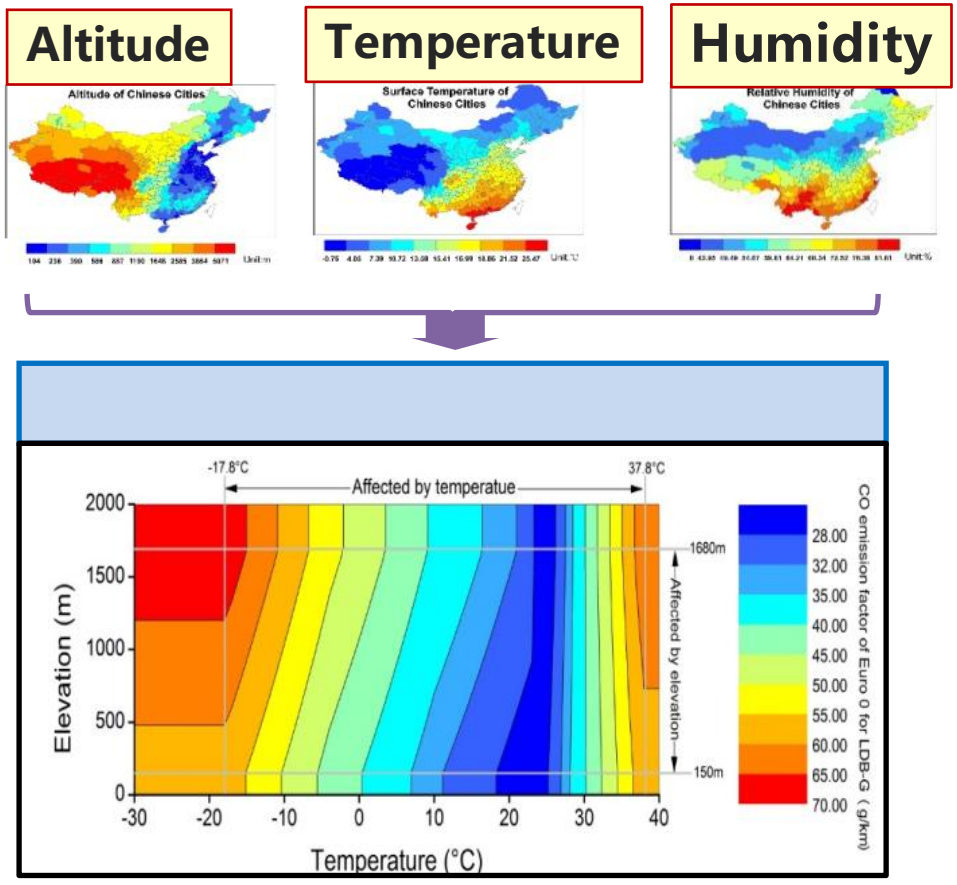
NO_X emission spatial distribution (High resolution-regional)

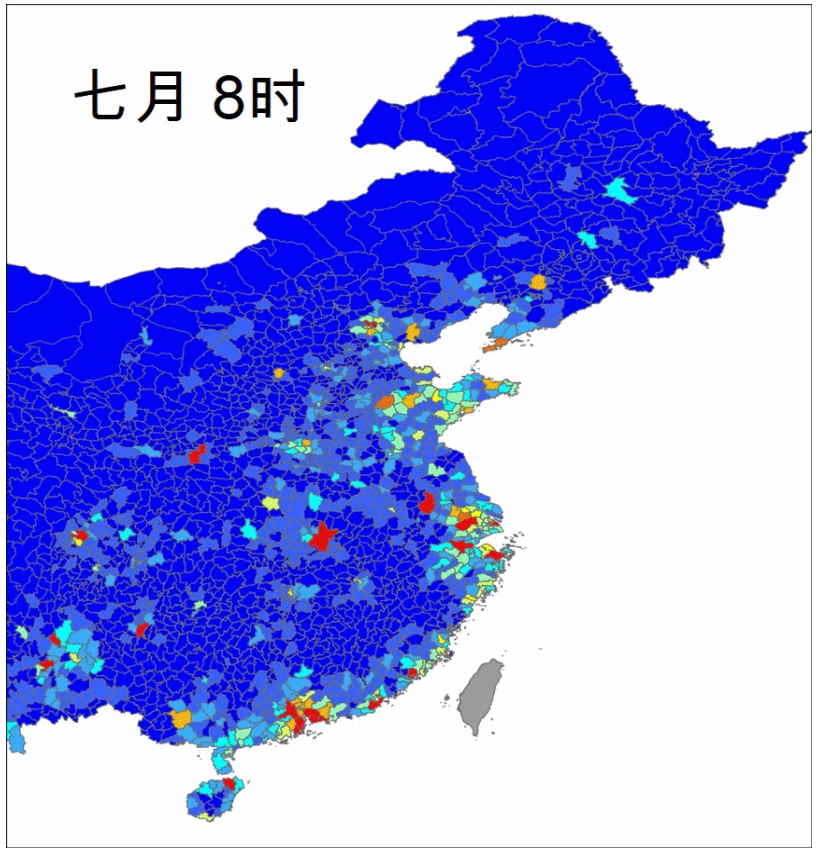


MEIC: overestimate in urban, underestimate in rural

Recent Improvement: High resolution inventories

- **On-road emissions of transportation sector are estimated at county level.**

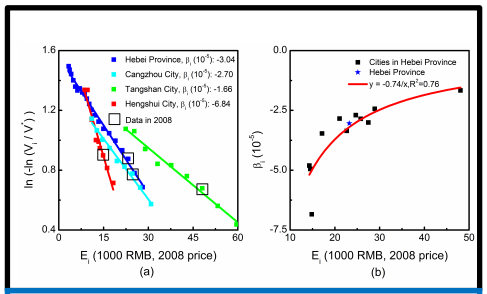




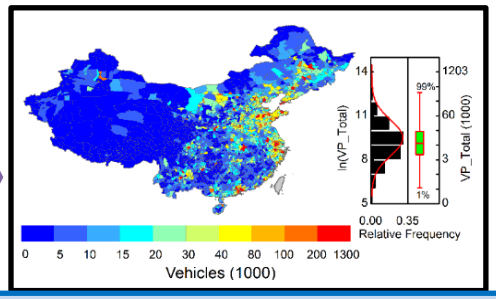
Eg. Environmental compensation factors matrix are built at county level, which can improve the spatial and temporal precision。

Recent Improvement: High resolution inventories

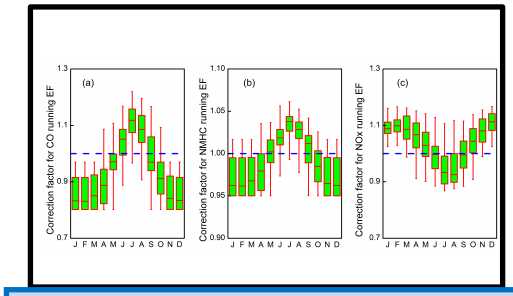
- **On-road emissions of transportation sector are estimated at county level.**



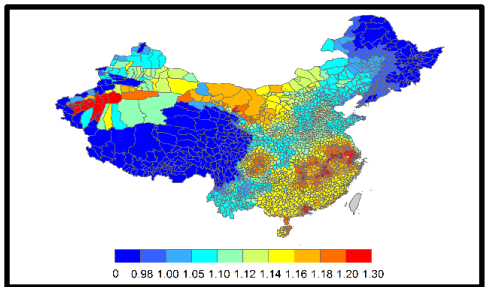
Spatial proxies



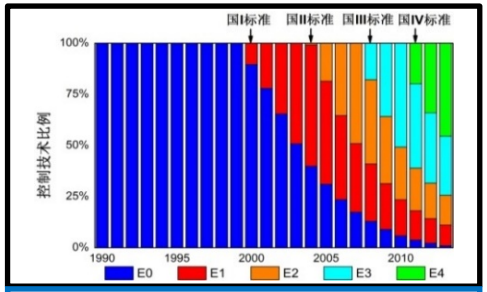
Activity at county level



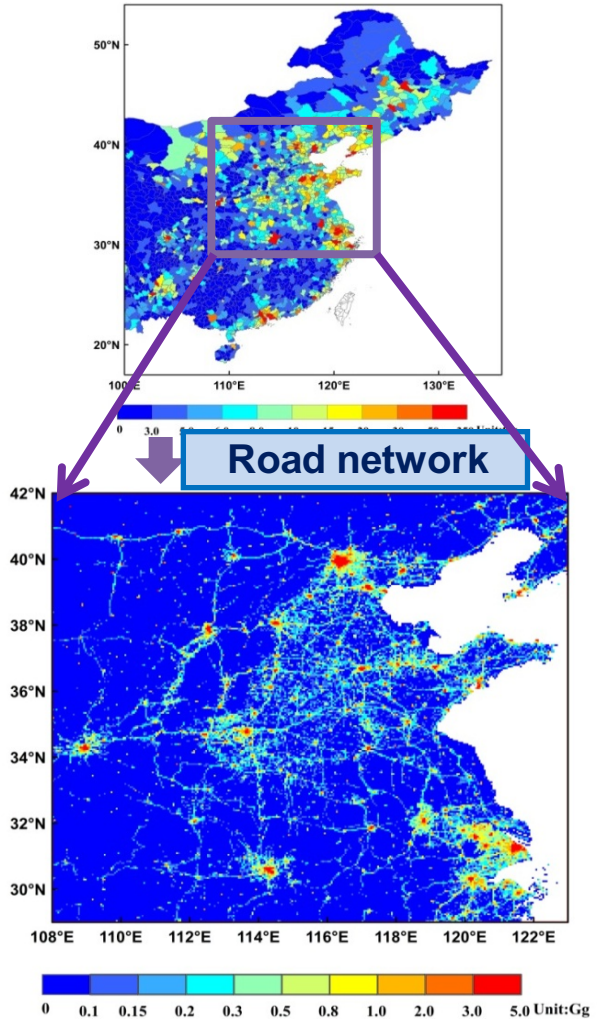
Compensation factors



Emission factor



Emission standards



Recent Improvement: High-resolution inventories

- **Spatial proxies used in MEIC and our new high-resolution inventory for Hebei province, 2013(HB-EI)**

Sector	Subsector	HB-EI		MEIC	
		Province to county	County to grid	Province to county	County to grid
Power		Point source		Point source	
Industry		**Point source**		Industrial GDP[b]	Urban population[d]
Residential	Urban	**Residential coal use[c]**	Urban population[d]	Urban population[b]	Urban population[d]
	Rural	**Residential coal and/or biofuel use[c]**	Rural population[d]	Rural population[b]	Rural population[d]
Transportation	On-road[e]	Vehicle numbers	Road network; traffic flow data	Vehicle numbers	Road network; traffic flow data
	Non-road: agriculture	Machine power[b]	Rural population[d]	Machine power[b]	Rural population[d]
	Non-road: construction	**Construction area[c]**	Urban population[d]	Total GDP[b]	Urban population[d]
	Non-road: other source	Total population[b]	Total population[d]	Total population[b]	Total population[d]
Agriculture	Fertilizer	Fertilizer use[b]	Rural population[d]	Fertilizer use[b]	Rural population[d]
	Livestock	**Livestock amount[c]**	Rural population[d]	Meat consumption[b]	Rural population[d]

[a] The proxies in bold are used in HB-EI and are different from those used in MEIC.
[b] Data source: National Bureau of Statistics (2014).
[c] Data source: statistics from local agencies.
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[e] Data source: Zheng et al. (2014).

Recent Improvement: High-resolution inventories

- **Spatial correlations between gridded emissions of HB-EI and various spatial proxies.**

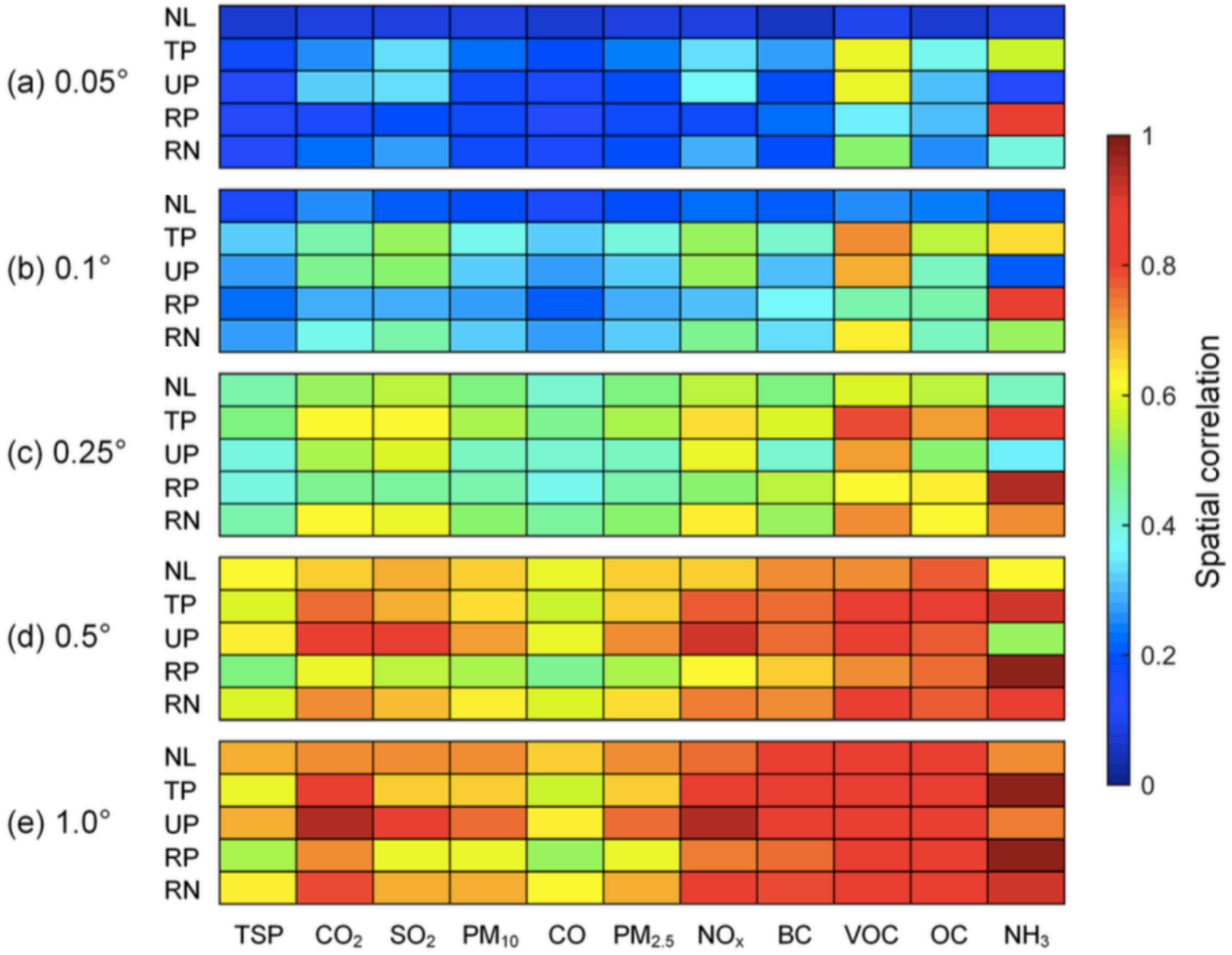
NL: nighttime light

TP: total population

UP: urban population

RP: rural population

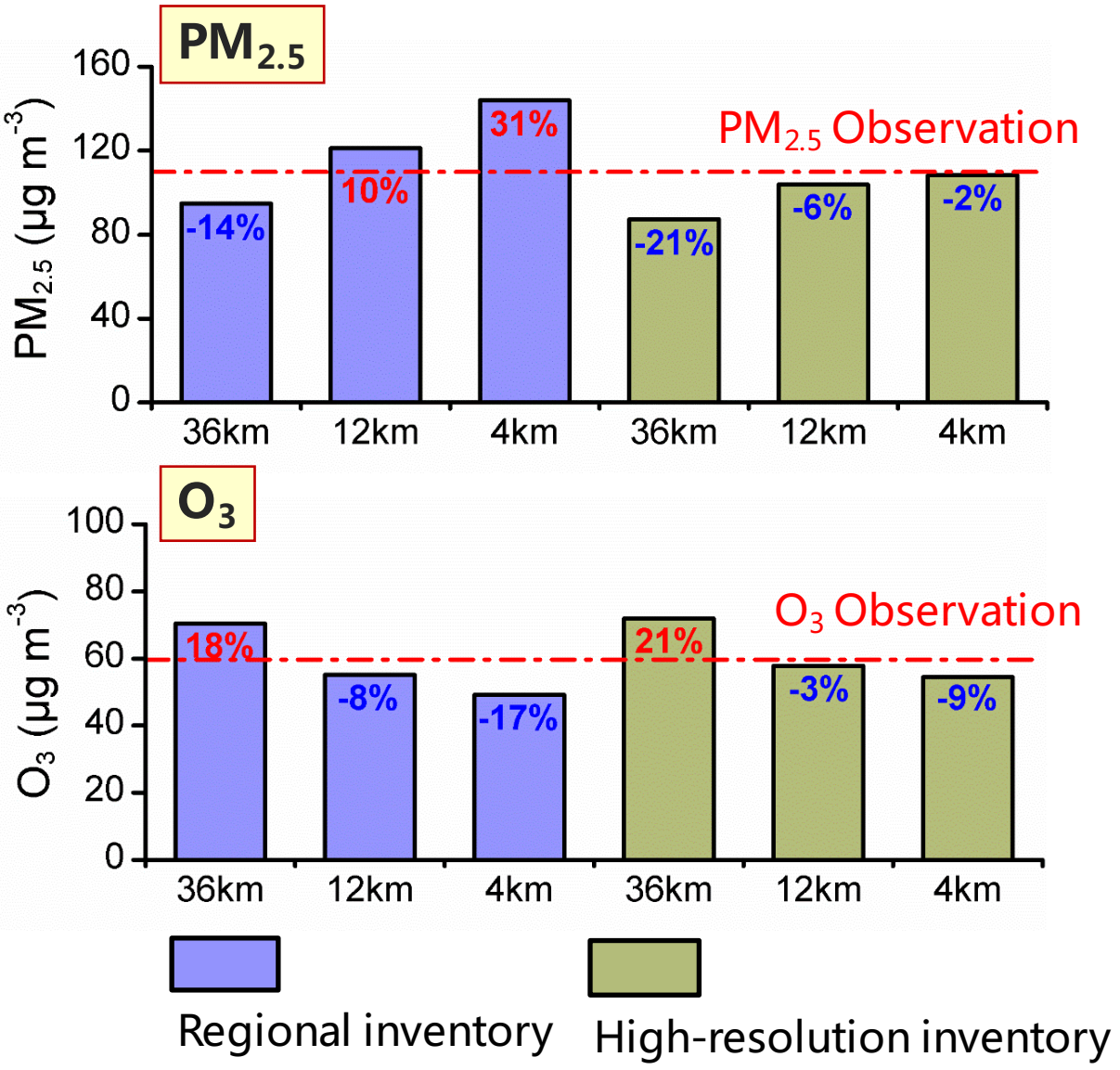
RN: road network



Recent Improvement: High resolution inventories

- **Evaluations against in situ measurements for atmospheric modeling (CMAQ) using MEIC and HB-EI**

- **Resolution: 36km(region scale)→4km(city scale), the simulation bias with regional inventory increases, but decreases with high resolution inventory.**
- **At 4km, using high resolution inventory can can shorten the $PM_{2.5}$ simulation bias from 31% to -2% ; O_3 from -17% to -9%。**



Thanks for your attention!