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Land Use/Cover Changes, Environment and Emissions in South/Southeast Asia – An International Regional Science Meeting

Historical Analysis and Inverse Modeling of Air Pollutants Emissions in Asia

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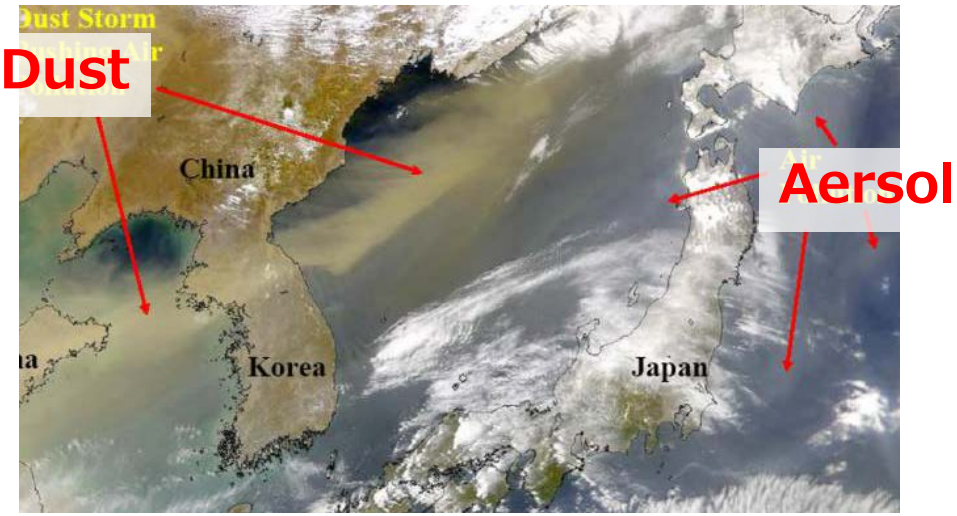
Today's talk

1. **Background and aim**
2. Historical emission inventory in Asia and emission control policy's effects
3. Recent change of NOx emissions by integrated analysis of bottom-up and top-down approaches
4. Summary

Air pollution in Asia



In Asia, huge amount of air pollutants are emitted from many kinds of emission sources. These pollutants causes severe air pollution such as $PM_{2.5}$ and tropospheric ozone in urban, regional, global scale.

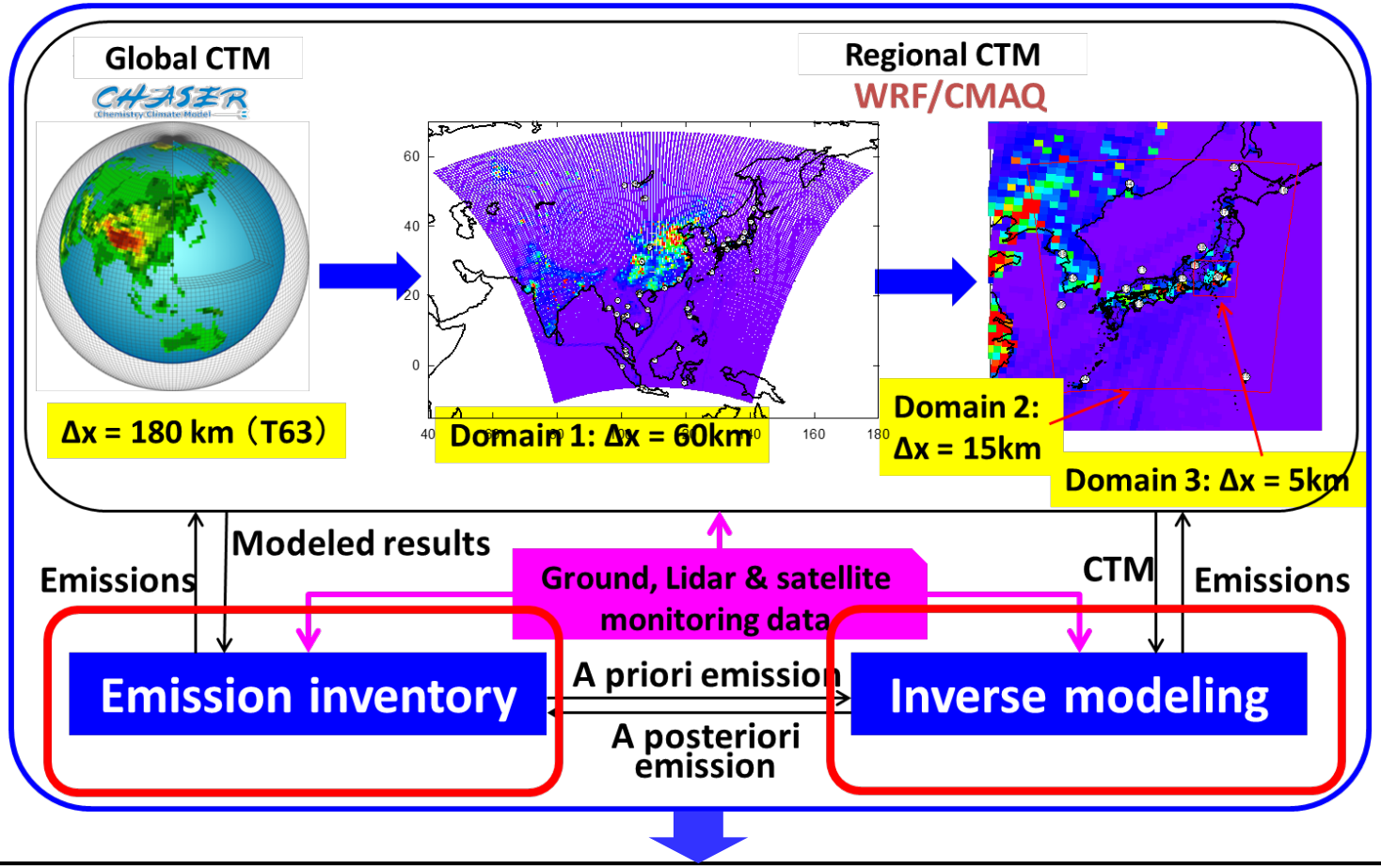
Background

- ✓Air pollutants emissions in Asia are still increasing in marked contrast with Europe and USA.

- ✓However, the trend is drastically changing due to the variation in socio-economic activity and the implementation of emission control. Hence, **the continuous and quick updating of emission inventory is needed** in Asia.

- ✓In addition, a **clear demonstration of the efficacy of atmospheric environmental measures is important** for further implementation of policies through evidence-based policy making (EBPM).

Integrated system for assessment and analysis of regional air quality changes in Asia



- ✓ Rapid monitoring of emission changes: Continuous and quick updating of emission inventory
- ✓ Quantifying evaluation of emissions reduction and air quality improvements due to policy implementation

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Regional Emission inventory in ASia (REAS)

✓ Anthropogenic, comprehensive, and historical inventory

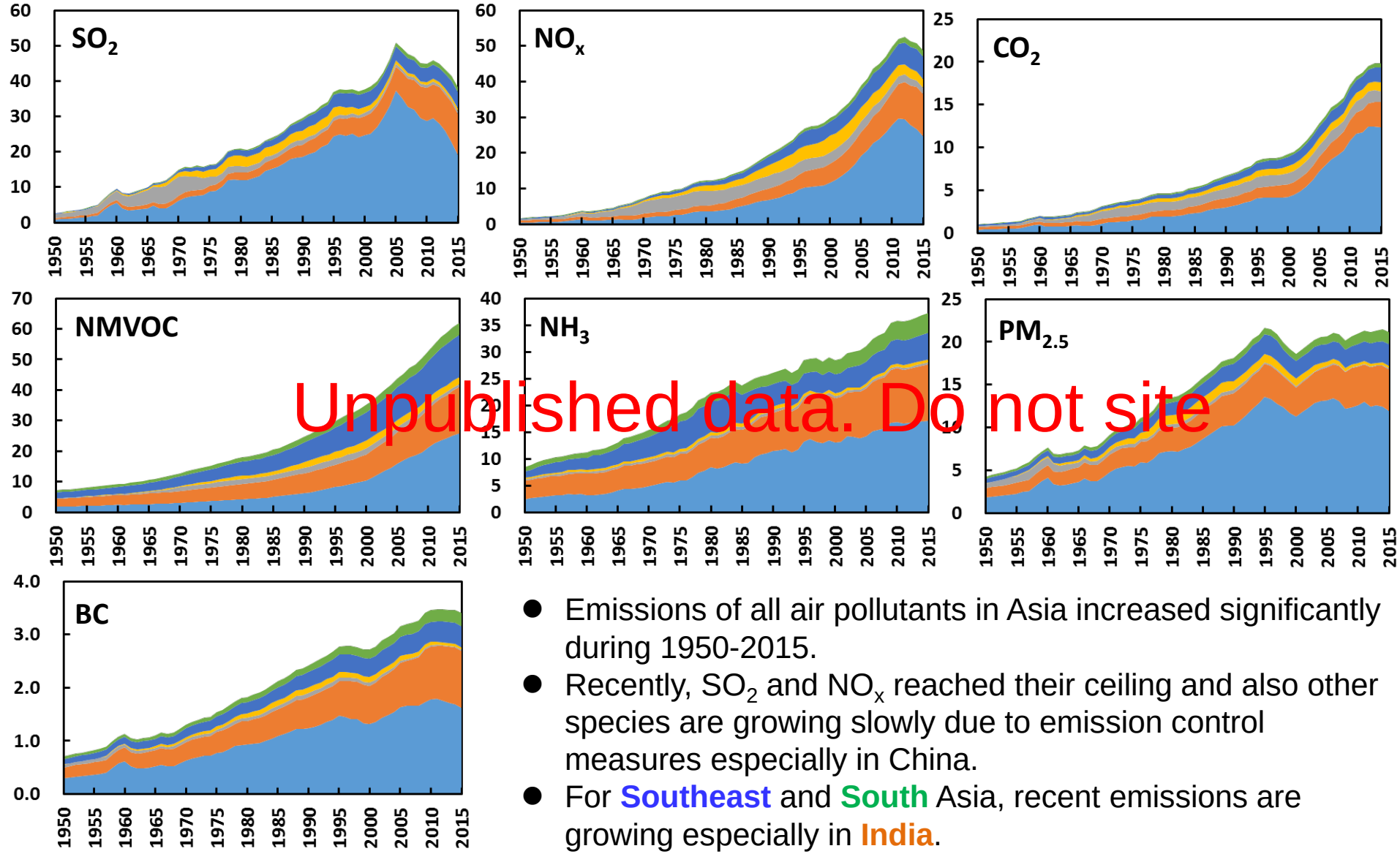
✓ Updated from v.2.1 to v.3

- **Country and regional emissions for detailed sources**
- **Gridded emissions for major sources**
- **Target Years：1950-2015**
- **Target Areas：East, Southeast, and South Asia**
- **Horizontal Resolution：0.25° × 0. 25°**
- **Temporal Resolution：Monthly**
- **Target Species：**

  SO_2, NO_x, CO, NMVOC, PM_{10}, $PM_{2.5}$, BC, OC, NH_3, and CO_2

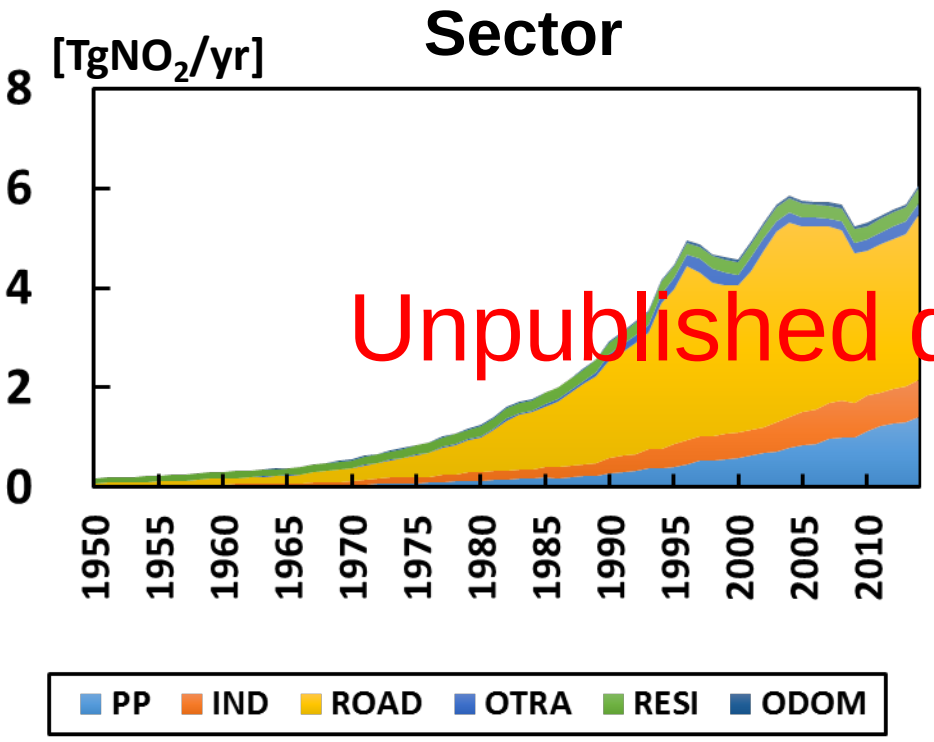
	SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$	BC	OC	NMV	NH_3	CO_2
Combustion	●	●	●	●	●	●	●	●	●	●
Industrial Process	●		●	●	●	●	●	●	●	●
Agriculture		●							●	
Others								●	●	

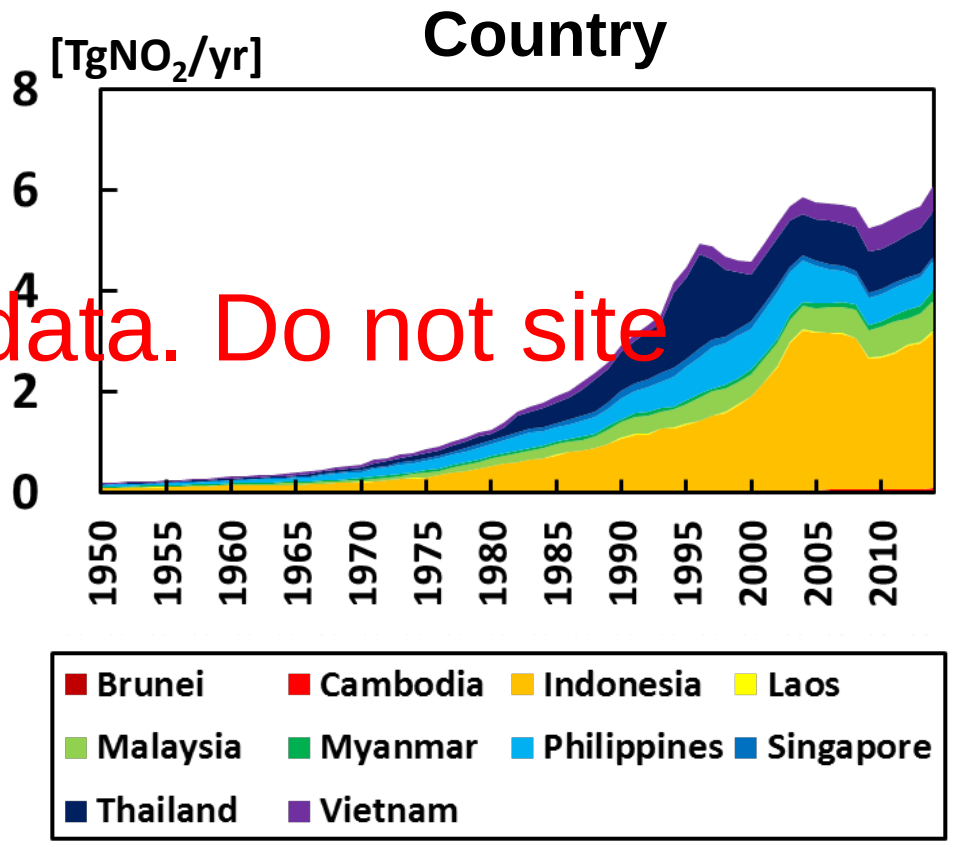
Historical emissions in Asia (unit: Mt/year)



- Emissions of all air pollutants in Asia increased significantly during 1950-2015.
- Recently, SO_2 and NO_x reached their ceiling and also other species are growing slowly due to emission control measures especially in China.
- For **Southeast** and **South** Asia, recent emissions are growing especially in **India**.

NOx emissions in Southeast Asia (by sector & country)





Unpublished data. Do not site

- Major sources was road transport. Recently, emissions from coal combustion in power and industry are increasing.
- For countries, the largest contributor for emissions is **Indonesia** followed by **Thailand**, **Philippines**, **Vietnam**, and **Malaysia**.
- **REAS has large uncertainty**.

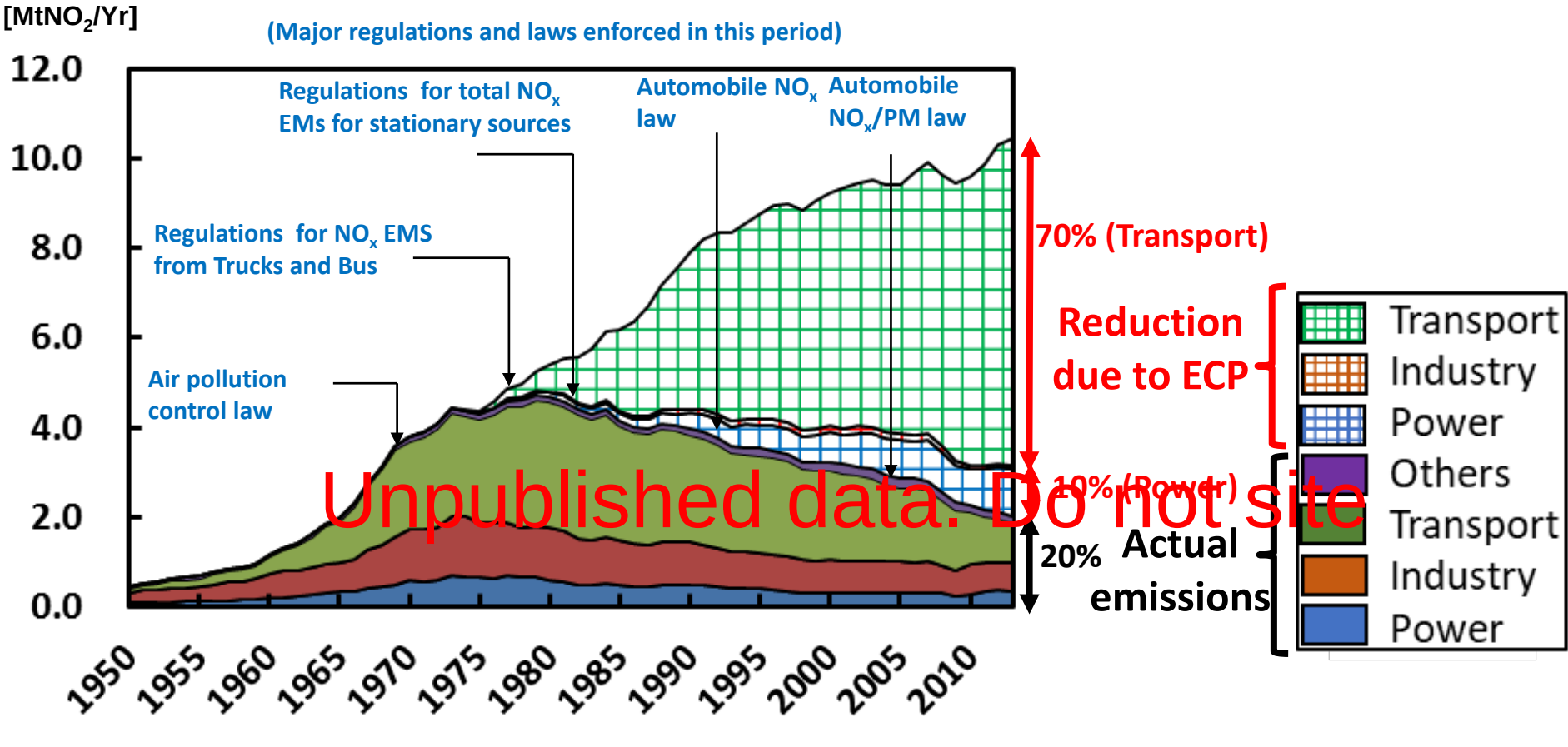
How to estimate the emission reduction due to emission control policy (ECP)

Emission reduction due to ECP
= (W/O ECP case) - (With ECP case)

Emission = Activity data × Emission factor (EF)

- ✓ Emissions in the W/O ECP case (With ECP case) were estimated by using unregulated EF (regulated EF).
- ✓ Activity data were fixed. This means that the countermeasures related to the activity (such as save energy, energy conversion and scrap of old facilities) were not a target in this estimation.

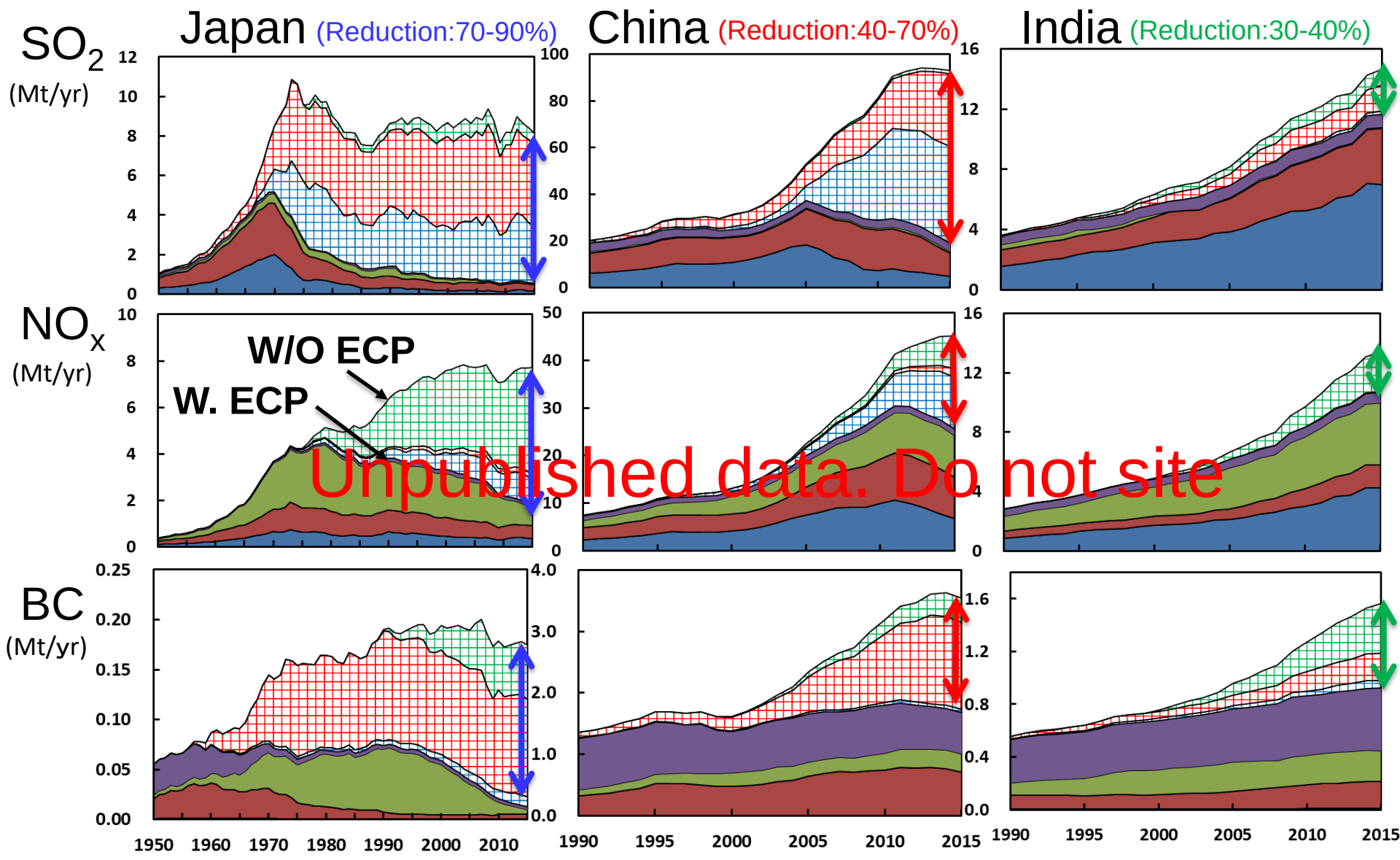
NO_x reduction due to emission control policy (ECP) in Japan



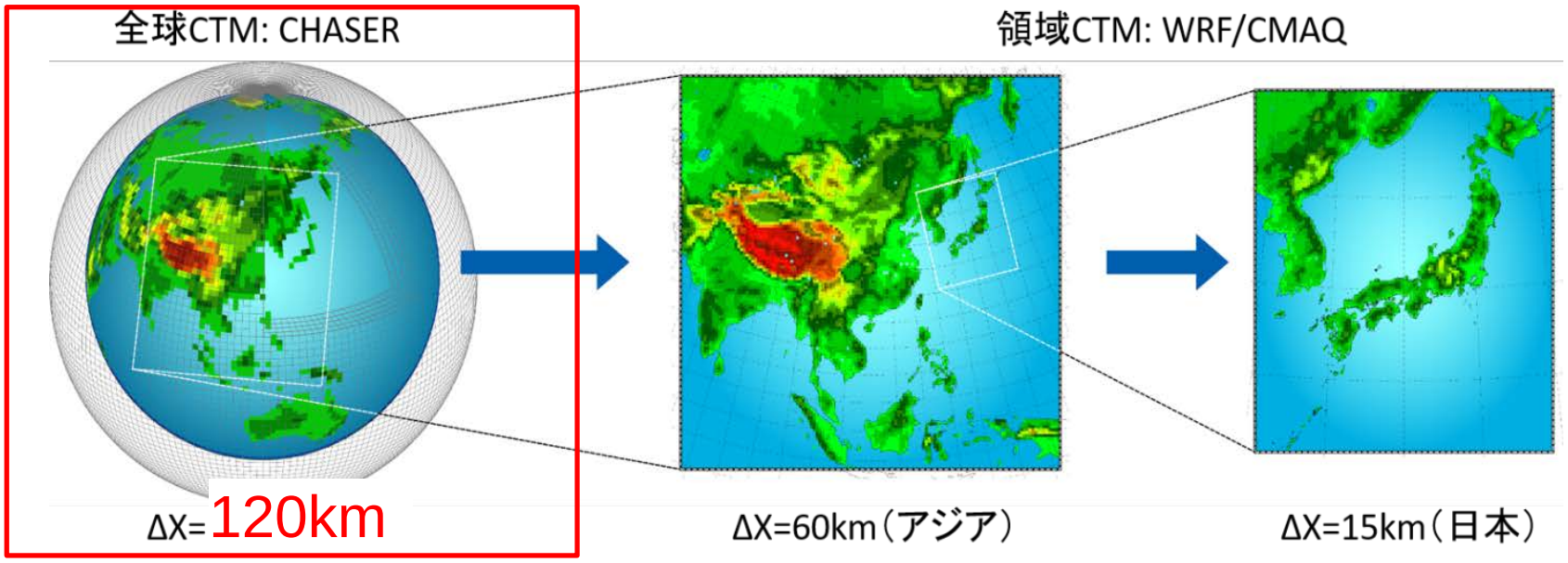
- NO_x increased rapidly in late 1960s, while it decreased after late 1970s due to strong emission control.
- In 2015, 70% and 10% of total emission potential were reduced by emission control for road transport and power plants, respectively.

Comparison of emission reduction among Japan, China and India

Shaded part shows amounts of emission reduction (= W/O ECP – W. ECP.)



Long-term numerical experiment using global CTM (CHASER) during 1960-2010

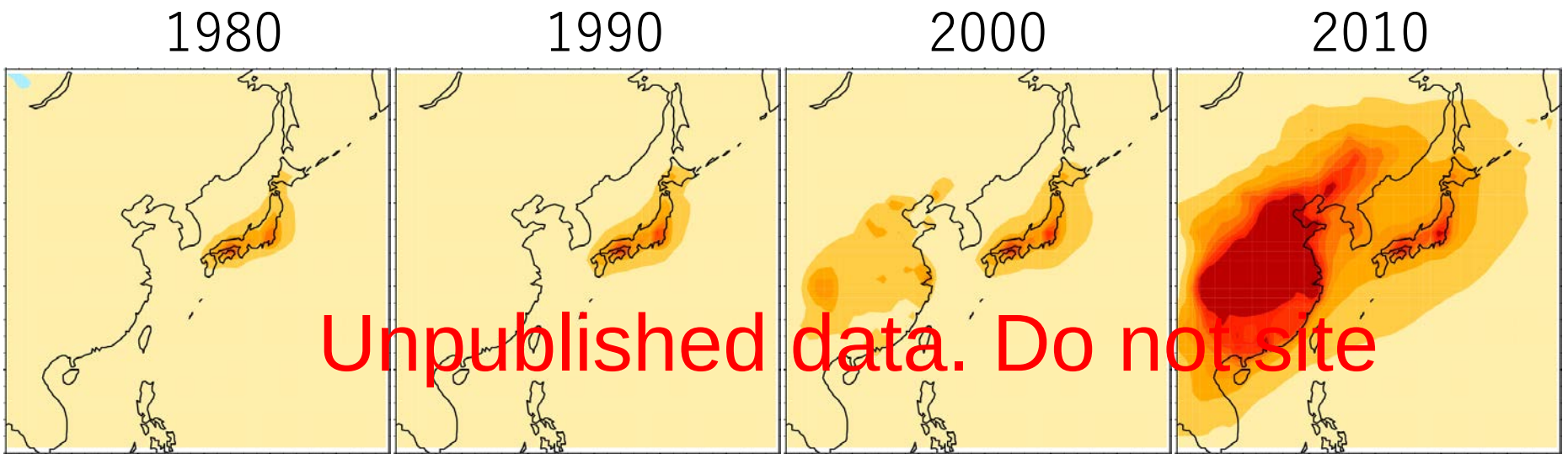


Emission data for global simulation

		1960-1969	1970-2010	
Anthropogenic	Asia	REAS v2.2		
	Out of Asia	MACCity	EDGAR 3.4.1(except NMHC), 4.3.2(NMHC)	
		1960-1996	1997-2010	
Biomass burning		MACCity	GFEDv4.1s	
		1960-1978	1979-2009	2010
Volcanoes (SO2)		= 1979	AEROCOM	= 2009

Reduction effects of $PM_{2.5}$ concentration due to emission control policy (ECP) in Japan and China

(W/O emission control) - (With emission control)

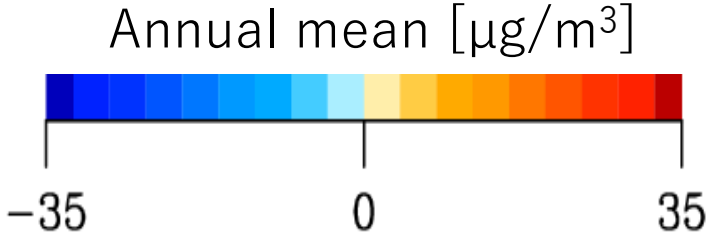


Large reduction in Japan due to domestic ECP

No reduction in China

Small reduction in China

Large reduction in China and also Improvement of transboundary pollution to Japan



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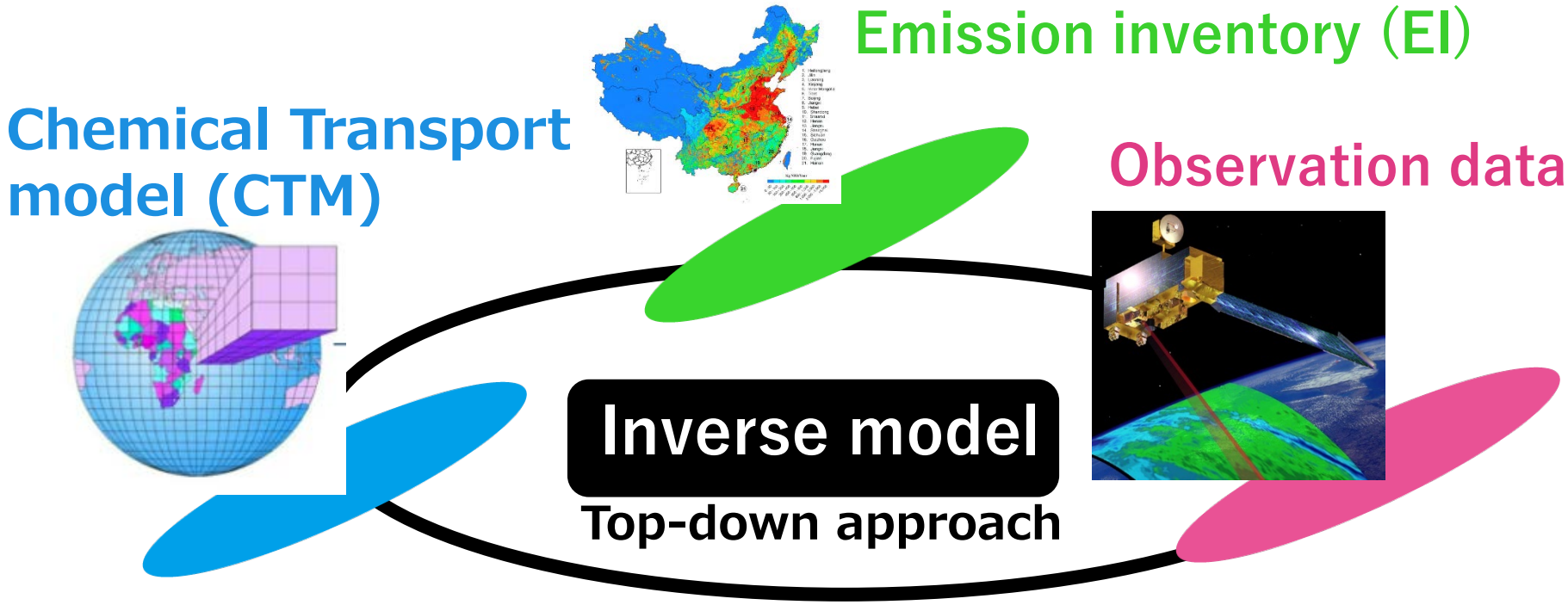
Inverse modeling (Top-down approach)

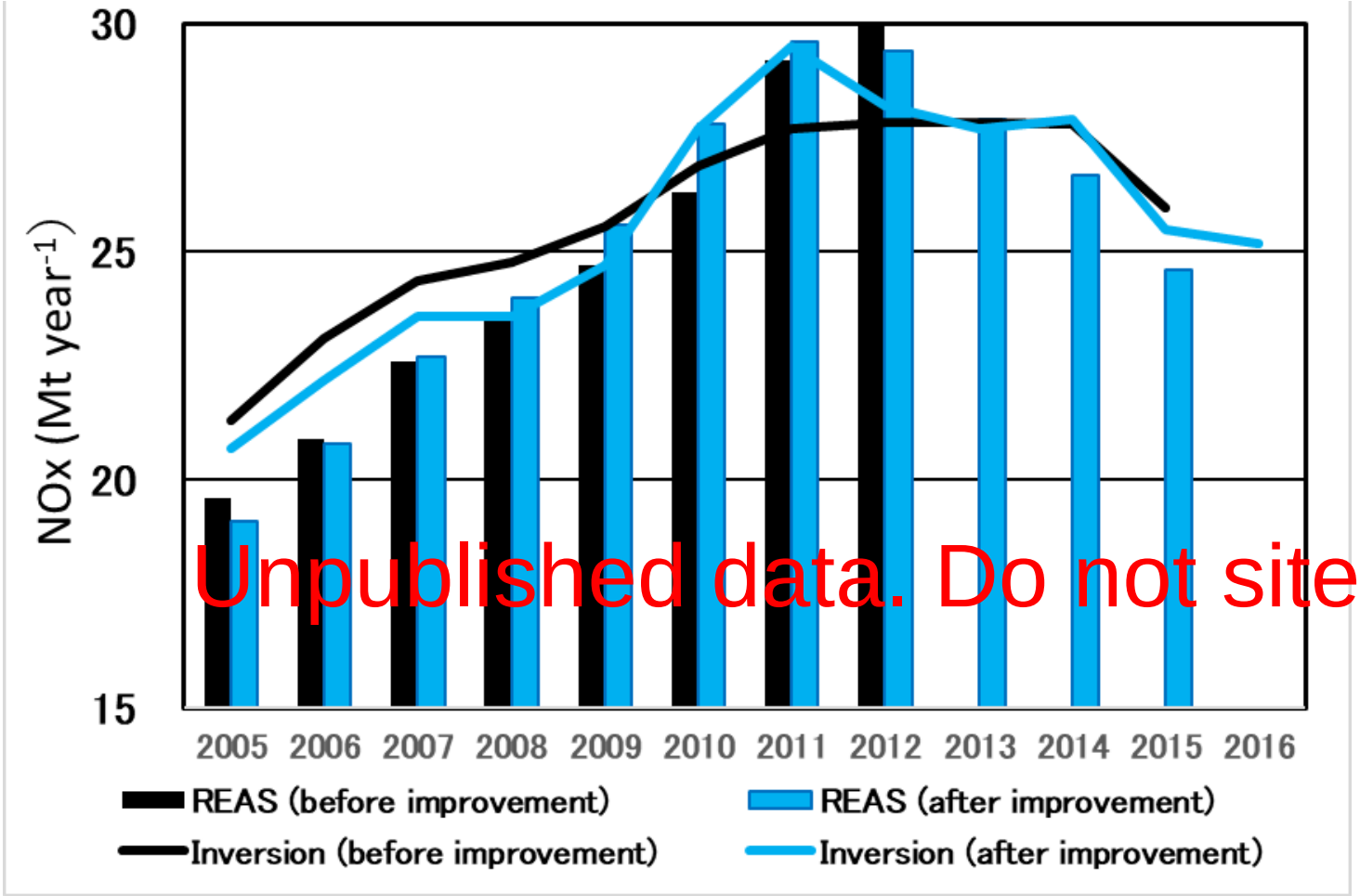


Inverse modeling integrates EI (a priori data), CTM and observation data to complement (optimize) emissions.

=Inverse estimation of emissions

Bottom-up approach: Estimate emissions from statistical data
Top-down approach : Estimate emissions from observations and CTM

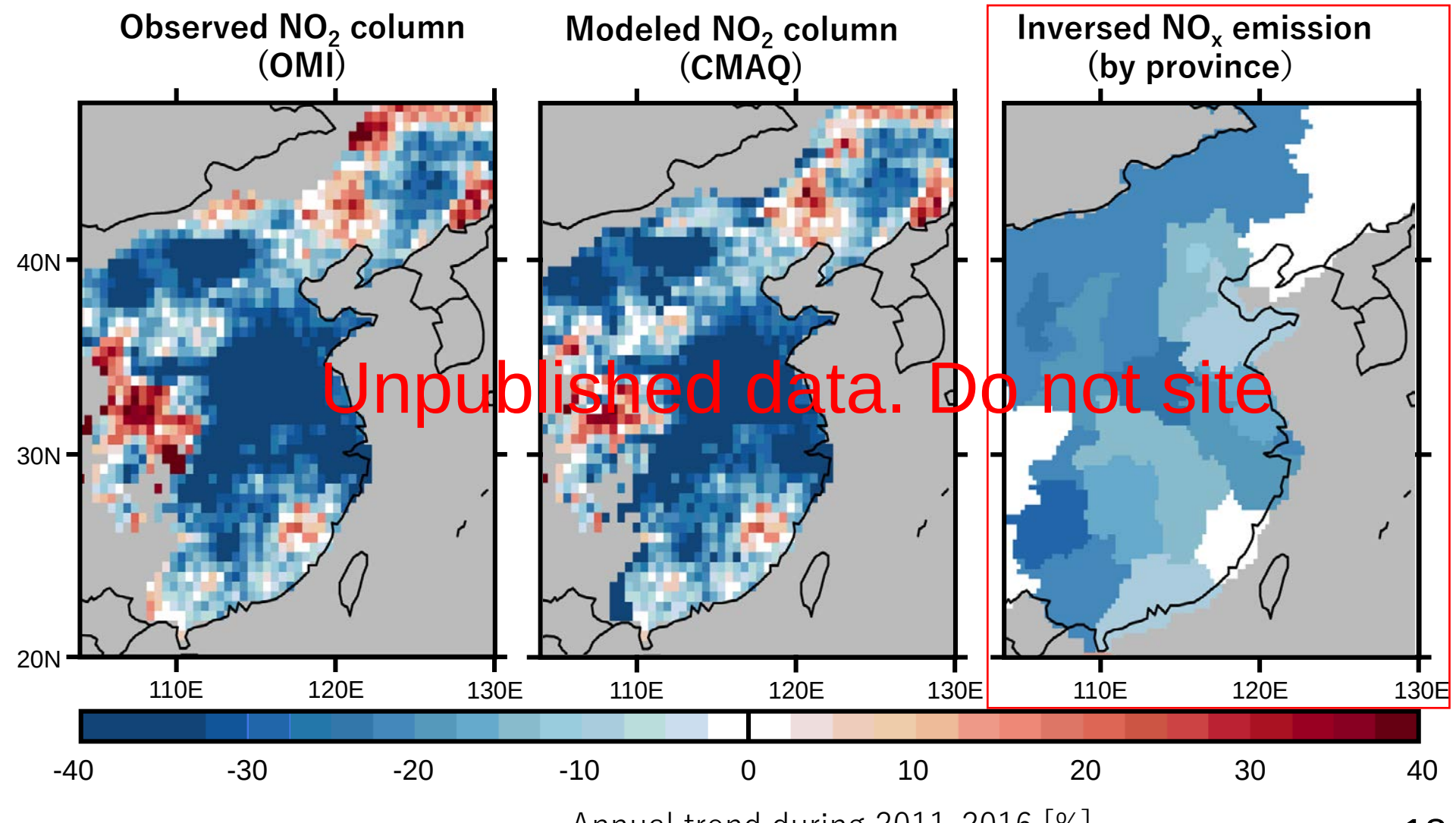
Comparison of NOx emission in China between REAS and inversed modeling



- Initially, some differences between two approaches. After improving, consistent.
- A new method for updating emission inventory based on the combination of the conventional inventory approach with an inversed modeling based on satellite observation

Spatial distribution of annual trend of NO_2 column concentration and NO_x emission in China

Annual trend during 2011-2016 ((2016-2011)/2011 * 100 [%])



Summary

- We have developed a historical emission inventory (REAS new version) in Asia during 1960-2015. Emissions in Southeast/South Asia have large uncertainty. REAS should be validated and improved by comparison with other inventories and inversed estimates based on satellite observation.
- The first quantifying evaluation of the effects of emissions reduction and air quality improvements due to emission control was made using the integrated system. Such clear demonstration of the effects of government policy will support to policy making/implementation. It is suggested that a similar system should be developed and applied in order to quantify the efficacy of regional air pollution policies in Asian countries.
- For updating the emission inventory on regional scales including developing countries in Asia, we have established a new method that combines the conventional inventory approach with an inversed approach based on satellite observation. Using similar system, continuous and quick updating of emission inventory is needed in Asia to reflect intense changes in socio-economic activity and environmental policies.