1 February 2023

International Meeting on Air Pollution in Asia
– Inventories, Monitoring and Mitigation –

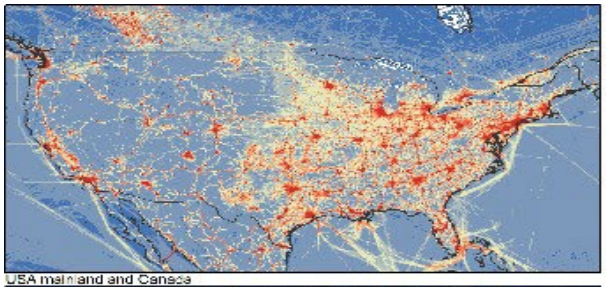
Long-term Trends of Anthropogenic Emissions in East/Southeast Asia

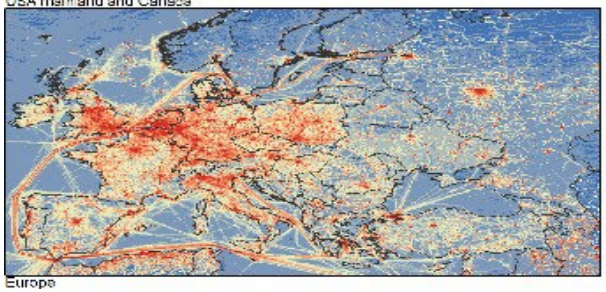
Toshimasa Ohara
Center for Environmental Science in Saitama (CESS), Japan
National Institute for Environmental Studies (NIES), Japan

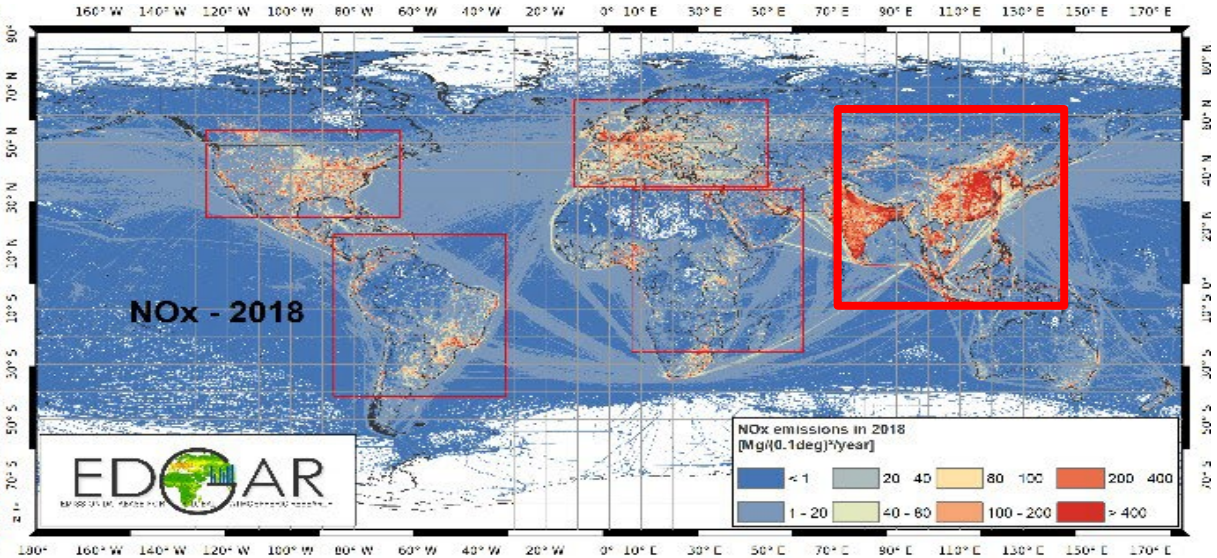
With Jun-ichi Kurokawa (ACAP) and Syuichi Itahashi (CRIEPI)

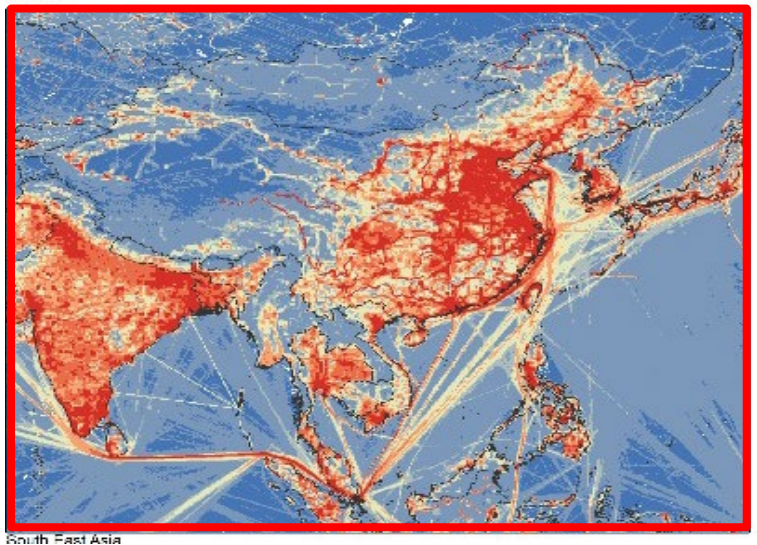
Global emission map for NO_x in 2018

HTAP_v3 emission mosaic (Crippa et al., 2023), anthropogenic emission inventory excluding LCLUC developed in the UNECE Air Convention



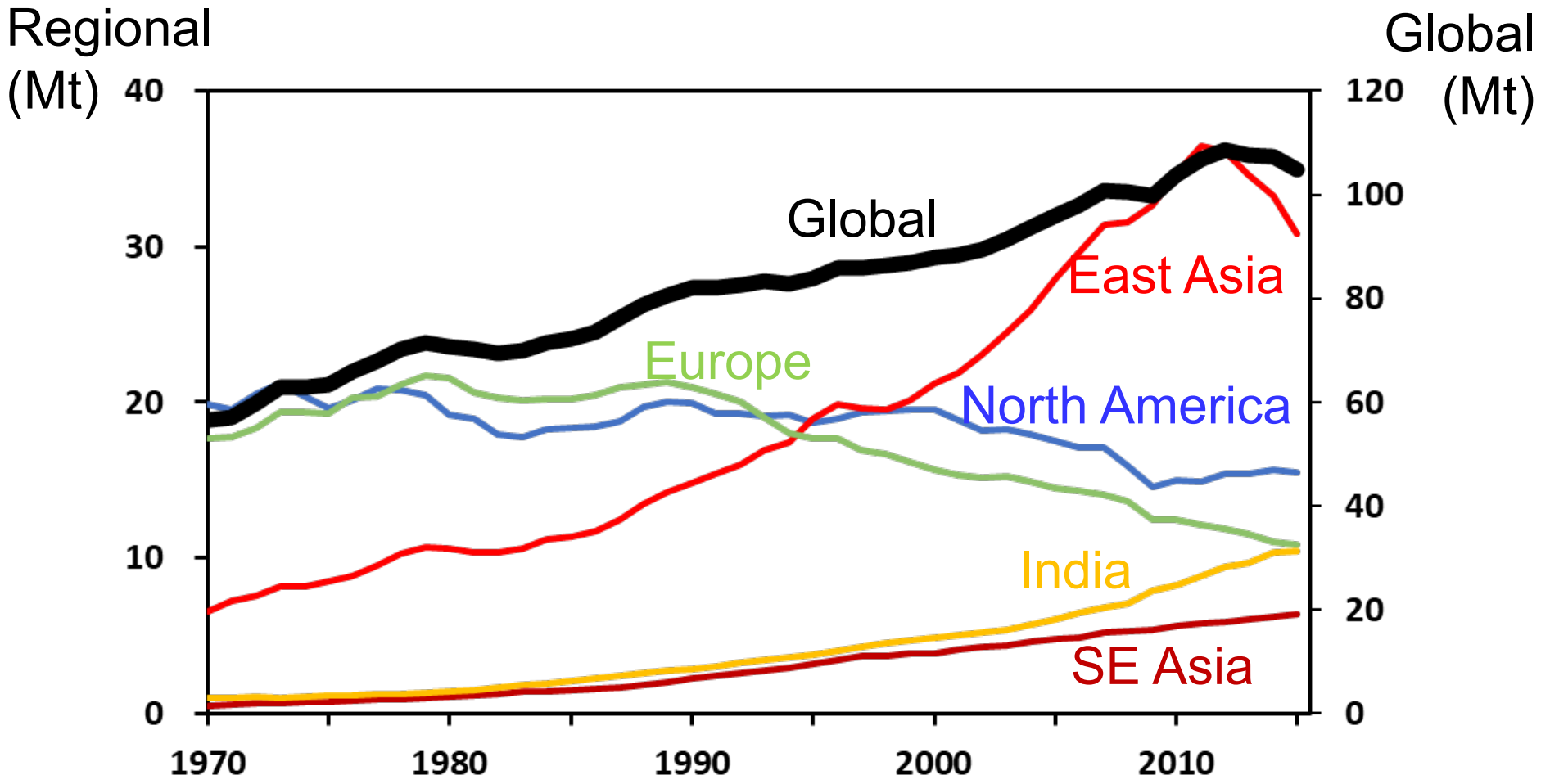






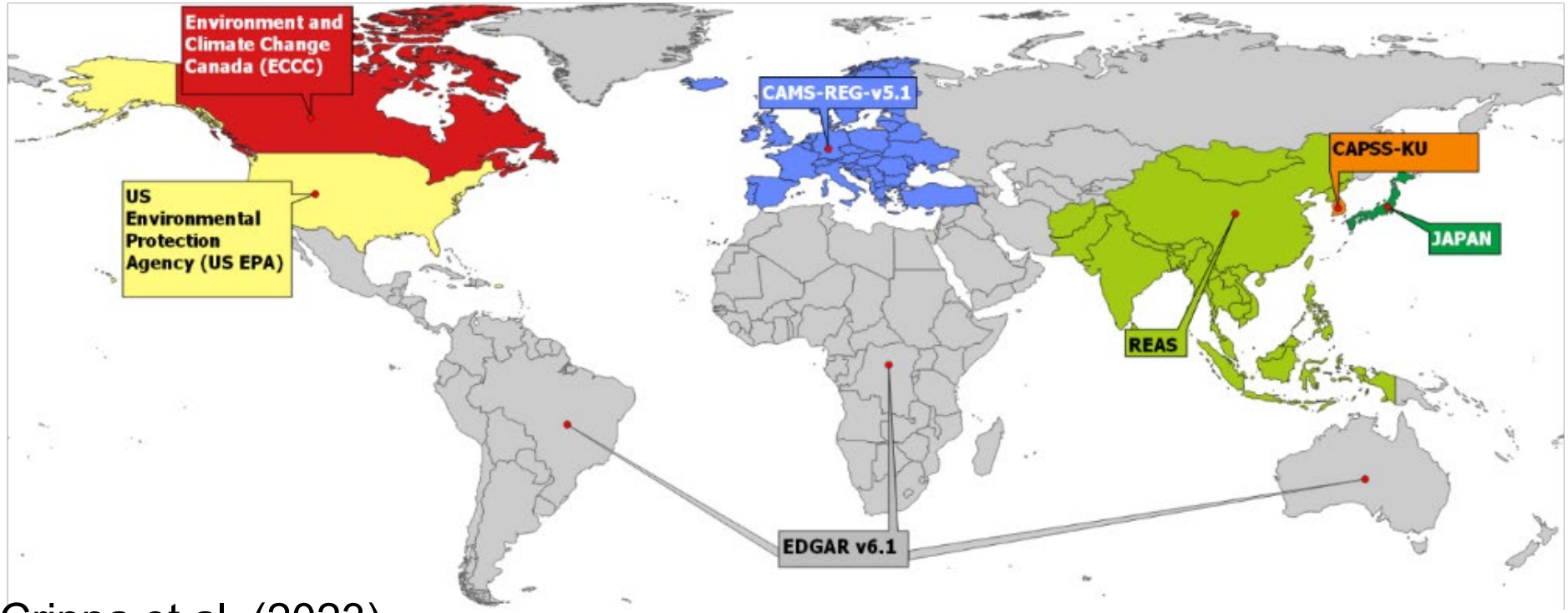
- ✓ Asia is most polluted region in global
- ✓ Asian emissions account for almost half of global

Historical trends of global and regional NO_x emissions



- ✓ In Global and East Asia, going up but recently turned to go down
- ✓ In Europe and NA, keeping down since 1980
- ✓ By contrast, in India and SE Asia, still going up.

HTAP mosaic emissions



Crippa et al. (2023)

Grid emission data have been collected from several different kinds of EIs, REAS* for most of the Asian domain except for Japan and South Korea.

- REAS (Regional Emission inventory in Asia)
  Ohara et al. (2007); Kurokawa, Ohara et al. (2013); Kurokawa & Ohara (2020)

Regional Emission inventory in ASia (REAS)

- ✓ **Anthropogenic, comprehensive, and historical inventory**
- ✓ **Version history: v1.0 (2007) to v.3.2.1 (now updating)**

- Country and regional emissions for detailed sources
- Gridded emissions for major sources
- Target Years： 1950-2015 **(➡1950-2018)**
- Target Areas： East, Southeast, and South Asia
- Horizontal Resolution： 0.25° × 0. 25° **(➡ 0.1° × 0.1°)**
- Temporal Resolution： Monthly
- Target Species：
  SO_2, NO_x, CO, NMVOC, PM_{10}, $PM_{2.5}$, BC, OC, NH_3, CO_2 and **CH_4**

	SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$	BC	NMV	NH_3	CO_2	CH_4
Combustion	●	●	●	●	●	●	●	●	●	●
Industrial Process	●		●	●	●	●	●	●	●	●
Agriculture		●						●		●
Others							●	●		●

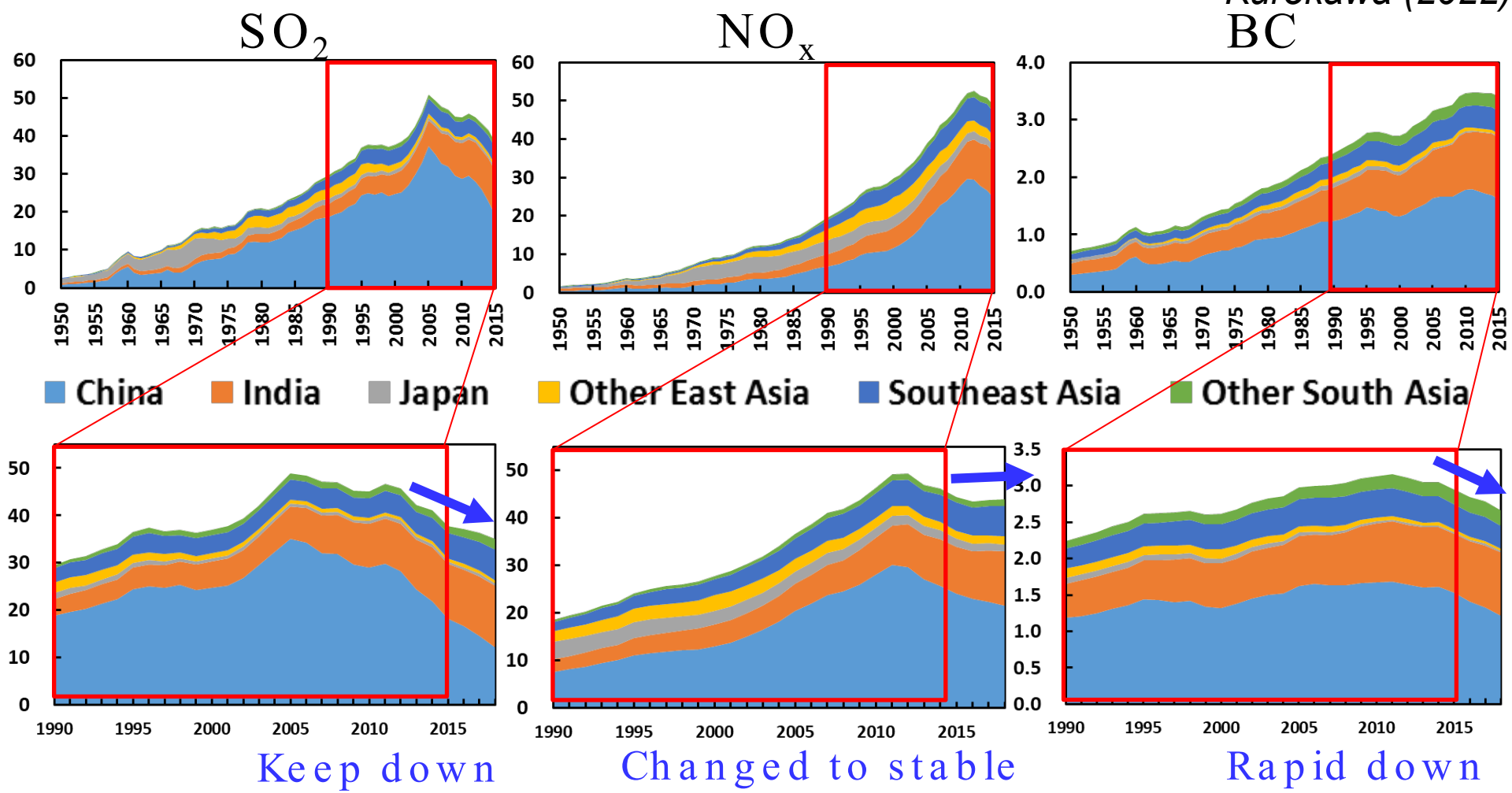
Key questions

1. **How about the long-term trends of air pollutant emissions in Asia, especially in Southeast Asia?**

2. Does the emission trends from bottom-up inventory consistent with satellite observation and inversed estimation?

Historical emissions in Asia (unit: Mt/year)

Kurokawa (2022)



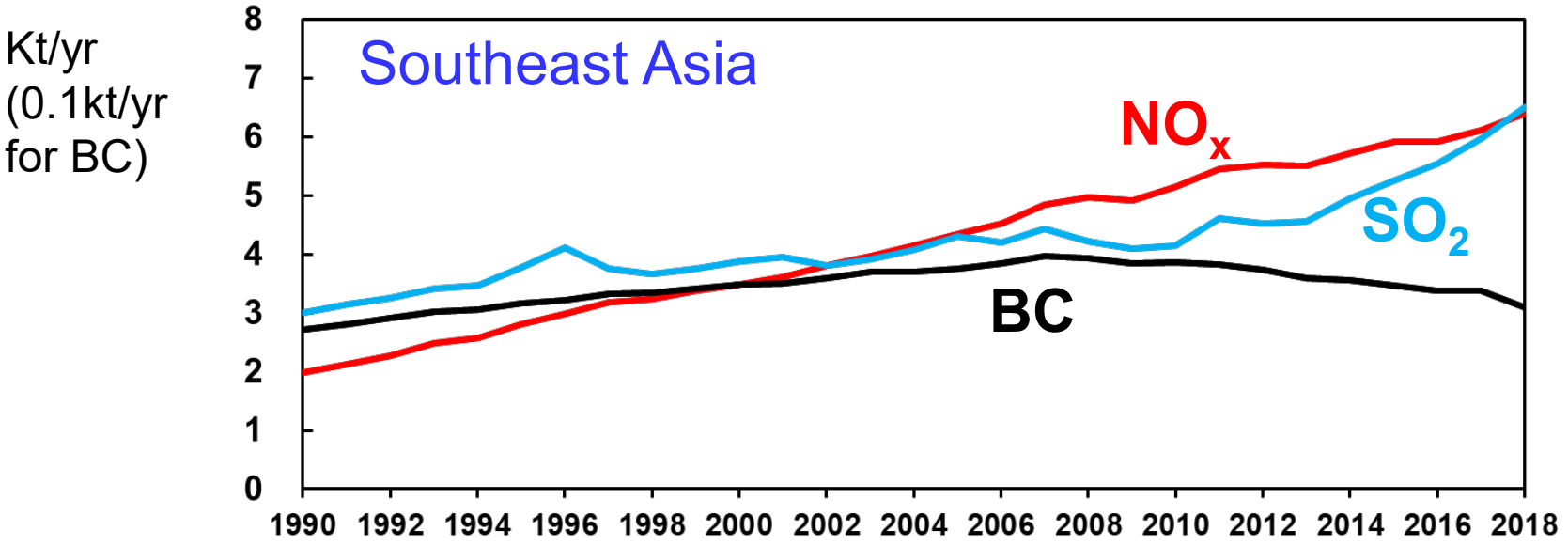
	2005	2018
China	72%	35%
India	14%	37%
SE Asia	9%	19%

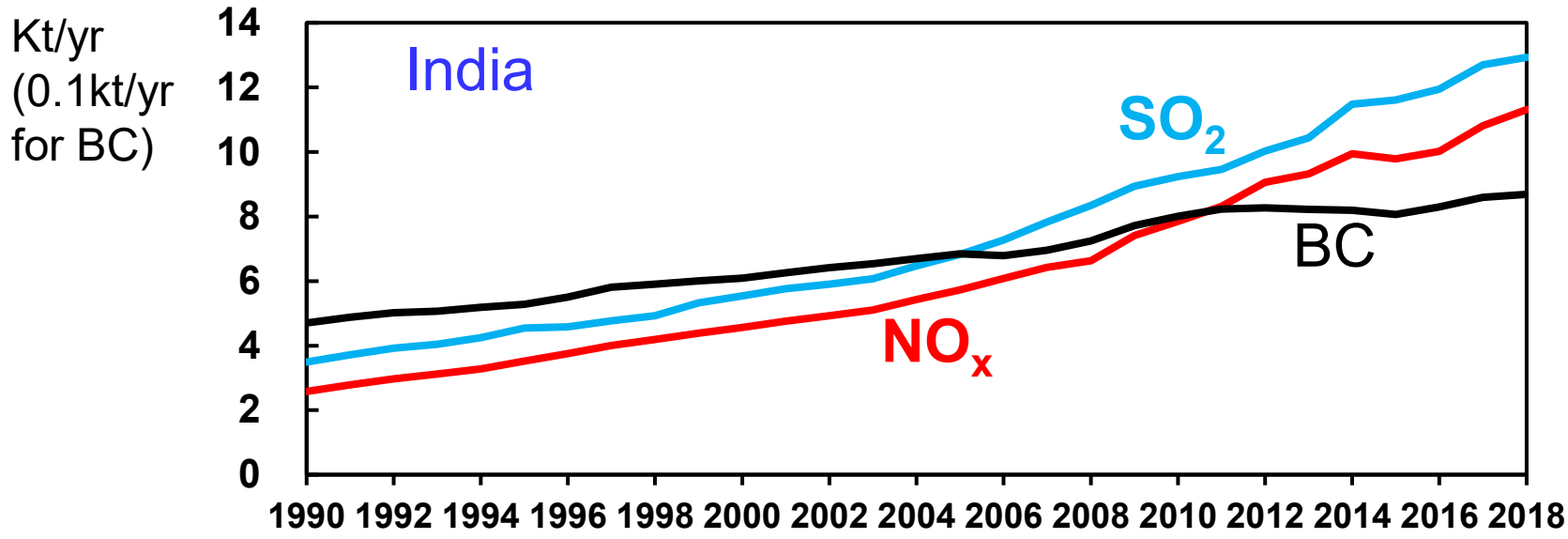
	2005	2018
China	67%	49%
India	17%	26%
SE Asia	11%	15%

	2005	2018
China	53%	46%
India	26%	33%
SE Asia	12%	12%

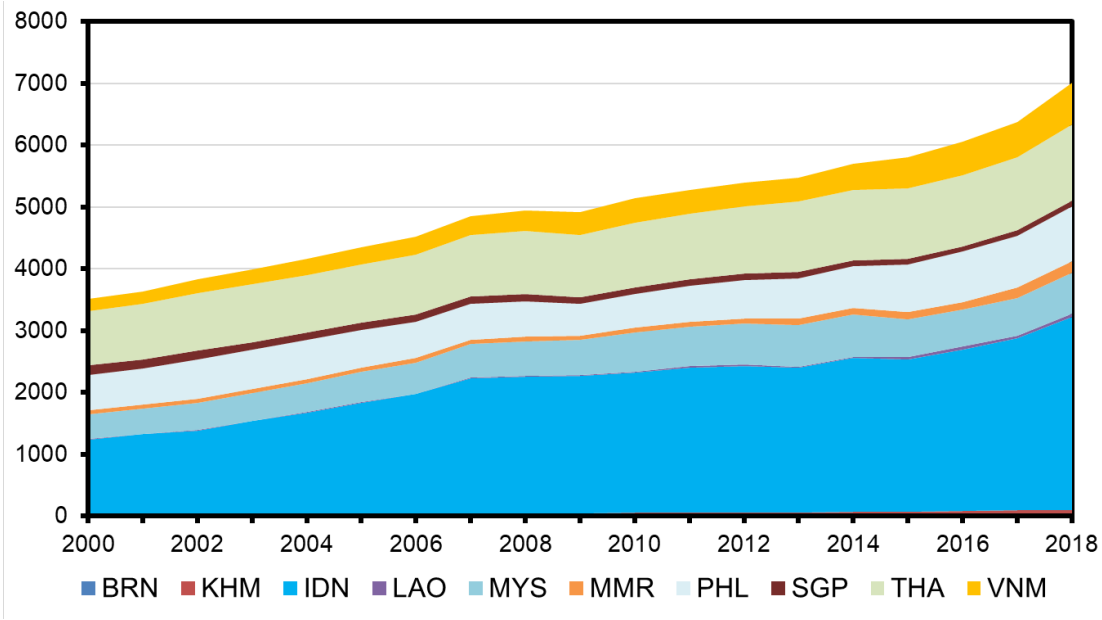
Recent trend of emissions in Southeast Asia and India

Kurokawa (2022)





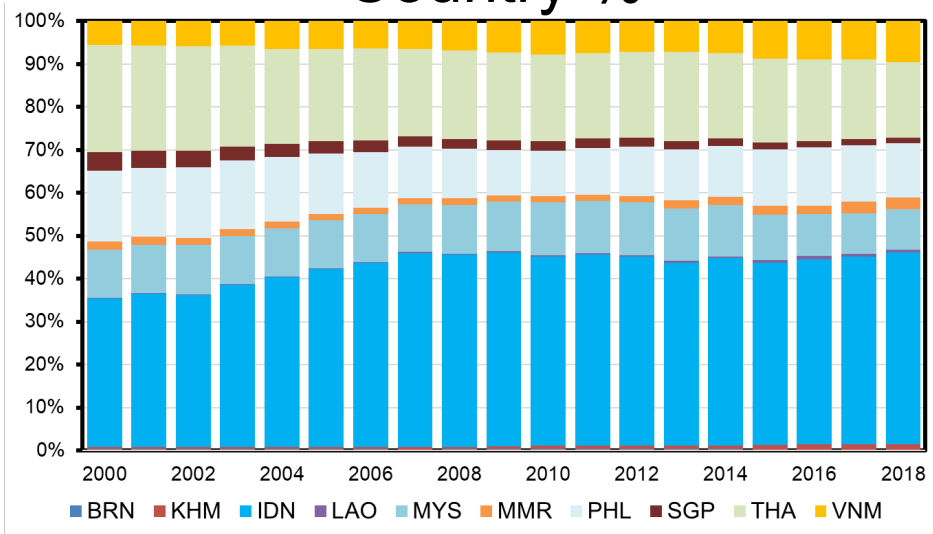
NOx emissions in Southeast Asia after 2000



Kurokawa (2022)

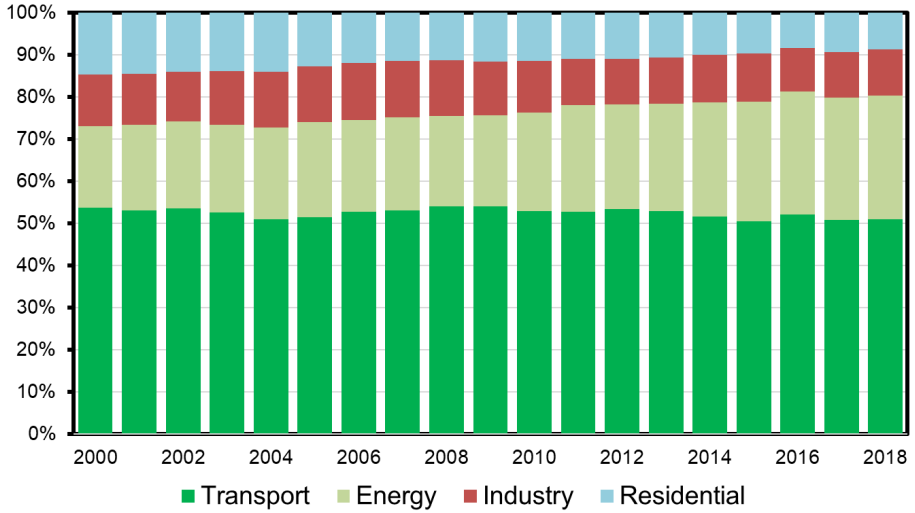
Trends are positive in every country

Country %



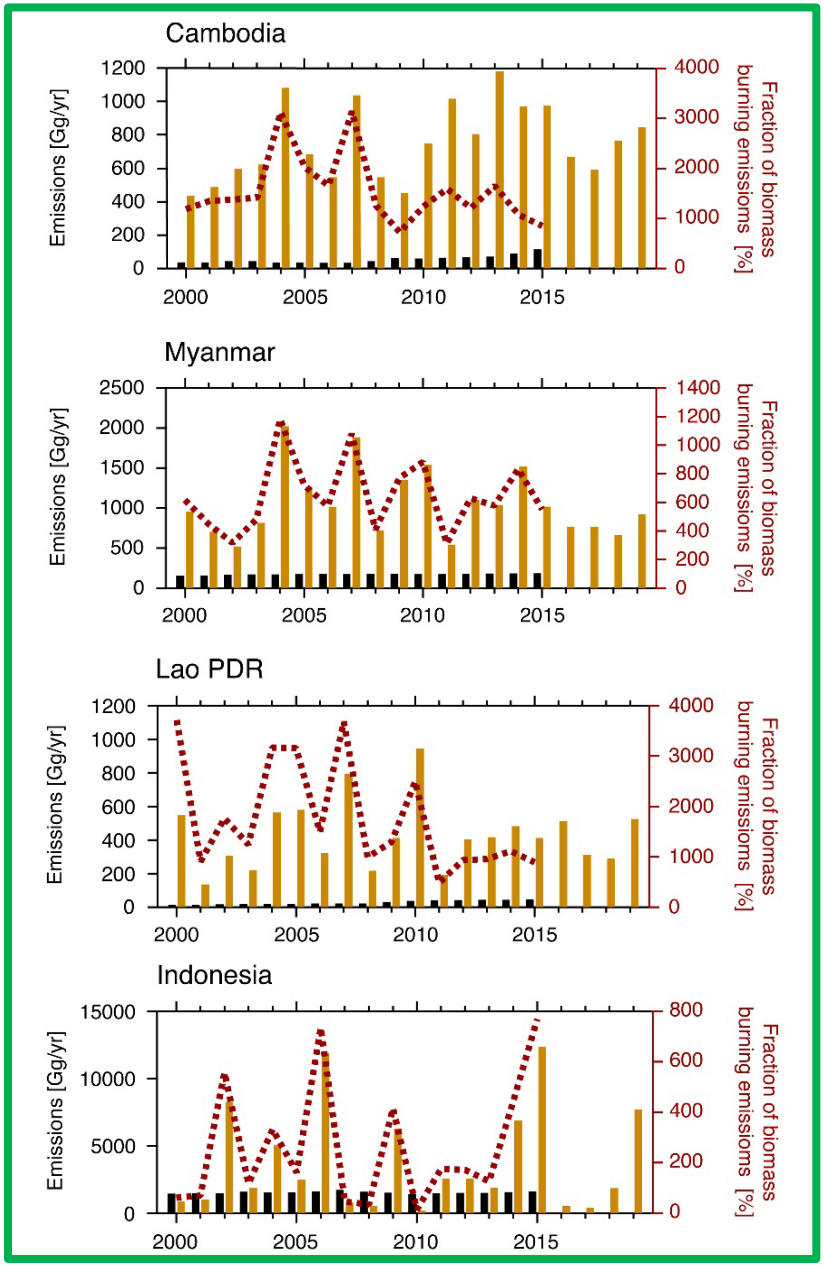
The largest contributor was Indonesia followed by Malaysia, Philippines, Thailand, and Vietnam.

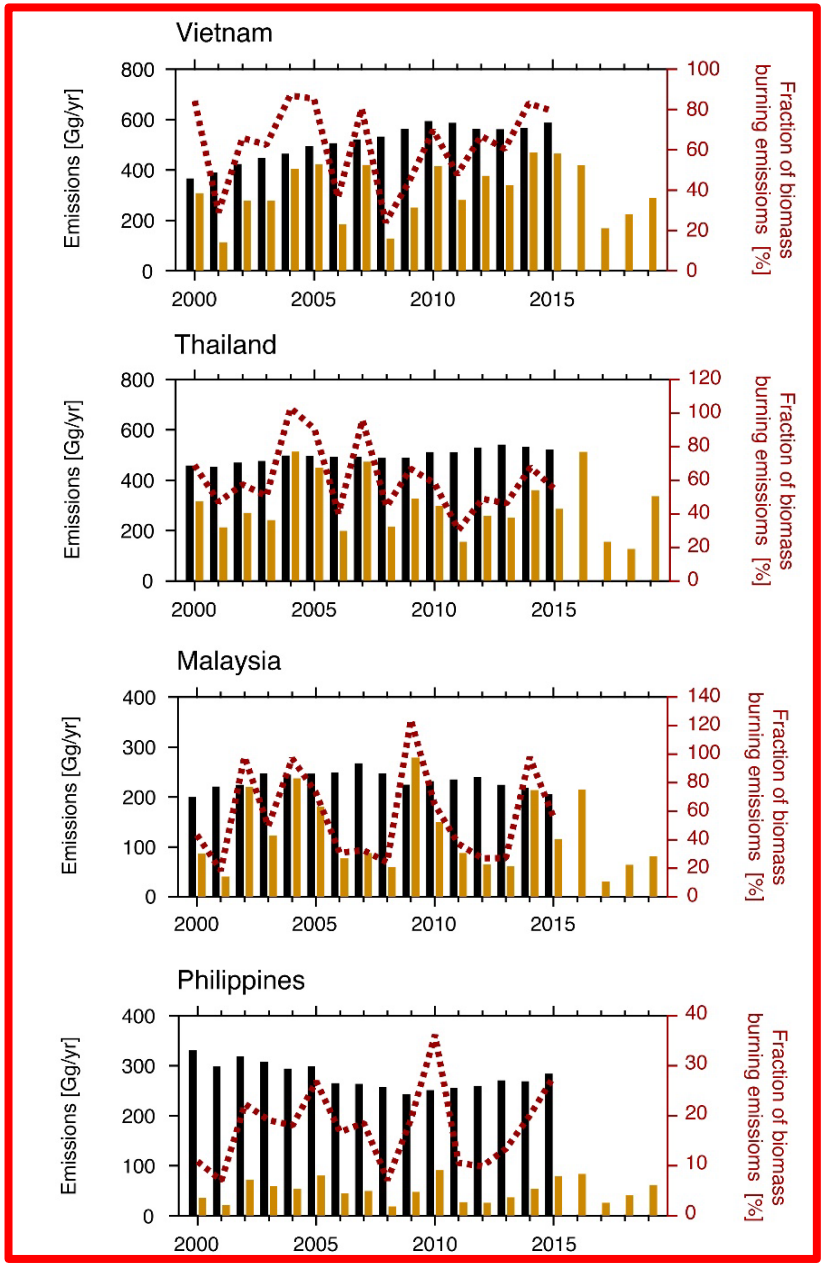
Sector %



Share of residential sector went down, while energy sector went up.

PM_{10} emissions in SE Asia: Anthro.(REAS) vs. BB (GFED v4)





BB >> Anthro

Itahashi, Kurokawa, Ohara (2022)

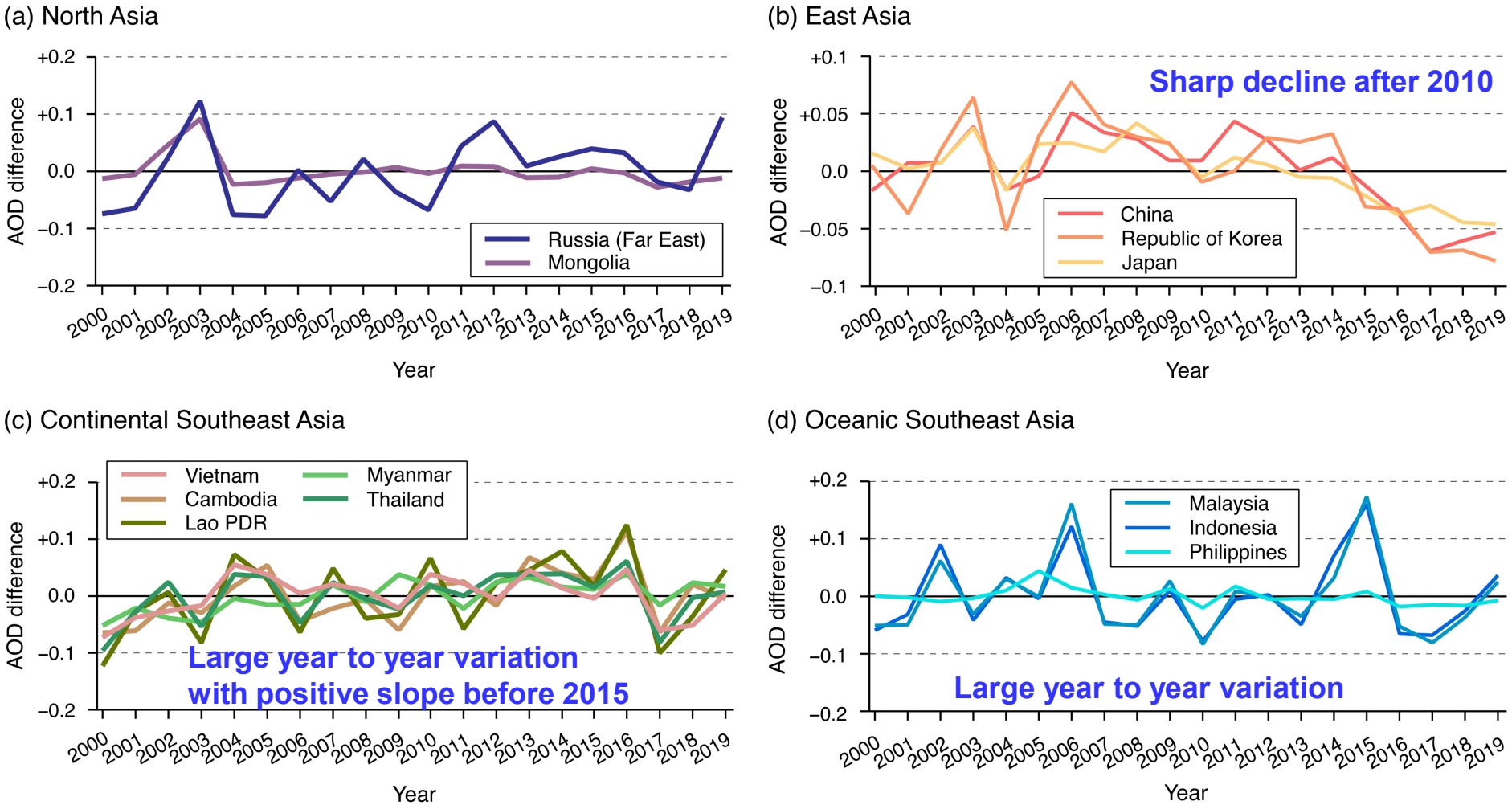
BB =< Anthro

Key questions

1. How about the long-term trends of air pollutant emissions in Asia, especially in Southeast Asia?

2. **Does the emission trends from bottom-up inventory consistent with satellite observation and inversed estimation?**

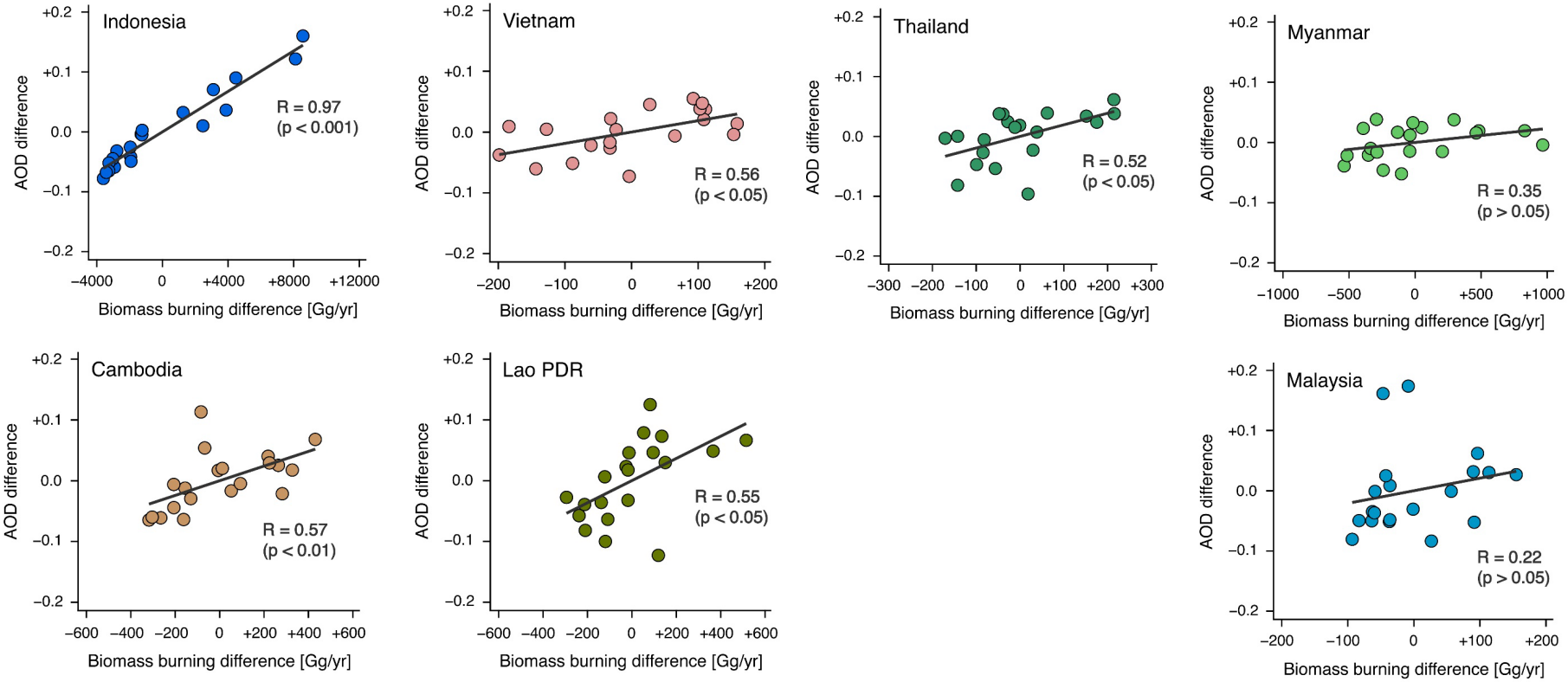
Temporal variation of annual mean and country-averaged AOD as the change from the 20-year



(Note) Level 3 of the MOD08_3D dataset in the MODIS product of the latest Collection 6.1. AOD product with the Dark Target/Dark Blue algorithms (NASA, 2021).

Itahashi, Kurokawa, Ohara (2022)

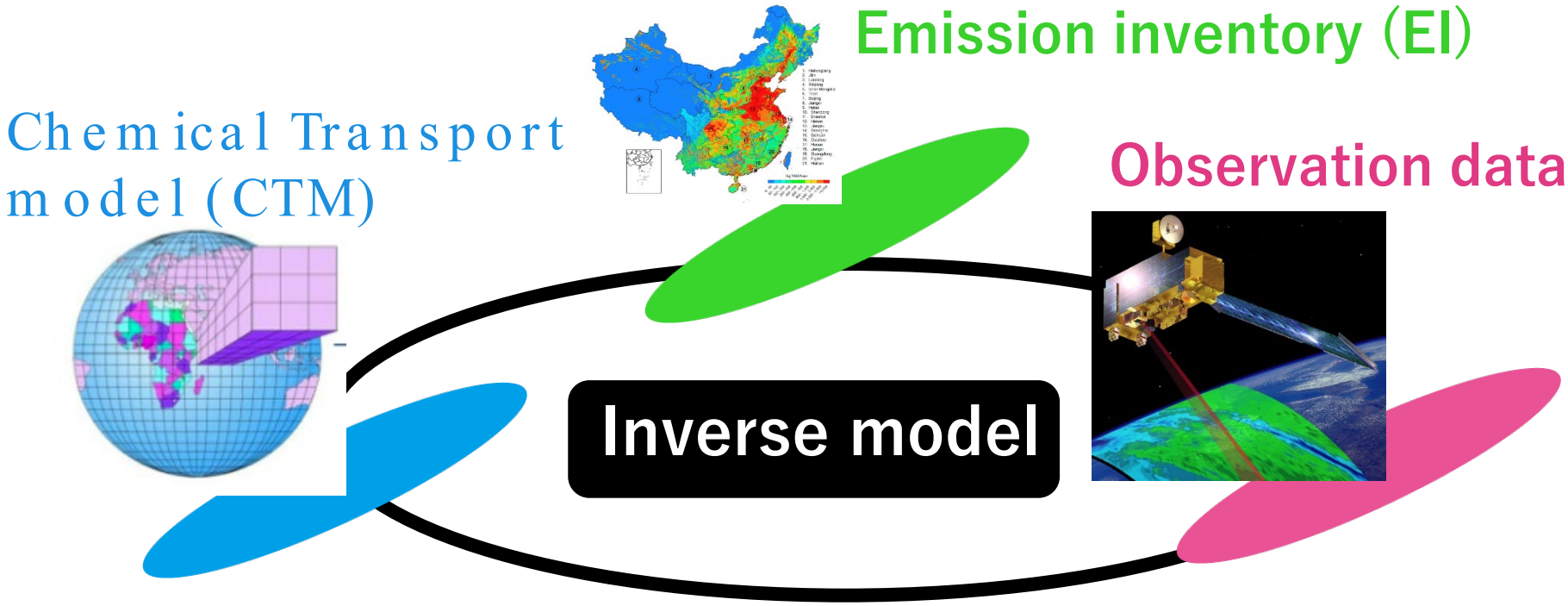
Scatter plot between AOD difference (change from the 20-year average) and biomass burning emission difference



- ✓ The correlation value over IND was very high with a positive slope; similar relationships with moderate correlation were observed in VNM, Cambodia, LAO, and THA.
- ✓ BB emissions were key in causing AOD variations, and hence led to aerosol pollution.

Itahashi, Kurokawa, Ohara (2022)

Inverse modeling

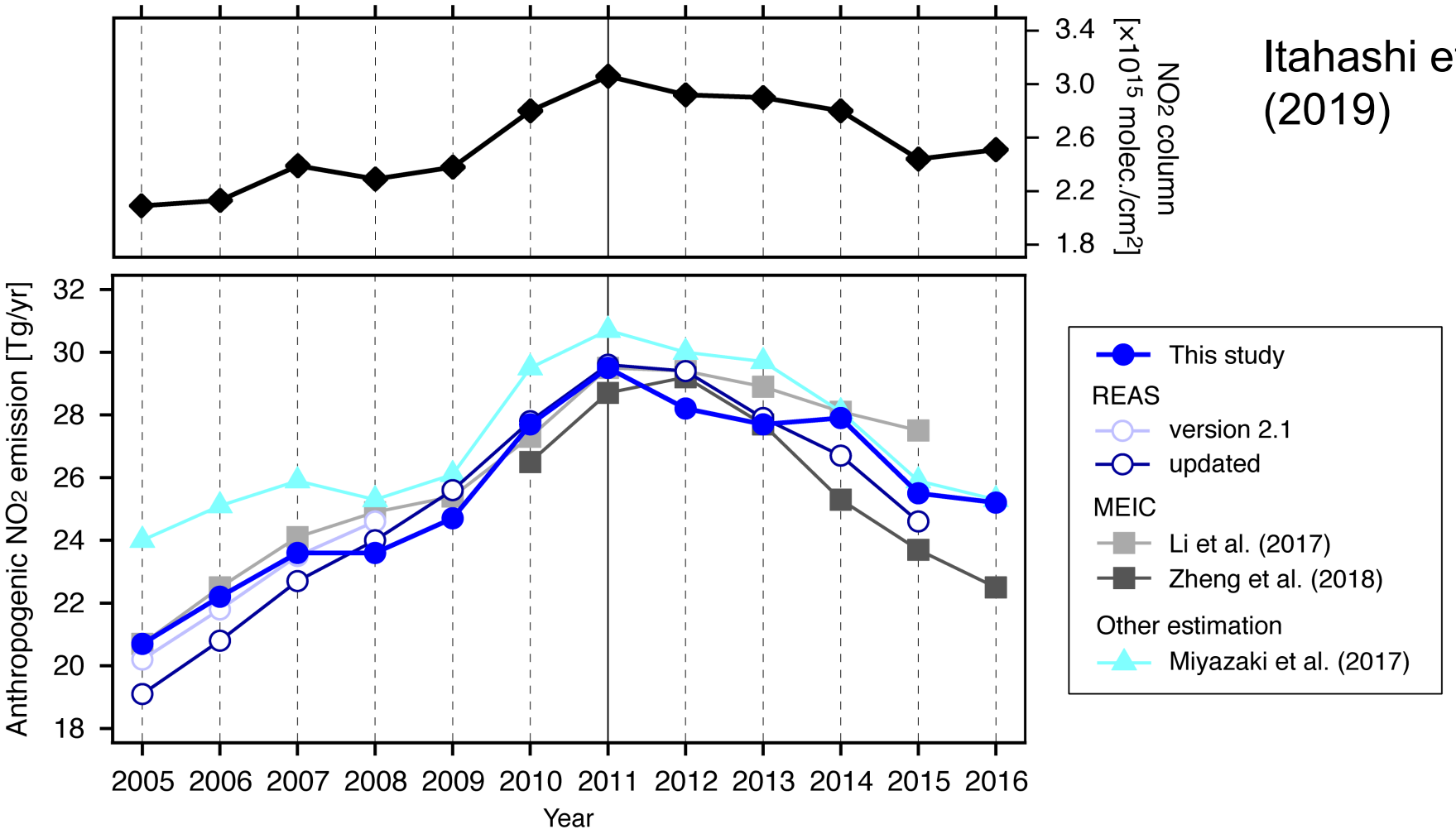


Inverse modeling integrates EI (a priori data), CTM and observation data to complement (optimize) emissions.

□ Inverse estimation of emissions

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

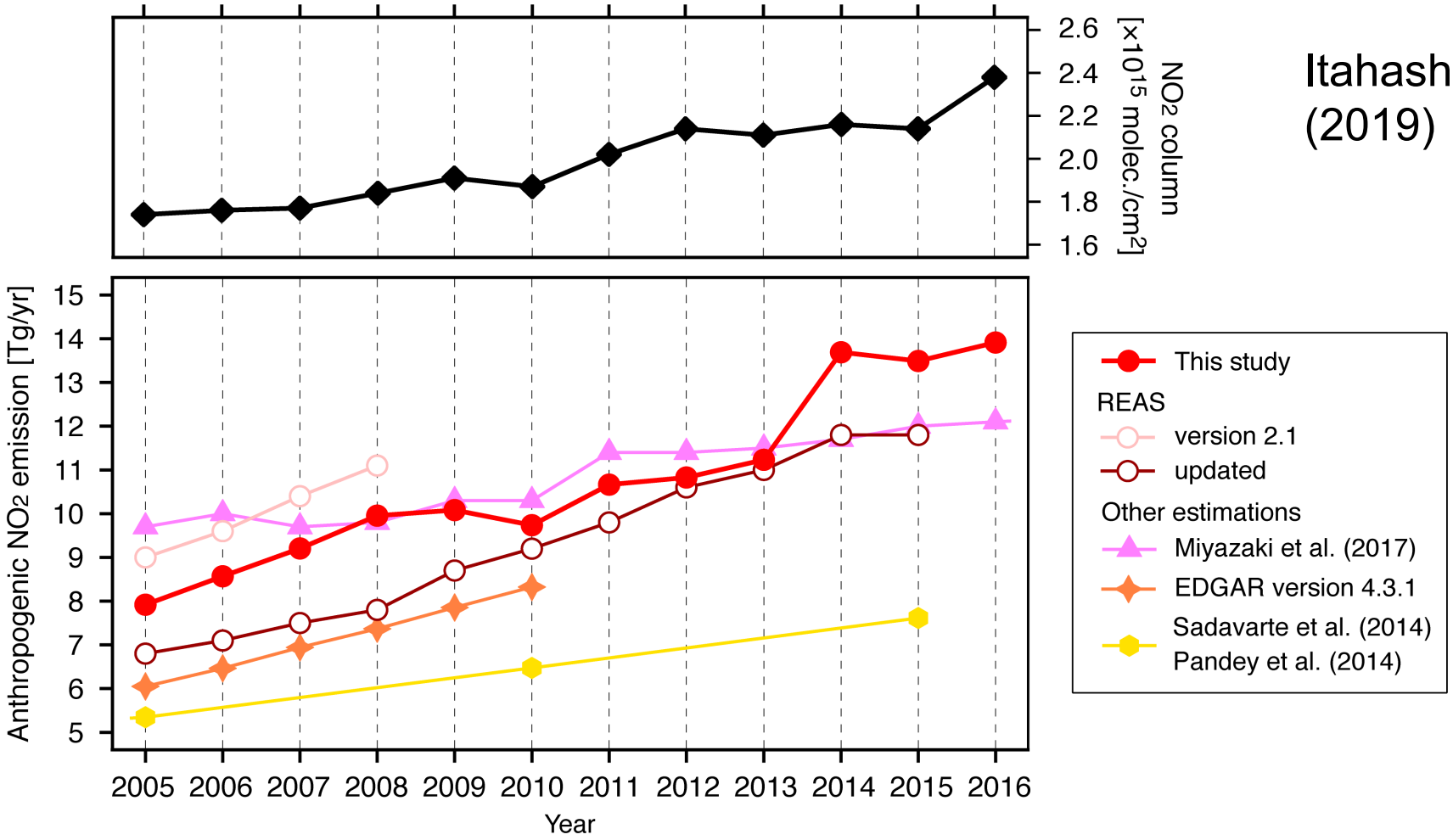
Temporal variation of (top) annual NO_2 column, and (bottom) annual NOx emissions amounts over **China**



Itahashi et al. (2019)

Inversed emissions (blue line) are consistent with the updated REAS emissions (black line with open circle) and other estimations.

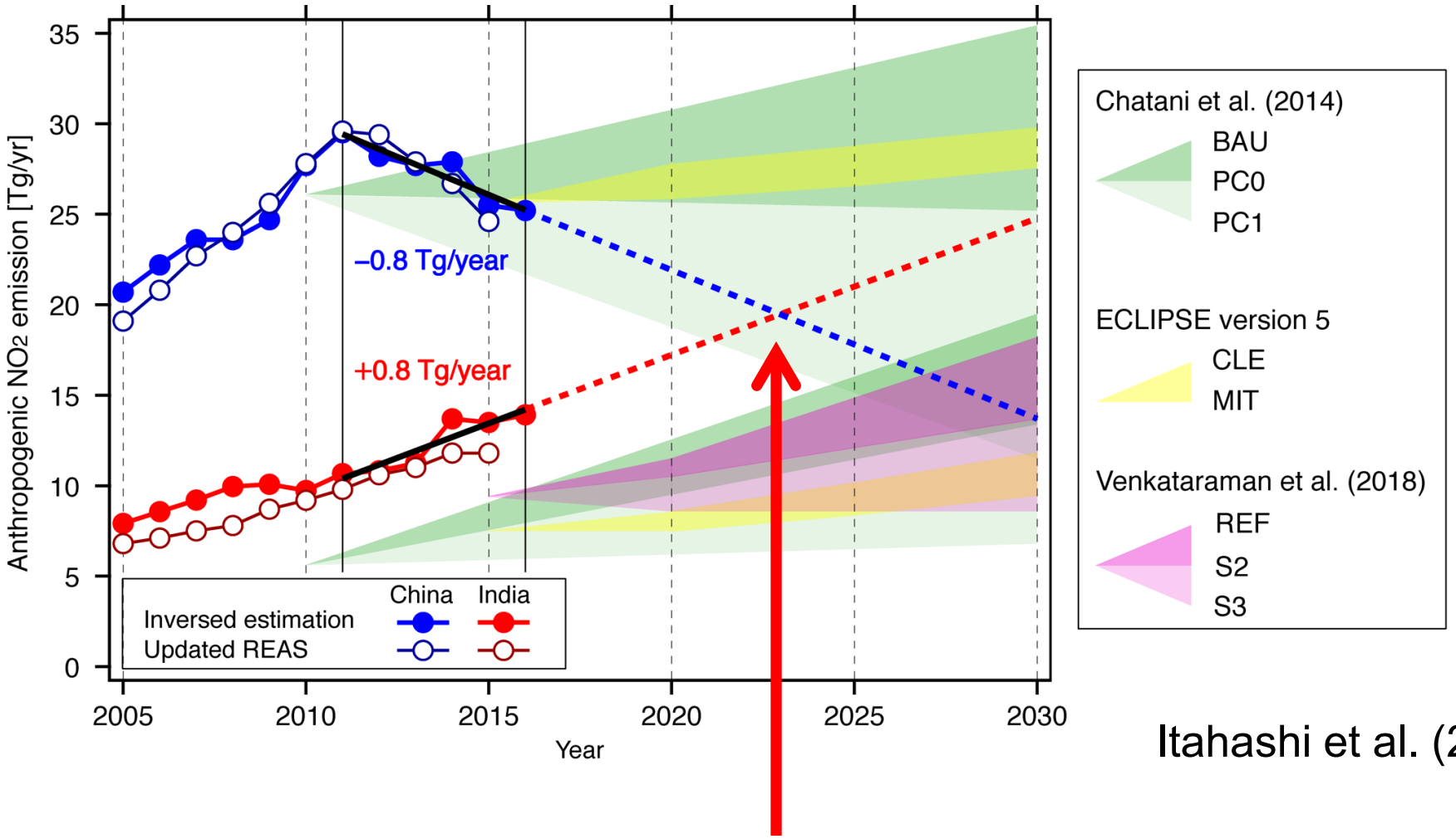
Temporal variation of (top) annual NO_2 column, and (bottom) annual NOx emissions amounts over **India**



Itahashi et al. (2019)

- ✓ All estimation shows that NOx emissions are going up linearly but there are large differences in emission amount among their estimations.
- ✓ Large uncertainty still remains and needs to be improved.

Future perspective of emission variation over China and India



Itahashi et al. (2019)

Indian NOx will exceed Chinese NOx soon?

Answer to key questions

1. How about the long-term trends of air pollutant emissions in Asia, especially in Southeast Asia?
   -> The emissions in SE Asia and India keep going up. The region is coming toward most polluted in global.

2. Does the emission trends from bottom-up inventory consistent with satellite observation and inversed estimation?
   -> Very likely for NOx and almost fairly for PM. Satellite observations are very useful for improving emission inventory in Asia.

For anthropogenic emission inventory development in Southeast/South Asia

My conceptual idea:
"Emission inventory (EI) initiative in Asia"

- Exchange of information related to EI
  in SARI meeting, EANET WS and others
- Grasping of current status of EI developing
- Intercomparison of EI (not only research base but also governmental base) (in next step)

CMAS-Asia-Pacific conference

https://confit.atlas.jp/cmas2023

- **2023 International Conference on CMAS-Asia-Pacific**
- **Conference**
  - Date: **July 19-21, 2023**
  - **OMIYA** SONIC CIVIC HALL @ SONIC CITY HALL

Access:
60-100 min from Tokyo Int'l Airport to Omiya city

- **Training**
  - Date: **July 17-18, 2023**
  - CONFERENCE ROOM 7B @ SAITAMA HALL

UNEP/EANET
(Acid Deposition Monitoring Network in East Asia)

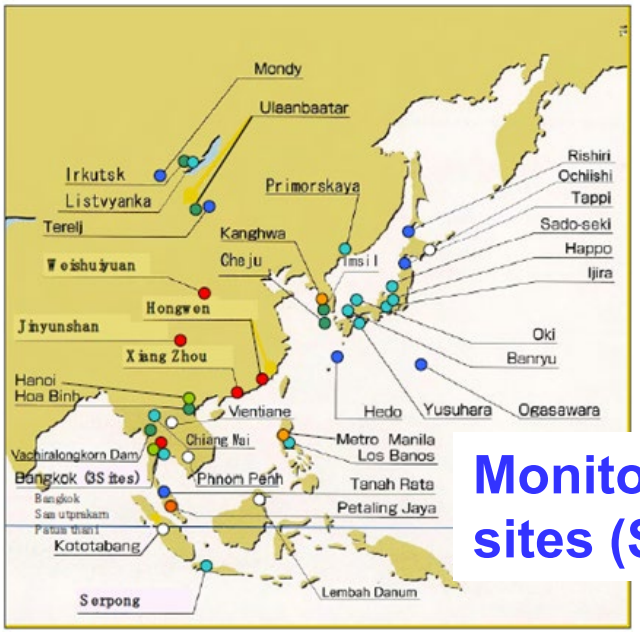
What's EANET?

EANET is an intergovernmental network, operating since 2001 to address acid deposition and related air pollution issues in East Asia and promoting cooperation among participating countries .

13 participating countries

Activities of EANET

- ✓ Major activities are monitoring and reporting, data management, technical assistance, capacity building, research and public awareness.
- ✓ The monitoring data is published annually and can be downloaded on the website.
- ✓ Using EANET data, scientific assessment reports and reports for policy makers are published periodically.



Monitoring sites (SO_2)

Current status of national emission inventories in Southeast Asia (excluding UNFCC GHG inventory)

Country	National EI
Cambodia	None
Indonesia	None
Lao PDR	None
Malaysia	None
Myanmar	None
Philippine	Philippine Emission Inventory 2018 (https://air.emb.gov.ph/emission-inventory-2018/)
Thailand	EI System Web Application has been developed in 2020 and still ongoing improved and revised. The EI is planned to use as AQM tool for local Administration
Vietnam	None

(Ref.) UNEP/EANET(2022)
Fourth Periodic Report
on the State of Acid Deposition in East Asia