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Historical Analysis and Inverse Modeling of Air Pollutants Emissions in Asia

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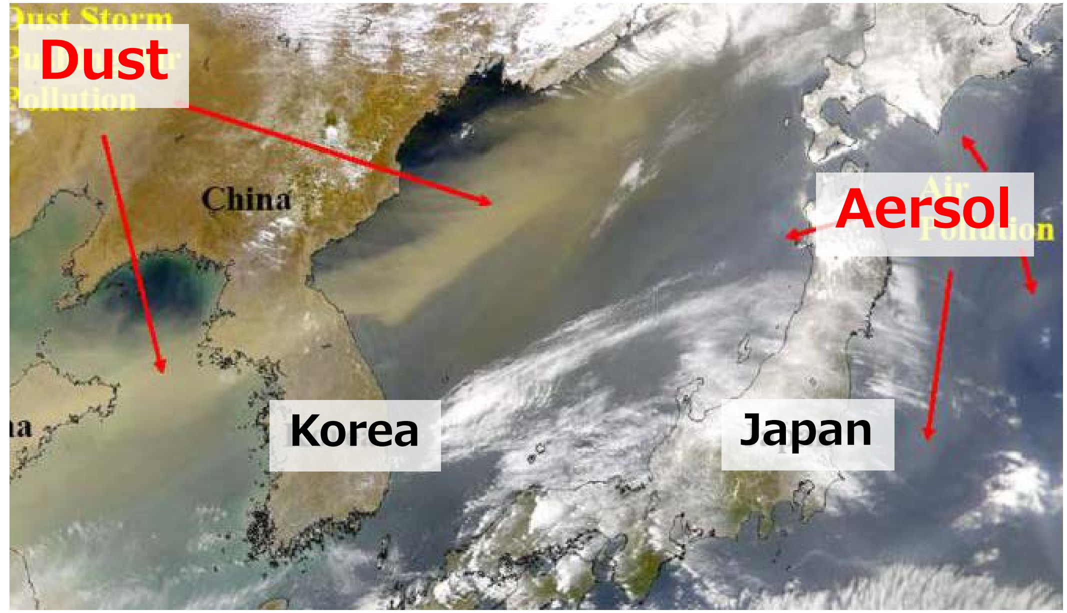
Today's presentation

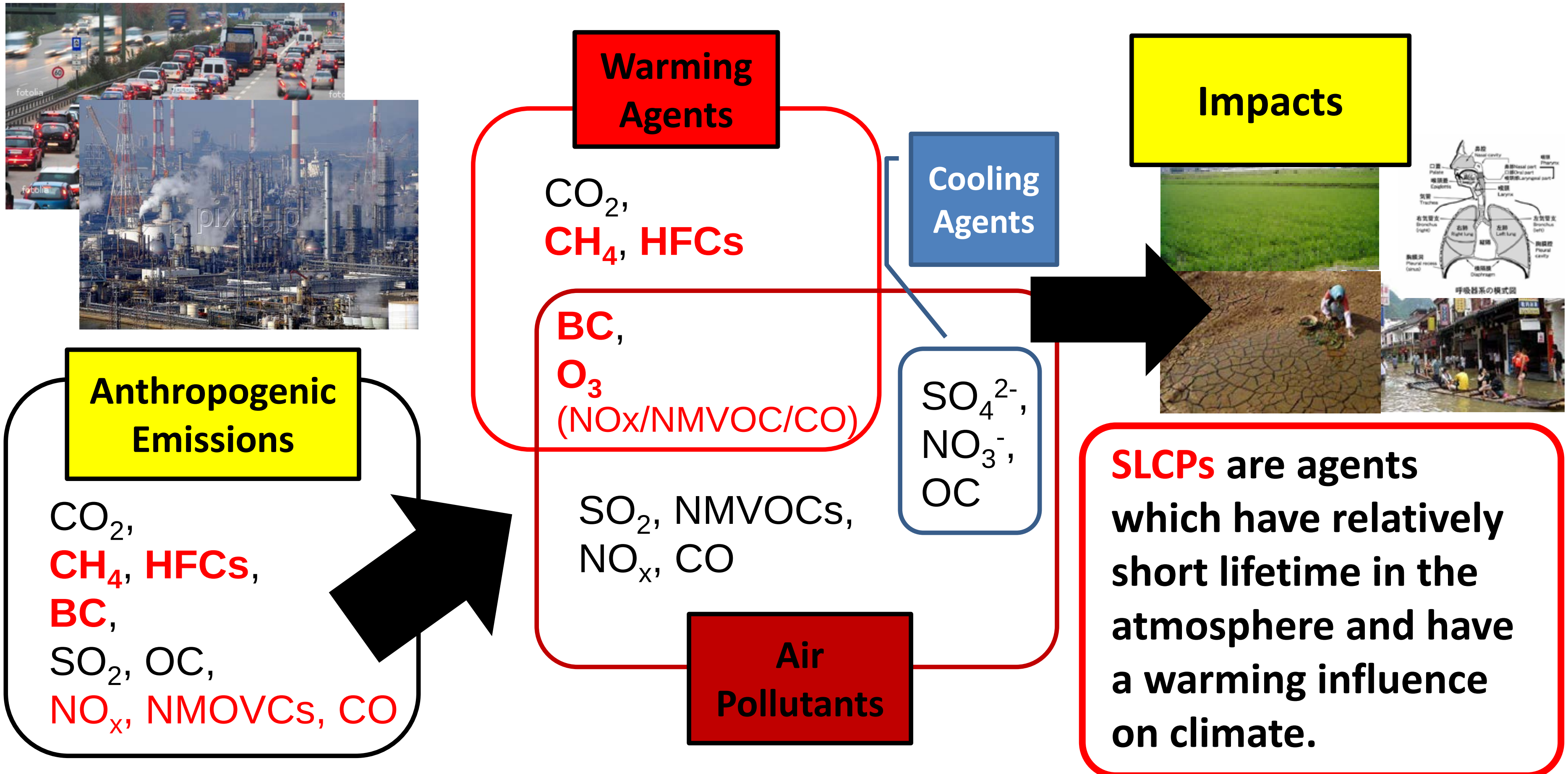
1. Air pollution in Asia and S-12 project
2. Historical trend of air pollutant emissions in Asia over the past six decades
3. Inverse modeling of air pollutants emissions
4. Brief introduction of our ongoing project: Research topics on Fukushima accident related to this workshop

Air pollutants in Asia



There are many air pollutant sources in Asia.

Many pollutants causes air pollution & climate change



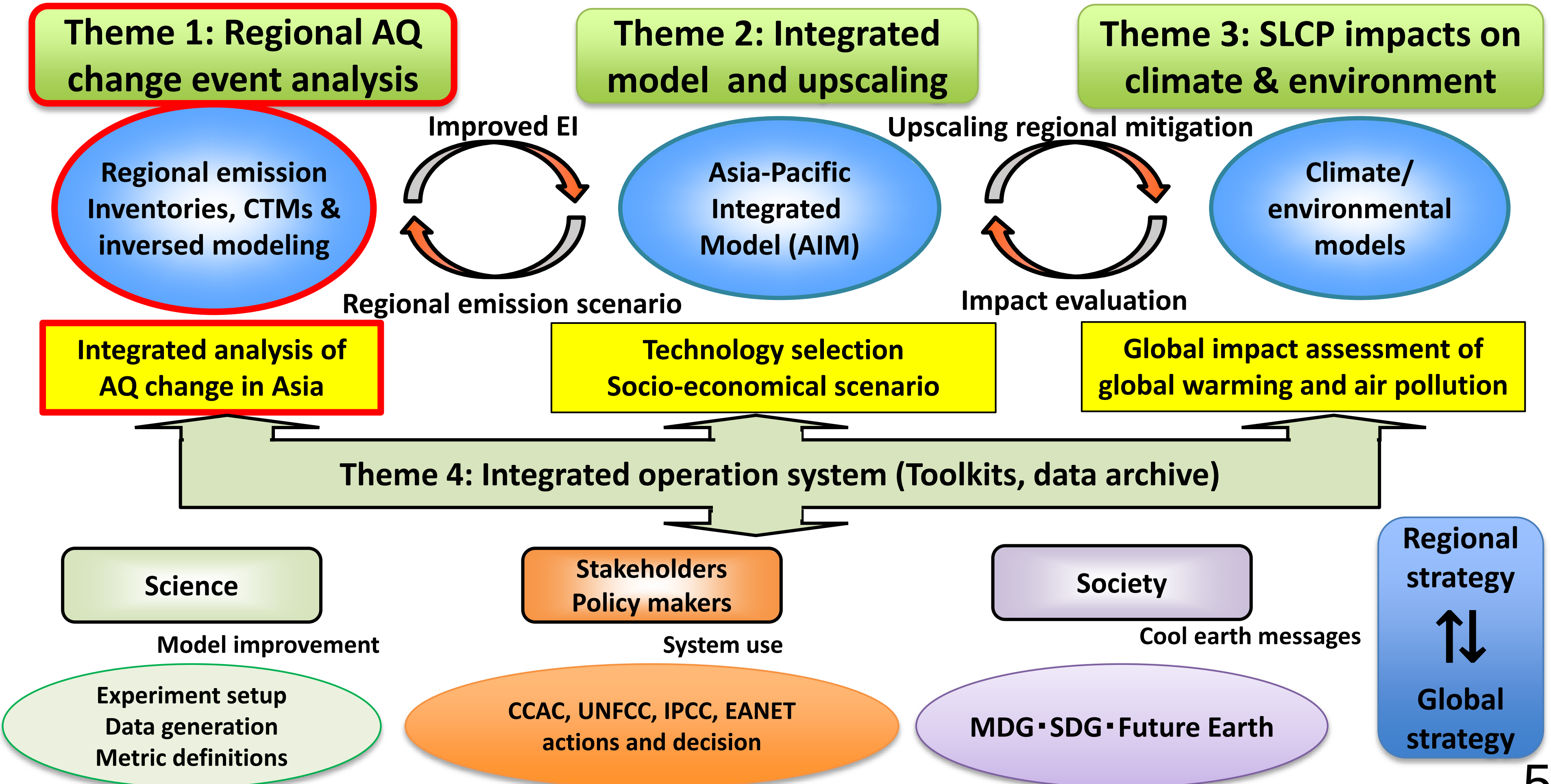
Red colored species: Short lived Climate Pollutants (SLCPs)

- Climate change is a serious global issue. Additionally, air pollution is regional issue which should be urgently solved especially in Asia.
- SLCP reduction for mitigating both air pollution and near term climate change is important in Asia.

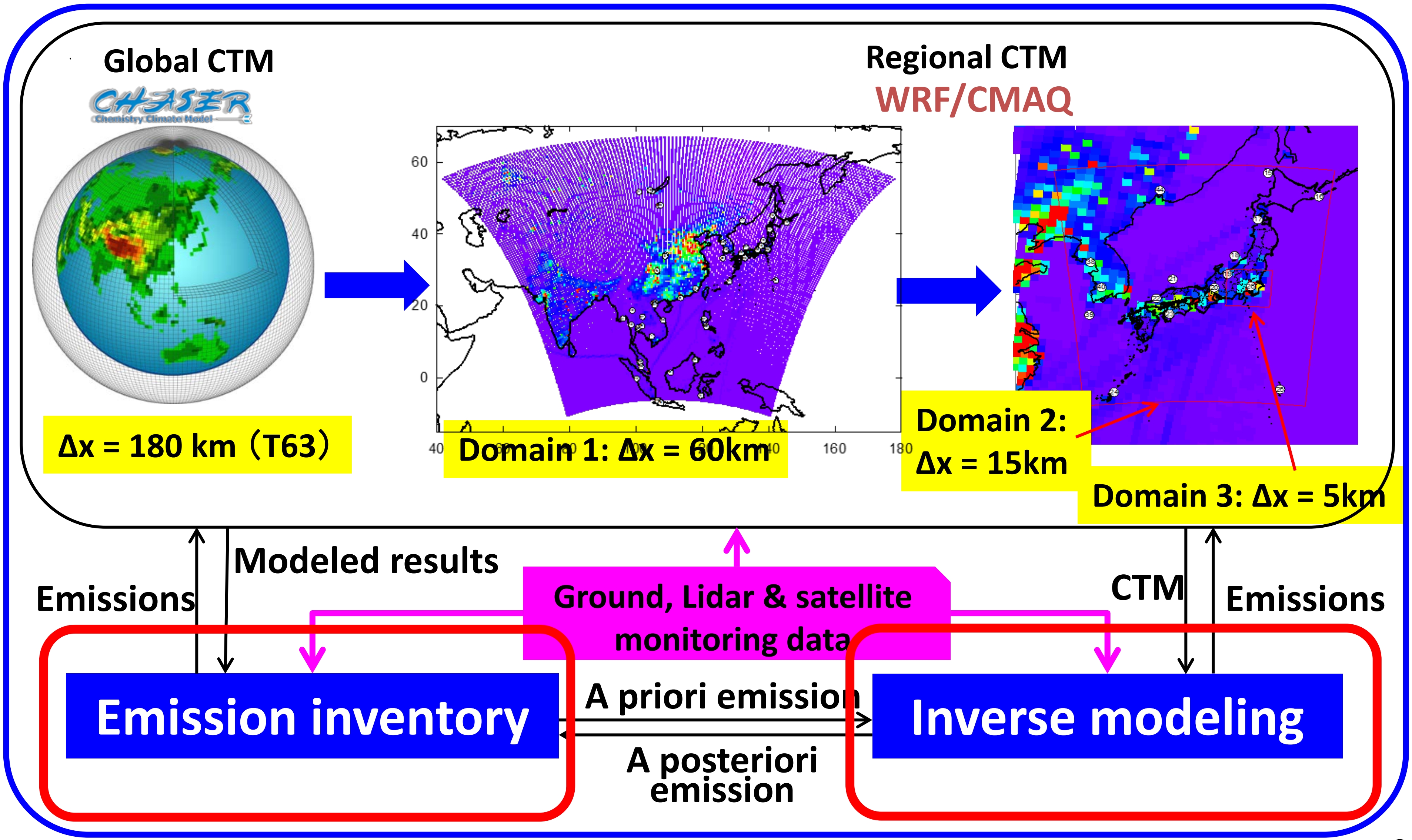
MOEJ-S12: Active evaluation of SLCP impacts and seeking the optimal pathway (2014-2018)

PI: Terry Nakajima

- Reduction of SLCP is easier than that of LLGHG due to their short lifetime, but the effects are very complex.
- Therefore, search for optimum mitigation paths is important for society.
- It is needed to develop an active evaluation system for LLGHG and SLCP mitigation policy, by overarching emission inventory, integrated models, and climate models.



Framework of analysis/verification system for regional air quality changes in Asia



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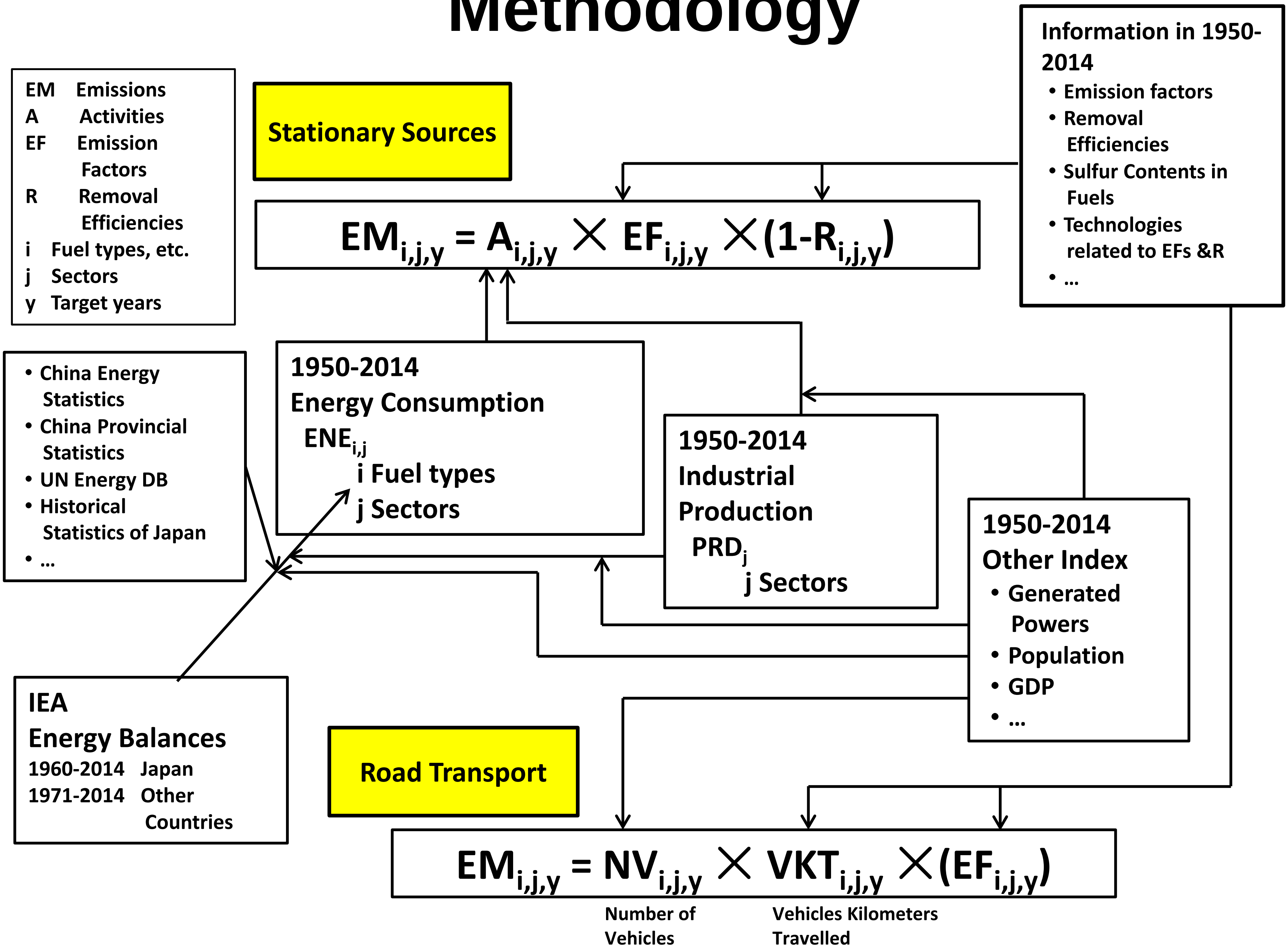
Regional Emission inventory in ASia (REAS)

Anthropogenic, comprehensive, and long-term inventory

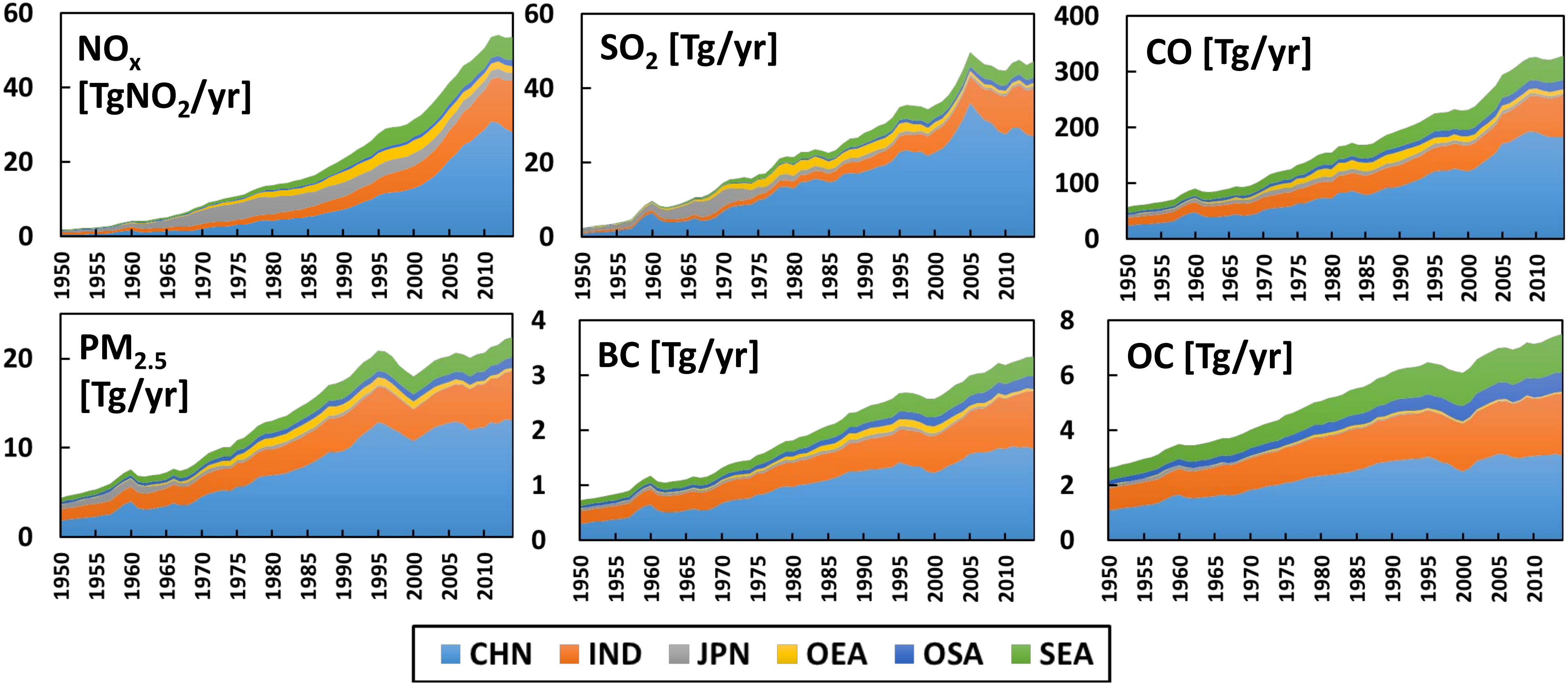
- **Country and regional emissions for detailed sources**
- **Gridded emissions for major sources**
- **Target Years：1950-2015 (currently until 2014)**
- **Target Areas：East, Southeast, and South Asia**
- **Horizontal Resolution：0.25° ×0. 25°**
- **Temporal Resolution：Monthly**
- **Target Species：**
  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								●	●	

Methodology

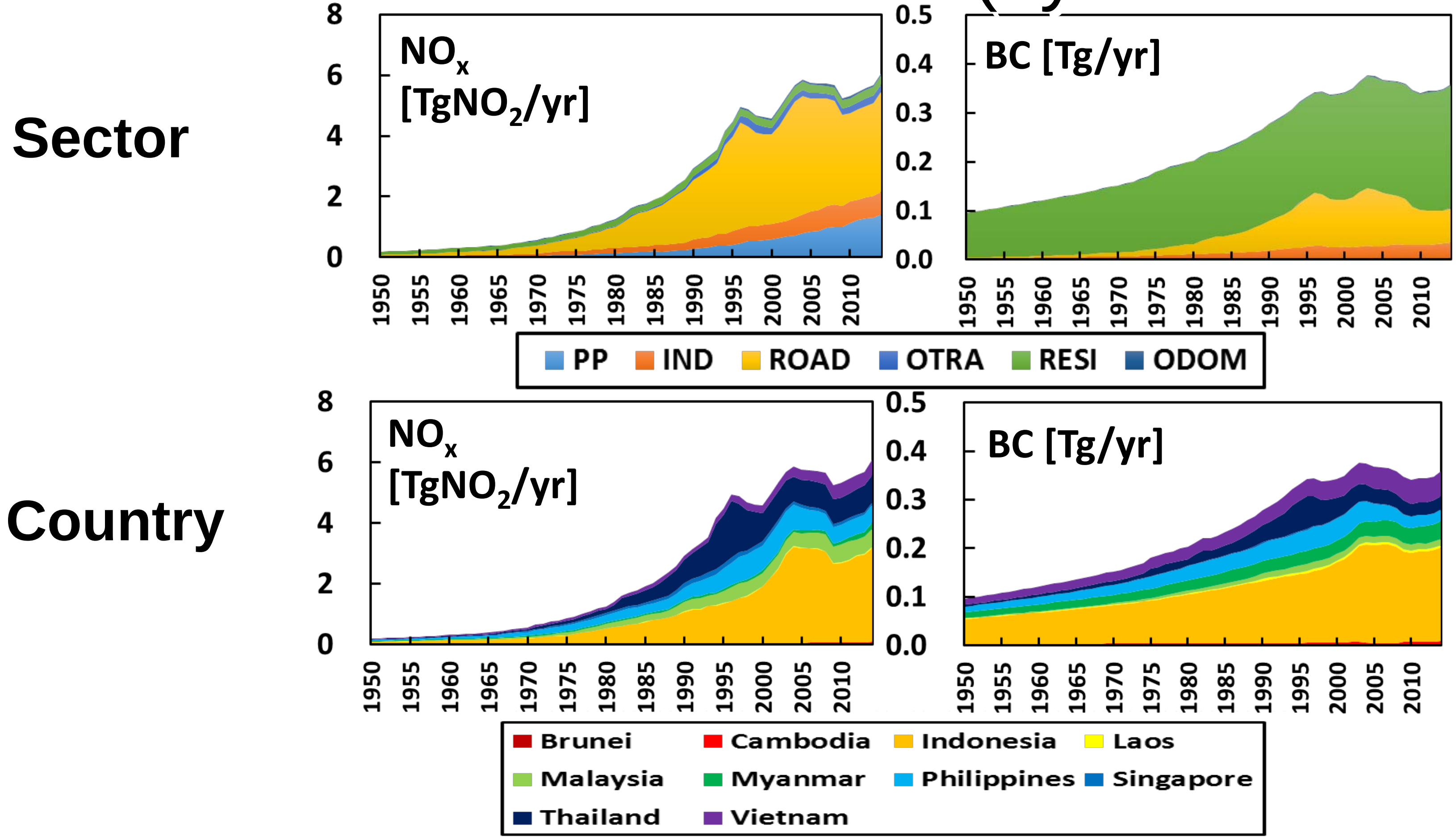


Emissions in Asia (by Region)



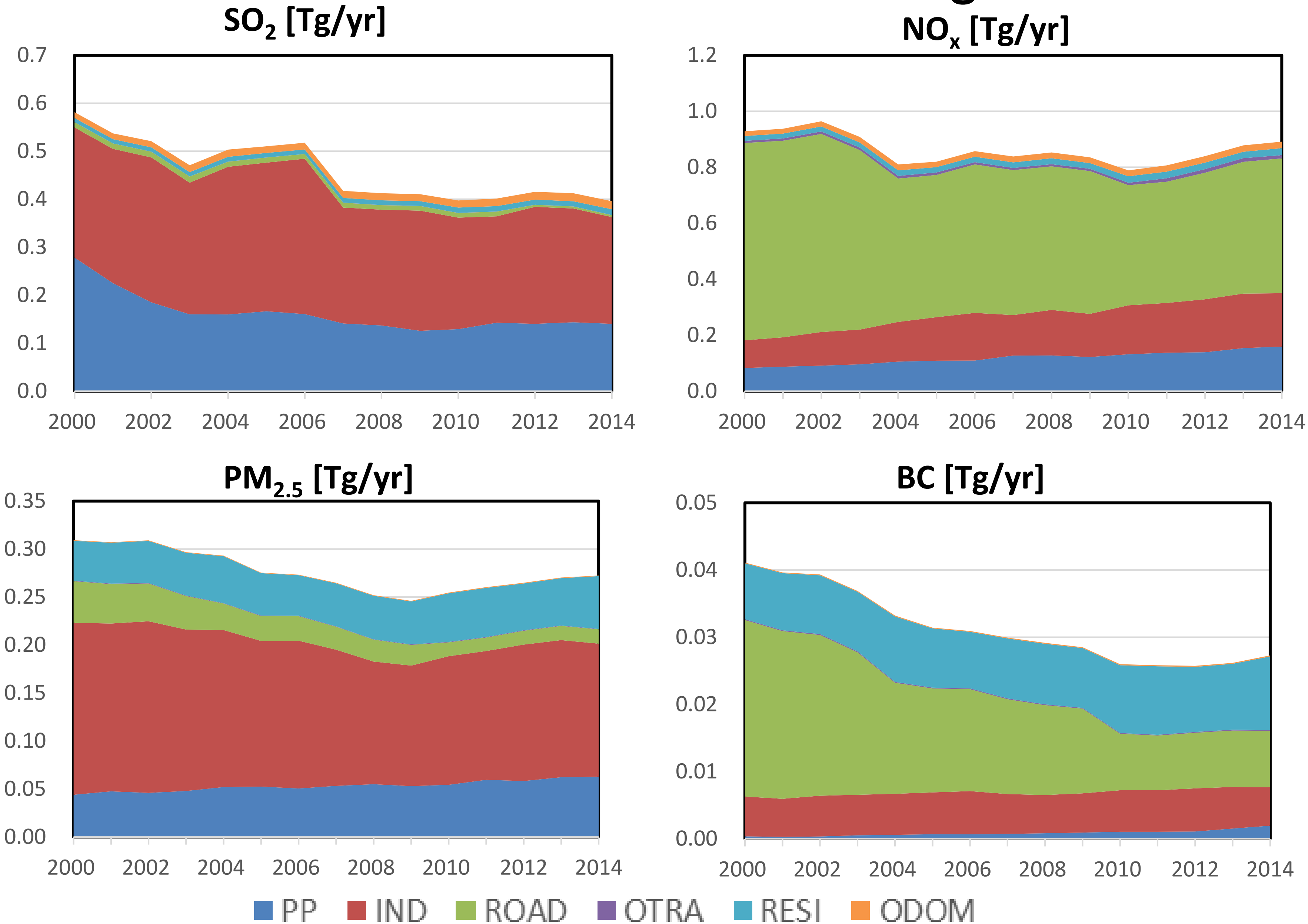
- Emissions of all air pollutants in Asia increased significantly during these six decades.
- Recently, SO_2 and NO_x seem to reach their ceiling. Other species are growing slowly. These tendencies are due to emission control measures especially in China.
- For SEA and SA (IND+OSA), recent emissions show growing especially in India.

Emissions in Southeast Asia (by sector & country)



- [NOx] Major sources was road transport.
  Recently, emissions from coal combustion in power and industry is increasing.
- [BC] The largest emission source is biofuel combustion in residential sector.
  Recently, emission trend of diesel vehicle influences to that of total emissions.
- For countries, the largest contributor for emissions is Indonesia followed by **Thailand**, Philippines, Vietnam, and Malaysia.

Emission trends in Thailand during 2000-2014



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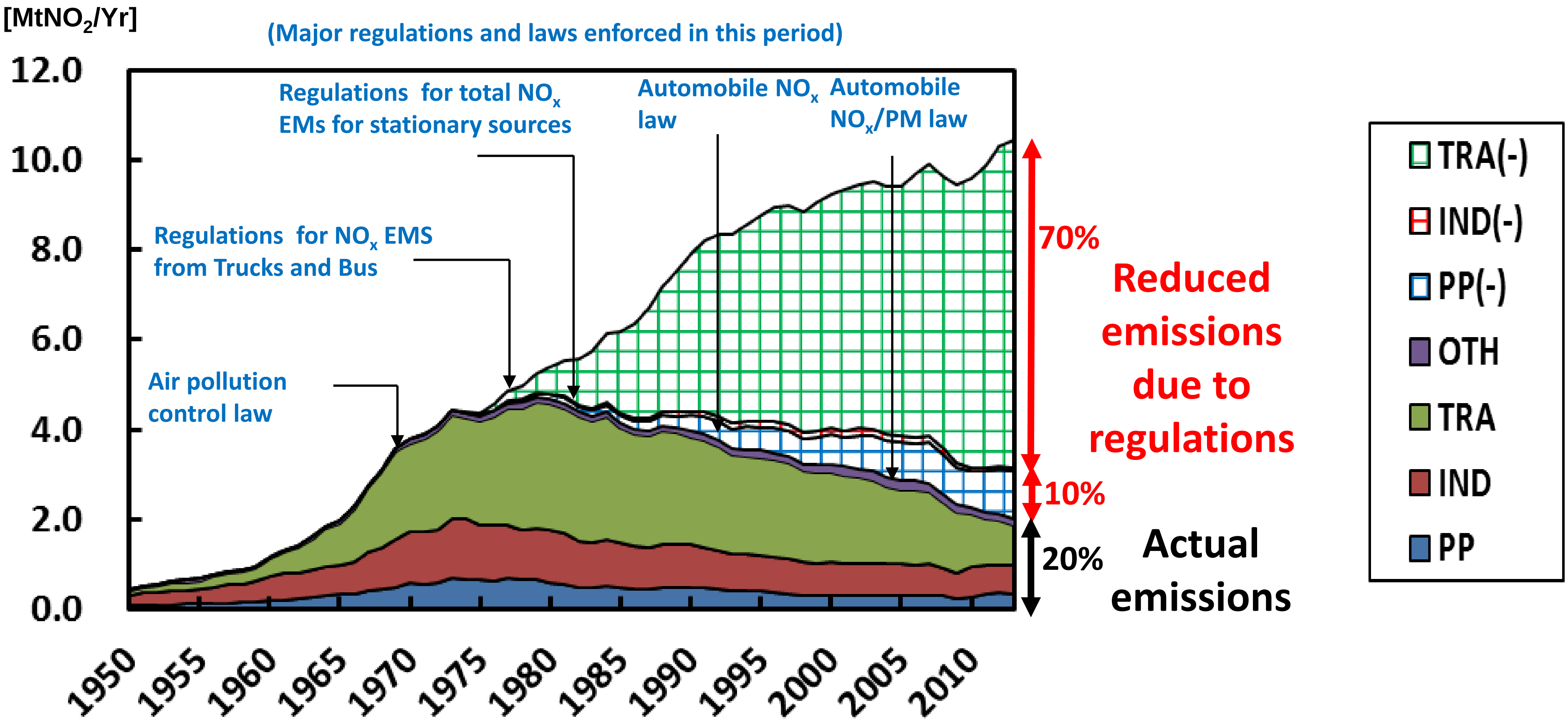
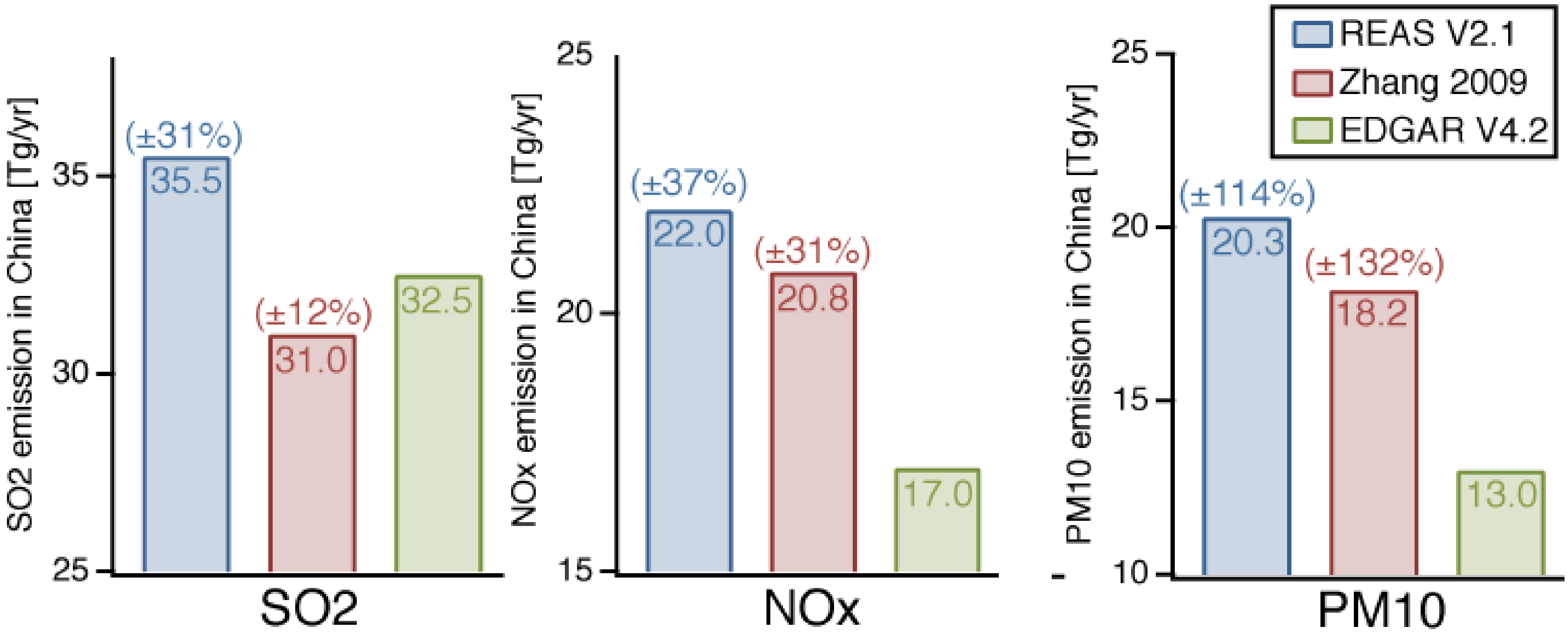
NO_x emission reduction due to regulations in Japan



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

Uncertainties of Emission inventory



Differences in Chinese emissions around 2008 among emission inventories

There are large differences between emission inventories

Next steps and remarks (for emission inventory)

Developing and improving REAS

- We are developing a historical emission inventory based on REAS and current status of emissions in Asia were presented.
- Using latest statistics and recently published literatures, REAS will be updated and extended to 2015.
- Emissions in Southeast/South Asia have large uncertainty, especially agricultural emissions and evaporative NMVOC. More comparison with other inventories is needed and REAS should be improved.

Need to collaborate with inverse modeling

- REAS emissions should be improved and updated by inverse modeling.
- It is needed to consider how to improve REAS historical inventory by combining feedbacks from forward and inverse modeling results.

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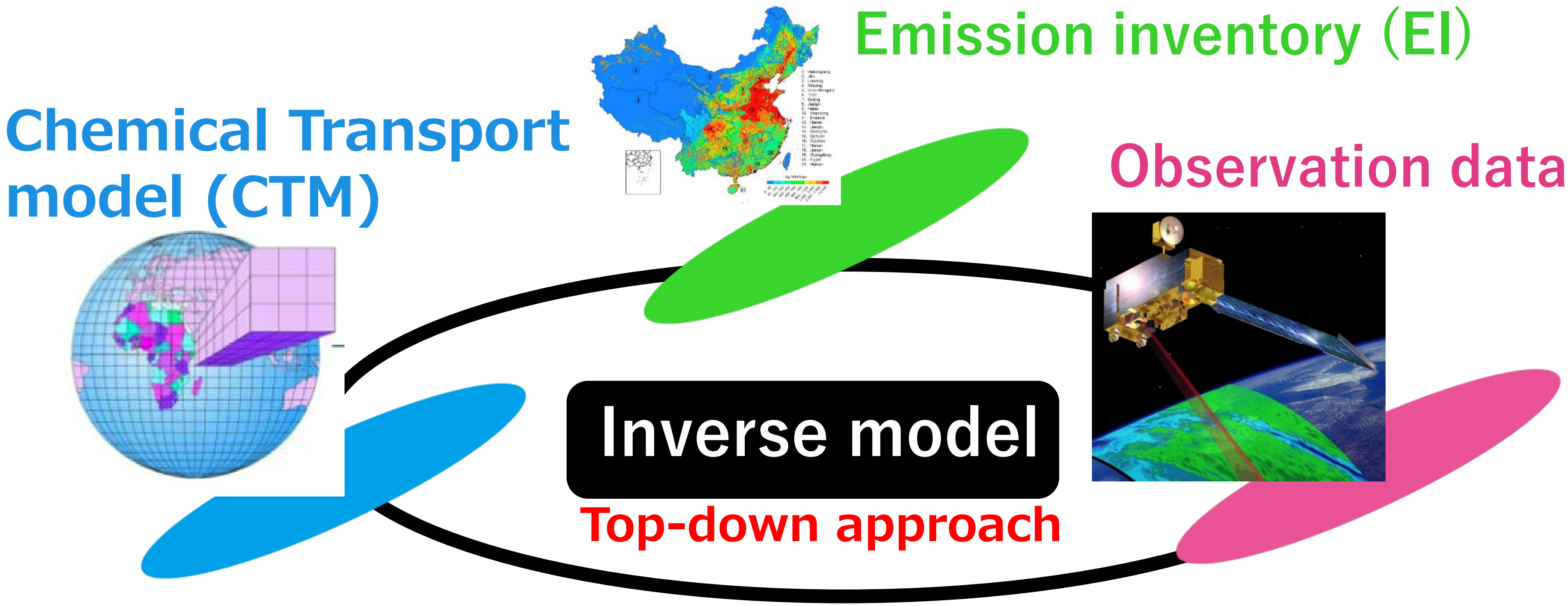
Inverse modeling (Top-down approach)

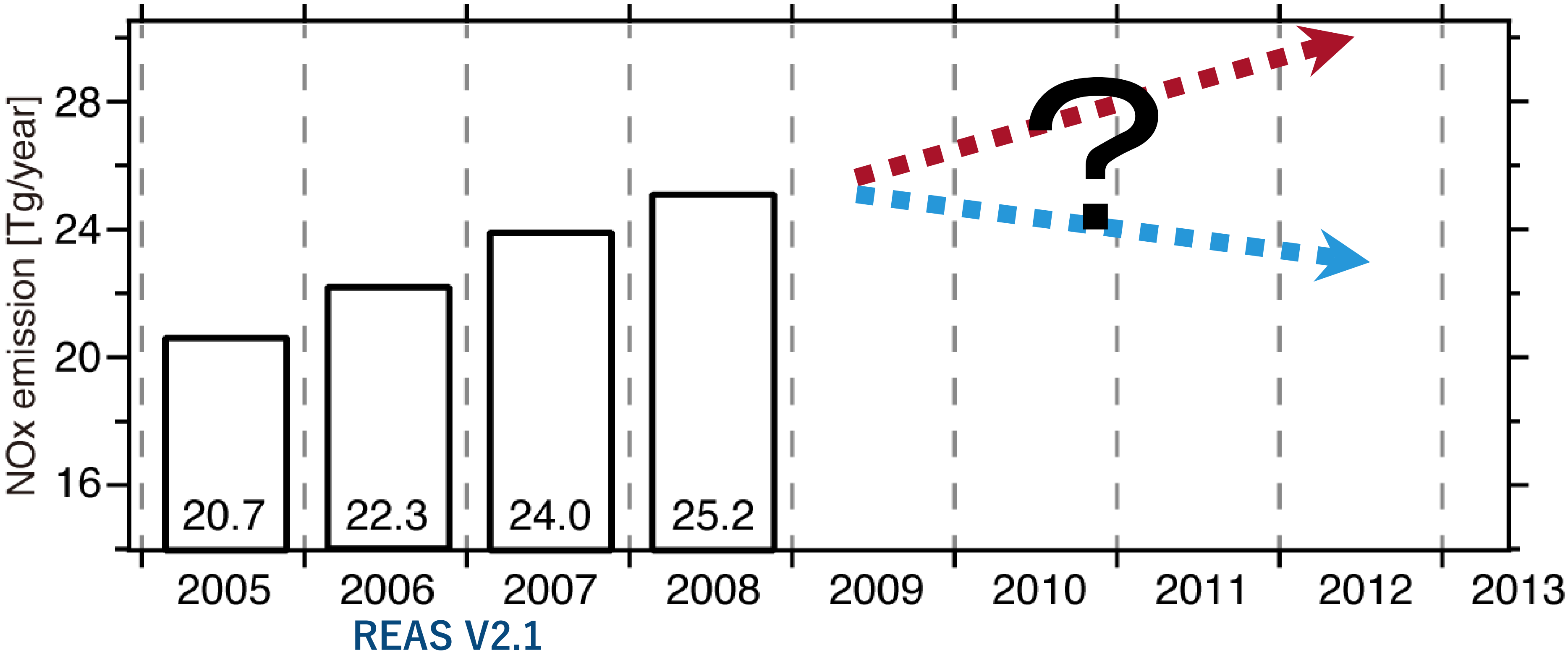


Inverse modeling integrate EI(a priori data), CTM and observation data to complement (optimize) emissions

＝Inverse estimation of emissions

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

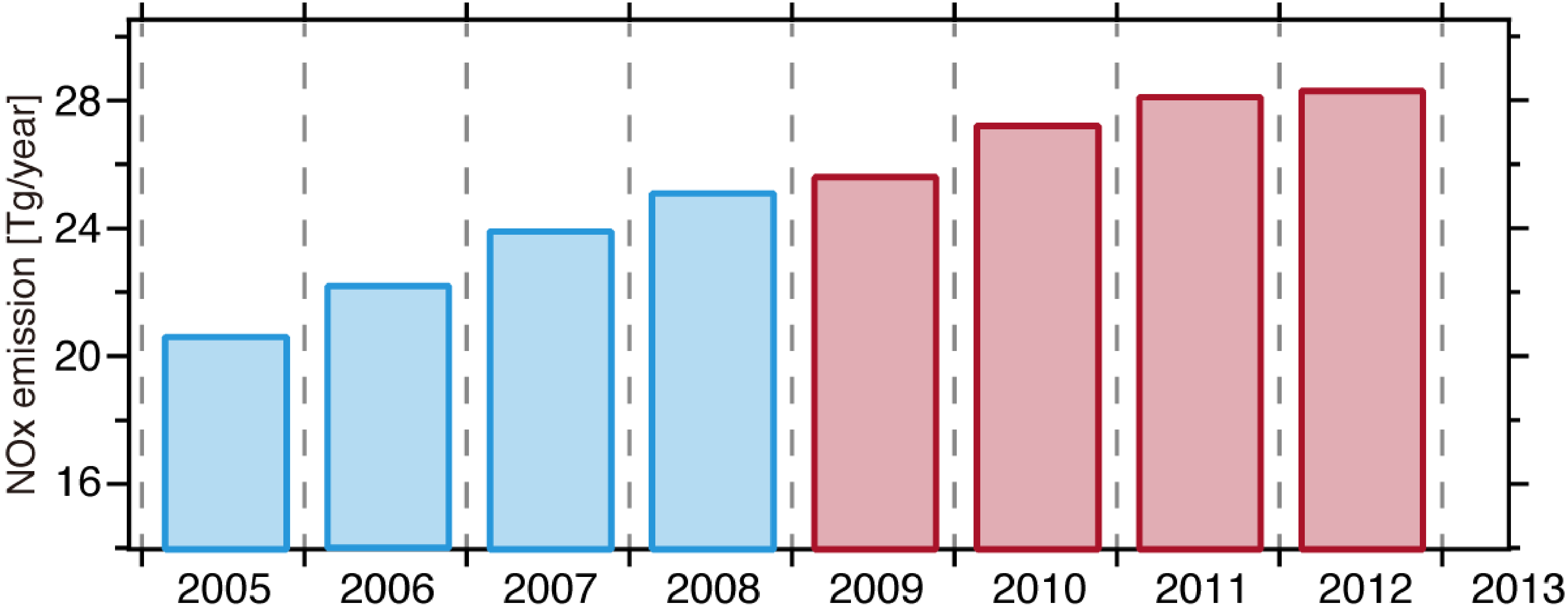
Importance of rapid update by Inversion



Changes in China's NOx emissions from year to year

- For better understanding the recent change of air quality, it is needed to estimate the recent trend of emissions.
  → Rapid update of emissions without statistical data (usually, a couple of years delayed), so based on top-down approach
- It can also be used to verify and improve past emissions inventories.

Importance of rapid update by Inversion



Verification and improvement of emissions

Top-down emissions using OMI NO2 VCD (estimated in 2013)

- For better understanding the recent change of air quality, it is needed to estimate the recent trend of emissions.
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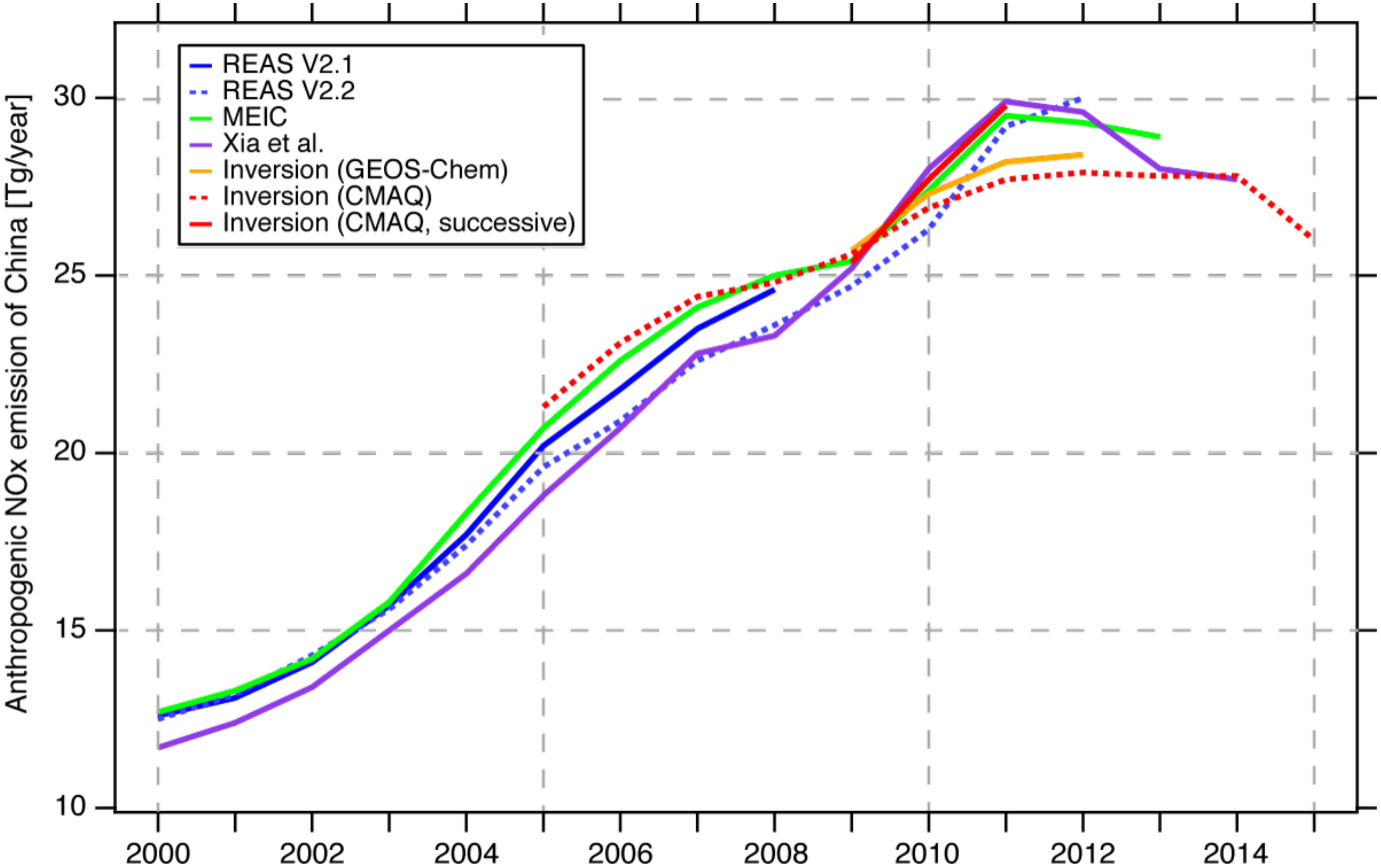
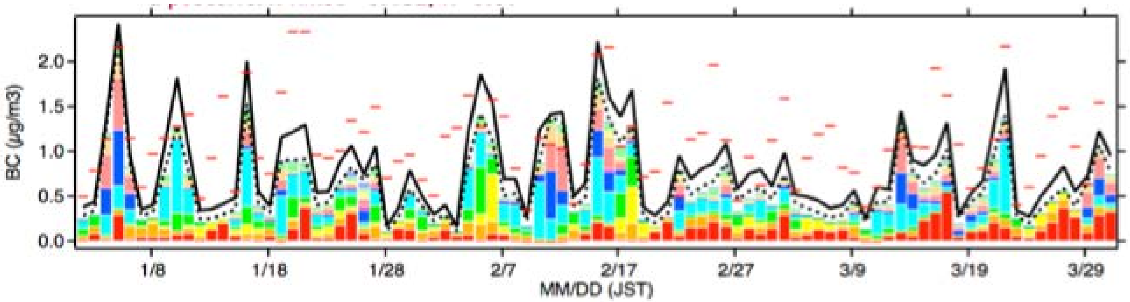
Recent trends of NOx emission in China



- Original inverse modeling (using a posteriori emission for base year (2008) as a priori emission) failed to capture the drastic change of NOx emission during 2009-2013.
- Modified inverse modeling (using a posteriori emission for previous year as a priori emission) captures higher growth rate during 2009-2011. We will extend estimation period (2009-2015) using this method.

Outline of BC inverse modeling



Example of tagged tracer transport simulations

- **CTM (MASINGAR mk-2)**

  Control run ＋ wet deposition off ＋ Tagged tracer transport simulations

- **Observation data**

  COSMOS@Hedo ＋ Fukue ＋ etc.
  Making use of Aethalometer observation （Estimation of observation error）

- **Inverse model**

  Bayesian Synthesis (Maki et al., 2011)
  Time resolution of emission data is monthly

Summary in this part

Inverse modeling can integrate chemical transport model, emission inventory and observation via statistical approach.

We successfully update NOx emissions in east Asia and found that Chinese NOx emission start to reduce from 2011. However, the growth rate is smaller than observations.

We modify our inverse modeling to use the analysis results from the previous year as a priori information to next year. The results show better agreement with other results.

We are developing BC inverse modeling system. The system integrate an global aerosol model, surface observations and REAS 2.2 emission inventory via Bayesian synthesis inversion.

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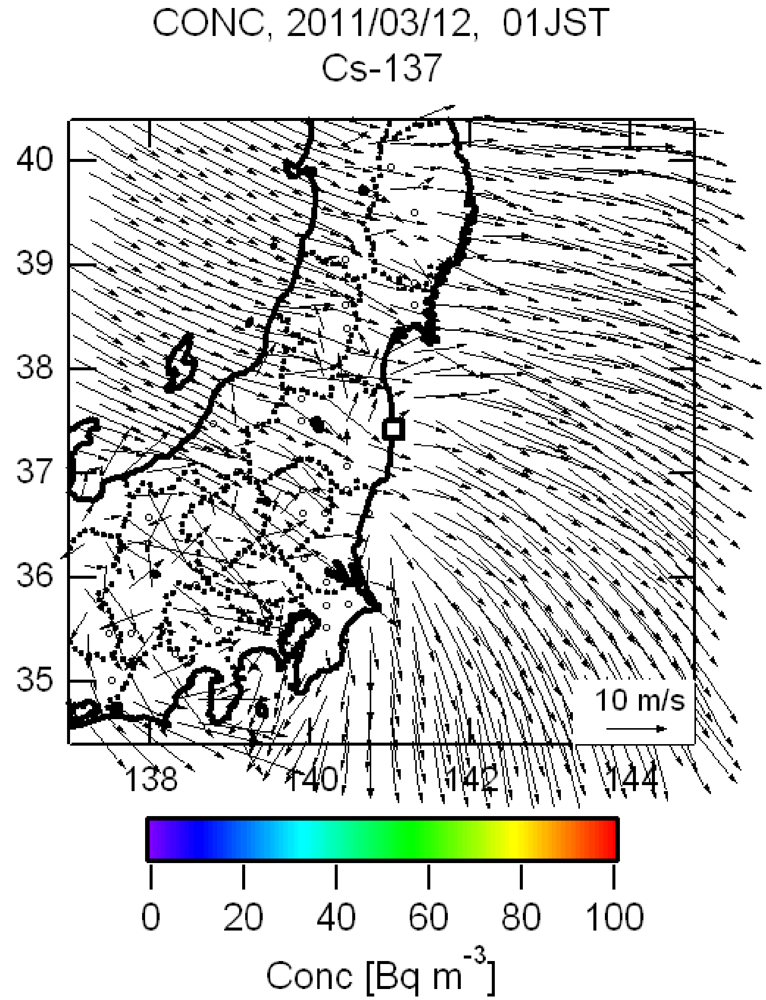
The Great East Japan earthquake (GEJE) has occurred on 11 March, 2011

Accident of Fukushima Daiichi Nuclear Power Station (FDNPS)

Massive radioactive materials were emitted into the environment



Research topics on Fukushima accident related to this workshop

1. Environmental impact assessment of resuspension of radioactive materials derived from forest fire

2. Inverse modeling for source term estimation of radioactive materials from the FDNPS

3. Inter-comparison of CTM for atmospheric concentration of radioactive materials immediately after the accident

4. Monitoring of land use change and its impacts to ecosystem in evaluation zone near FDNPS

Fukushima accident provided research field for many kinds of environmental studies based on interdisciplinary approach.

Thank you very much for your attention!