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International workshop on "Inventory, Modeling and Climate Impacts of GHG's and Aerosols in the Asian Region"

Regional emission inventory in Asia (REAS) version 2

Toshimasa Ohara

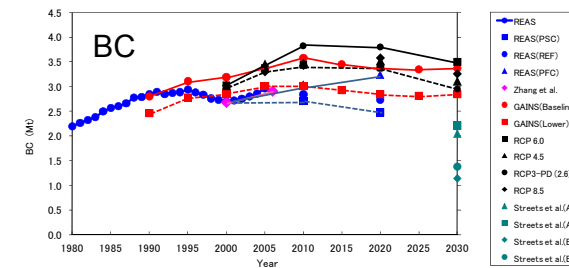
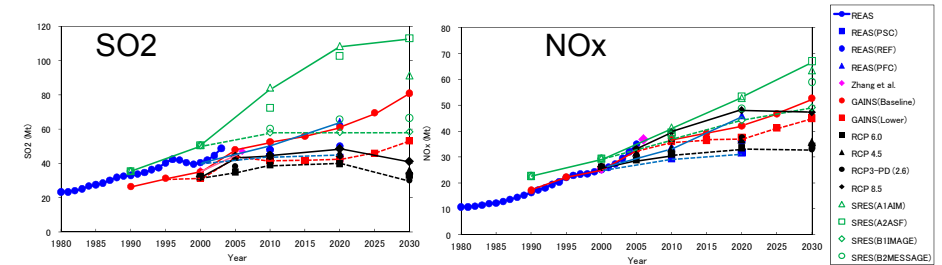
National Institute for Environmental Studies (NIES), Japan

Jun-ichi Kurokawa

Asian Research Center for Air Pollution (ACAP), Japan

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Historical and projected emissions in Asia



In past emissions,
big uncertainty !

In future emissions,
big scattering !

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Background and aims

- (1) The rapid growth in many Asian countries in recent years led to the significant increase of urban, regional, and trans-boundary air pollution.
- (2) An understanding of long-term and future changes for Asian emissions is an area of increasing scientific interest and political concern.
- (3) To understand the current status, recent trend, and future change of anthropogenic emissions in Asia,
 - (a) update of the REAS v.1 to the **REAS 2.1**.
 - (b) verification and improvement of the REAS 2.1

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Introduction of Regional Emission inventory in **ASia (REAS)** version 2.1

Kurokawa, Ohara et al. (2013) ACPD

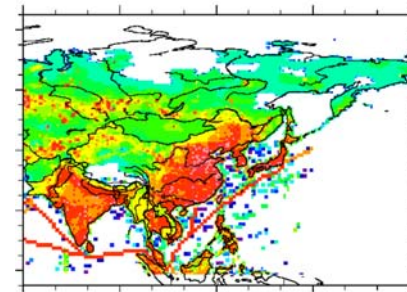
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Limitation of REAS v.1

Ohara et al. (2007) ACP

- Latest year of historical emissions and the base year of projected emissions become older.
 - Energy consumption in Asia is growing continuously.
- Recent changes of EFs due to emission control were not taken into account.
 - Ex. FGD for coal-fired power plants.
- Request from recent simulation models:
 - Fine spatial resolution
 - Seasonal variation
 - Expansion of model domain and species

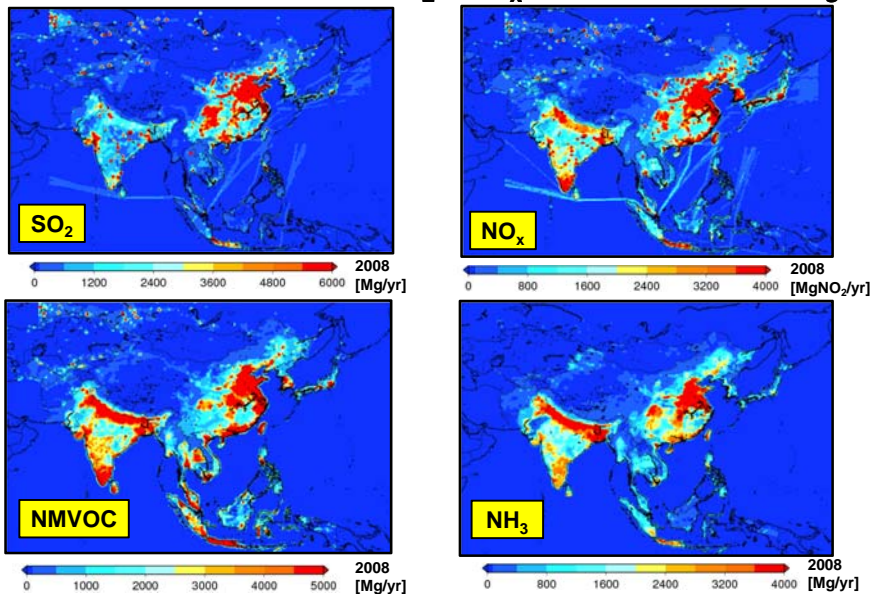
Outline of REAS 2.1



Item	Description
Target Areas	E, SE, and S Asia + Russian & Central Asia
Target Years	2000-2008 (→ 2010)
Spatial Resolution	0.25 x 0.25 degree
Temporal Resolution	Monthly
* Japan	JATOP inventory
* Korea and Taiwan	Official report

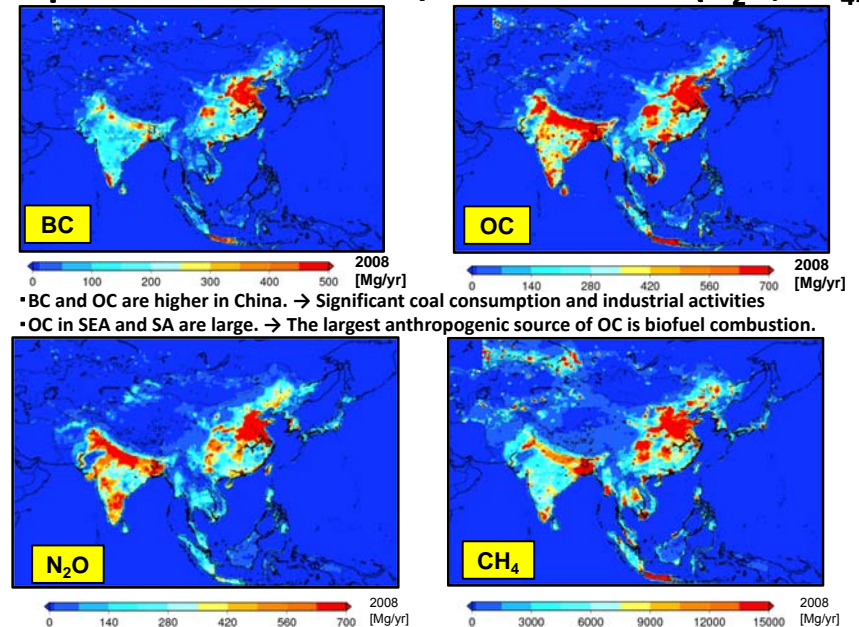
	SO ₂	NO _x	CO	PM ₁₀	PM _{2.5}	BC	OC	NMV	NH ₃	CH ₄	N ₂ O	CO ₂
Fossil Fuel Biofuel	●	●	●	●	●	●	●	●	●	●	●	●
Industrial Process	●		●	●	●	●	●	●	●		●	●
Fertilizer use		●							●	●	●	
Livestock									●	●	●	
Others								●	●	●	●	

Spatial distribution: SO₂, NO_x, NMVOC, and NH₃



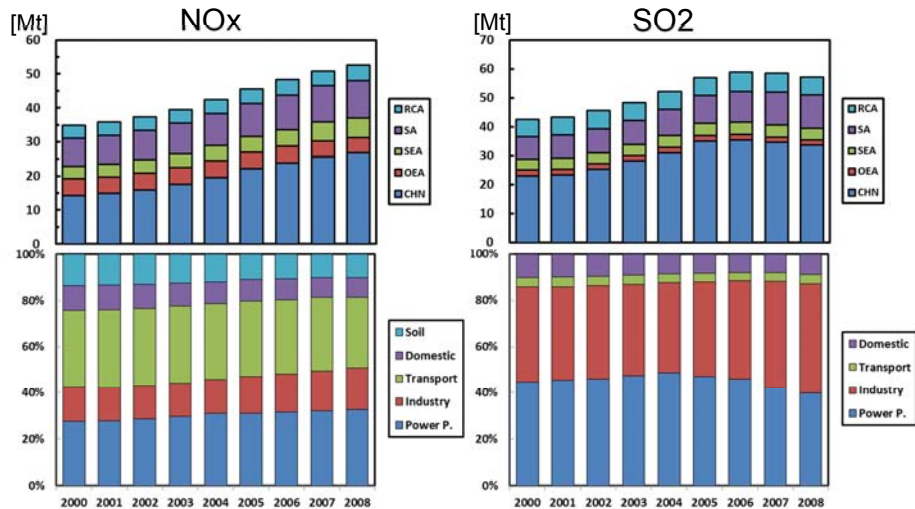
Eastern China, Chongqing and Sichuan province, the Indo-Gangetic Plain, Southern India, and Indonesia: → These area have large population and significant economic and industrial activities

Spatial distribution: BC/OC and LLGHG (N₂O, CH₄)



• BC and OC are higher in China. → Significant coal consumption and industrial activities
 • OC in SEA and SA are large. → The largest anthropogenic source of OC is biofuel combustion.

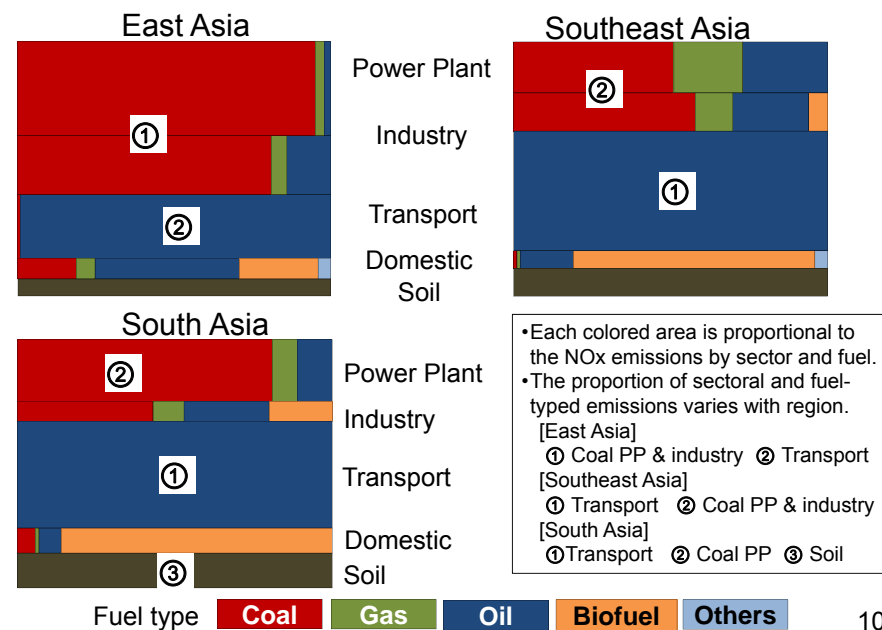
Temporal variation of annual emissions in Asia



- Asian NO_x emissions were increased by 50 %.
- China's NO_x was more than doubled, but increase rate becomes smaller recently.
- NO_x in SE Asia and India also increased rapidly (65% and 40%, respectively) due to the increase of energy consumption in power plants and road transport.
- Asian SO₂ emissions were increased by 50 %.
- However, that were decreased after 2006.
- The contribution of power plants was decreased after 2004.
- India's SO₂ were still increasing rapidly (50%).

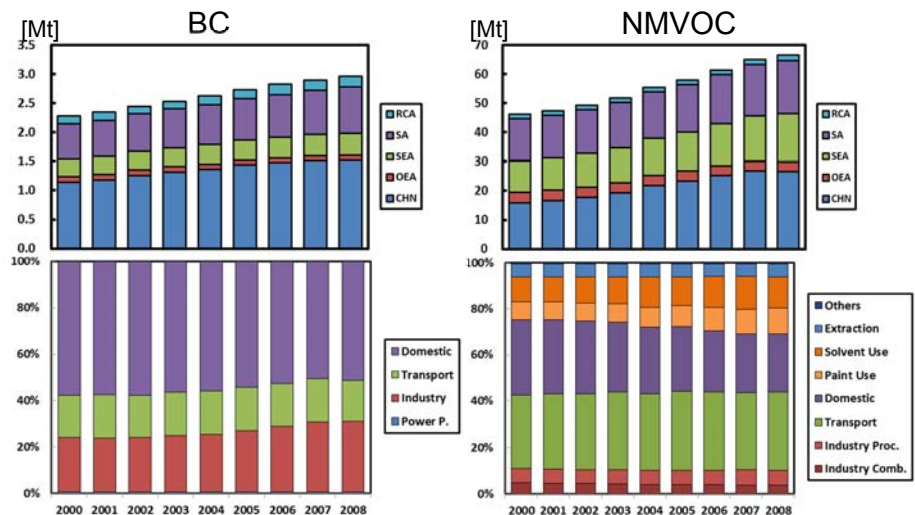
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Fuel/sector matrix of NO_x emissions in Asia



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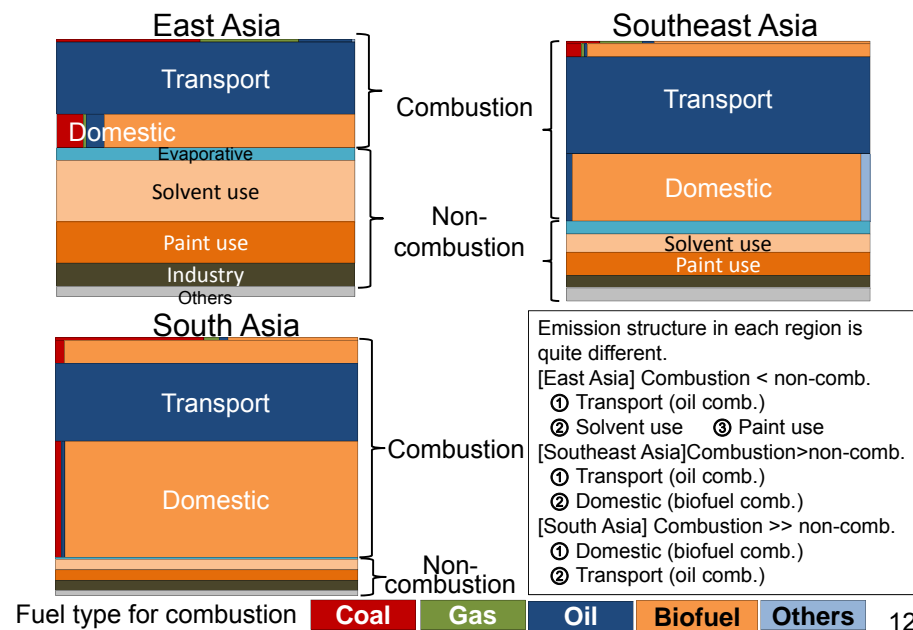
Temporal variation of annual emissions in Asia



- Asian BC emissions were increased by 30 %.
- Domestic sector is the largest and industry is the second.
- Domestic % went down due to the decrease of coal and biofuel consumption.
- Asian VOC emissions were increased by 44 %.
- Sectoral % in Asia increased in solvent and paint use while it decreased in domestic sector.

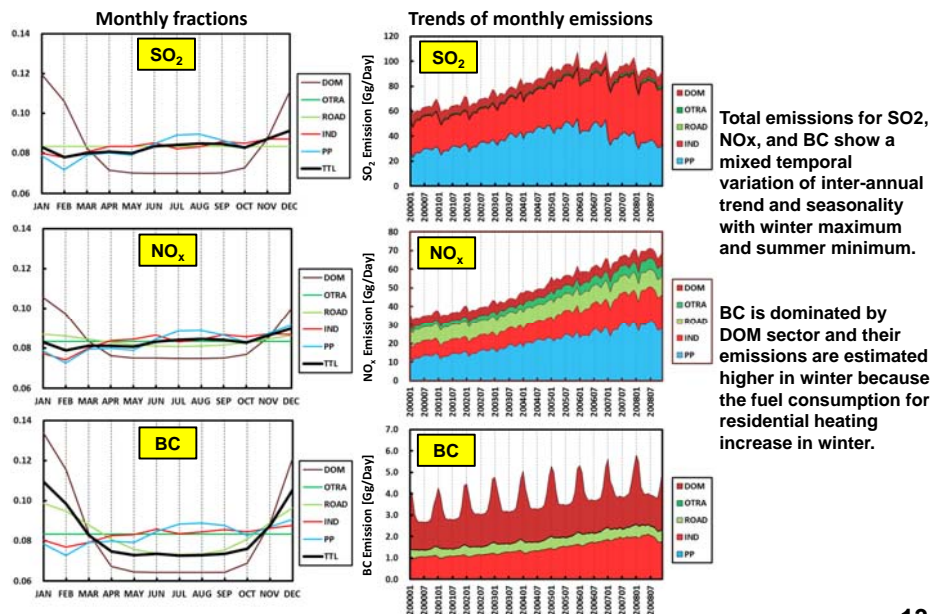
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Fuel/sector matrix of NMVOC emissions in Asia



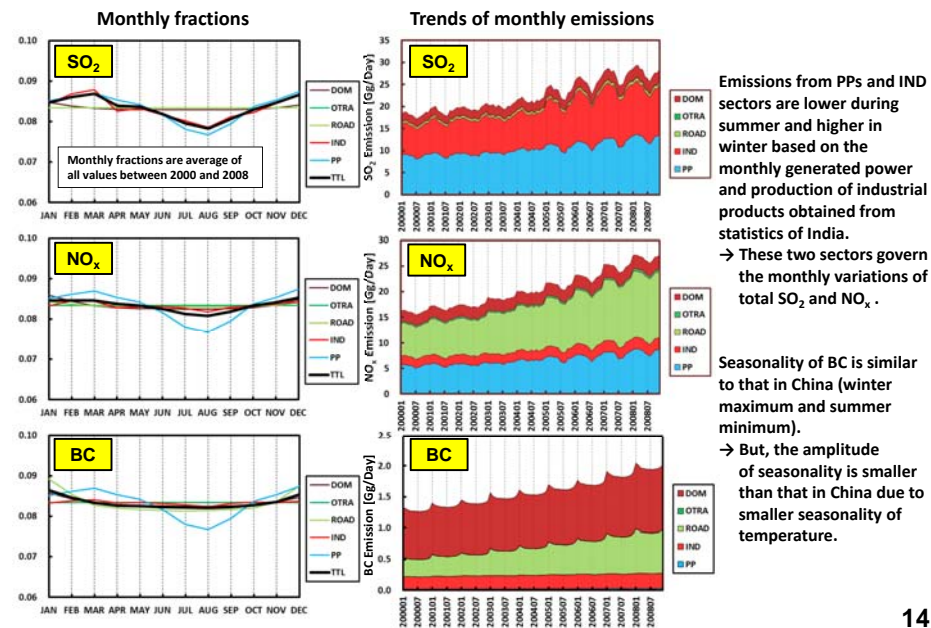
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Fractions and trends of monthly emissions in China



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Fractions and trends of monthly emissions in India

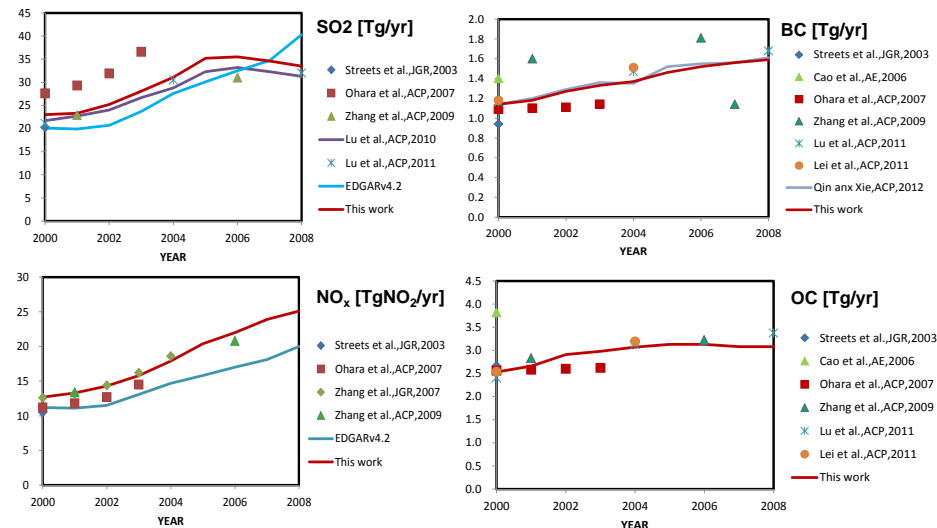


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Verification of REAS 2.1 based on comparison with other inventories and satellite observations

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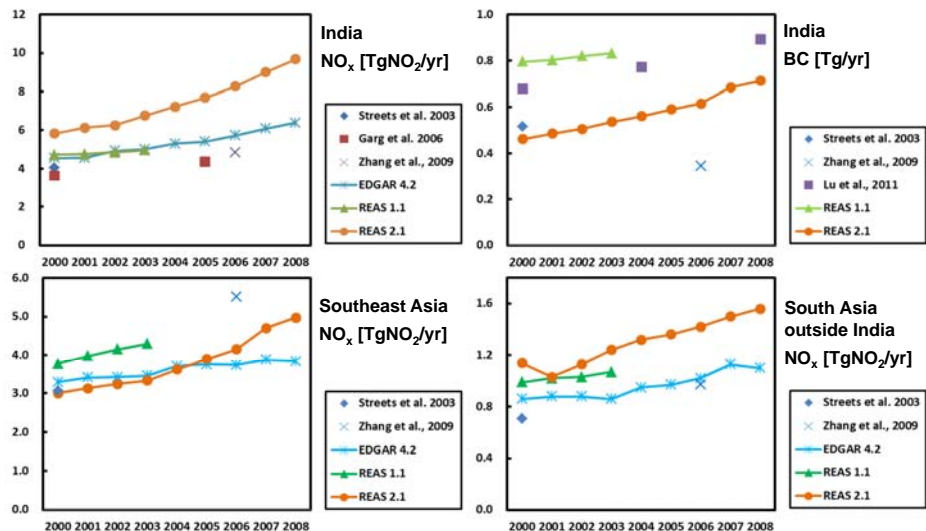
Comparison with other inventories (China)



REAS 2.1 is consistent with Chinese inventories. Global inventory, EDGAR 4.2, shows a different situation.

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Comparison with other inventories (South and Southeast Asia)

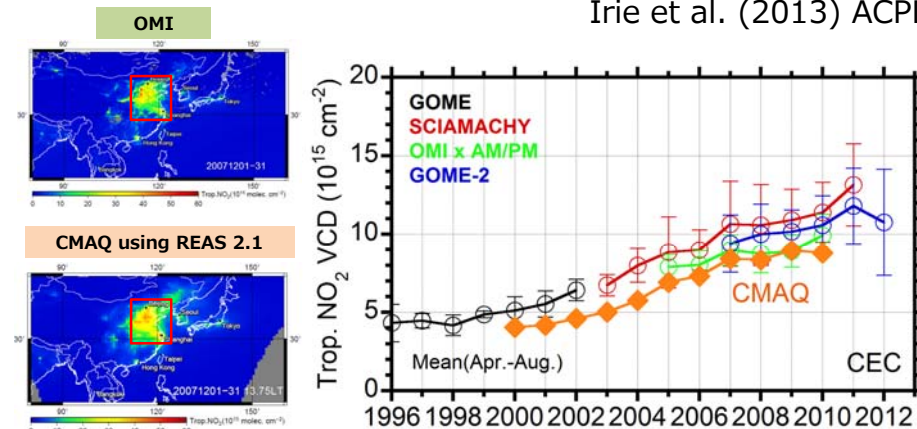


There are large differences among inventories. Much efforts for evaluation and improvement of emission inventory for SE and S Asian regions are required. 17

Trends of NO₂ VCD in CEC

– CMAQ (based on REAS 2.1) and satellite –

Irie et al. (2013) ACPD

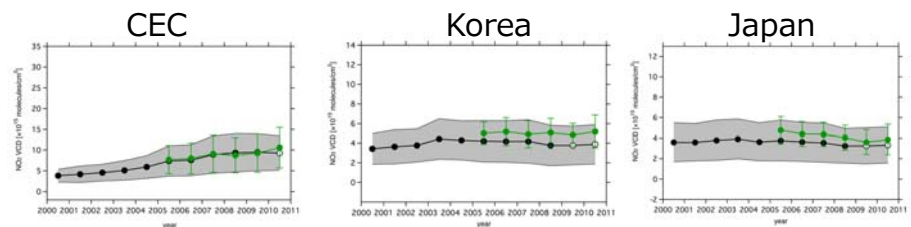
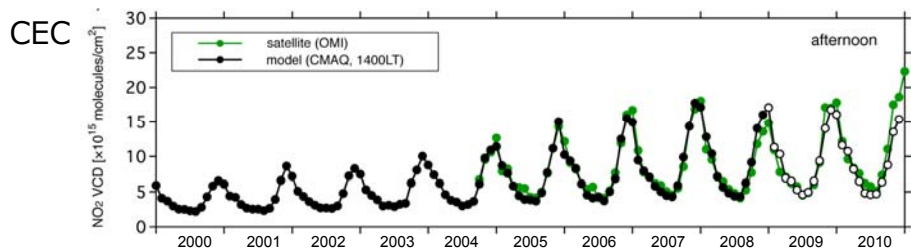


Trop. NO₂ VCD from satellite and CMAQ/REAS2.1 are consistent well though CMAQ is lower than satellite due to the coarse resolution of CMAQ. (Sensitivity analysis shows ~20% higher in fine resolution case)

Temporal variation of NO₂ VCD

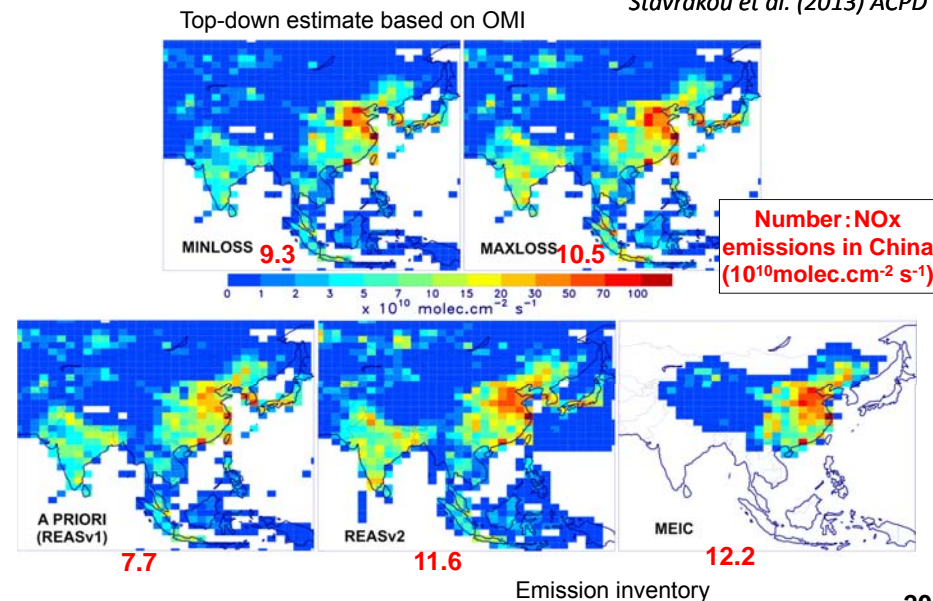
– CMAQ (based on REAS 2.1) and OMI –

Itahashi et al. (2013) ACPD

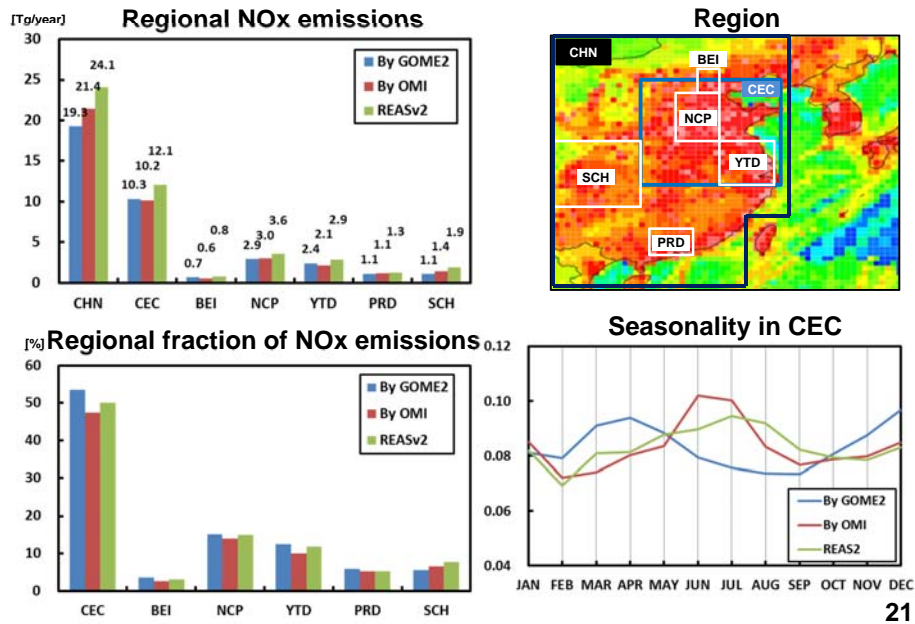


Top-down and bottom-up NO_x emissions

Stavrakou et al. (2013) ACPD



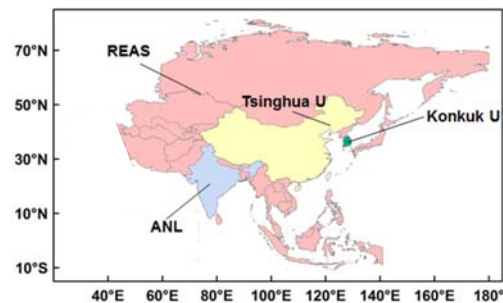
Top-down and bottom-up NOx emissions



Ongoing works

(Harmonization and future projection)

MICS-Asia (Model Inter-Comparison Study - Asia) III



Best MIX anthropogenic emission inventory in Asia

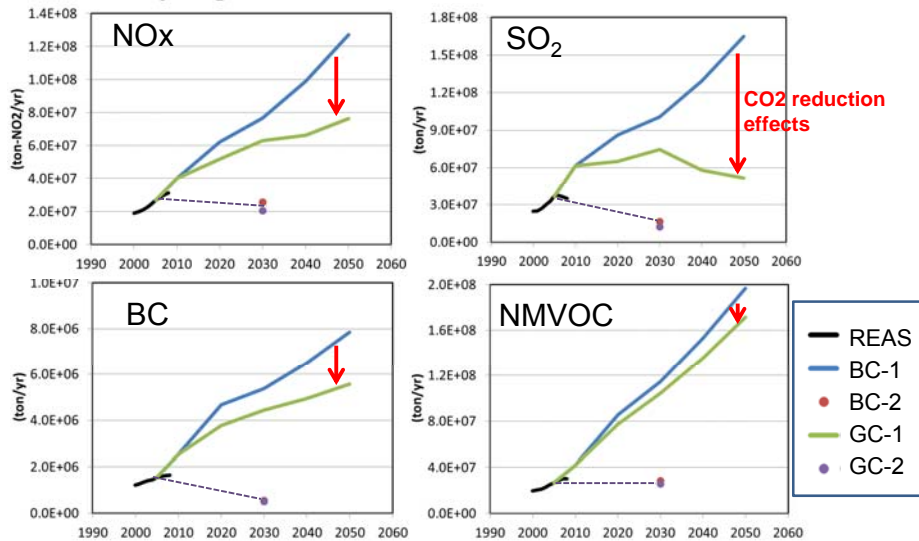
- **China**, from MEIC (Multi-resolution Emission Inventory for China) database developed by Q. Zhang and K. B. He at Tsinghua University
- **India (SO₂, BC, and OC)**, from D. G. Streets at Argonne National Lab
- **South Korea**, from J.-H. Woo at Konkuk University
- **Other Asia and India (other than SO₂, BC, and OC)**, from REAS version 2.1
- **New emission inventories of Thailand, Malaysia, and Vietnam are now under development by researchers in each country.**

Outline of emission scenario

Baseline scenario	Air pollution control	
	Current legislation	Reinforcement scenario
BAU	BC-1	BC-2
CO2 half reduction	GC-1	GC-2

- Base year: 2005
- Projected year: 2010-2050
- Activity data: AIM (Asia-Pacific Integrated Model; model for RCP6.0) output
- Air pollution control reinforcement scenario for 2030:
 (Developed countries) Reasonably Available Control Technologies/Measures
 (Developing countries) Control technol./Meas. level for 2005 in Japan

Future projection of emissions in Northeast Asia



- CO₂ reduction is effective for reduction for SO₂ and NO_x, but is ineffective for BC and NMVOC.
- However, only CO₂ reduction is insufficient for air pollution reduction. Reinforcement of air pollution control is needed.
- Air quality in NE Asia can be improved by the introduction of current emission control in Japan.

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Summary

- We have updated the regional emission inventory in Asia (REAS v1) to the REAS 2.1 and verified it by top-down approach. The REAS 2.1 covers the anthropogenic emission sources in Asia during 2000-2008.
- Asian emissions for all species (except SO₂) show increasing trend during 2000 and 2008.
- The contributions from China are the largest in Asian emissions. However, the growth of China's emissions are slowing down due to a series of reinforcement of emission control.
- Relative importance of emissions from Southeast, India, Russian and Central Asia is increasing.
- Information for developing accurate emission inventory is not enough, especially in Southeast and South Asia.
 - Continuous surveys of activity data and parameters
 - Verification using model simulation and monitoring data

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Data download site of REAS 2.1

<http://web.nies.go.jp/REAS/>

(Ref.) Kurokawa et al., ACPD, 2013

Regional Emission inventory in ASia (REAS)
Data Download Site

REAS 2.1

Gridded Data Sets (Information for Data)

	SO ₂	NO _x	CO	PM ₁₀	PM _{2.5}	BC	OC	NMVC	NH ₃	CH ₄	N ₂ O	CO ₂
2000	•	•	•	•	•	•	•	•	•	•	•	•
2001	•	•	•	•	•	•	•	•	•	•	•	•
2002	•	•	•	•	•	•	•	•	•	•	•	•
2003	•	•	•	•	•	•	•	•	•	•	•	•
2004	•	•	•	•	•	•	•	•	•	•	•	•
2005	•	•	•	•	•	•	•	•	•	•	•	•
2006	•	•	•	•	•	•	•	•	•	•	•	•
2007	•	•	•	•	•	•	•	•	•	•	•	•
2008	•	•	•	•	•	•	•	•	•	•	•	•

Monthly gridded emission data sets at 0.25 degree by 0.25 degree resolution for each major sector for all species

Country and Regional Tables (Information for Data)

	SO ₂	NO _x	CO	PM ₁₀	PM _{2.5}	BC	OC	NMVC	NH ₃	CH ₄	N ₂ O	CO ₂
2000	•	•	•	•	•	•	•	•	•	•	•	•
2001	•	•	•	•	•	•	•	•	•	•	•	•
2002	•	•	•	•	•	•	•	•	•	•	•	•
2003	•	•	•	•	•	•	•	•	•	•	•	•
2004	•	•	•	•	•	•	•	•	•	•	•	•
2005	•	•	•	•	•	•	•	•	•	•	•	•
2006	•	•	•	•	•	•	•	•	•	•	•	•
2007	•	•	•	•	•	•	•	•	•	•	•	•
2008	•	•	•	•	•	•	•	•	•	•	•	•

Country and regional emission tables that present annual emissions for detailed sub-sectors and fuel types

Please use REAS and give us critical feedbacks!

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