International Workshop on Air Quality in Asia, 24-26 June 2014, Hanoi, Vietnam

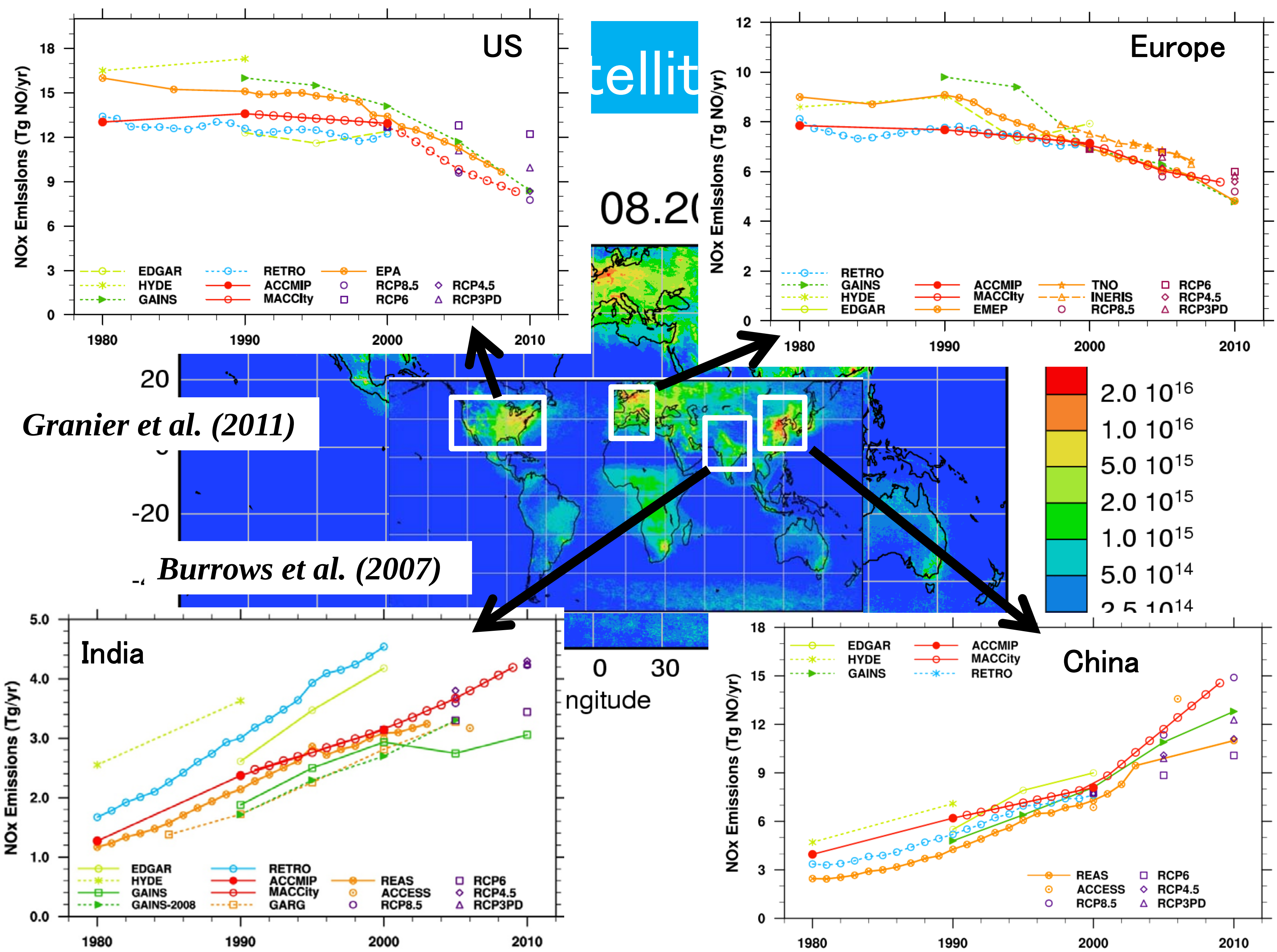
Trends of anthropogenic emissions of air pollutants over Southeast and South Asia

Jun-ichi Kurokawa

Asia Center for Air Pollution Research (ACAP), Niigata, Japan

Toshimasa Ohara

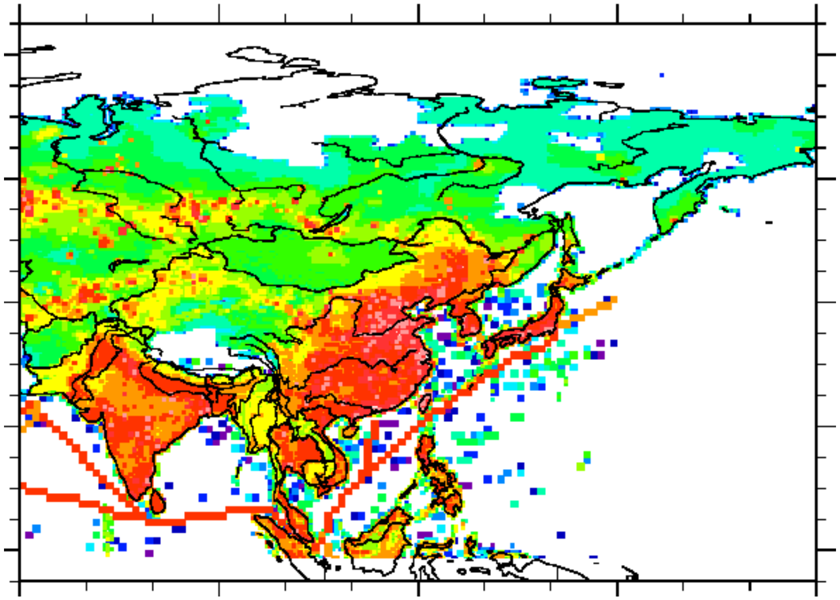
National Institute for Environmental Studies (NIES), Tsukuba, Japan



US
NOx Emissions (Tg NO/yr)
EDGAR
HYDE
GAINS
RETRO
ACCMIP
MACCity
EPA
RCP8.5
RCP6
RCP4.5
RCP3PD
Europe
NOx Emissions (Tg NO/yr)
RETRO
GAINS
HYDE
EDGAR
ACCMIP
MACCity
EMEP
TNO
INERIS
RCP8.5
RCP6
RCP4.5
RCP3PD
Granier et al. (2011)
Burrows et al. (2007)
2.0 10^16
1.0 10^16
5.0 10^15
2.0 10^15
1.0 10^15
5.0 10^14
India
NOx Emissions (Tg/yr)
EDGAR
HYDE
GAINS
GAINS-2008
RETRO
ACCMIP
MACCity
GARG
REAS
ACCESS
RCP8.5
RCP6
RCP4.5
RCP3PD
China
NOx Emissions (Tg NO/yr)
EDGAR
HYDE
GAINS
ACCMIP
MACCity
RETRO
REAS
ACCESS
RCP8.5
RCP6
RCP4.5
RCP3PD

Introduction
of
Regional Emission inventory
in ASia (REAS)

General information on REAS version 2.1



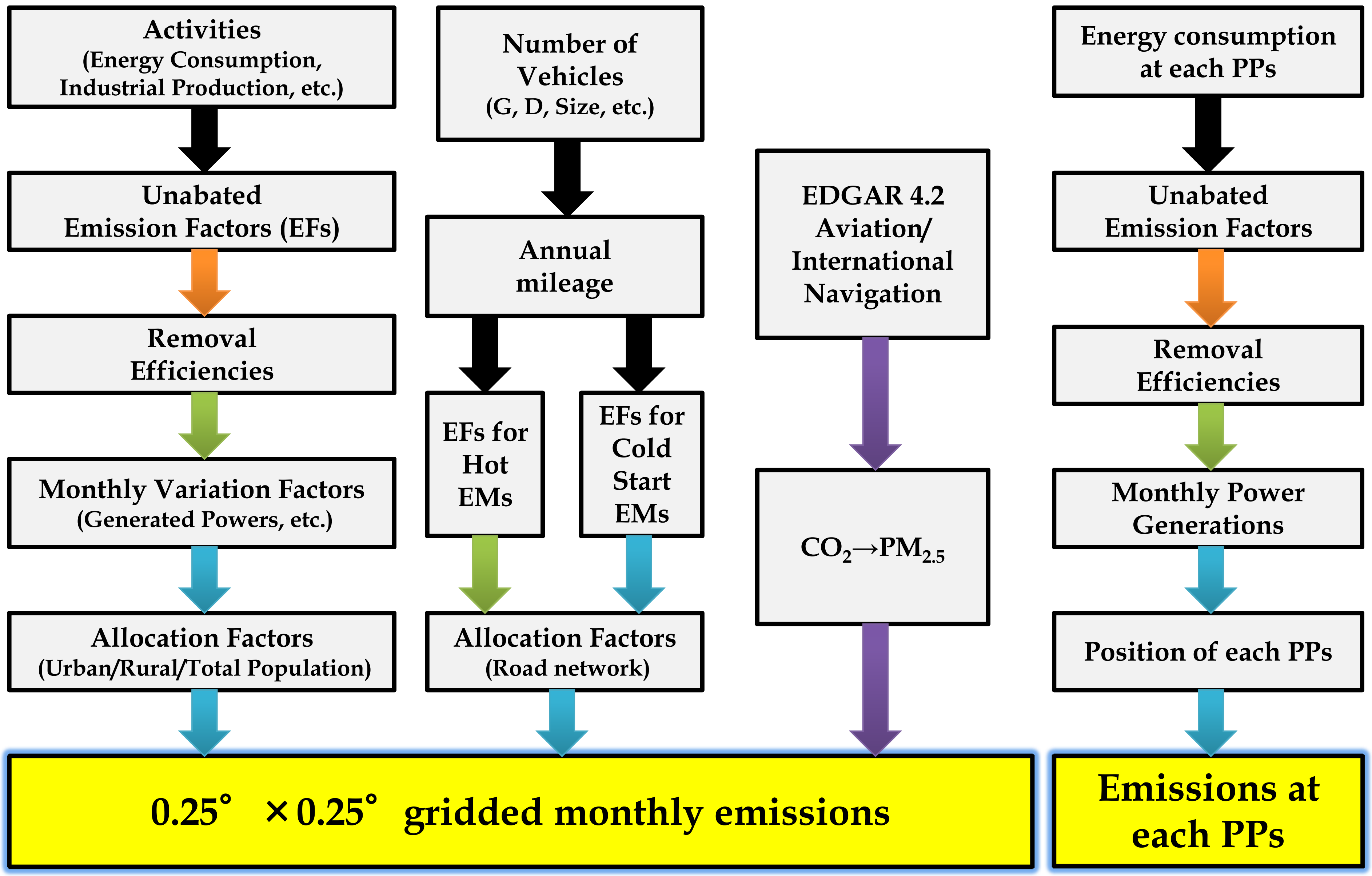
Kurokawa et al., ACP, 2013

Item	Description
Target Areas	E, SE, S, and Central Asia Asian part of Russia
Target Years	2000-2008 (- 2011)
Spatial Resolution	0.25 x 0.25 degree
Temporal Resolution	Monthly (if possible)
Japan	JEI-DB/OPRF*
Korea and Taiwan	Officially estimated data

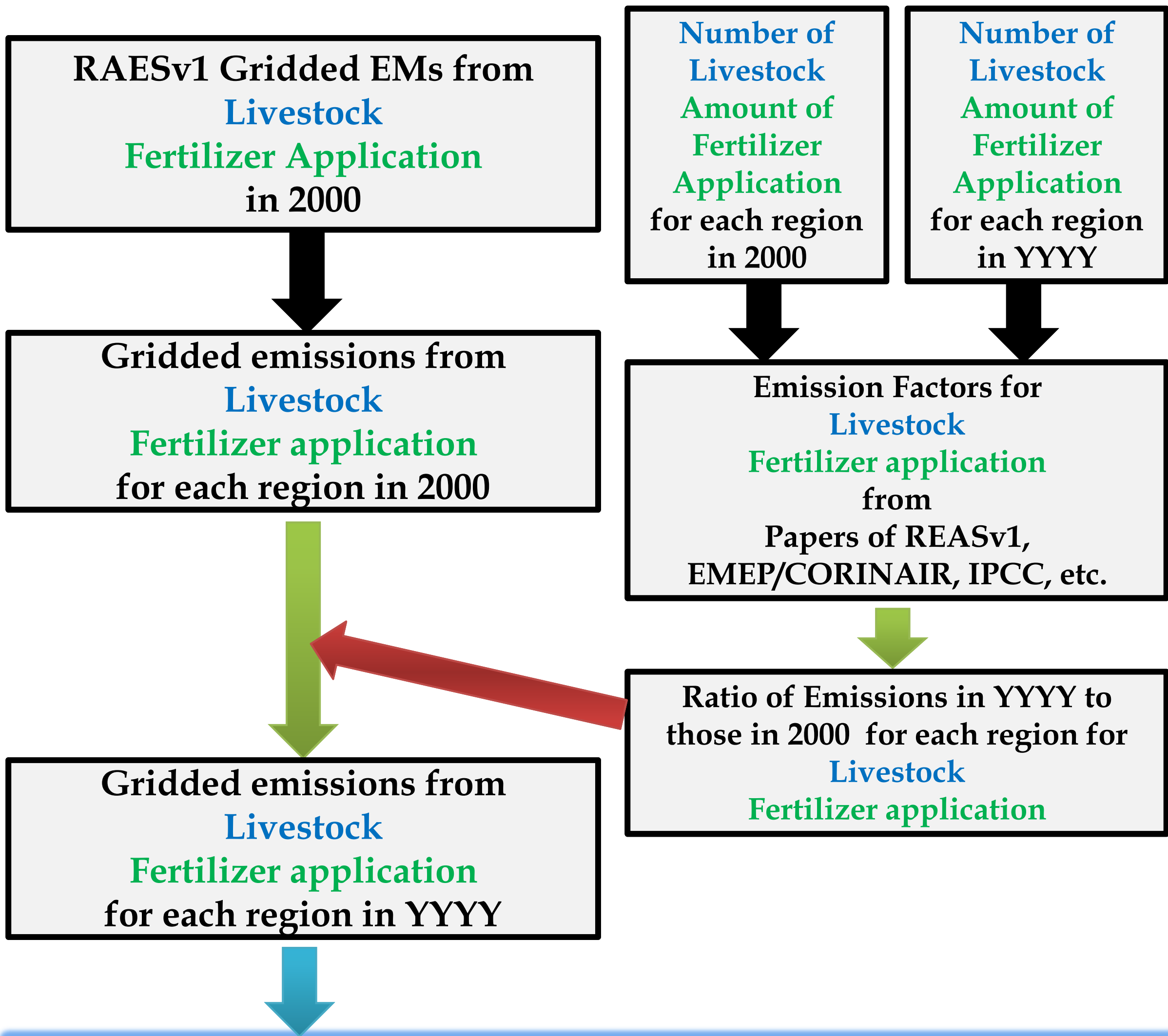
* JEI-DB (Japan Auto-Oil Program (JATOP) Emission Inventory-Data Base)
OPRF (Ocean Policy Research Foundation)

	SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$	BC	OC	NMV	NH_3	CH_4	N_2O	CO_2
Fossil Fuel Biofuel	●	●	●	●	●	●	●	●	●	●	●	●
Industrial Process	●		●	●	●	●	●	●	●		●	●
Fertilizer use		●							●	●	●	
Livestock									●	●	●	
Others								●	●	●	●	

Methodology for REASv2 (Combustion, etc.)



Methodology for REASv2 (Agriculture)



Agricultural Emissions

NH_3
- Manure Management
- Fertilizer Application

CH_4
- Enteric Fermentation
- Manure Management
- Rice Paddy Fields

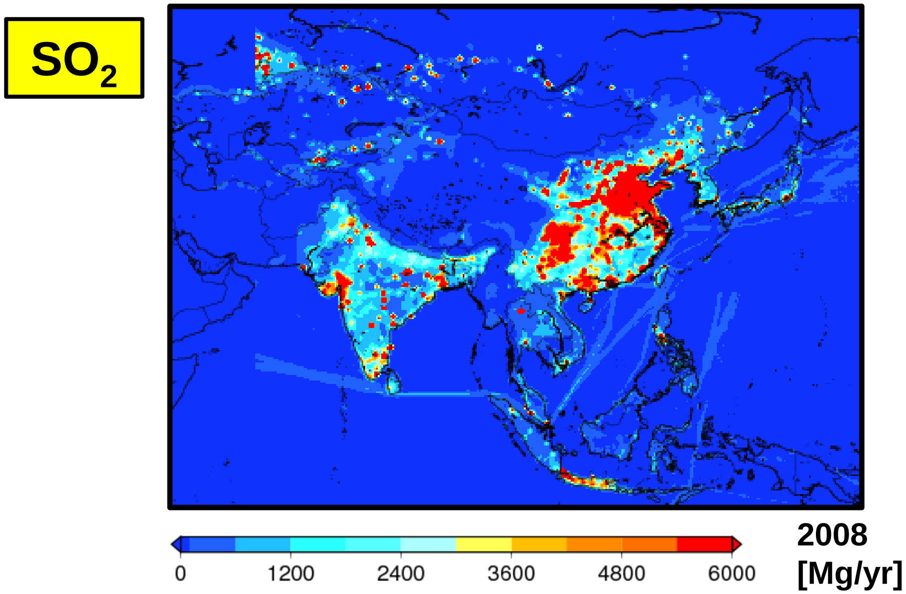
N_2O
- Manure Management
- Fertilizer Application
  (Direct and Indirect Soil)

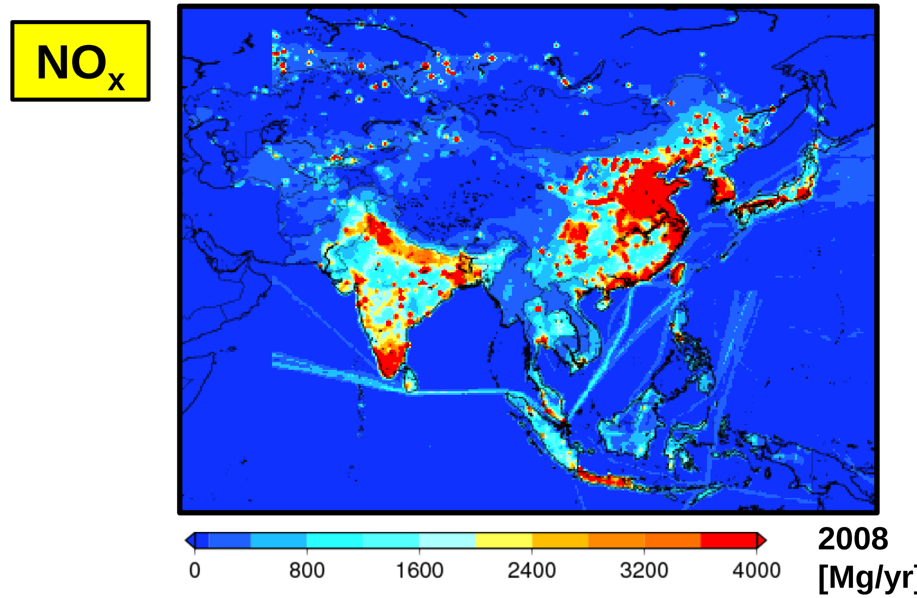
NO_x
- Soil (Croplands/Grasslands/
  Savanna)

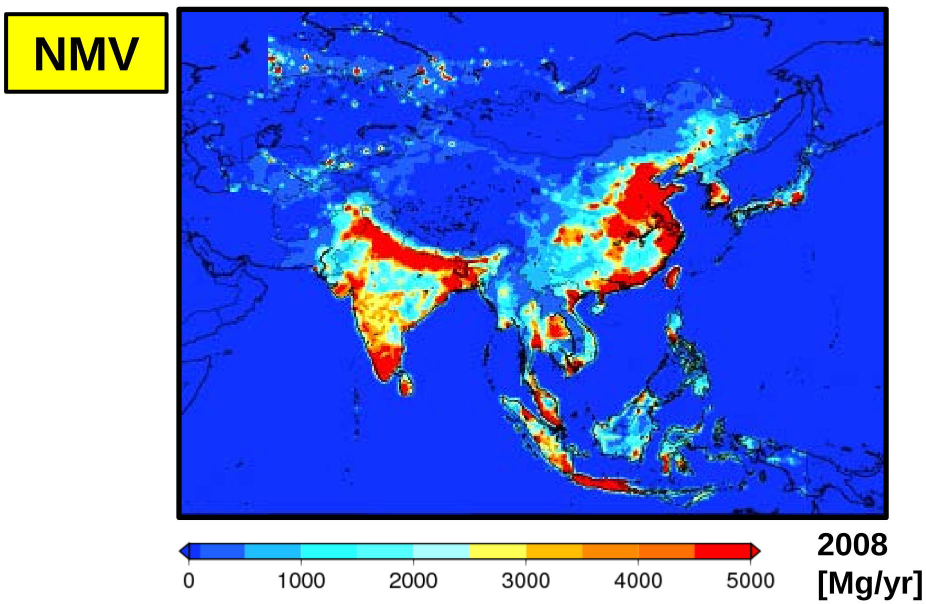
Livestock : Yamaji et al.
Agricultural Soil : Yan et al.

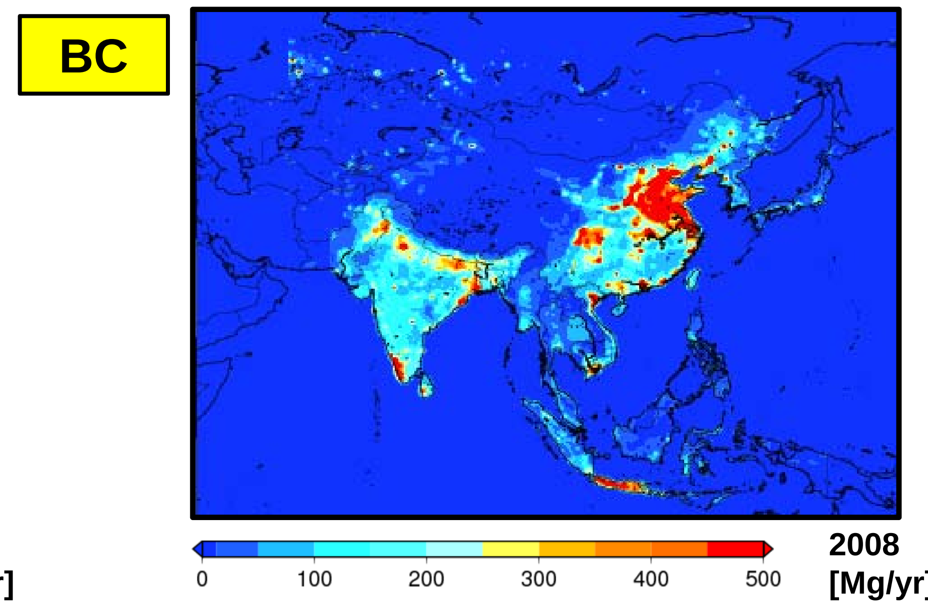
0.25° ×0.25° gridded emissions

Spatial distribution: SO_2, NO_x, NMVOC, and BC





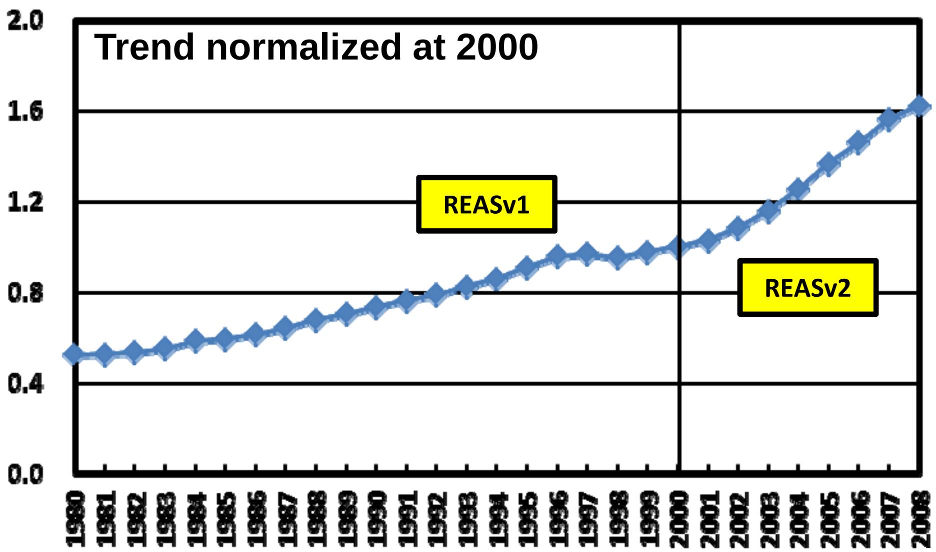


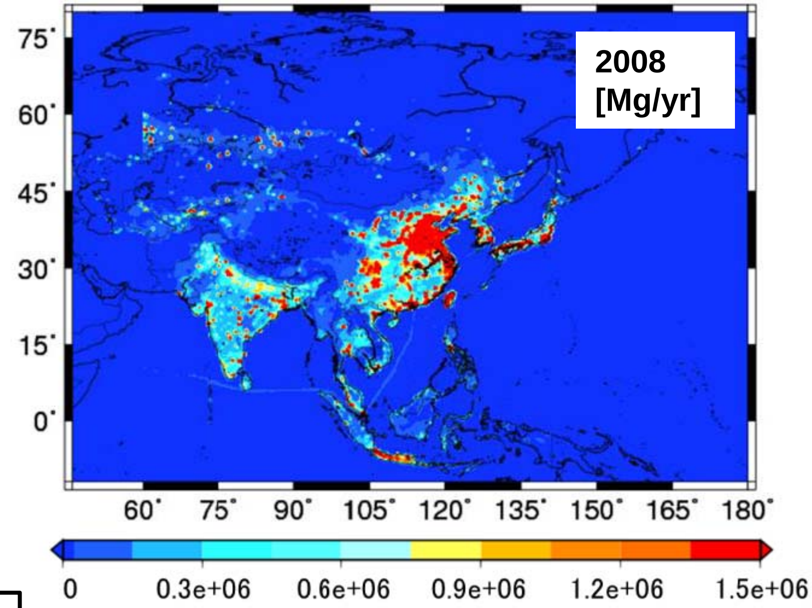


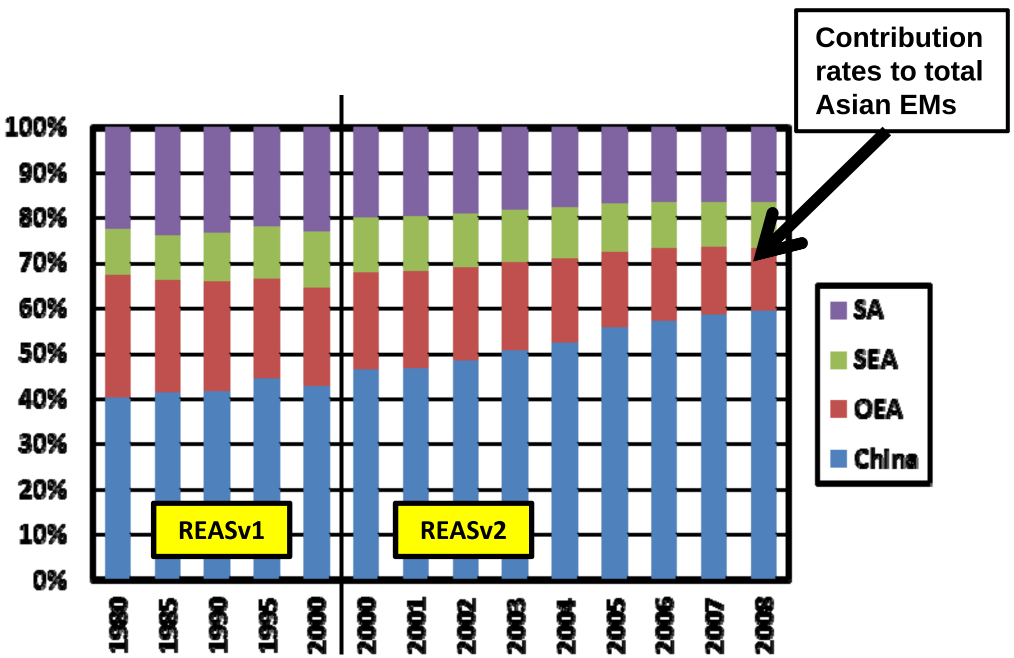
Eastern China, Chongqing and Sichuan province, the Indo-Gangetic Plain, Southern India, Indonesia, etc.

→ These area have large population and significant economic and industrial activities

CO_2 emissions in Asia



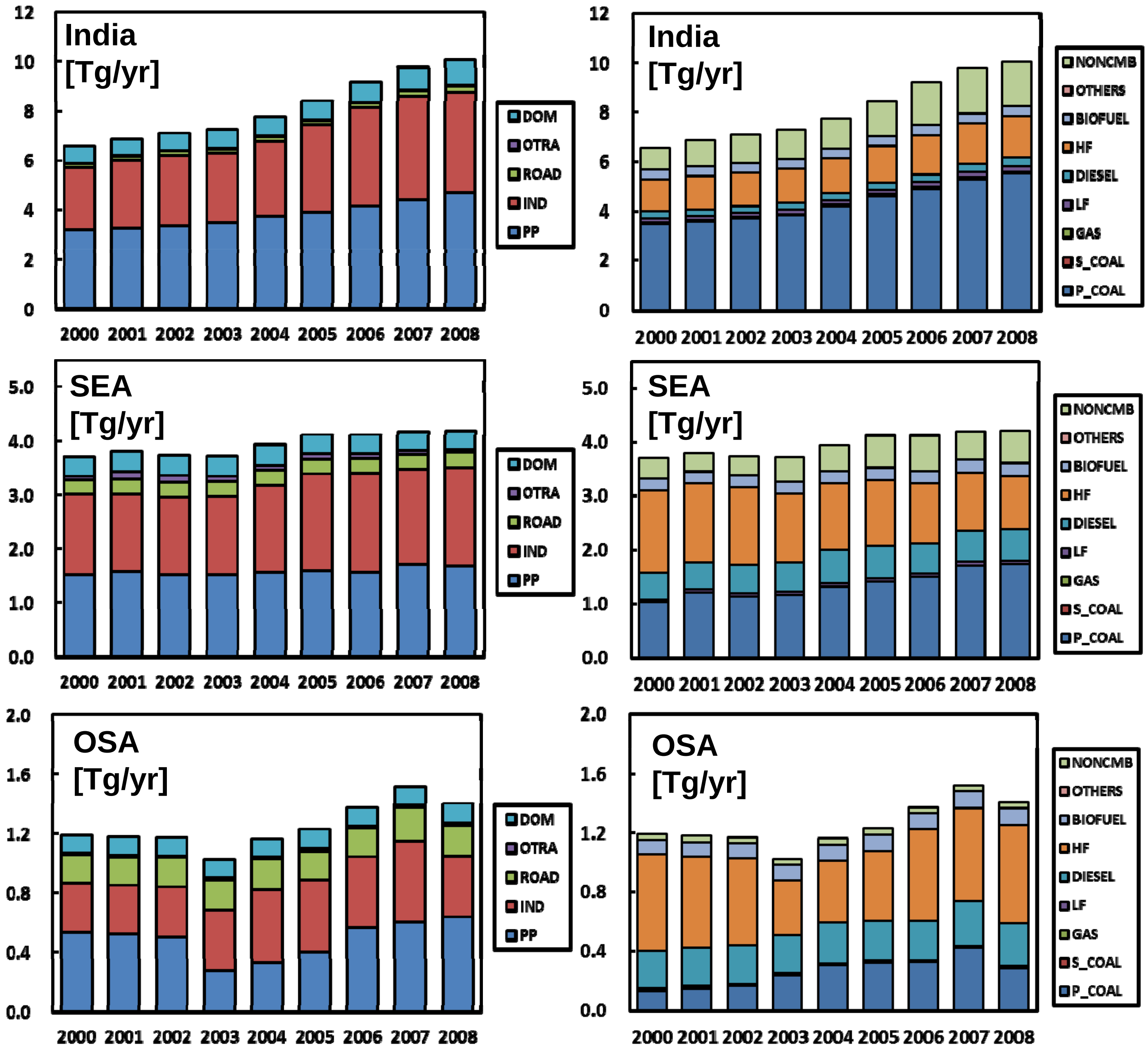




- In general, CO_2 EMs in Asia increased monotonically from 1980 to 2008 and grew rapidly especially after 2002.
- EMs of most species show similar trends which were mainly controlled by China.
- Especially recently, relative ratio of OEA were decreased because of small economic growth, compared to other Asian countries.
- The second largest growth rate was shown in India and relative contributions from SEA and OSA were also increasing.

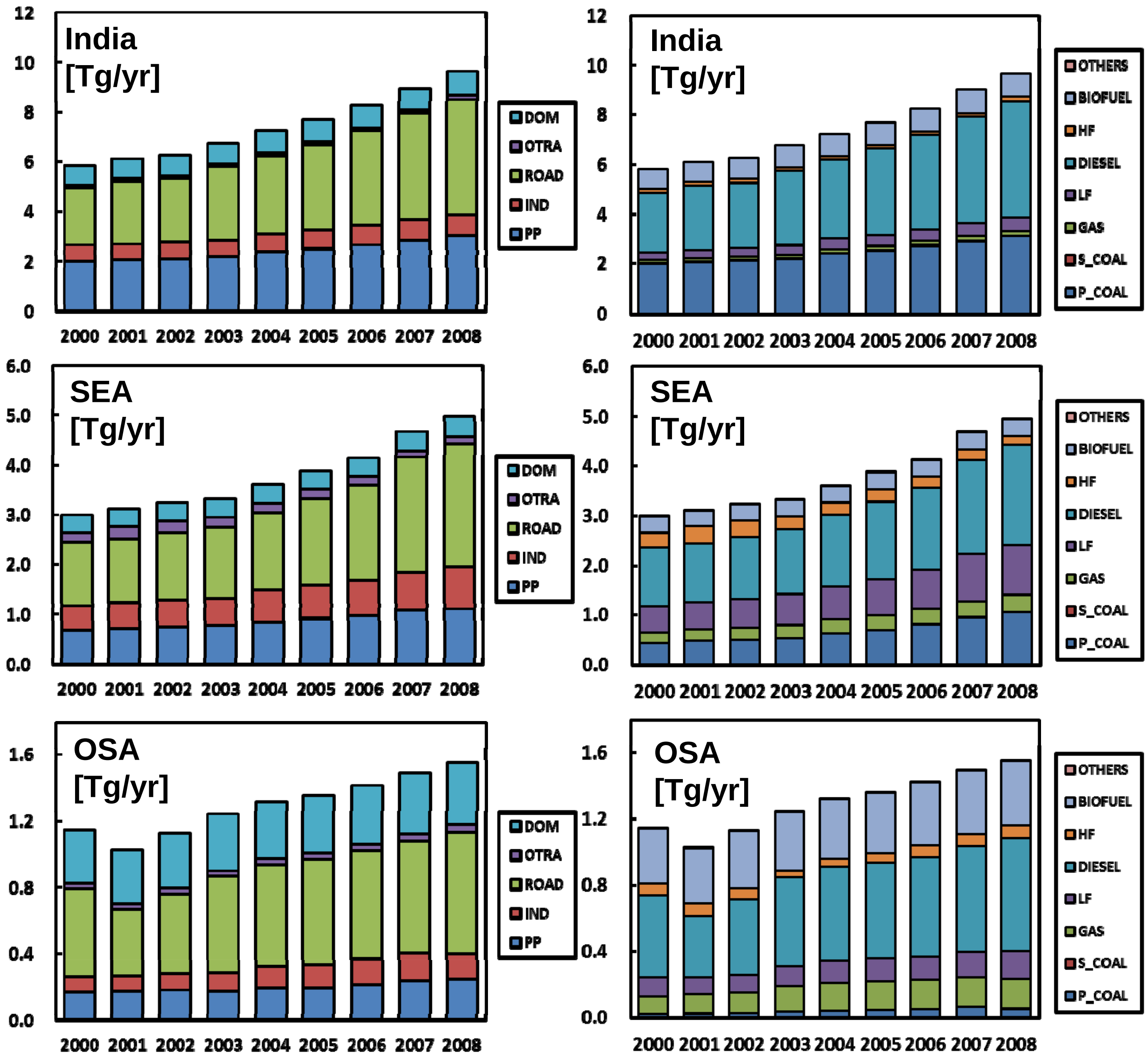
Review of
emissions of air pollutants
in Southeast and South Asia
estimated in REAS 2.1

SO_2 emissions in India, SEA, and OSA



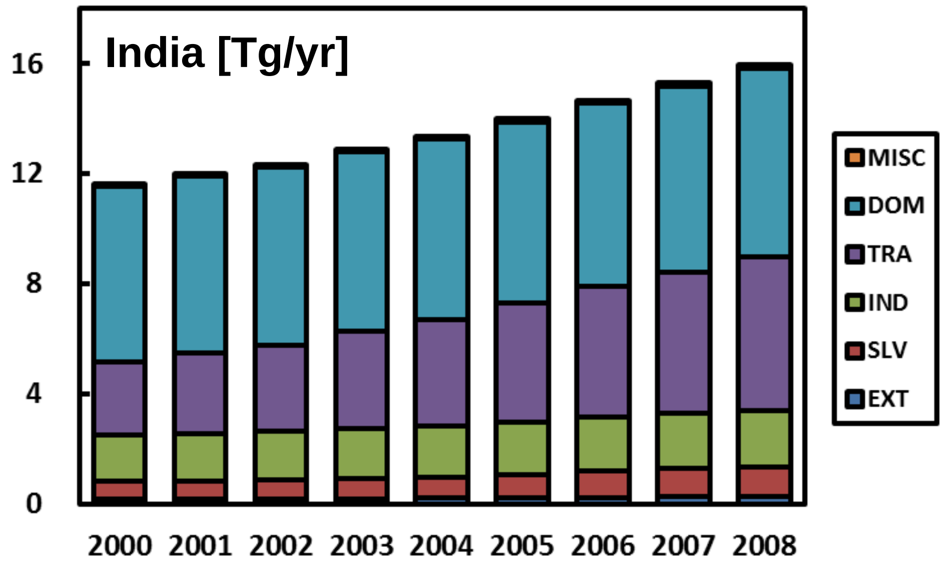
- In India and SEA, EMs from PP and IND were almost comparable and dominated the total EMs.
- For India, EMs from coal combustion and industrial processes were increasing and thus, growth rate was the largest in IND.
- For SEA, interannual variation is relatively small, but EMs from coal were increasing and those from HF were decreasing.
- For OSA, there were some gaps after 2003 due to the decreases of HF consumption in PPs and the increase of coal usage in IND.

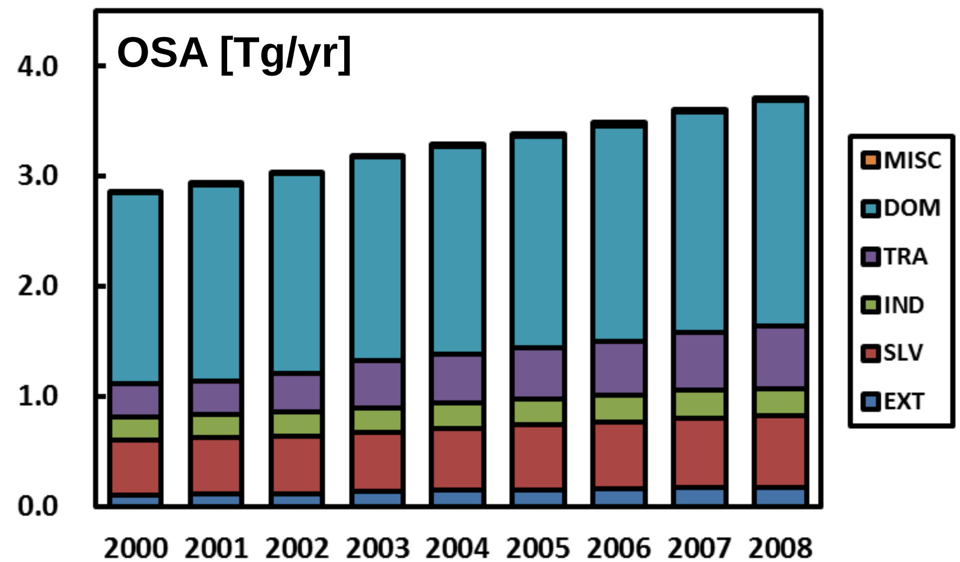
NO_x emissions in India, SEA, and OSA

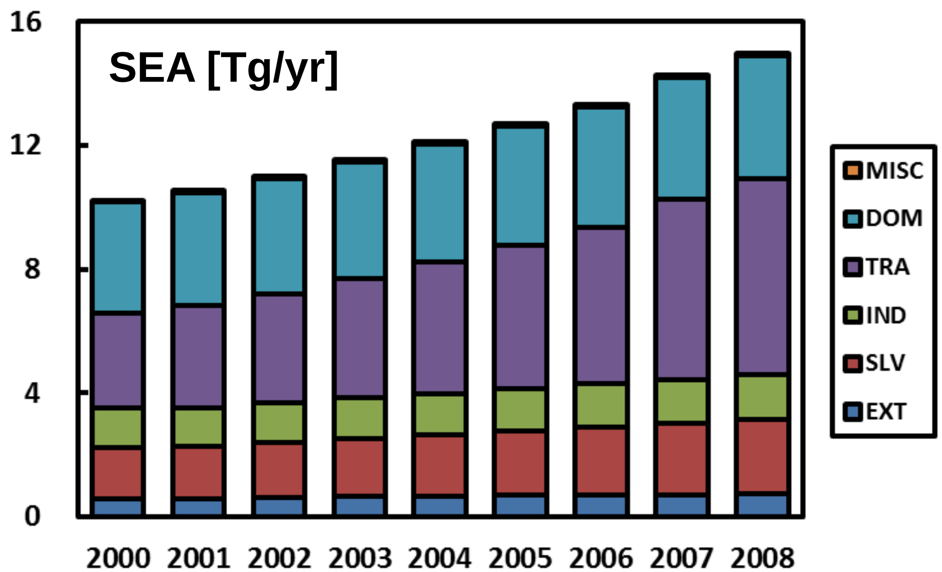


- For SEA and SA, EMs from diesel vehicles were the largest contributing source and increasing almost constantly.
- In India and SEA, contributions from coal combustion in PP and IND were also increasing.
- In OSA, relative ratio of EMs from biofuel combustion in DOM was larger.
- In REAS2, EFs and annual distance traveled per vehicle were assumed to be constant during target years which should be revised in the next version.

NMVOC emissions in India, and SEA, and OSA



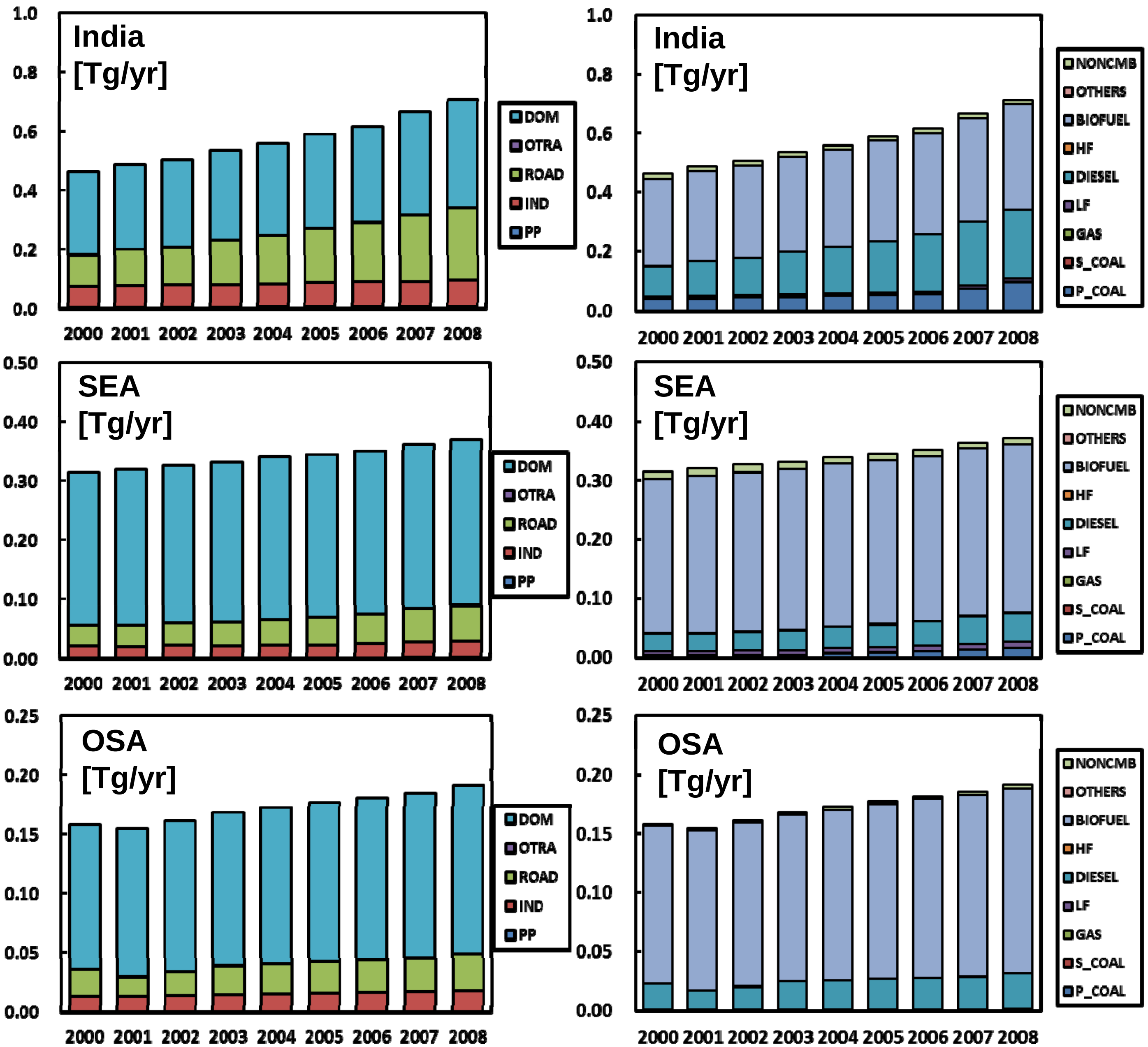




EXT: Extraction processes, SLV: Solvent and paint use,
IND: Industrial processes, TRA: Transport incl. evaporation
DOM: Domestic, MISC: Miscellaneous

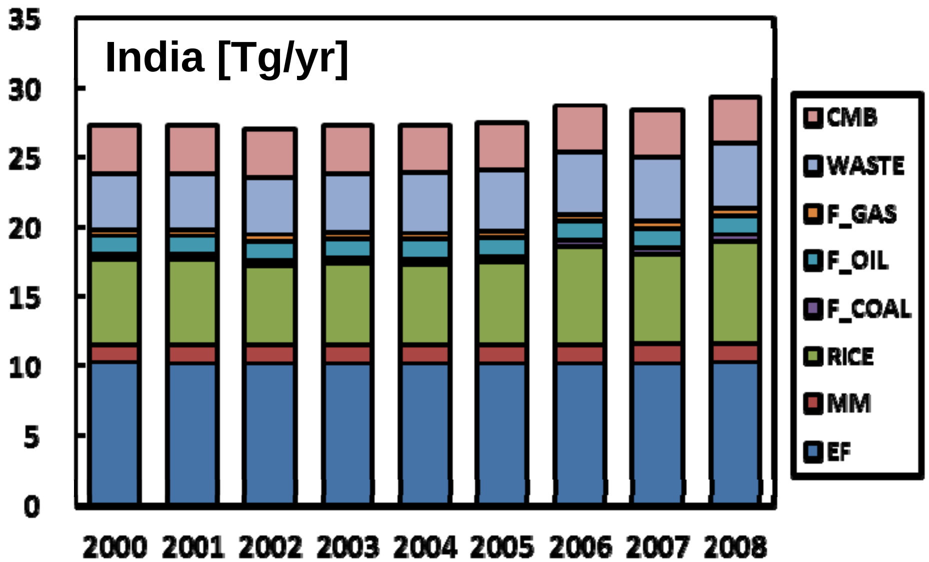
- For India, EMs from biofuel combustion in DOM was the largest contributor and values were slightly increasing. But growth rate of EMs from road vehicles were much larger. In 2008, EMs from TRA became comparable to DOM.
- Similar tendencies were shown in SEA, but relative ratios of EMs from solvent and paint use were larger than India and increasing.
- For OSA, majority of emissions were from biofuel combustion in DOM, but the largest growth rate was shown in road transport sector.

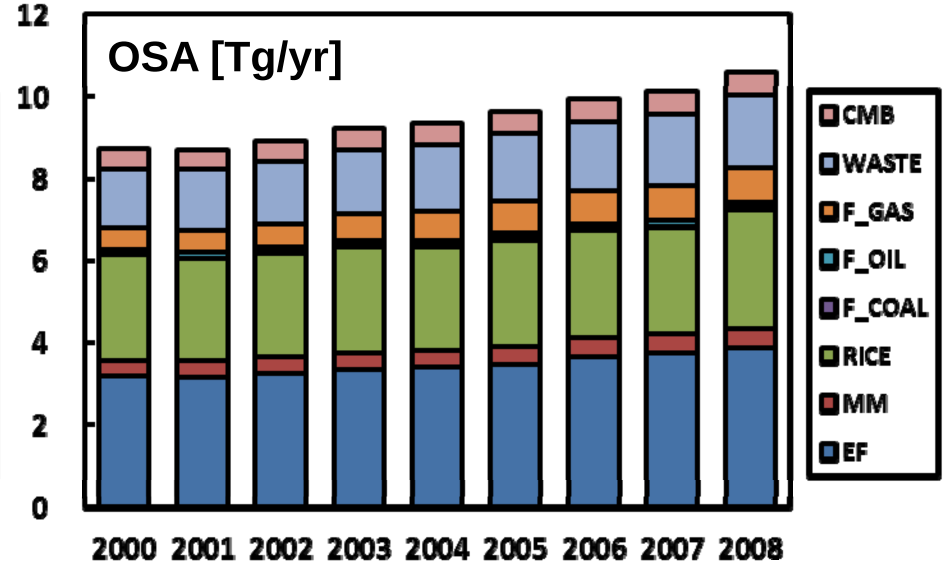
BC emissions in India, SEA, and OSA

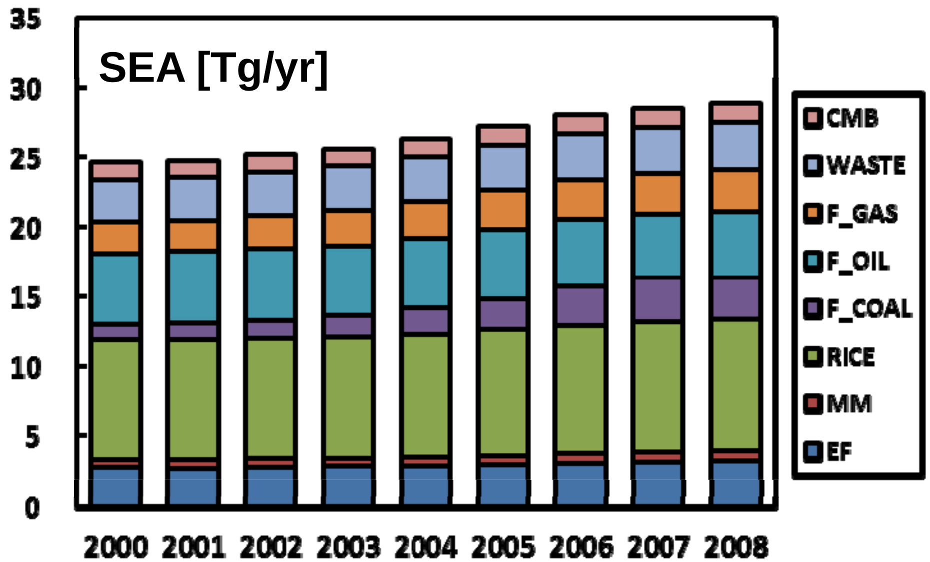


- BC EMs from PP were negligible for all countries.
- Biofuel combustion in DOM was the largest BC EMs source for SEA and SA.
- For India, Growth rates of BC EMs from diesel vehicles were larger than those from biofuel combustion and then, in 2008, EMs from DOM were comparable to those from TRA and IND.
- Brick kiln is considered to be important EM source but in REAS2, its EMs in SEA and SA were calculated as a part of EMs from non-metallic minerals IND which should be revised in the next version.

CH_4 emissions in India, and SEA, and OSA



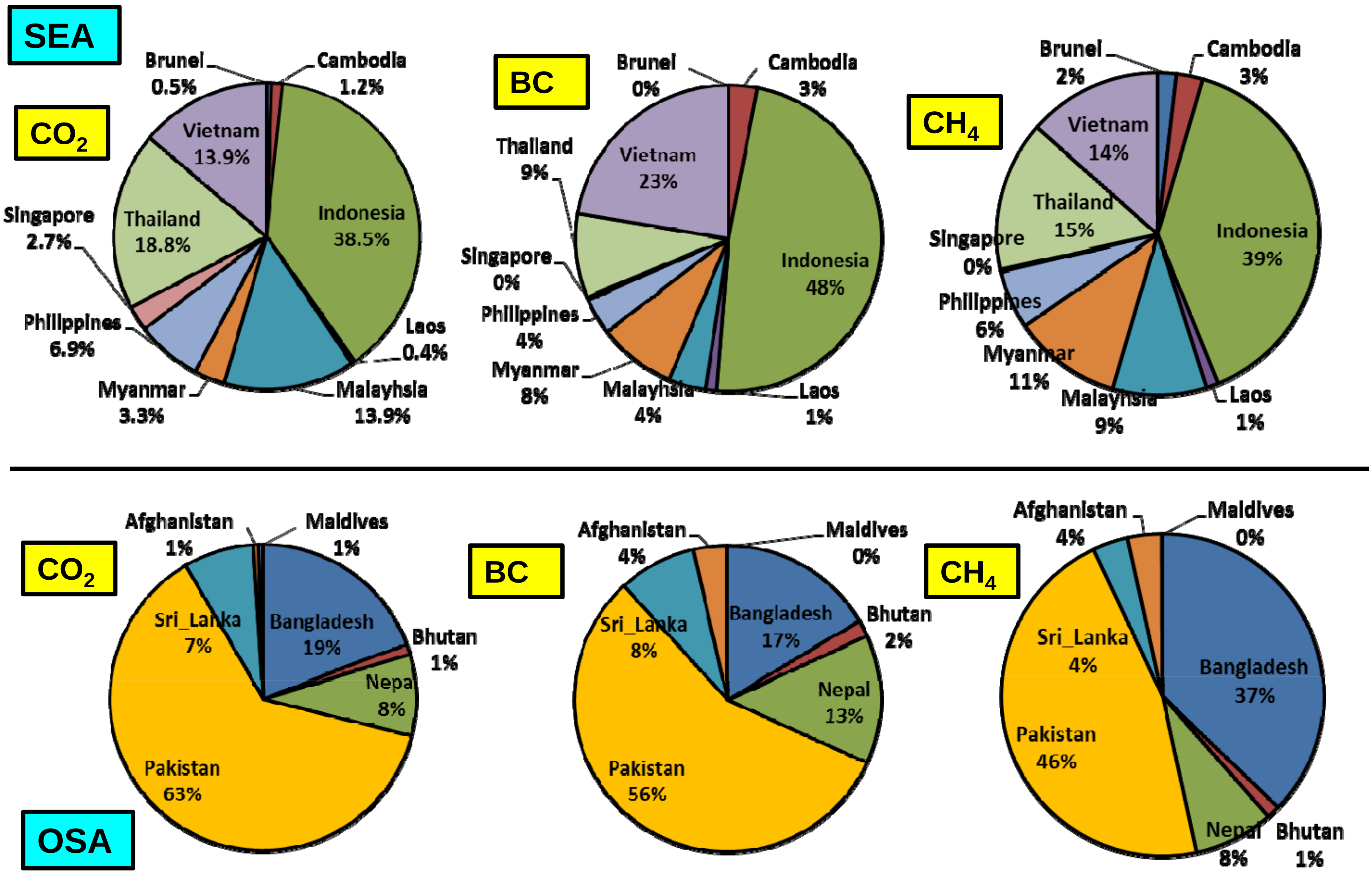




EF: Enteric Fermentation, MM: Manure Management,
RICE: Rice Cultivation, F_COAL/OIL/GAS: Fugitive Emissions
WASTE: Waste treatment, CMB: Fuel combustion

- In India, agriculture such as enteric fermentation and rice cultivation are the dominant EMs sources and similar tendencies were also shown in OSA.
- CH_4 EMs from coal production were very small in India because coal mining in India is mainly at surface whose EF was assumed to be small.
- For SEA, contribution from agricultural activities, especially rice field was also the major EMs sources, but fugitive EMs of oil and gas were also estimated to be large .
- Further studies for fugitive emissions are needed.

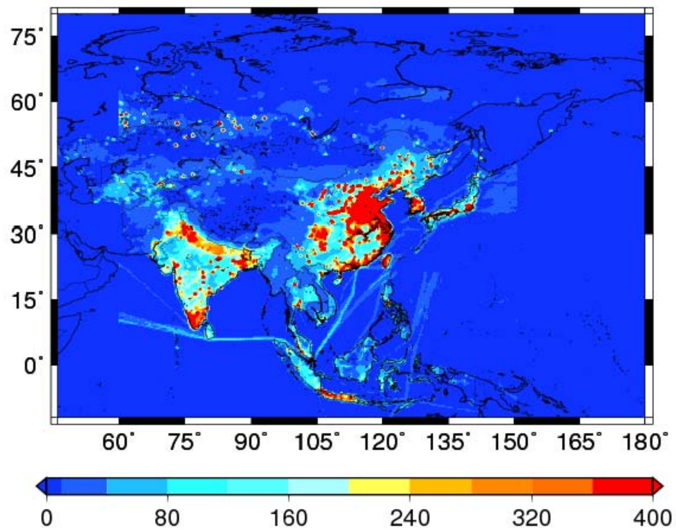
Contribution rates of each country in 2008



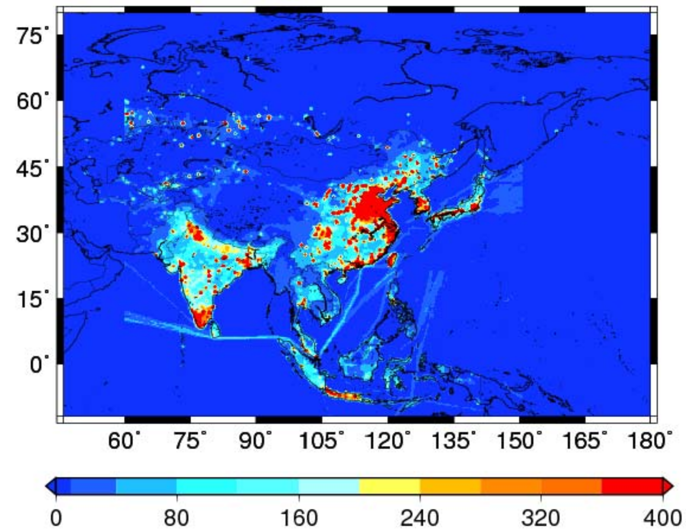
India: 84% of SA　　India: 79% of SA　　India: 74% of SA

Monthly variation

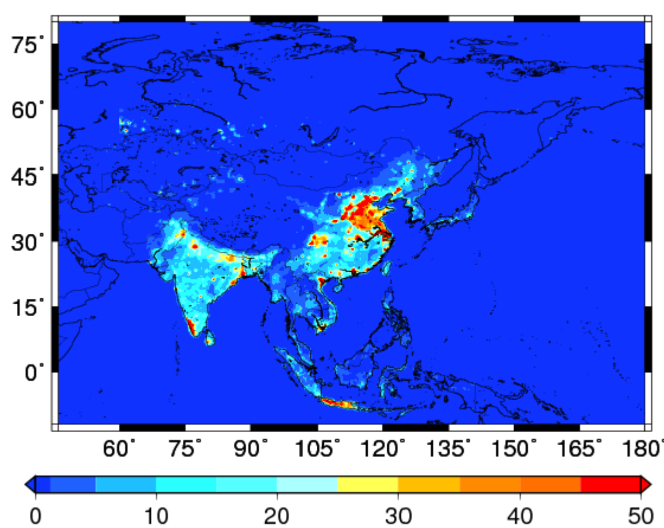
NO_x in July 2008



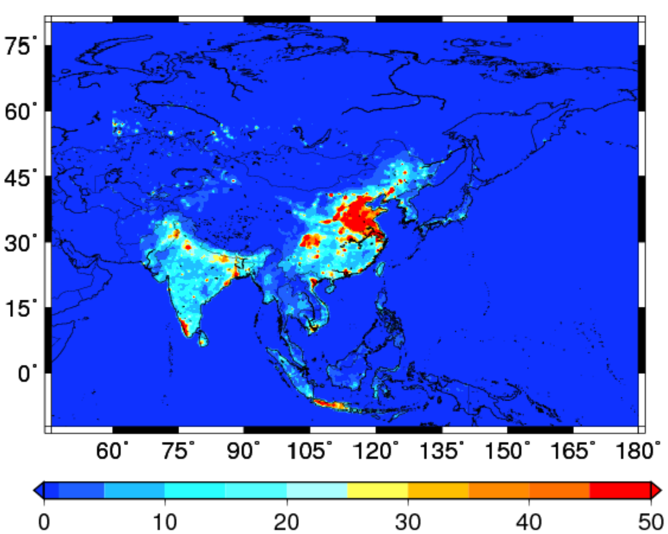
NO_x in December 2008



BC in July 2008



BC in December 2008

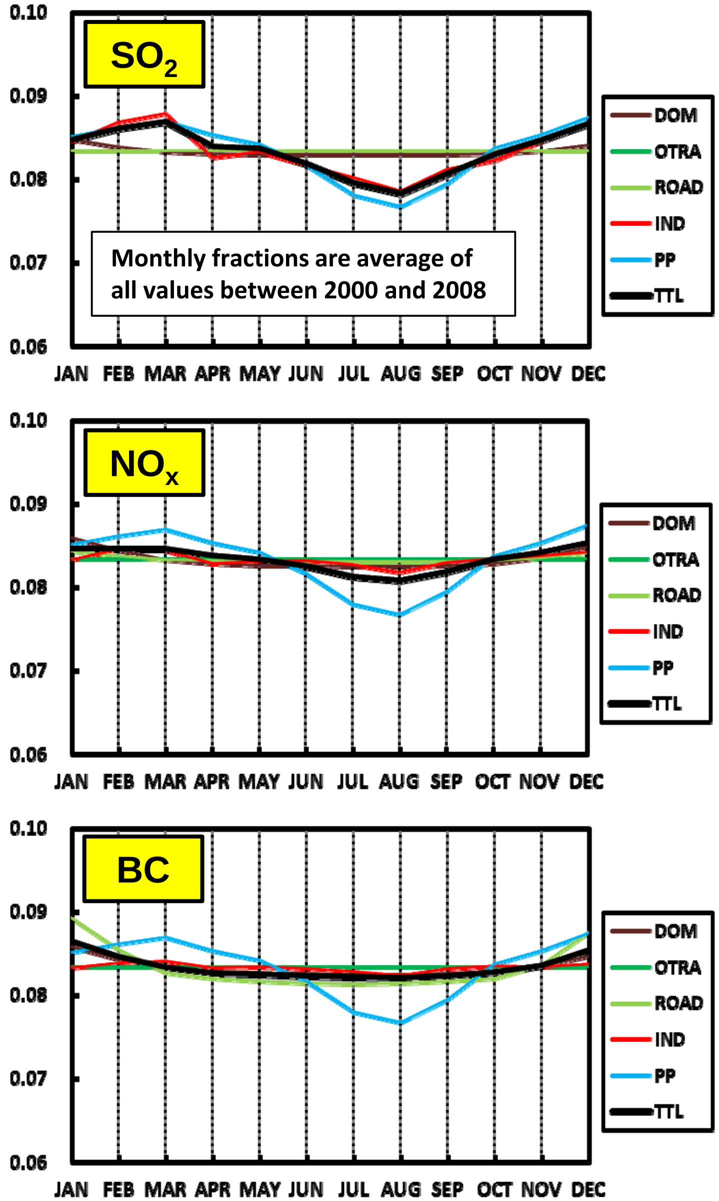


- **For NO_x, EMs were higher in Jul than in Dec, especially over rural and higher latitude areas.**
- **Most of these seasonal differences were caused by soil NO_x EMs.**
- **Seasonal variation of NO_x anthropogenic emission was relatively small.**

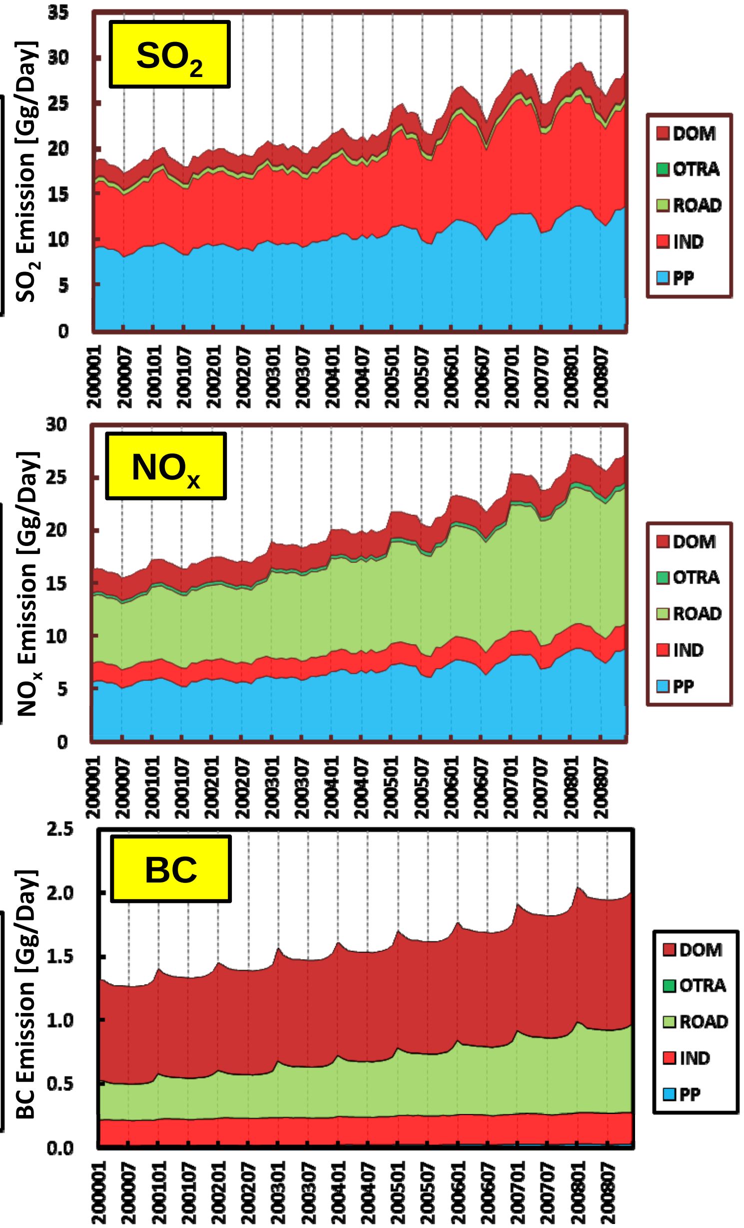
- **EMs of BC were higher in Dec than in Jul.**
- **BC EMs are dominated by DOM and their seasonal variation is controlled by fuel consumption for residential heating and the fuel consumption was assumed based on monthly surface temperature.**
- **This tendency is basically shown in northern part of Asia.**

Fractions and trends of monthly emissions in India

Monthly fractions



Trends of monthly emissions



Emissions from PPs and IND sectors are lower during summer and higher in winter based on the monthly generated power and production of industrial products obtained from statistics of India.

→ These two sectors govern the monthly variations of total SO_2 and NO_x anthropogenic EMs.

BC EMs are dominated by DOM but amplitude of seasonality is small.

→ In general, temperature in India is relatively warm.

→ Similar features were shown in SEA and OSA.

→ Similar tendencies were also shown in other aerosols and CO EMs.

Problems in bottom-up emission inventory

Uncertainties [%] of annual total emissions in REAS 2.1

	SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$	BC	OC	NMV	NH_3	CH_4	N_2O	CO_2
China	31	37	86	114	133	176	271	78	153	211	130	31
India	32	49	114	120	145	178	233	137	144	154	153	49
Others	35	47	131	194	208	257	286	111	148	204	135	44

For the calculations of uncertainties in this table, emissions in Japan are not considered except for CH_4 and N_2O and those in South Korea and Taiwan were included only for CO_2, NH_3, and N_2O. In addition, uncertainties of emissions related to agricultural soils and livestock for NO_x, NH_3, CH_4, and N_2O were not assessed in this study.

- Bottom-up EI has inevitable uncertainties associated with the statistics, emission factors, temporal and spatial allocation factors.
- Uncertainties in SEA and OSA are larger than those in China and India due to the limitation of available information and reference literatures.
- Estimating uncertainties of gridded emissions are basically impossible, but at least much larger than those of annual total emissions.

- More detailed region specific studies are needed.
- Validation using monitoring data and atmospheric chemistry models (both forward model and inverse model) is essential.

Remarks

- We have developed Regional Emission inventory in ASia (REAS) 2.1 and trends and general features of estimated emissions in Southeast and South Asian regions presented.
- Emissions of air pollutants in Southeast and South Asia increased for all species from 2000 to 2008 and their influences on air quality are becoming serious issues.
- Information for developing accurate emission inventory in Southeast and South Asia is not enough and uncertainties of emissions are larger than other regions. So, to develop reliable emission inventory which can be used for considering effective measures to mitigate emissions, more detailed region specific studies are required.
- Verification of emission inventory using model simulation and monitoring data is important. Especially, evaluation and improvement of bottom-up emission inventory using inverse modeling technique is very important issues.

Data download site of REAS 2.1

http://web.nies.go.jp/REAS/ Ref. Kurokawa et al., ACP, 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	NMV	NH_3	CH_4	N_2O	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	NMV	NH_3	CH_4	N_2O	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!

Thank you for your attention!