The EANET Emission Inventory Workshop
Outline

1. Objectives

In order to tackle problems of atmospheric environment, it is essential to understand current status of emissions of air pollutants and consider effectivities of mitigation measures. Emission inventory is essential to obtain such information and helps to make appropriate atmospheric environmental policies.

The objectives of the Emission Inventory Workshop are to understand roles of emission inventory in air quality management, obtain general information of emission inventory, and learn basic knowledge of development and application of emission inventory. Five experts of development and application of emission inventory will be invited as lecturers and they will join discussions with participants. It is expected that this workshop will provide useful experiences for planning and developing the national emission inventory of each country.

2. Participants

Expected participants to the workshop are technical officers involved in air quality management administration, who are in charge of or interested in developing national emission inventory. Note that several participants can be nominated by the NFP of each country and one of them also selected by the NFP of each country is required to make a short presentation about issues related to national emission inventory in each country at the workshop. Because the workshop will be held in virtual, the workshop will be announced to the EANET participating countries and opened to registered persons.

3. Date and Venue

- Date: 18 October 2021 (UTC 05:30-09:30)
- Venue: Web-based workshop in virtual meeting room (The link of the workshop will be informed to registered participants separately.)

4. Organizer

The workshop is organized by the Asia Center for Air Pollution Research (ACAP), the Network Center (NC) for the EANET. (Contact: Jun-ichi Kurokawa of ACAP; kurokawa@acap.asia)

5. Program of the workshop

Monday, October 18, 2021 UTC 5:30-9:30 (14:30-18:30 in Japan local time)		
05:30-05:35	Opening remarks	Shiro Hatakeyama (NC/Director General of ACAP)
05-35-05:40	Introduction of the workshop + Group photo (Screen shot)	Jun-ichi Kurokawa (NC/ACAP)
	Lecture presentations from experts[1]	
05:40-06:00	Roles of emission inventory in air quality management	Toshimasa Ohara
06:00-06:30	Emission estimation for air pollutants emission inventory	Tazuko Morikawa
06:30-07:00	Japan's National GHG Inventory	Elsa Hatanaka
07:00-07:30	Development of biomass open burning emission inventory for air quality management at national and regional levels in Thailand	Savitri Garivait
07:30-08:00	Application of emission inventory to air quality simulation	Satoru Chatani
	Presentations from participants nominated by the NFPs[2] ➢ Introduction of air quality management activities in your country. ➢ Current status and/or plans of the national emission inventory. (If no specific information, what are major emission sources need to be reduced in your country.) ➢ Opinions for necessary roles and required activities related to emission inventory in EANET.	
08:00-08:05	Cambodia	Chandath Him
08:05-08:10	Lao PDR	Bounmany Soulideth
08:10-08:15	Malaysia	Farah Diyana Rusli
08:15-08:20	Mongolia	Bayarmagnai Jambaldorj
08:20-08:25	Myanmar	Kyu Kyu Sein
08:25-08:30	Philippines	Paul Nathan Vallar
08:30-08:35	Russia	Alisa Trifonova-Yakovleva
08:35-08:40	Thailand	Naboon Riddhiraksa
08:40-08:45	Viet Nam	Van Sy Pham
08:45-08:55	Q & A for the presentations from participants	
08:55-09:25	General discussion among participants and experts	
	Closing	
09:25-09:30	Announcement and closing	

[1]Each lecture presentation includes time for Q & A.

[2]Presentation time (5 min) for each participant DOES NOT include time for Q & A.

6. List of lecturers and presenters from participants

Lectures	
Name	Affiliation
Toshimasa Ohara	Research director, Center for Environmental Science in Saitama, Japan
Tazuko Morikawa	Senior Chief Researcher, Environment Protection Research Group, Environment Research Division, Japan Automobile Research Institute, Japan
Elsa Hatanaka	Manager, Greenhouse Gas Inventory Office of Japan (GIO), National Institute for Environmental Studies (NIES), Japan
Savitri Garivait	Associate Professor, Chairperson of Environmental Division, The Joint Graduate School of Energy and Environment (JGSEE) - Center of Excellence on Energy Technology and Environment (CEE), King Mongkut's University of Technology Thonburi (KMUTT), Thailand
Satoru Chatani	Chief Senior Researcher, Regional Environment Conservation Division, Regional Atmospheric Modeling Section, National Institute for Environmental Studies (NIES), Japan
Presenters from participants	
Name	Affiliation
Chandath Him	Air Quality and Noise Management, Ministry of Environment, Cambodia
Bounmany Soulideth	Natural Resources and Environmental Research and Statistic Institute, Ministry of Natural Resources and Environment, Lao PDR
Farah Diyana Rusli	Air Division, Department of Environment, Putrajaya, Malaysia
Bayarmagnai Jambaldori	Environmental Monitoring Division of National Agency for Meteorology and Environmental Monitoring, Mongolia
Kyu Kyu Sein	Hydrological Division, Department of Meteorology and Hydrology, Myanmar
Paul Nathan Vallar	Environmental Quality Management Division, Air Quality Management Section. Philippines
Alisa Trifonova-Yakovleva	Institute of Geography, Russian Academy of Sciences, Russia
Naboon Riddhiraksa	Planning and Evaluation Subdivision, Air Quality and Noise Management Division, Pollution Control Department, Thailand
Van Sy Pham	Environmental Forecast and Technology department, Center For Environmental Research, Vietnam Institute of Meteorology Hydrology and Climate Change, Vietnam

Roles of Emission Inventory in Air Quality Management
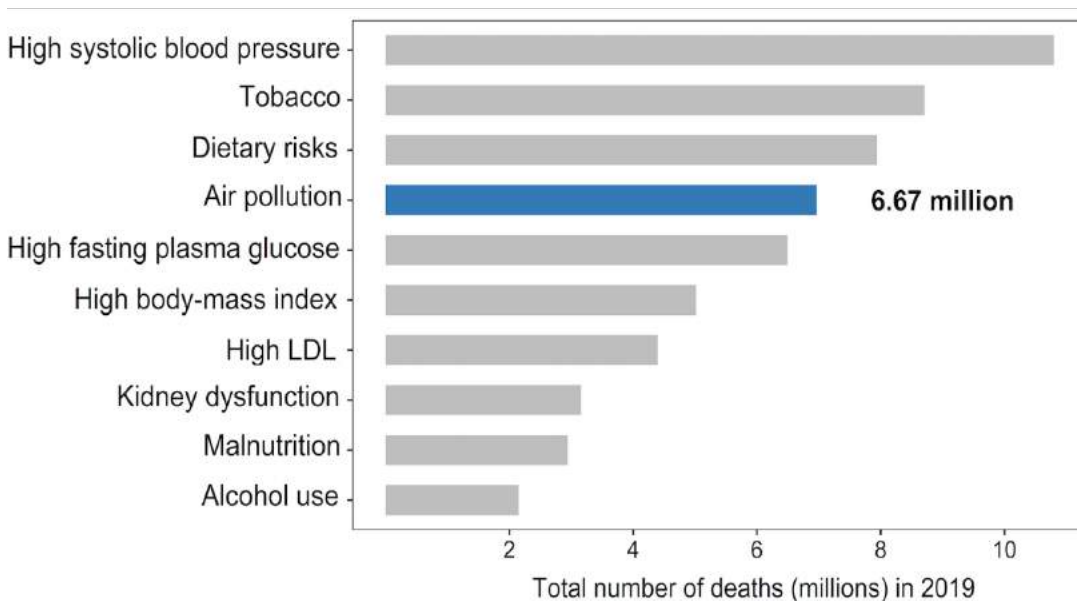
Toshimasa Ohara

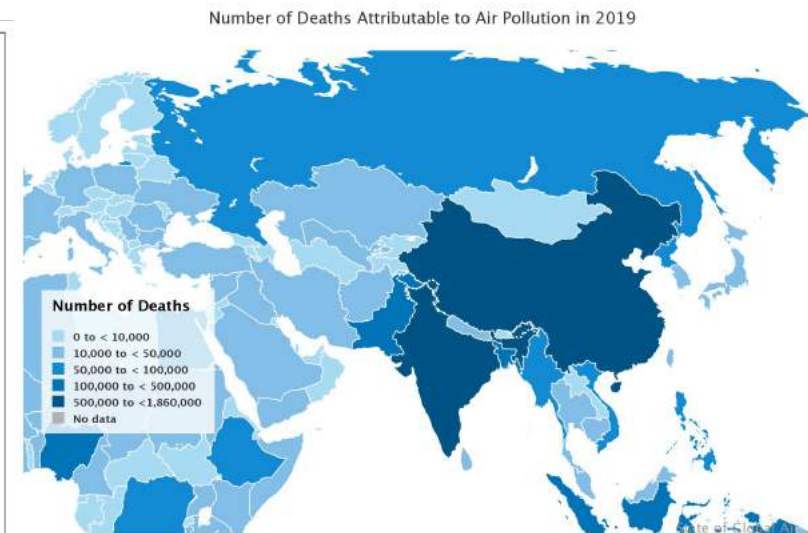Center for Environmental Science in Saitama, Japan

Global Ranking of Risk Factors by Total Deaths from all Causes in 2019

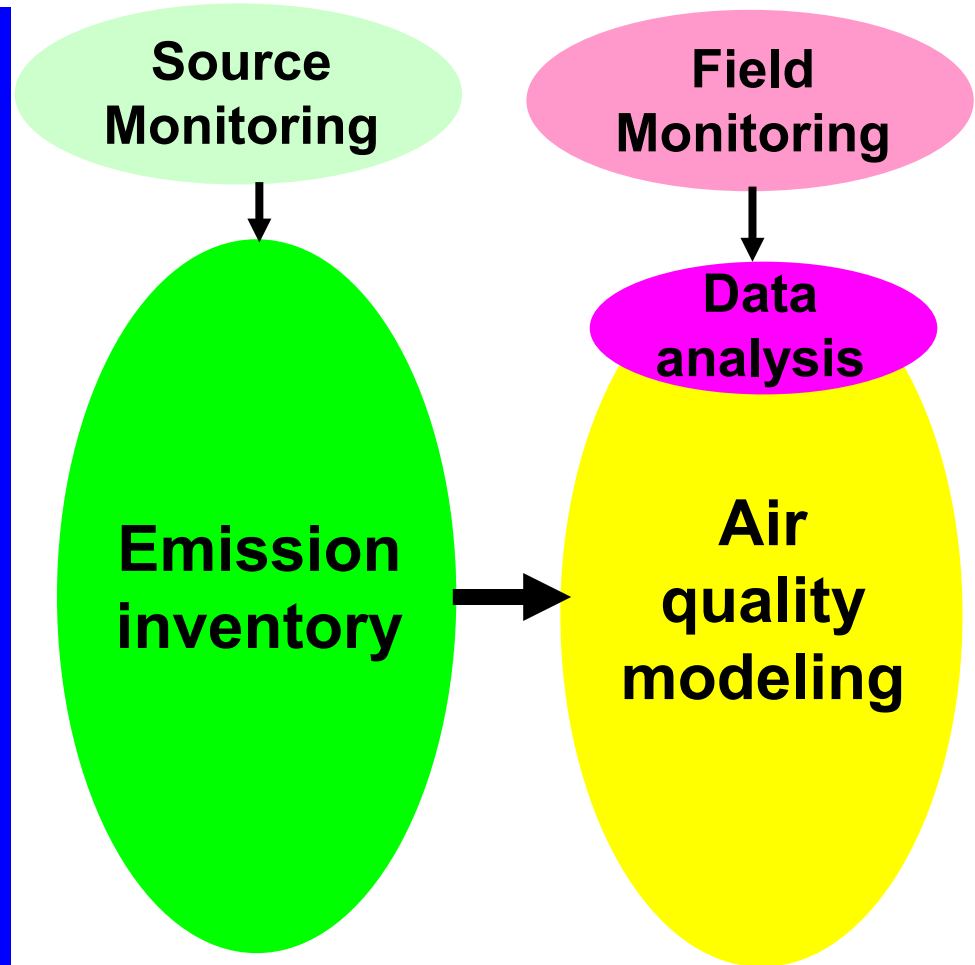## Number of Deaths Attributable to total air pollution in 2019

Number of Deaths Attributable to Air Pollution in 2019

Total number of deaths (millions) in 2019

Data: State of Global Air 2020

Data: https://www.stateofglobalair.org/health/global

Flow chart of management system


```
Monitoring
  ↓
Assessing current & future air quality
  ↓
Policy making for emission reduction
  ↓
Environmental Impact Assessment
  ↓
Implementation of measures
```
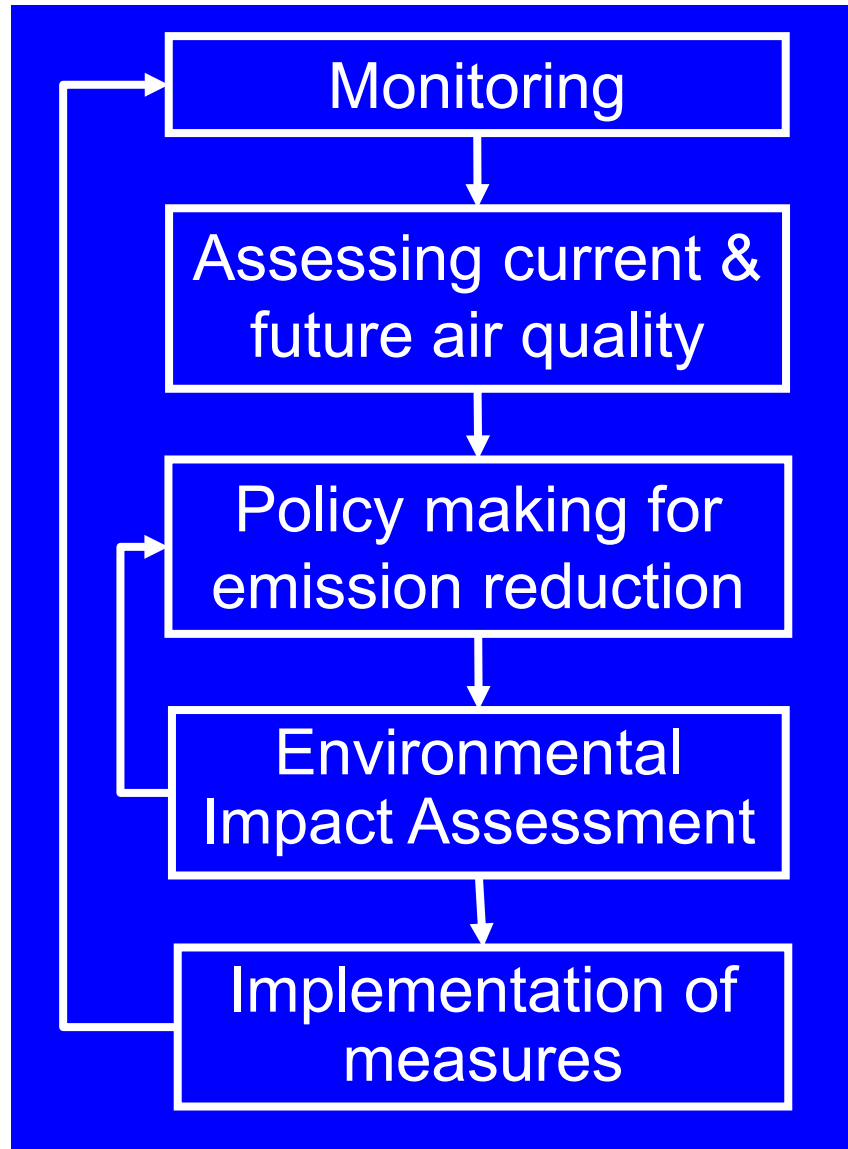
Method & tool for management

Source Monitoring → Emission inventory → Air quality modeling

Field Monitoring → Data analysis

[If you have following question,]
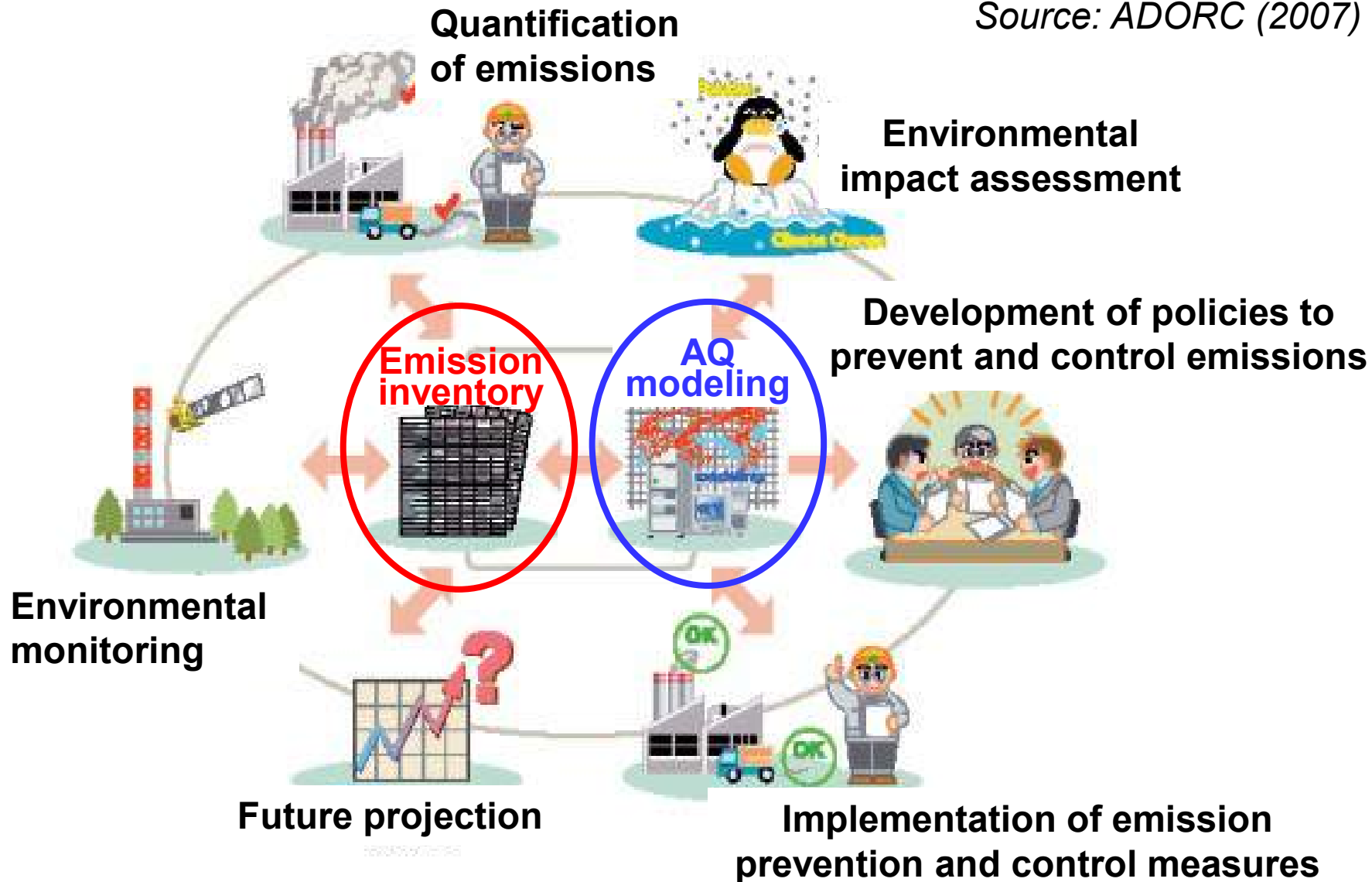What quantities of air pollutants are emitted
and where do they come from?

[The best way to answer these questions is]
to prepare an air pollutant emission inventory

Inventory of estimated emissions (of air pollutants)
based on available information

Roles of an emission inventory in Air Quality Management

Source: ADORC (2007)

Quantification of emissions

Environmental impact assessment

Development of policies to prevent and control emissions

Emission inventory

AQ modeling

Environmental monitoring

Future projection

Implementation of emission prevention and control measures

An emission inventory can be utilized for the following purposes

(1) Quantitative understanding of actual emissions

✓ The quantitative emissions estimated by an inventory promote a better understanding of the actual emissions.

✓ Through this process, the major emission sources can be identified, priorities for emission reduction defined and any data gaps requiring further work are revealed.

(2) Input data for air quality modeling

✓ Emissions data allocated geographically and temporally can be used as input data for chemical transport models (CTM).

✓ The modeled air concentration and deposition estimates obtained by CTM will be important information for air quality management decision-making.

To be continued

(3) Use for future projections and setting of targets & scenarios

✓ A current emission inventory can be used as the basis for estimating future emissions according to projected changes in socio-economic indices, introduction of better control measures, fuel switching and so forth.

✓ Projected future emissions provide important information for setting emissions targets.

(4) Use for the consideration of mitigation measures

✓ An emission inventory enables the expected effects of introducing various prevention and control measures to be assessed and compared, both now and in the future.

✓ Combined with knowledge of costs of the different options, this also enables the most cost-effective emission reduction measures to be identified.

Emission = Emission Factor x Activity Data

Average rate of emission of a pollutant per unit of activity data for a given emission source.

Measure of the scale of activity causing the emissions. The data basically can be collected from statistics and surveys.

	Emission Factor	Activity Data
Fuel combustion in power plant	Emission per the amount of fuel burnt	Amount of fuel burnt
Exhaust gas from vehicles	Emission per distance	Vehicle travelled distance

Image of (standard) emission inventory

Emission inventory for year (X) in country (Y)

Main emission sources
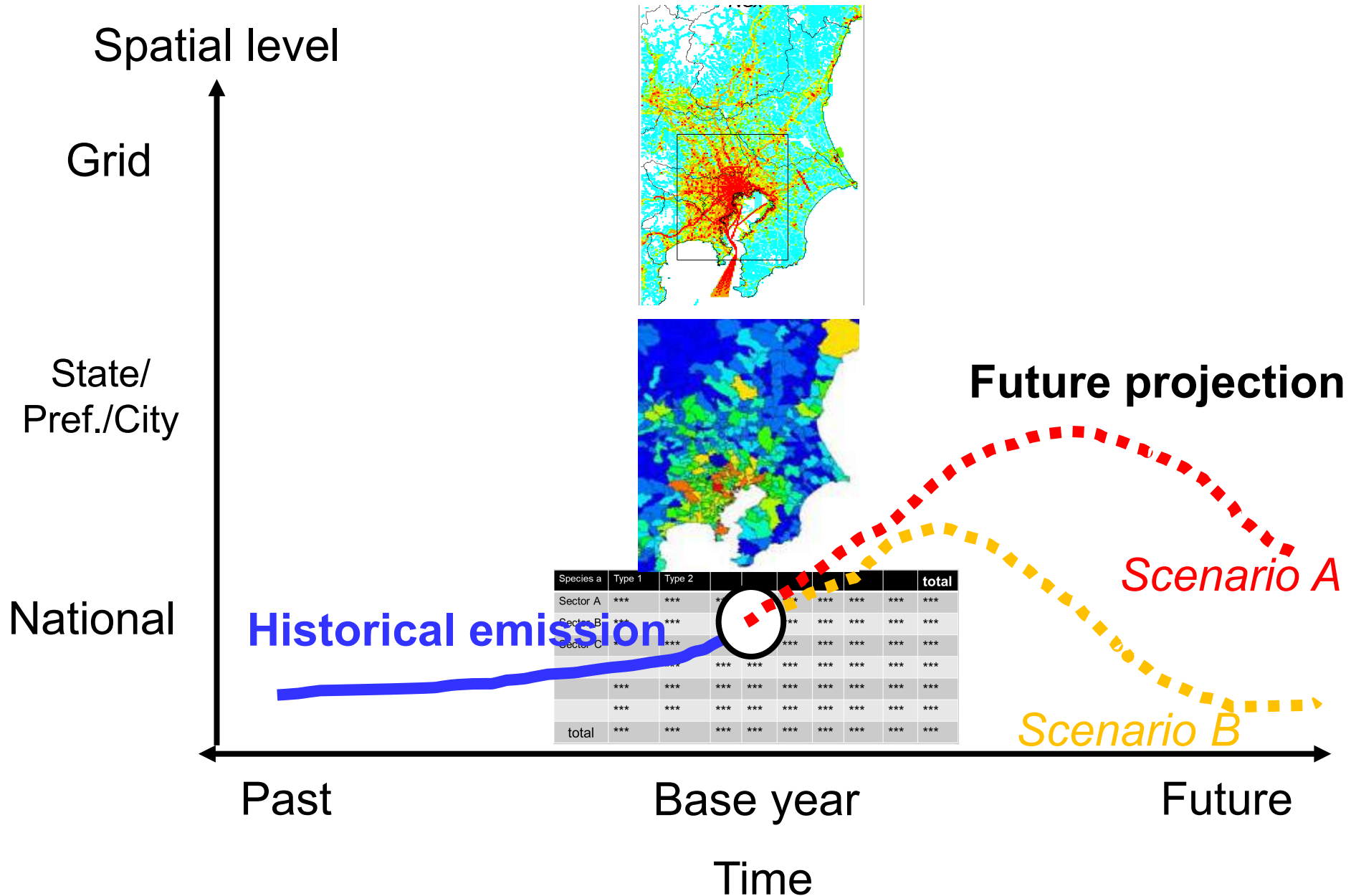
Anthropogenic sources

Energy use
○ Power plants
○ Industrial boilers
○ Vehicles,ship,airplanes etc.
○ Commercial / Residential

Industrial process

Agriculture (open burning, fertilizer, livestock etc.)

Waste management

Forest fire

Natural sources

Ocean

Lighting

Volcanoes

Soil

Natural dust

Dust

Factory

Car

Forest fire

Volcano

Species	Main emission sources （Anthropogenic）	Chemical species in air	Adverse effects	
			Health	Climate change
NOx	Power plant, industry, vehicles	NO_2	☠	
		O_3	☠	+
		Nitrate	☠	—
SO_2	Power plant, industry	SO_2	☠	
		Sulfate	☠	—
VOC	Vehicles, evaporative stationary sources	VOC	☠	
		O_3	☠	+
		Secondary OC	☠	—
CO	Industry, vehicles	CO	☠	
		O_3	☠	+
BC	Vehicles, industry, biofuel combustion	BC	☠	+
OC	Vehicles, biofuel combustion, open burning	Primary OC	☠	—
NH_3	Fertilizer, Livestock	NH_3		
		NH_4^+	☠	—
CH_4	Agriculture, Livestock, waste treatments, coal mining	CH_4		+
		O_3	☠	+
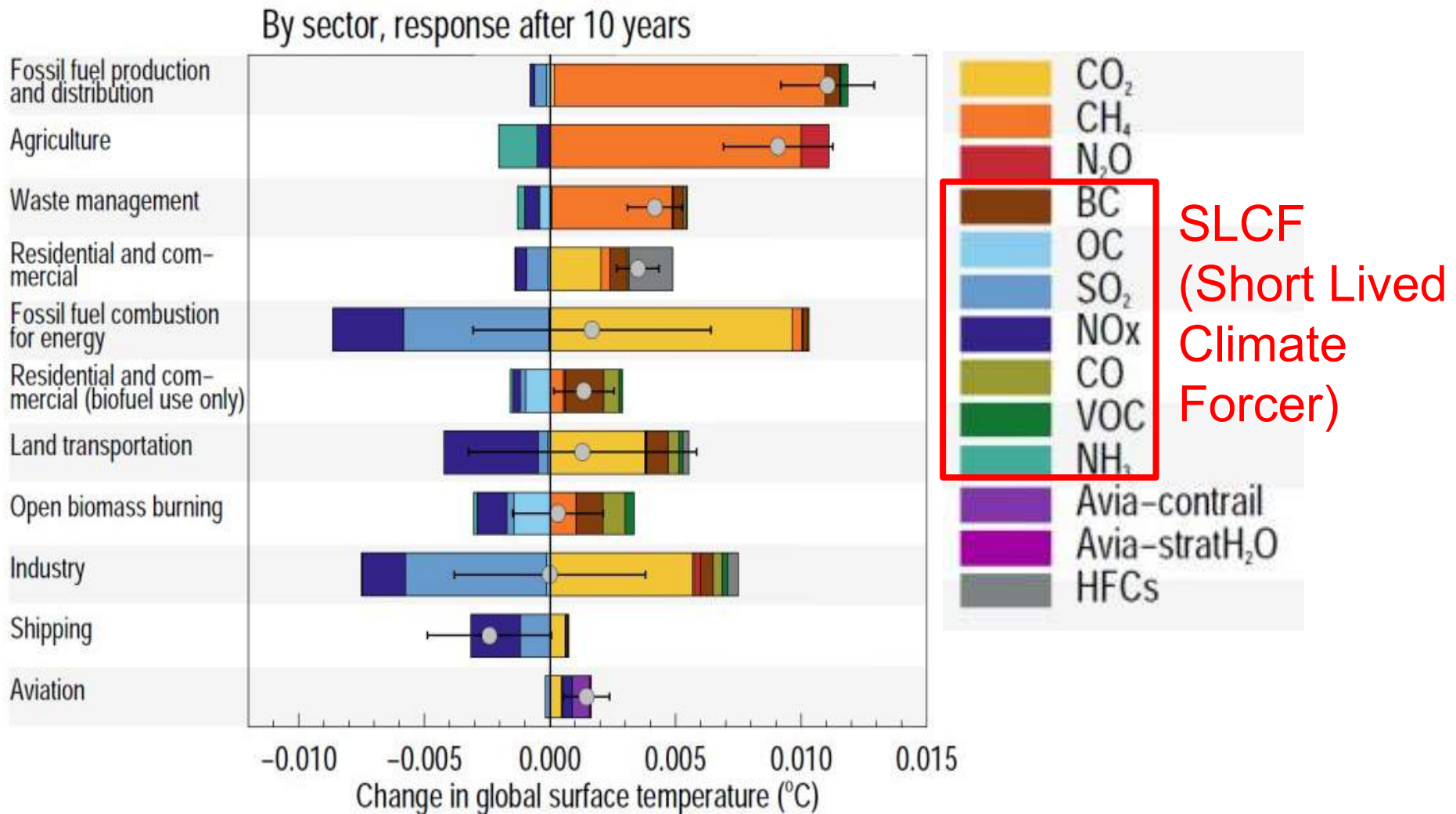
Global surface temperature change 10 years after a one year pulse of present-day emissions. (IPCC AR6 report)

- **Bottom-up based emission inventory**
- **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**

NO_x emissions in 2015 [tNO_2/year]
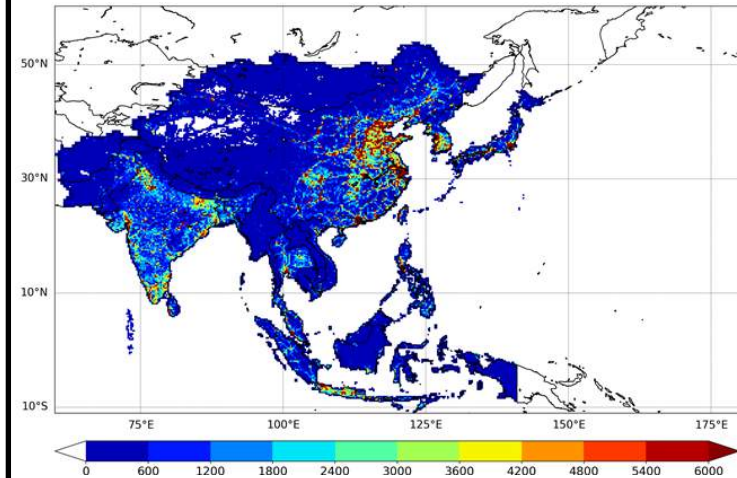
	SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$	BC	OC	NMVOC	NH_3	CO_2
Combustion	●	●	●	●	●	●	●	●	●	●
Industrial Process	●		●	●	●	●	●	●	●	●
Agriculture (Non-Combustion)									●	
Others				●	●			●	●	

Datasets and related papers are available from https://www.nies.go.jp/REAS/

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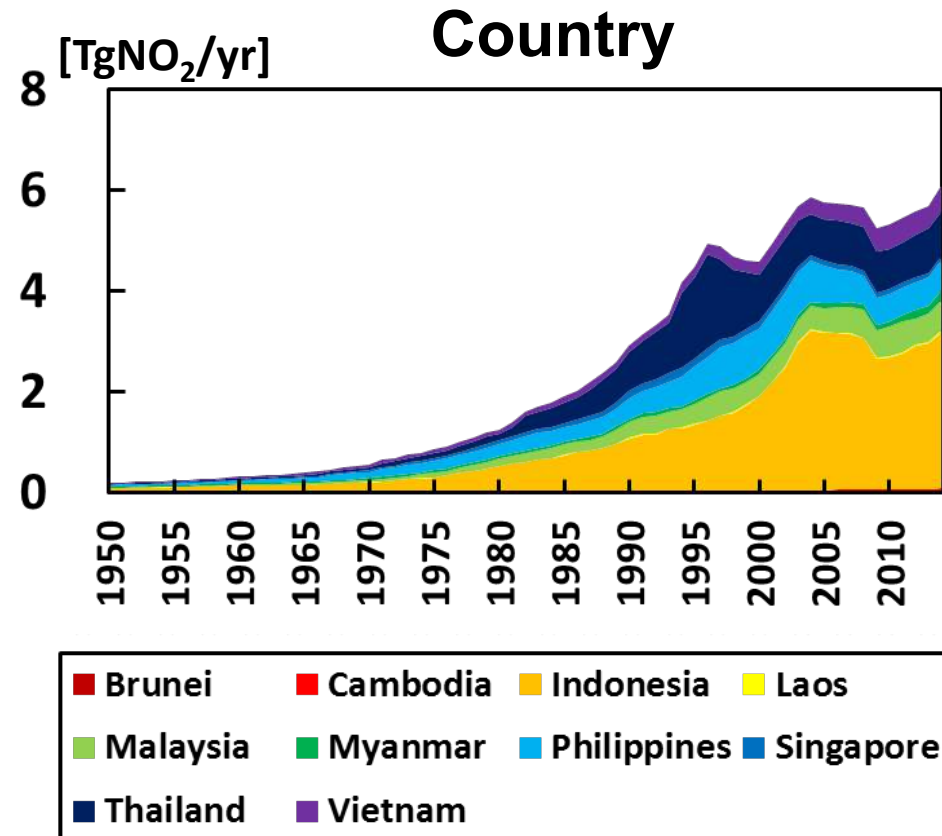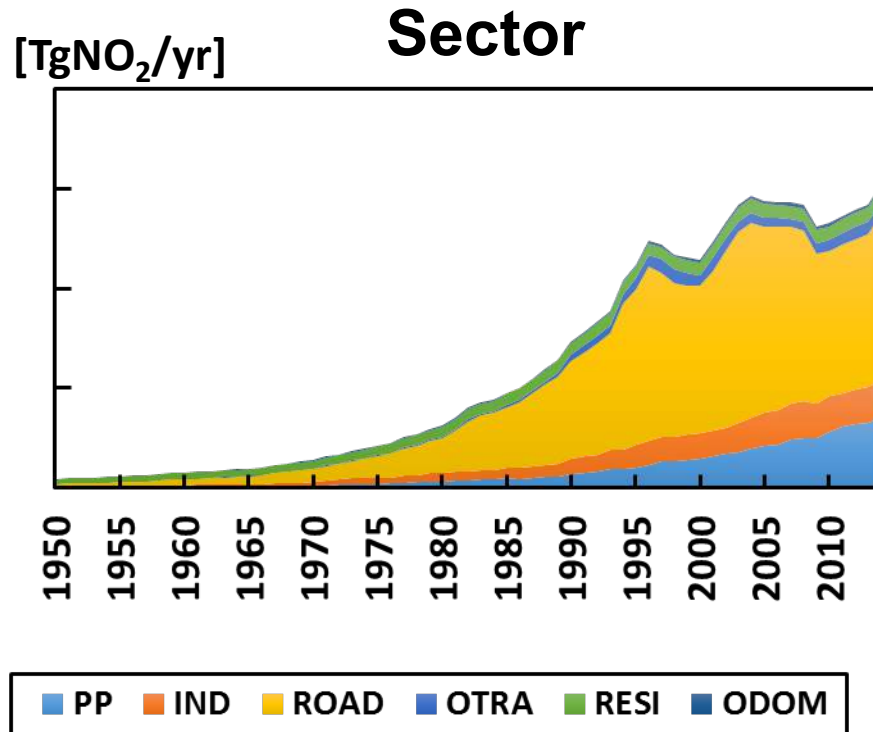
- Major sources was road transport. Recently, emissions from coal combustion in power and industry are increasing.
- For countries, the largest contributor for emissions is Indonesia followed by Thailand, Philippines, Vietnam, and Malaysia.

Air pollution and acid deposition caused by NOx emissions in East Asia

NOx emissions **(inventory)**
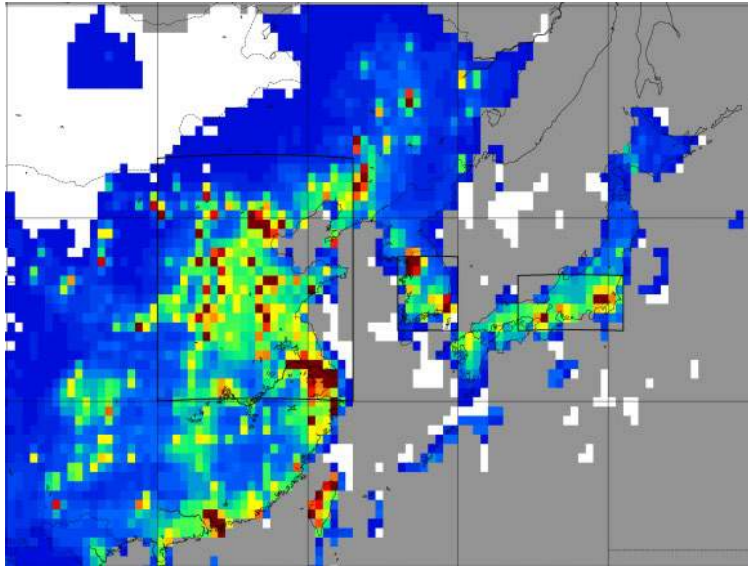
Transport/reaction/deposition
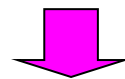
NO$_2$ conc. **(model)**
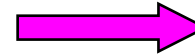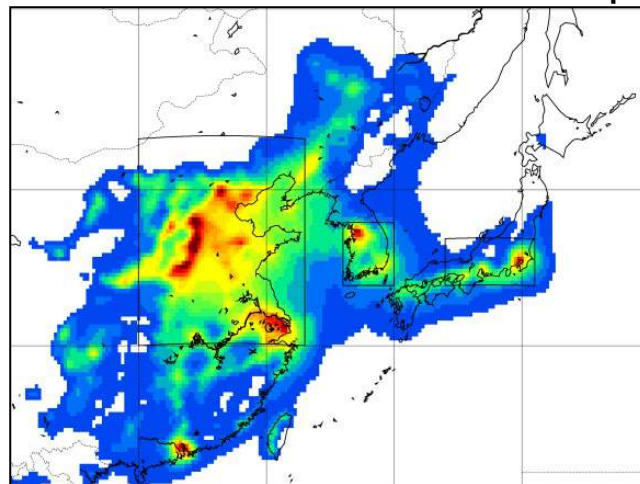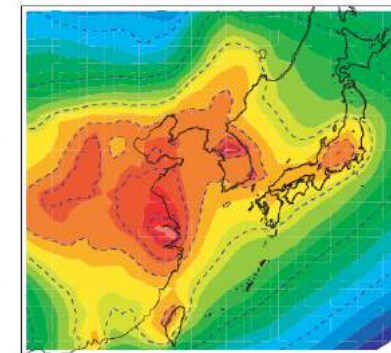
Particulate NO$_3^-$ conc. （model）

Deposition
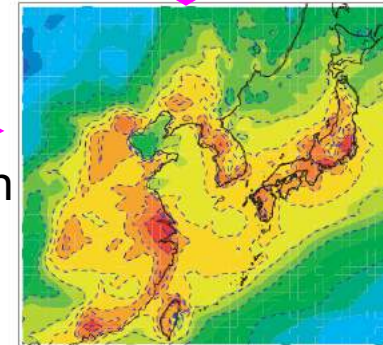
Deposition

NO$_3^-$ deposition （model）

NO$_x$ reduction due to emission regulation in Japan

[MtNO$_2$/Yr]

(Major regulations and laws enforced in this period)

- Regulations for total NO$_x$ EMs for stationary sources
- Automobile NO$_x$ law
- Automobile NO$_x$/PM law
- Regulations for NO$_x$ EMS from Trucks and Bus
- Air pollution control law

70% (Transport)

Reduction

10% (Power)

20% Actual emissions

Legend:
- Transport
- Industry
- Power
- Others
- Transport
- Industry
- Power
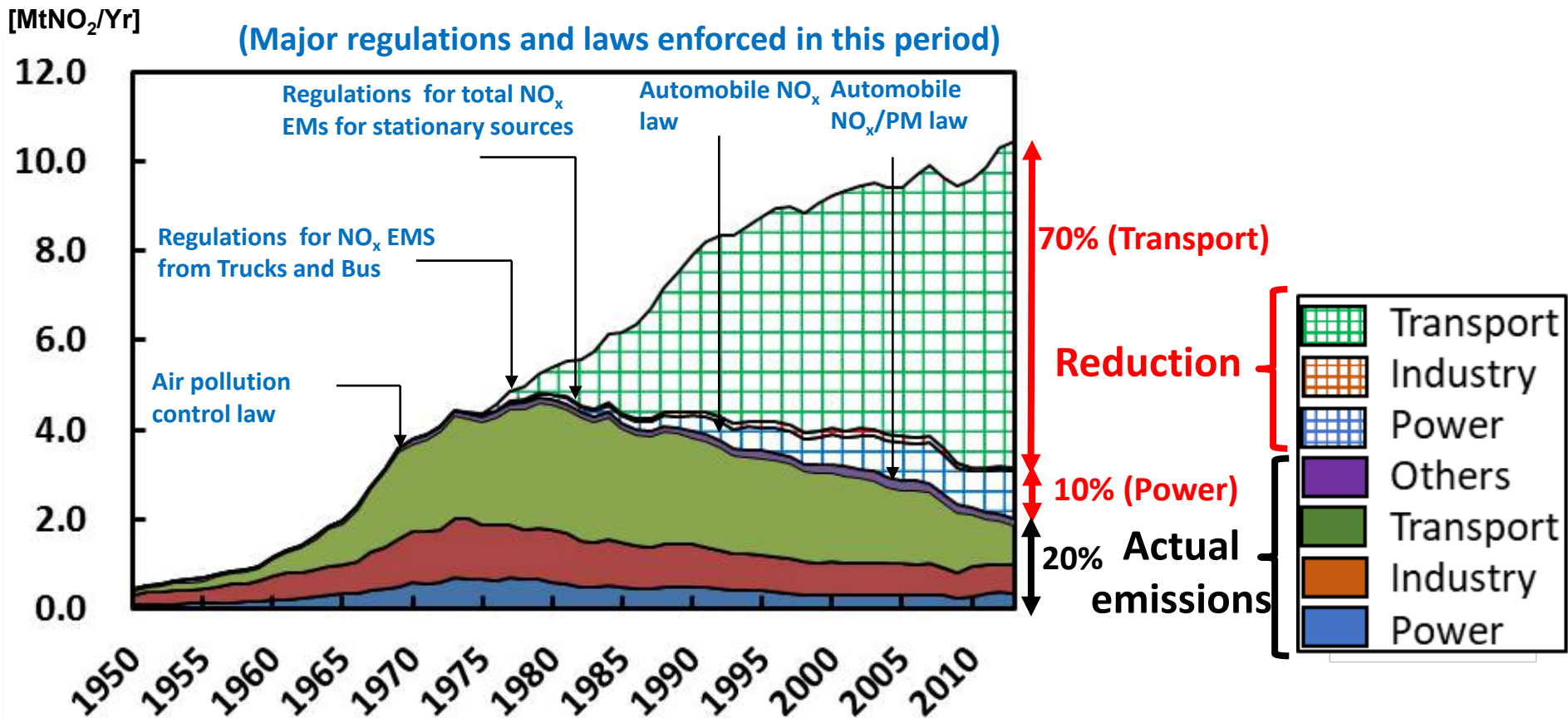
- NO$_x$ increased rapidly in late 1960s, while it decreased after late 1970s due to strong emission regulation.
- In 2015, 70% and 10% of total emission potential were reduced by emission regulation for road transport and power plants, respectively.

To be continued

Air quality improvement due to emission regulation in Japan
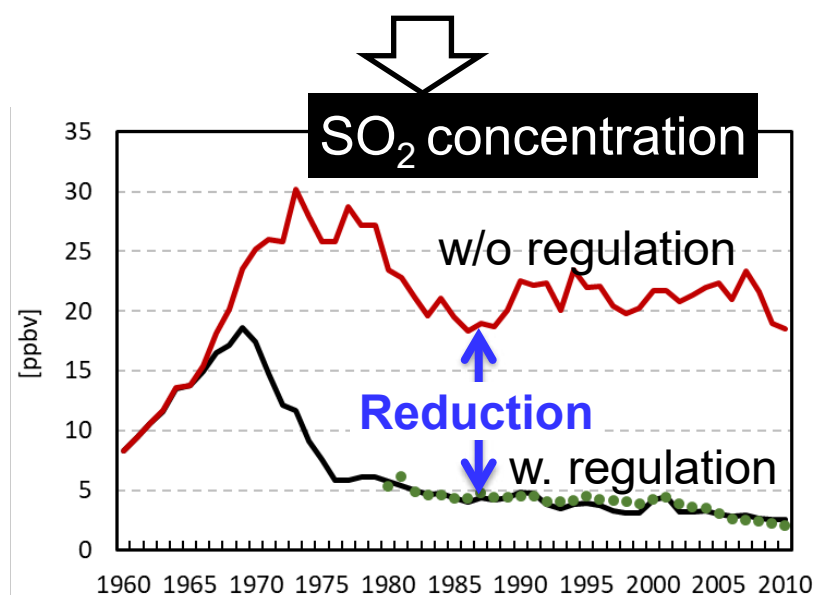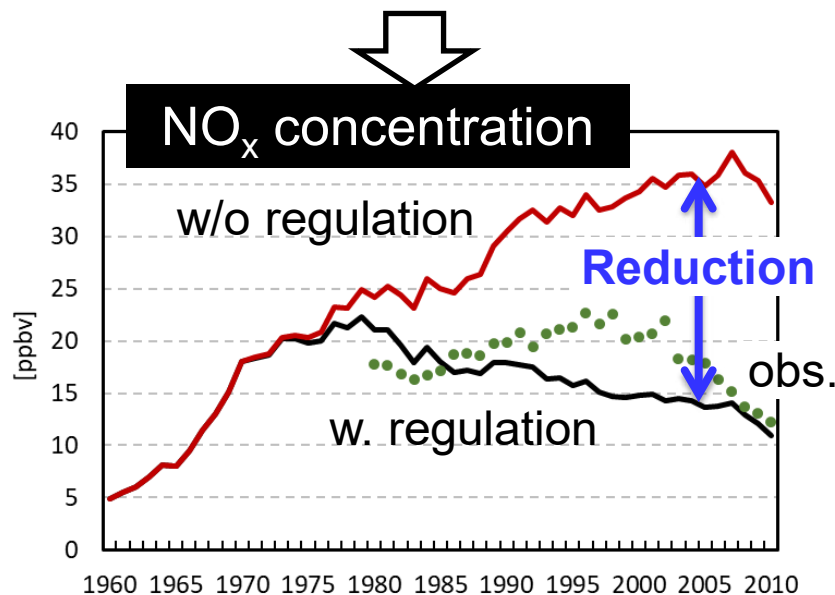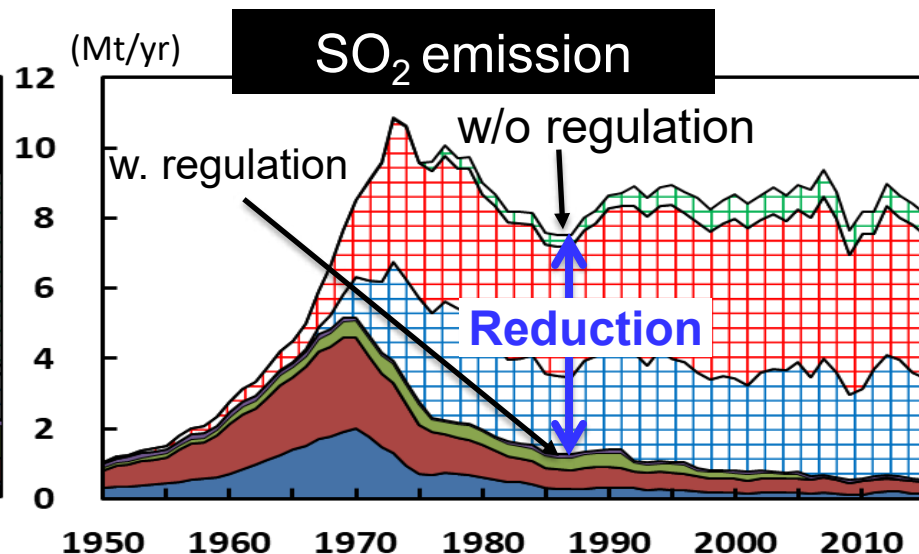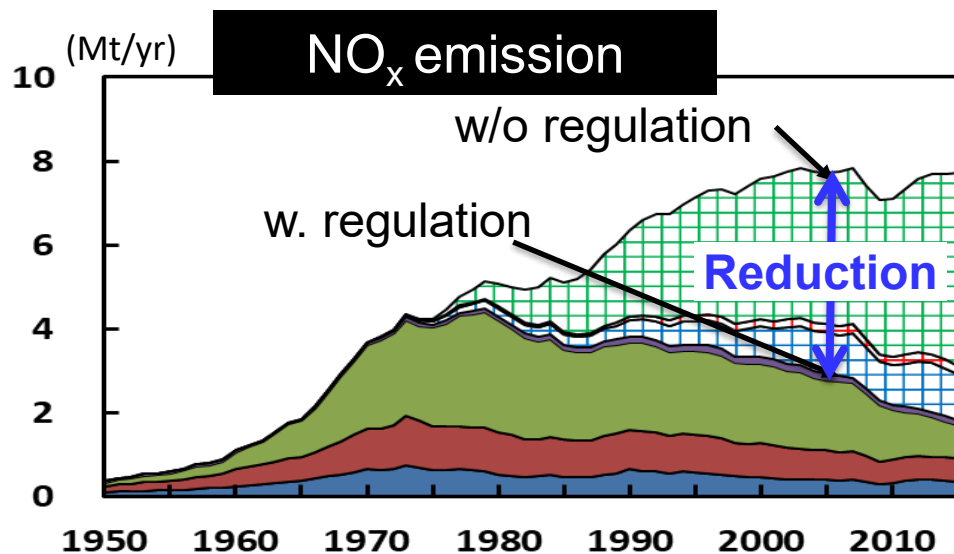
(From draft of PRSAD4)

Country	Status	Species
Cambodia	UNFCC National GHG EI	CO_2, CH_4, N_2O, HFCs
Lao PDR	UNFCCC National GHG EI	CO_2, CH_4, N_2O
Malaysia	UNFCCC National GHG EI	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3
Mongolia	Case study of National EI (by NAMEM)	SO_2, NO_x, TSP, PM_{10}, $PM_{2.5}$, CO, NMVOC, NH_3
Myanmar	UNFCCC National GHG EI	CO_2, CH_4, N_2O, CO, NO_x, NMVOCs, SO_x, SF_6, ODSs
Philippines	EI of EMB (Environmental Management Bureau)	PM, SO_x, NO_x, CO, VOC
Russia	UNFCCC National GHG EI	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3, SO_2, NO_x, CO, NMVOC
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 (not yet implemented)	$PM_{2.5}$, PM_{10}, NO_x, N_2O, SO_2, CO, NMVOC, NH_3, BC, OC
	UNFCCC National GHG EI	CO_2, CH_4, N_2O, SO_2, NO_x, CO, NMVOCs
Vietnam	UNFCCC National GHG EI	CO_2, CH_4, N_2O, HFCs

Summary

- For mitigating severe air pollution in Asia, the air quality management in national and regional scales is very important.

- Emission inventory (EI) is a fundamental tool for air quality management.

- The development of EI should be further strengthened in each participating country of EANET.

- For comprehensive management of atmospheric environment, the EI covering air pollutants as well as climate forcers is needed.

Emission estimation for air pollutants emission inventory

Tazuko MORIKAWA

Japan Automobile Research Institute

2021.10.18 The EANET Emission Inventory Workshop

Relationship between Air Pollution and Scale

Scale of air pollution phenomena → **wide**

Chemical reaction speed → **Low**

Small

Fast
(can be ignored)

The world
Substances that rarely react and affect global conditions

Substances involved in the Greenhouse effect
(CO_2, CH_4, N_2O)
Depletion of the ozone layer
(CFCs)

The entire globe

Regions and countries
Pollutants that are produced through relatively slow reactions
Substances that are hard to eliminate
Pollutants that are transported to remote regions
(in one to several days)
SO_2, acid rain

Large cities
Pollutants produced through relatively fast reactions
(several minutes to several hours)
NO_2
Photochemical oxidants
Particulate matter

Roadsides
Substances directly toxic to humans
CO, NOx, particulate matter,Lead, Benzene, 1,3-butadiene, etc.

Mountainous regions near large cities
Within and across boundaries

Large metropolitan areas, including peripheral regions

Trunk road intersections

Pollutants and Chemical Reactions in Urban Air

In order to reduce $PM_{2.5}$, it is important not only **to control the emission of $PM_{2.5}$**, but also **to understand the role of precursors in the air and to control their emission.**

O_3
PM

VOC generated from plants

VOC (Volatile Organic Compounds)

NH_3 (Ammonia)

NO

$PM_{2.5}$

HNO_3 (Nitrate)

O_3

NO_2

VOC

NO

Formation of secondary pollutants

SO_2

Transported from Background

Reactions in the air

O_3 Formation

Photolysis

O atm → O_3

NO

O_3

NO_2

VOC contributes to oxidation

Secondary Inorganic PM Formation

Acid gas mainly reacts with NH_3 to form PM

SO_2 → SO_4^{2-} → **Sulfate**

NO_3^- → **Nitrate**

Secondary Inorganic PM

Secondary Organic PM Formation

Vapor pressure reduction due to oxidation → **Secondary Organic PM**

Emission Inventory as input data of air quality models.

In order to reproduce the concentration change of the moving air mass, it is important to know which region, when, what kind of pollutant is emitted.

Regional and temporal distribution information is necessary for air pollutants emission inventory.

$PM_{2.5}$ HNO_3

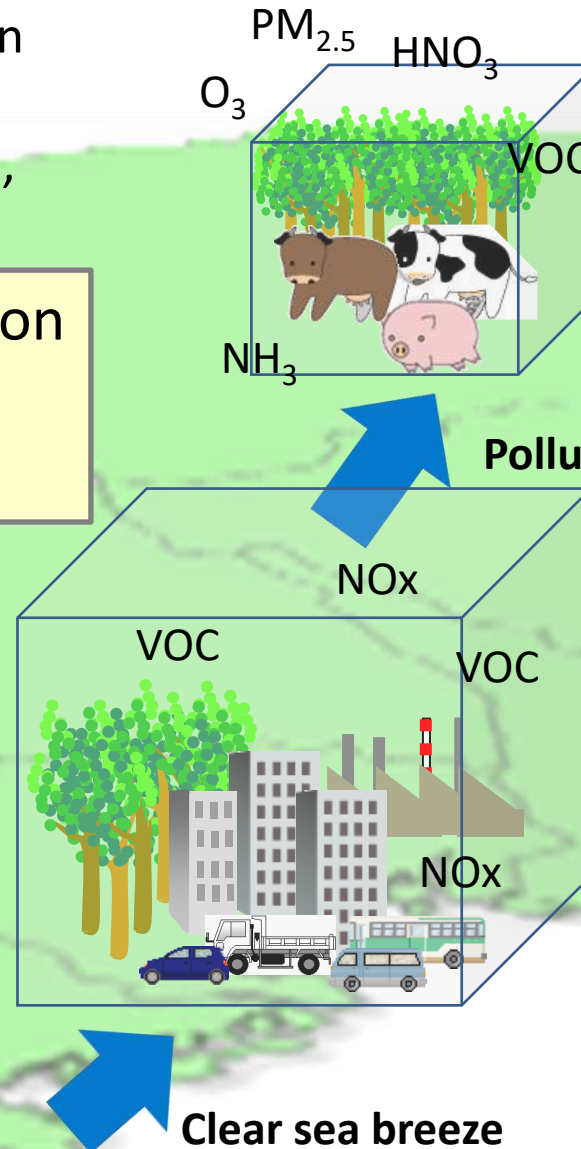O_3

VOC

NH_3

Several hours later, the air mass reaches rural area, with continue to react and receive new pollutants.

Polluted air mass is moving

NOx

VOC

VOC

NOx

The chemical reaction proceeds while air mass moving, and the pollutants concentration decreases with diffusing and depositing. New pollutants in the area are added. Solar radiation and weather conditions change from moment to moment.

Within each grid, it is reproduced physical and chemical events such as pollutants emission, advection/diffusion, chemical reaction, and deposition.
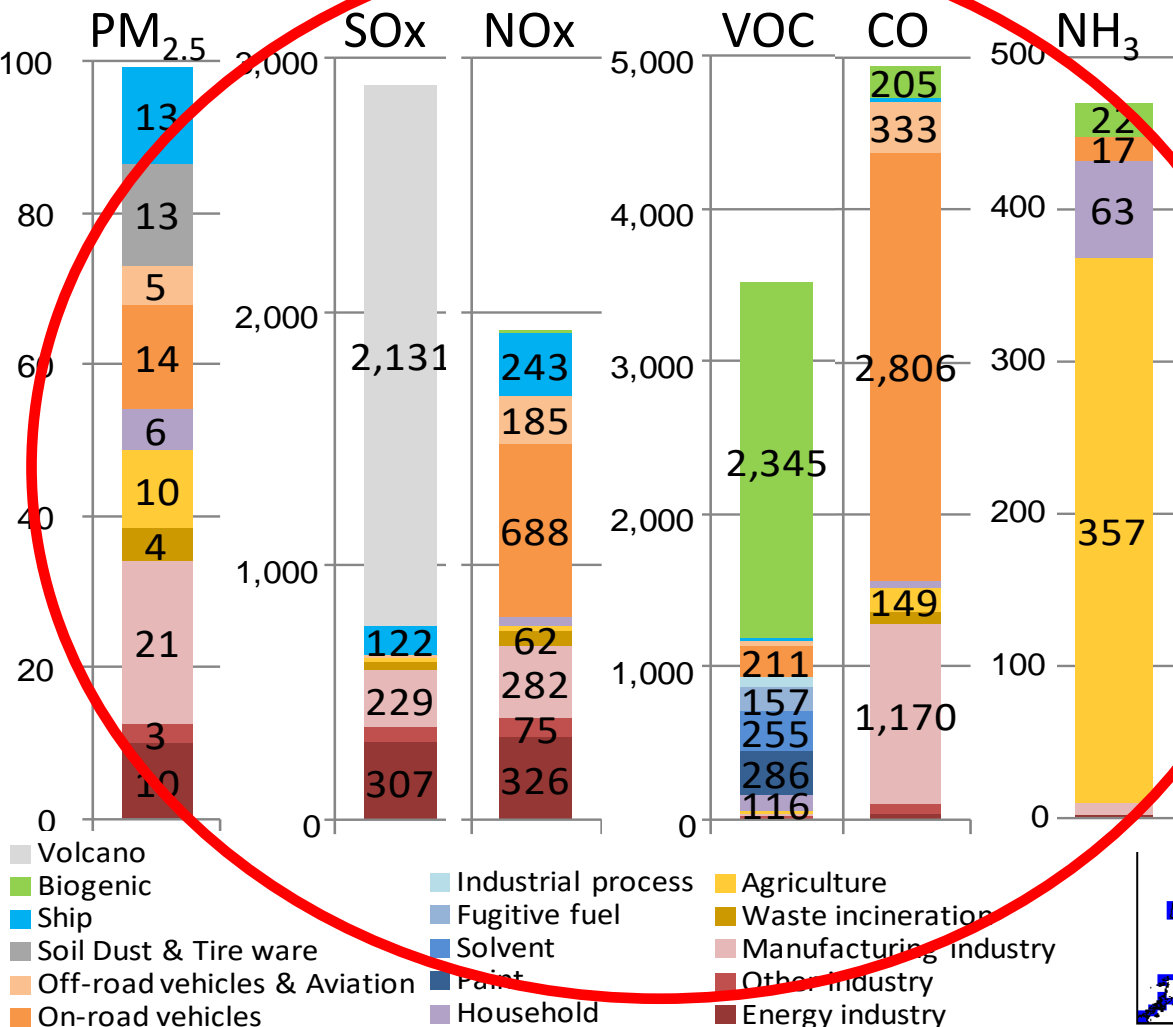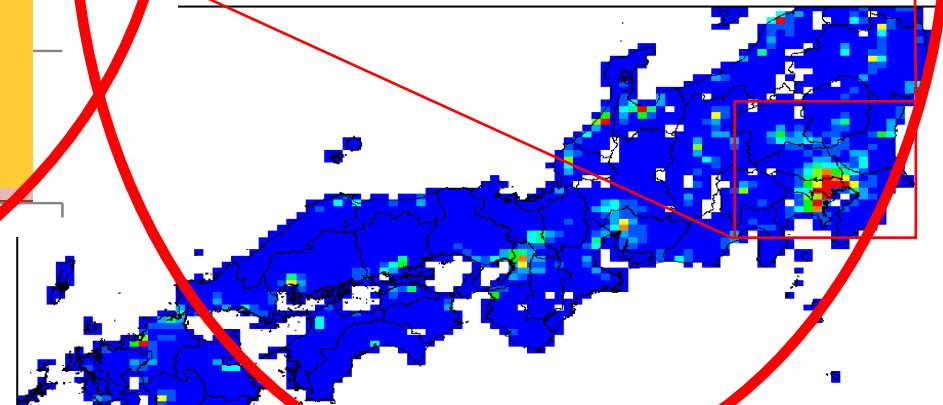
Clear sea breeze

Air Pollutants Emission Inventory, "PM2.5 Emission Inventory, PM2.5EI"

Total Emission Amount in Japan FY2012 (kt/y)

PM$_{2.5}$: 13, 13, 5, 14, 6, 10, 4, 21, 3, 10

SOx: 2,131, 122, 229, 307

NOx: 243, 185, 688, 62, 282, 75, 326

VOC: 2,345, 211, 157, 255, 286, 116

CO: 205, 333, 2,806, 149, 1,170

NH$_3$: 22, 17, 63, 357

Legend:
- Volcano
- Biogenic
- Ship
- Soil Dust & Tire ware
- Off-road vehicles & Aviation
- On-road vehicles
- Industrial process
- Fugitive fuel
- Solvent
- Paint
- Household
- Agriculture
- Waste incineration
- Manufacturing industry
- Other industry
- Energy industry

Example of spatial distribution
Emissions from home with fuel use (hot-water supply/heating)

1.80E2～3.43E2
1.60E2～1.80E2
1.40E2～1.60E2
1.20E2～1.40E2
1.00E2～1.20E2
80.6～1.00E2
60.7～80.6
40.8～60.7
20.9～40.8
1～20.9
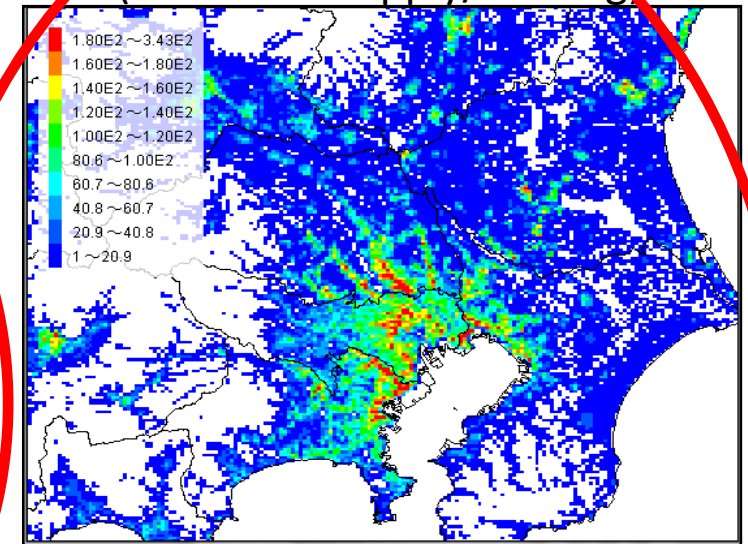
The time distribution is equally important.

Emission data form and what we can be examined -1

National Total Emission

- ✓ Check whether policies and measures are functioning
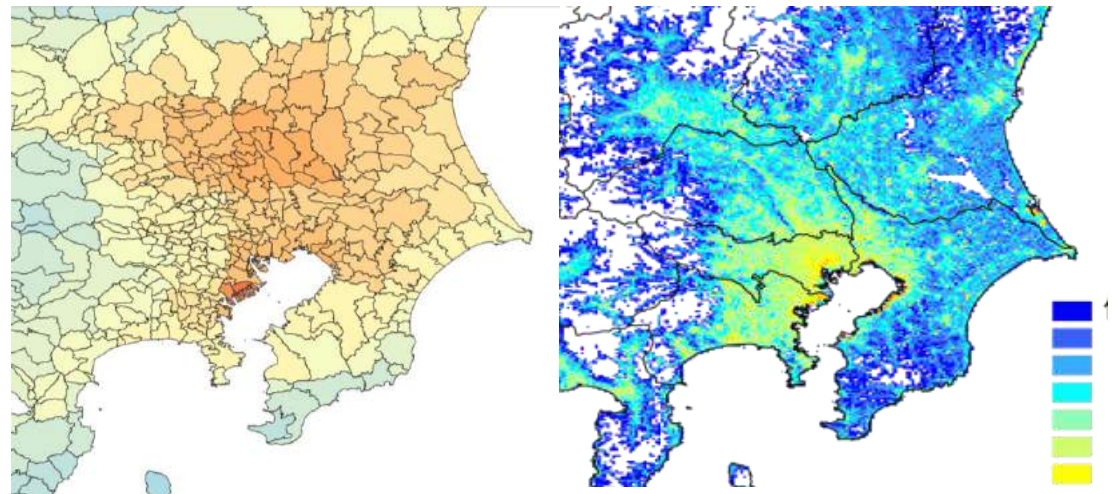- ✓ Identifying sources to be addressed

Regional Emission

- ✓ Check whether policies and measures are functioning
- ✓ Identifying sources to be addressed
- ✓ Identifying regional issues
- ✓ Evaluation of secondary air pollutants (Input data for air quality models)

Change in primary $PM_{2.5}$ emissions
(national annual emissions)

kt/FY year

Ship

Resuspension of Road Dust and Tire waer

Vehicle

Agriculture

Manufactures

'00 '05 '10 '12 '15
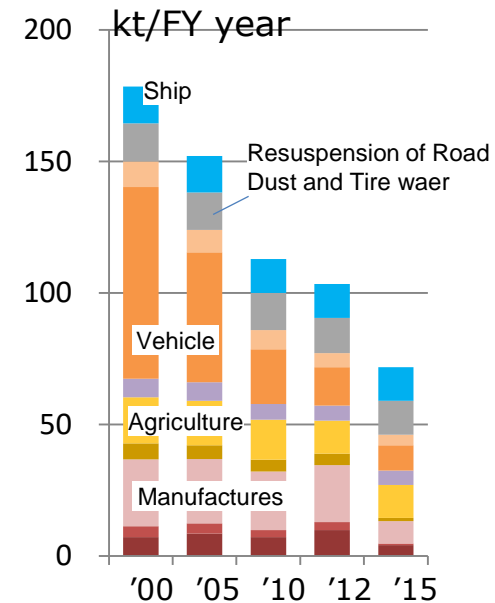
Emission distribution by municipality   Emission distribution in grid

Emission data form and what we can be examined -2

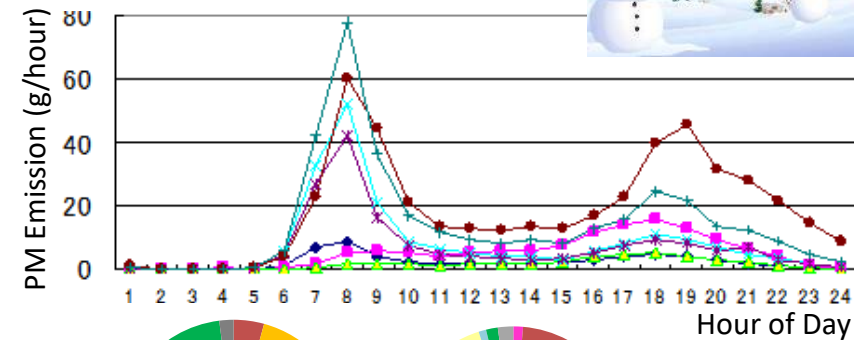## Seasonal, Monthly, Daily (weekday and holiday), Hourly Emissions

- ✓ Identifying regional and/or local issues
- ✓ Evaluation of secondary air pollutants (Input data for air quality models)

Detailed air pollutant composition

- ✓ Evaluation of secondary air pollutants (Input data for air quality models)
- ✓ Evaluation of hazardous air pollutants

Gasoline   Gasoline Vapor

Diurnal Breathing Loss
(After canister breakthrough)   Hot Soak Loss
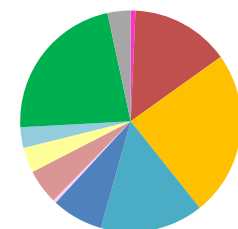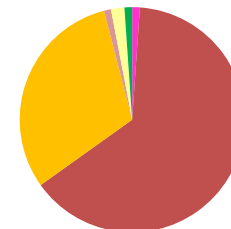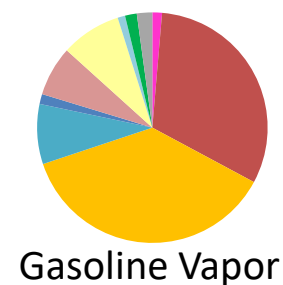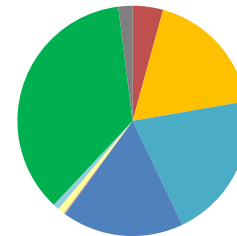
- C3 > Alkane
- C4 Alkane
- C5 Alkane
- C6 Alkane
- C7 < Alkane
- C3 > Alkene
- C4 Alkene
- C5 Alkene
- C6 < Alkene
- Aromatics
- Others

The Most Common Emission Estimation Approach

Emission Factor $\times$ Activity Data $=$ Emission

Quantify the emissions or
removals per unit activity

Information on the extent to which
a human activity takes place

<Top Down Approach>   **<Bottom Up Approach>**

National Emission

Distribution ↓   ↑ Summation

Prefectural Emissions

Distribution ↓   ↑ Summation

Municipality emissions

Distribution ↓   ↑ Summation

Gridded emissions   ←   Individual source emissions

Summation
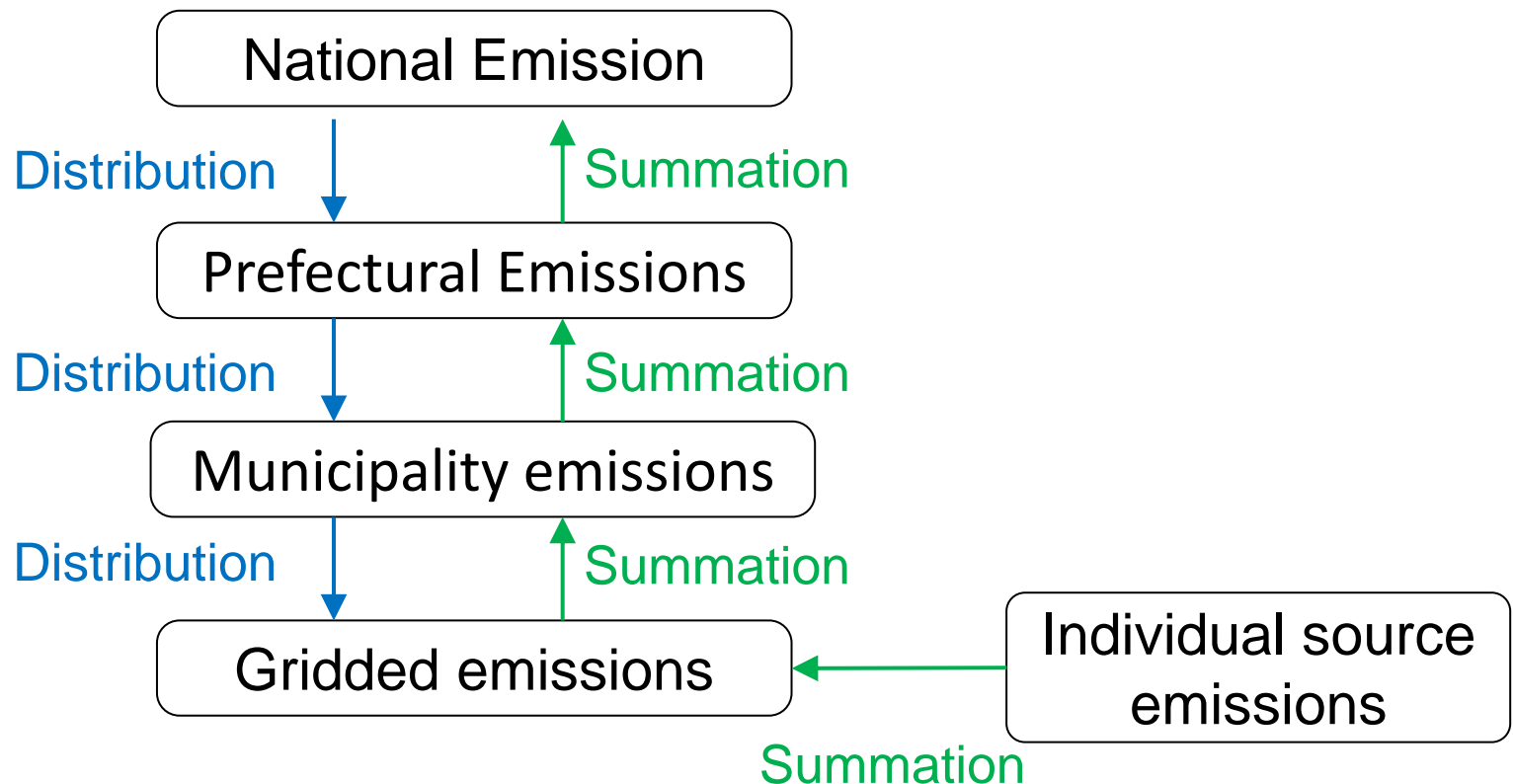
Top Down Approach ... the starting point is the total emission

NOx

1kL
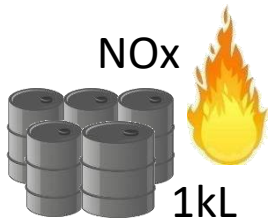
Amount of NOx emitted when using heavy oil at 1 kL(kg/kL)

Emission Factor

×

Activity

Consumption of heavy oil in certain industrial sectors for one year in Japan(kL)

=

NOx emissions from heavy oil burning in certain industry sectors throughout Japan in one year (kg).

However, detailed distribution is required for the air quality model

Spatial distribution

Prefecture

1km^2 resolution

※ 3次メッシュ推計地域のみ

低

高

Temporal distribution
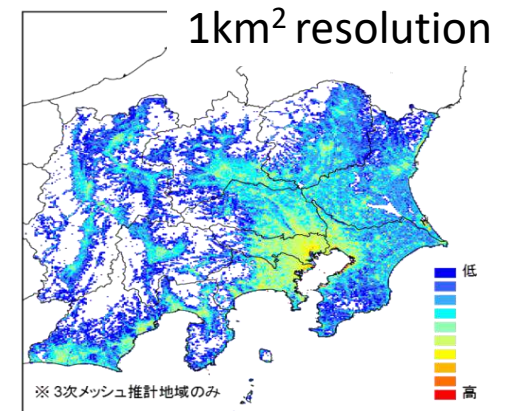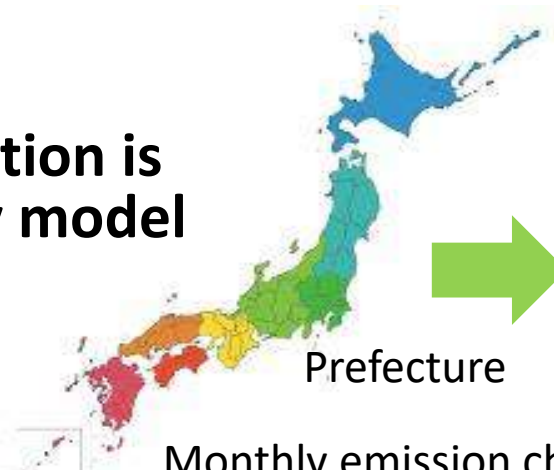
Monthly emission change
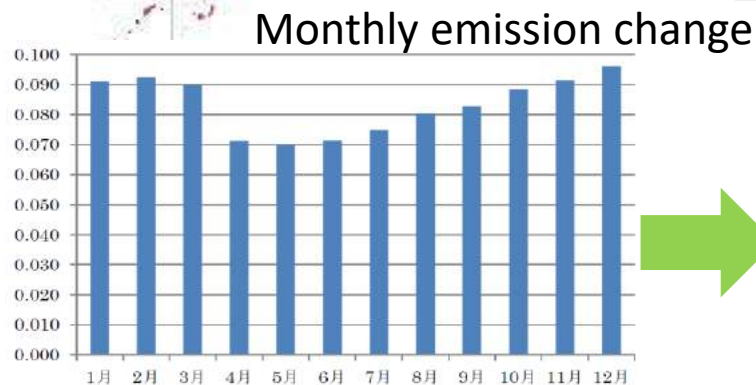
Hourly emission change
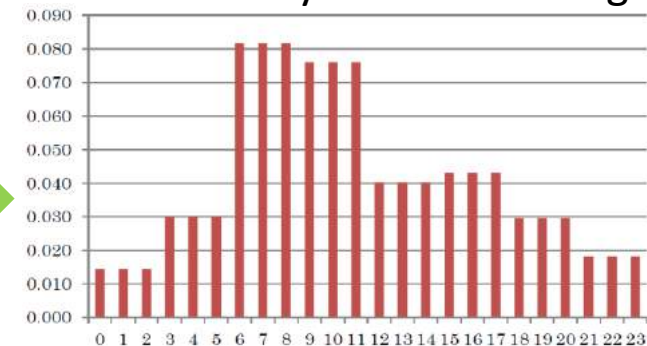
Composition distribution

NOx = NO 90% + NO$_2$ 10%

Emission Estimation -1 Combustion Sources

Emission Factor ✕ Activity Data = Emissions ??

(✕ abatement ratio)   **Fuel Consumption**

✓ First, it is recommended to use literature values for emission factors and composition distribution.

✓ Apply activity data and allocation indicators for one's country.
- ✓ Use existing statistical data
- ✓ Conduct questionnaire survey

✓ Change the data little by little with
- ✓ Adding one's origin category
- ✓ Formulate emission factors that reflect the situation in one's country.
- ✓ Measurement of VOC and PM components of sources.

> The activity data is fuel consumption, so it is easy to obtain (one of the statistics data that are easy to collect). Data for estimating CO2 emissions can be used. It is easy to specify the emission location and time.

> If national energy consumption is known, emissions from combustion sources will be downscaled from national emissions to regional emissions. It can also be considered as a point source from the fuel consumption of individual sources.

Emission Estimation -2 Evaporative VOCs

Emission Factor ✕ Activity Data = Emissions ??

✓ VOC emissions due to solvent use and fuel leakage.
✓ Large factories tend to take measures, then the amount of emissions is not necessarily proportional to the amount of activity.

✓ Solvents often contain toxic substances such as benzene, toluene, xylene, etc., so it is convenient to investigate VOC emissions together with a survey of toxic substance emissions.
　　✓ Ask the solvent user (company) <u>to report the VOC emissions</u>.
　　✓ At the same time, ask <u>the individual components of VOCs.</u>

Assuming that the solvent has been volatilized and lost(=emission), solvent users would know how much is lost because it is their loss.

Some users know what VOC components are in the solvent.

Evaporative VOC Emission, Japanese Industrially-related Sources

Voluntary approaches in VOC emission reduction policy

A Company

company does not belong to the industry group

Report

Investigation

Industrial Structure Council

Voluntary Action Support Board

The Japan Environmental Management Association for Industry

Results reported

Measures Proposed

Results reported

Results reported

Industry Group

Advice

Report

Ministry of Economic Trade and Industry

VOC emissions reported by each Industry Group

Participating Industry Group: 41
Participating Companies : 20,100
(as of year 2020)

Ministry of Environment

Studies to develop the national emissions inventory for VOCs

Revision VOC emission with company does not belong to the industry group to estimate <u>total VOC emission in Japan</u>

"PM2.5 EI"

Spatial distribution conducted by using Appropriate statistical data

THE JAPAN GAS ASSOCIATION

PAJ   JPIF   JRMA

Japan Adhesive Industry Association

JAPA   JAPIA   JPMA

KZK   JAA   JAMA   The Japan Iron and Steel Federation

JOIFA   JCIA   JGA

Bottom-up Approach ... the starting point is each emission

2005 Regulation, Gasoline fueled
Passenger Car, Average speed = 25 km/h

EF: NOx=0.03 g/km

Other Required Variables

Vehicle speed, Temperature,
Humidity, Regulation, Total mileage
(Degradation of catalyst)
Ratio of broken vehicles, pay load

New short term Regulation:
GVW=5t, Gasoline fueled Bus
Passengers=20=1.3t
Average Speed = 25km/h

EF: NOx=0.3 g/km

Post new term Regulation, GVW=8t
Diesel fueled Heavy Duty Truck
Pay load=5t,
Average speed = 25km/h

EF: NOx=0.2 g/km/t

Traffic Volume Surveys

×

=

NOx emissions
per link length of
a certain main
road (kg)

Link length of a certain main road(2~10km)

Traffic volume by type of vehicle

Japanese Emission Factors for Vehicle Running Emission

Function of average speed, by vehicle type (fuel) and regulation

Velocity-dependent emission factors for CO, NOx, PM, THC and NH_3 are provided by 13 Vehicle type, regulation year.
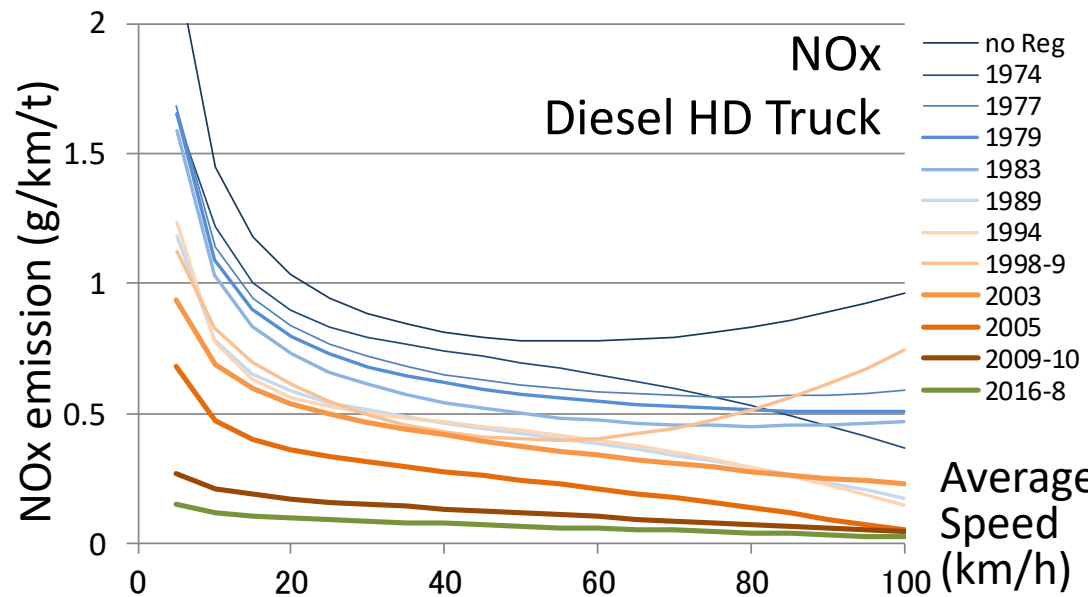
All Emission Factor EF is expressed by:

$$EF = a + b/V + c \cdot V + d \cdot V^2$$

V: Vehicle average speed

Fuel type	Vehicle type	Vehicle weight
Gasoline /LPG	Mini-Passenger-Cars	
	Small Passenger-Car	IW <= 1.25t
	Middle Passenger-Car	IW >1.25t
	Mini-Cargos	
	Light-Duty-Trucks	GVW <= 1.7t
	Medium-Duty-Trucks	1.7t < GVW <= 3.5t
	Heavy-Duty-Trucks	3.5t < GVW
Diesel	Small Passenger-Car	IW <= 1.25t
	Middle Passenger-Car	IW >1.25t
	Light-Duty-Trucks	GVW <= 1.7t
	Medium-Duty-Trucks	1.7t < GVW <= 3.5t
	Heavy-Duty-Trucks （GVW≦5.0t）	3.5t < GVW <= 5t
	Heavy-Duty-Trucks （GVW>5.0t）	5t < GVW

Example) NOx, Diesel HD Trucks（DI,GVW>5.0t）

Reg. Year	a	b	c	d
-	7.49E-01	7.53E+00	-6.08E-03	7.46E-05
1974	4.53E-01	7.18E+00	5.62E-03	-7.21E-05
1977	6.63E-01	5.22E+00	-5.03E-03	3.76E-05
1979	5.80E-01	5.45E+00	-3.25E-03	1.96E-05
1983	5.43E-01	5.33E+00	-4.68E-03	3.40E-05
1989	3.75E-01	4.01E+00	1.18E-03	-3.58E-05
1994	2.46E-01	4.83E+00	5.16E-03	-6.65E-05
1998,1999	7.43E-01	2.27E+00	-1.52E-02	1.50E-04
2003	4.95E-01	2.31E+00	-3.73E-03	8.34E-06
2005	2.78E-01	2.02E+00	-5.08E-04	-1.96E-05
2009,2010	1.74E-01	5.07E-01	-1.33E-03	0.00E+00
2016-2018	9.95E-02	2.90E-01	-7.59E-04	0.00E+00

NOx Diesel HD Truck

Legend: no Reg, 1974, 1977, 1979, 1983, 1989, 1994, 1998-9, 2003, 2005, 2009-10, 2016-8

Y-axis: NOx emission (g/km/t)
X-axis: Average Speed (km/h)

Traffic Volume Surveys

Road Traffic Census by Ministry of Land, Infrastructure and Transport (MLIT) since 1928

Example of investigative road map

40 km
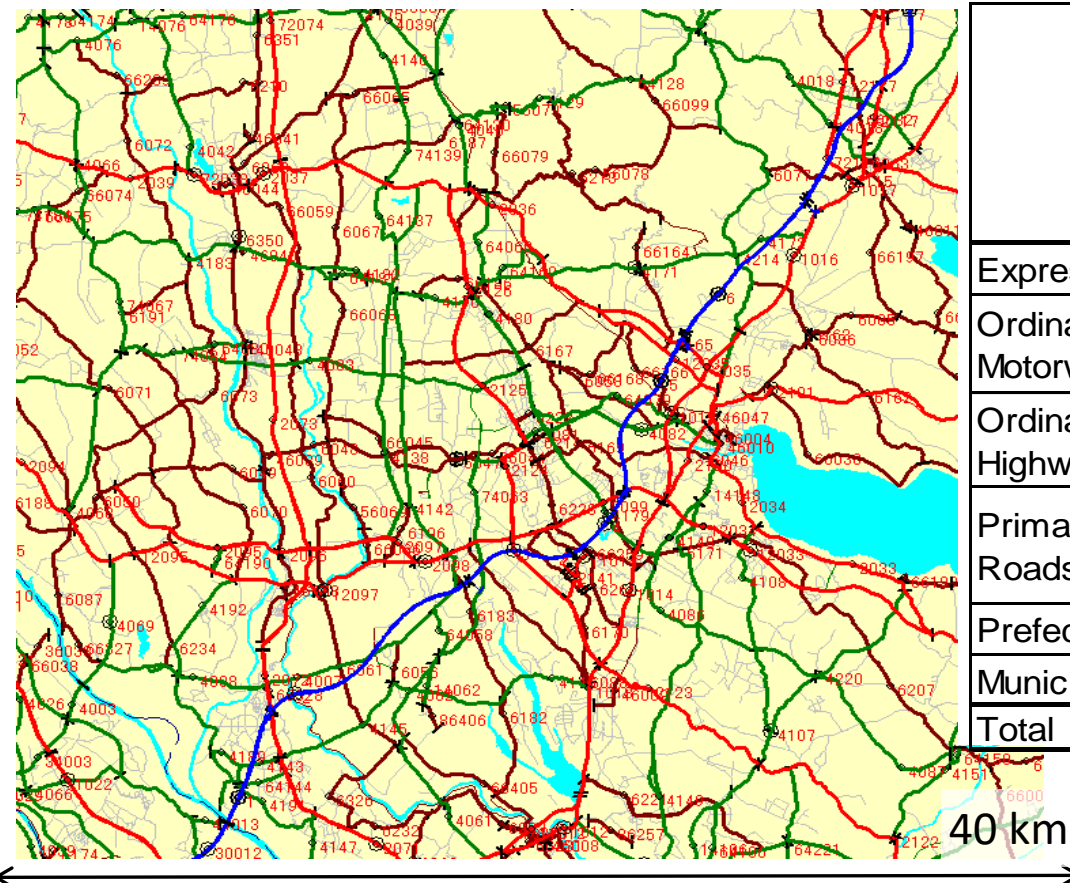
━━━ Express ways and Motorways
━━━ Ordinary National Highways
━━━ Primary Prefectural Roads
━━━ Prefectural Roads
━━━ Municipal Roads

Investigative road and length

	Total Investigated Length (km)	Number of Investigated Sections	Average Investigated Distance (Average Link) (km)
Express Ways	6457	787	8.2
Ordinary National Motorways	604	118	5.1
Ordinary National Highways	53669	9,469	5.7
Primary Prefectural Roads	57340	9,831	5.8
Prefectural Road	69964	14,902	4.7
Municipal Roads	698	331	2.1
Total	188731	35438	5.3

Survey Items

For weekday, 24hrs or 12hrs
  ✔ Traffic volume by vehicle type
  ✔ Traffic congestion
With average vehicle speed at rush hours and non-rush hours, each 1hr average vehicle speed is calculated.
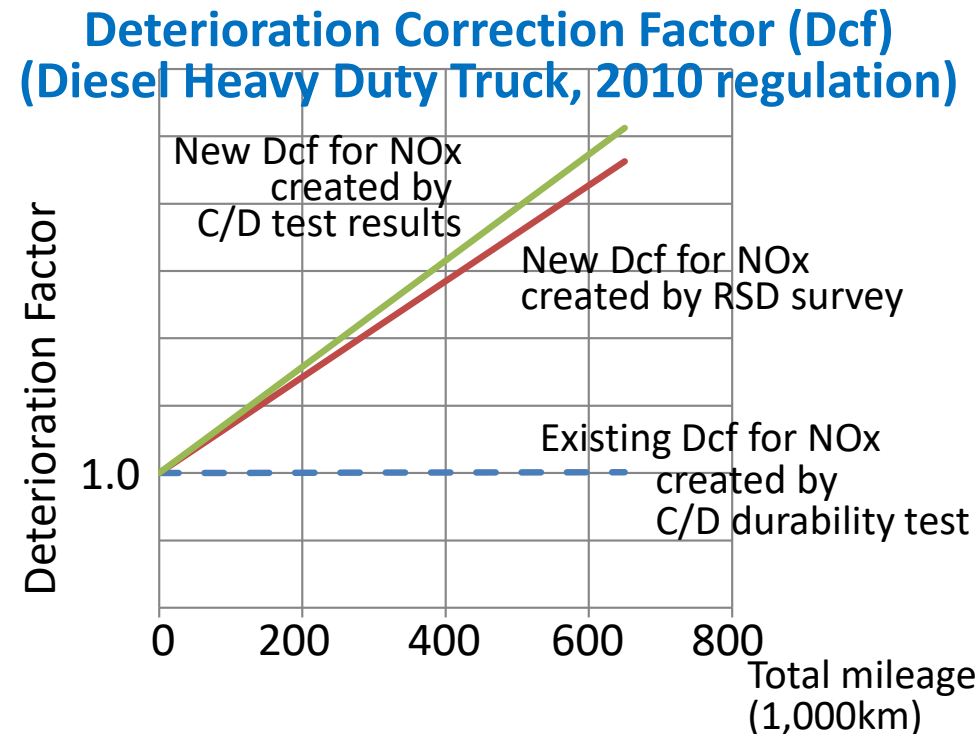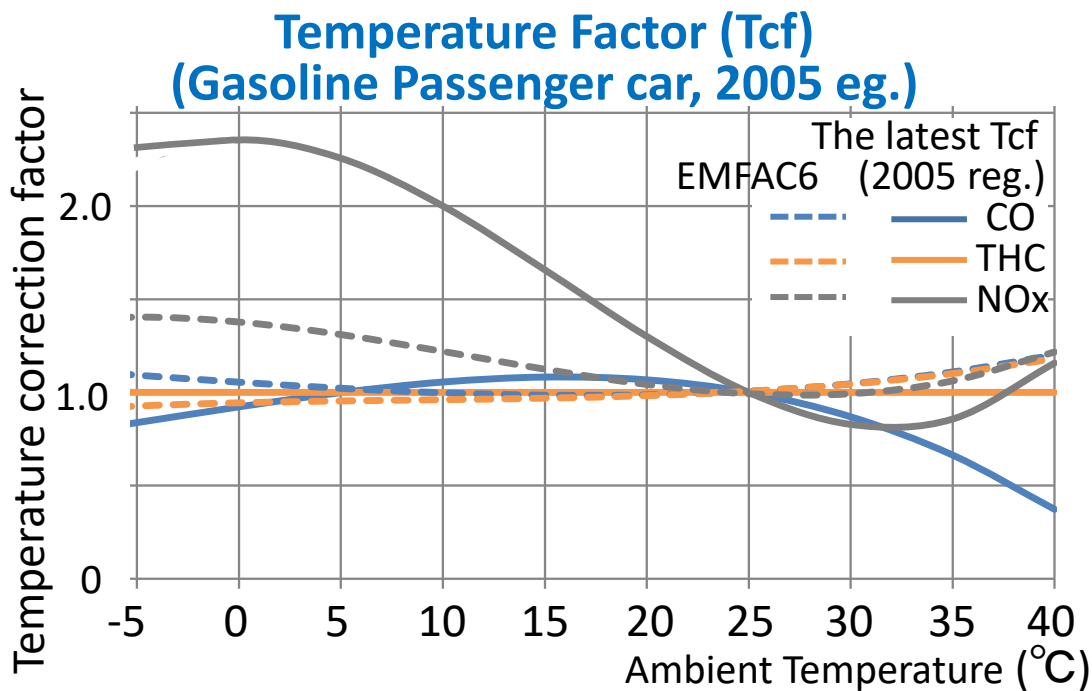
Various emission correction factors

Various correction factors have been introduced to represent the actual real-world emission.

Emission factor EF under real driving conditions = basic EF
- × **Temperature** correction factor × **Humidity** correction factor (for NOx)
- × **Deterioration** correction factor
- × Correction Factor for **regeneration of DPF** (for diesel vehicles)
- × **Soak time** correction factor (for start emission)

Temperature Factor (Tcf)
(Gasoline Passenger car, 2005 eg.)

The latest Tcf
EMFAC6   (2005 reg.)
CO
THC
NOx

Temperature correction factor

Ambient Temperature (°C)

Deterioration Correction Factor (Dcf)
(Diesel Heavy Duty Truck, 2010 regulation)

New Dcf for NOx created by C/D test results

New Dcf for NOx created by RSD survey

Existing Dcf for NOx created by C/D durability test

Deterioration Factor

Total mileage (1,000km)

Gridded Emissions of Air Pollutants for Asia countries: Regional Emission inventory in ASia (REAS) version 3.2
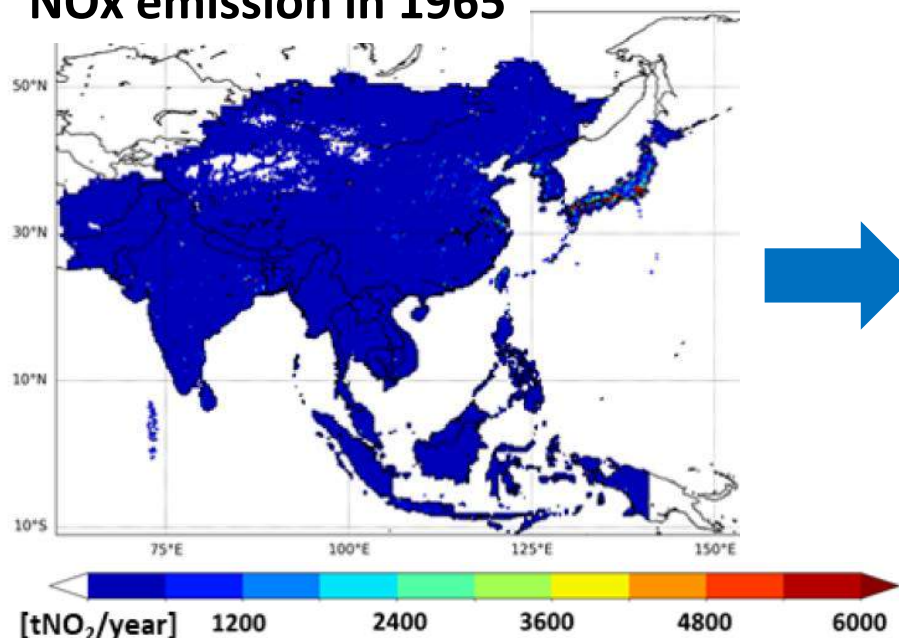
A long-term historical emission inventory, 1950-2015

For each country and its sub-regions with major sectors and fuel types

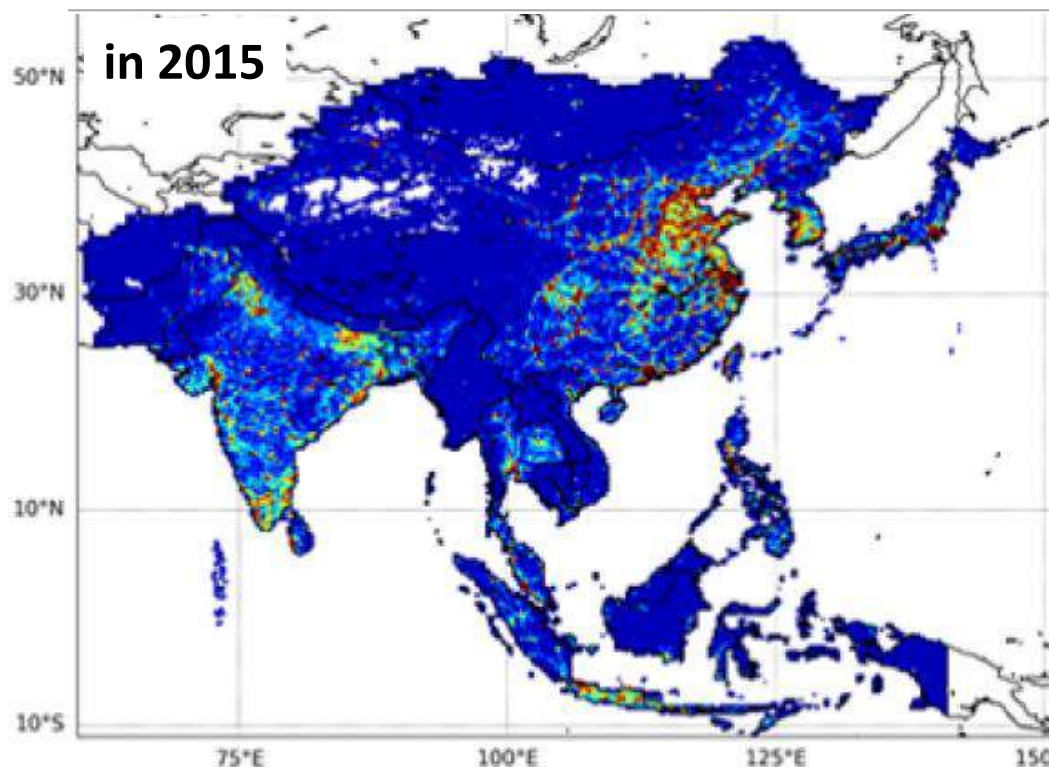Provides monthly gridded data with 0.25 x 0.25 resolution.

Pollutants: SO2, NOx, CO, NMVOC, NH3, CO2, PM10, PM2, BC and OC

The following 19 VOCs are considered: C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, Other Alkans, C_2H_4, C_3H_6, Terminal Alkenes, Internal Alkenes, C_2H_2, Benzene, Toluene, Xylenes, Other Aromatics, HCHO, Other Aldehyde, Ketones, Halocarbons, Others
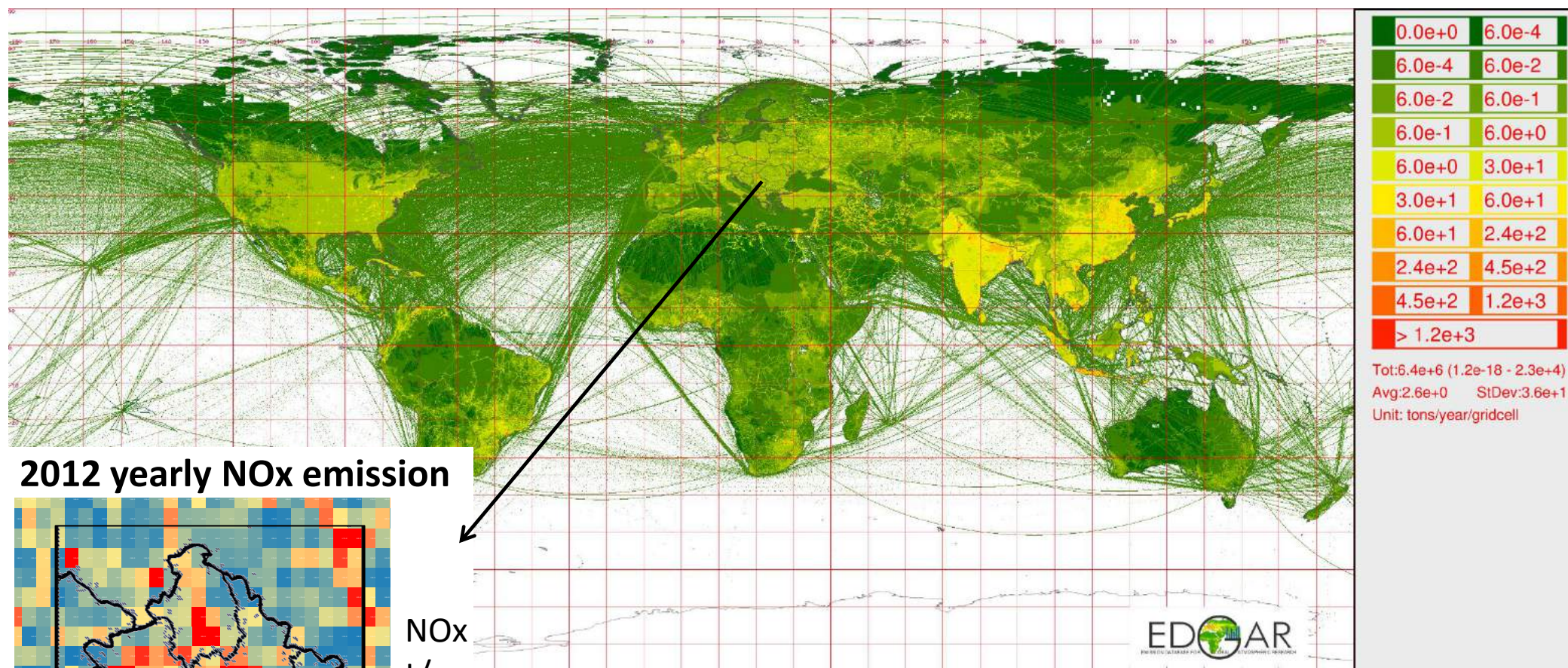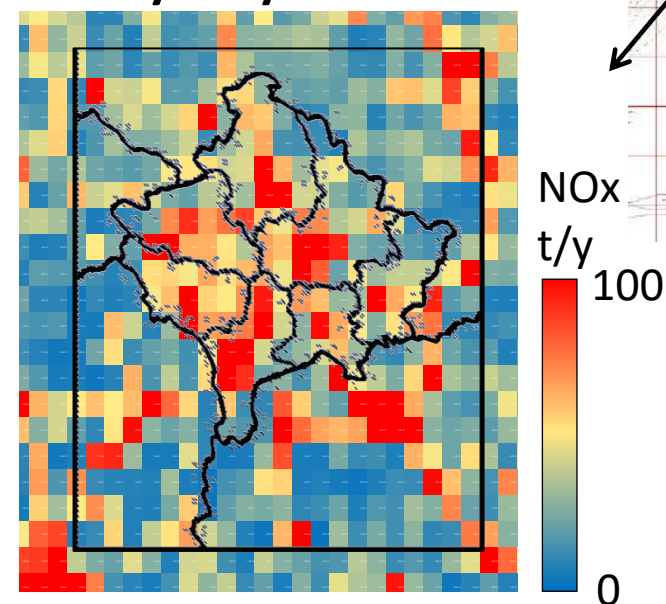

NOx emission in 1965 → in 2015

$[tNO_2/year]$ 1200 2400 3600 4800 6000

Kurokawa, J. and Ohara, T., Atmos. Chem. Phys., 20, 12761–12793, 2020, https://doi.org/10.5194/acp-20-12761-2020

Gridded Emissions of Air Pollutants for the Period 1970–2012 within EDGAR v4.3.2

2012 yearly NOx emission

NOx t/y

100

0

Air Pollutants: CO,NOx,NMVOC,CH$_4$,NH$_3$,SO$_2$,PM$_{10}$, PM$_{2.5}$,BC,OC and 25 NMVOC species, Hg

Greenhouse Gases : CO$_2$, N$_2$O, CH$_4$

Resolution: 0.1 degree x 0.1 degree (Approximately 10km x 10km)

0.0e+0	6.0e-4
6.0e-4	6.0e-2
6.0e-2	6.0e-1
6.0e-1	6.0e+0
6.0e+0	3.0e+1
3.0e+1	6.0e+1
6.0e+1	2.4e+2
2.4e+2	4.5e+2
4.5e+2	1.2e+3
> 1.2e+3	

Tot:6.4e+6 (1.2e-18 - 2.3e+4)
Avg:2.6e+0   StDev:3.6e+1
Unit: tons/year/gridcell

Advantages and disadvantages of how to obtaining of the air pollutants emission

National emission, estimated by EF x Activity Data

✓ Emissions can be re-calculated to reflect specific changes in EF and/or Activity Data.
    ✓ Confirmation of countermeasure effect
    ✓ Future estimation
    ✓ Various analyzes such as cost effectiveness
✓ It can be organized by detailed source category.
✓ Allocation of area and time is possible.

✓ Terribly hard work.

Using existing emission inventory, for example, REAS3

✓ It can immediately know the emission amount by air pollutant.
✓ It also provides information on the regional distribution of various air pollutant.

✓ It is unknown to detailed source category.
✓ Re-calculation of emissions is difficult.

APPENDIX

Air pollutants emission inventory, "PM2.5 Emission Inventory, PM2.5EI"

Target year: **FY2012, FY2015. FY2018 data is in preparation.**

	Vehicles		Other than Vehicles	Natural Source
Process / Target industries etc.	Running exhaust, Start emission, Evaporative emission (Running loss, Hot soak loss, Diurnal breathing loss) Dust, Tire ware		Stationary fuel combustion, Incineration plant, Off-road vehicles, Air plane, Field burning, Tabaco, Cooking. etc. (**VOC only**) Petroleum industries, Chemical product manufacturing, Gas stations, Painting, Printing, Solvent utilization, Dry cleaning, etc. (**NH$_3$ only**) Livestock Waste, Fertilizer application Sewage plant, Human breath & Perspiration, Pets	Volcano
pollutants	NOx, NO$_2$, SPM, THC, NMHC, CO, SOx, NH$_3$, CO$_2$ THC & NMHC → 133 VOC components PM → 18 PM2.5 components		NOx, TSP, NMVOC, CO, SOx, NH$_3$ NMVOC → 256 VOC components PM → 18 PM2.5 components	SO$_2$ HCl
temporal resolution	Monthly-hourly value by weekdays / holidays (except DBL)		Monthly-hourly value, by weekdays / holidays with thermal power plants	Daily
spatial resolution	1km^2 for Nationwide		10x10km for Nationwide 1km^2 for Kanto and Kansai Area Some source category have a vertical distribution.	12 volcanos

SPM is defined as airborne particles with aerodynamic diameters less than or equal to 10 μm. Nearly equal to PM7.1.
Ship emission is not included.
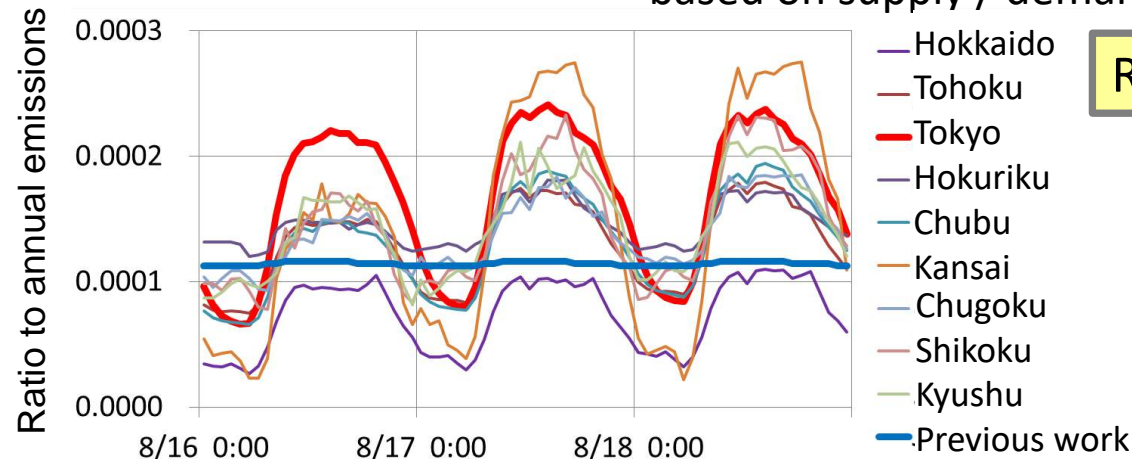
Emission from Other Anthropogenic Sources

Some emission factors are from literatures, but activity data are from Japanese statistics.

	Emission Factor	Activity Rate
Off-road vehicles Construction Machines Agricultural Machines Industrial Machines	By machine type, fuel type and regulation (g/kWh) by MOE. Number of categories for construction:28, agricultural: 12, industrial: 5	Machine numbers by regulation year. Energy consumption is lead by operation hours, effective full power, average power for each machine category
Aviation (Civil aviation only)	Aircraft specific LTO EFs, for 48 model by EMEP/EEA	Duration time of LTO cycle (s) by main airport
Small Combustion Sources Heating for Domestic Use Heating for Business Use	Japanese measurement data by fuel, except NMVOC from EMEP/EEA	Energy Supply and Demand Report by METI
Field Burning	NOx and CO: IPCC Guidelines for National Greenhouse Gas Inventories, Others: AP-42, etc.	Survey of harvest yield of agricultural products by MAFF
Ammonium Livestock Fertilization Swage Plant	EMEP/EEA air pollutant emission inventory guidebook	Number of livestock farm households and livestock by MAFF Population categorized by human waste processing by MOE
Pets Human Breath & Perspiration	Gharib, S. & Cass, R. H.(1984)	The registration number of dogs, MHLW Population by the national census

Example of temporal distribution from fixed sources
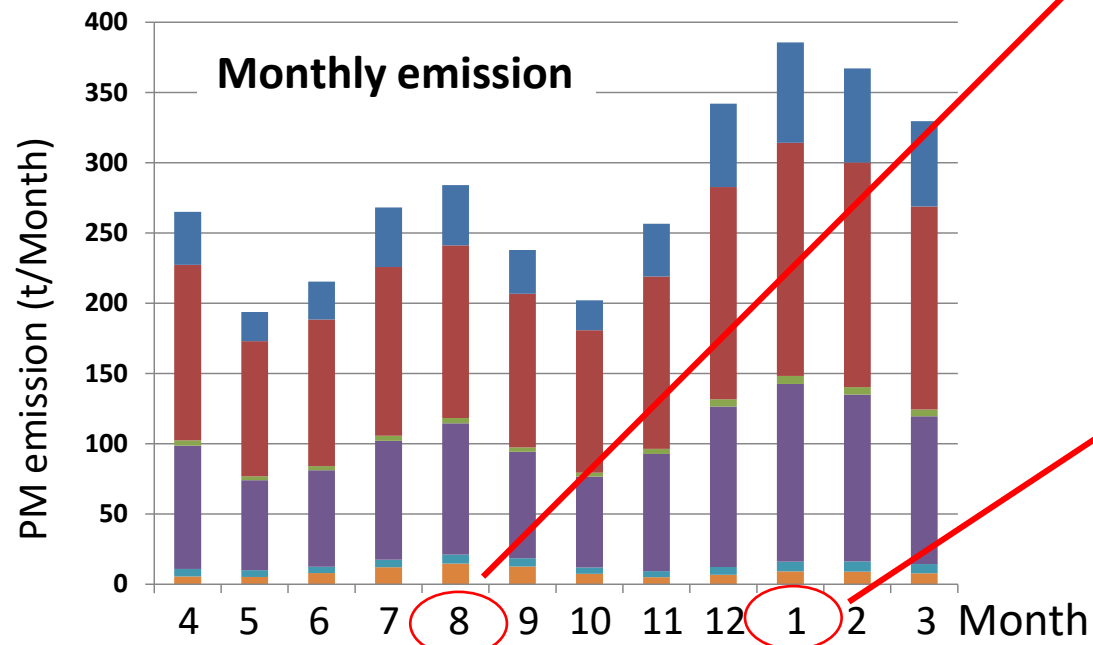
① Thermal Power Plant

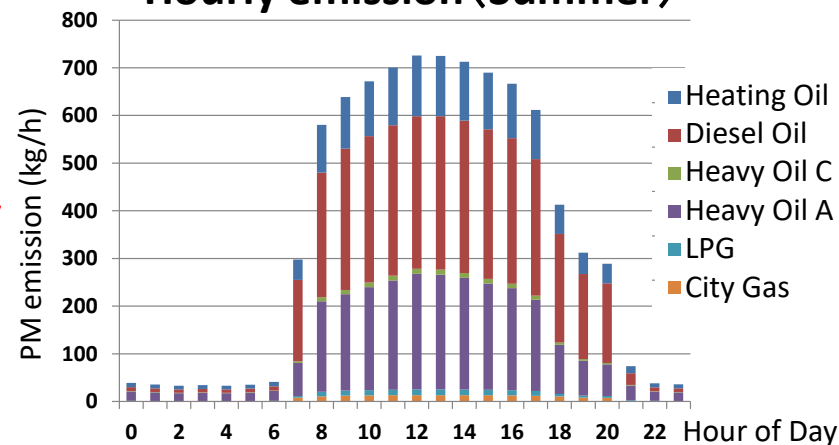Emission ratio per hour by thermal power plant by company, based on supply / demand power data
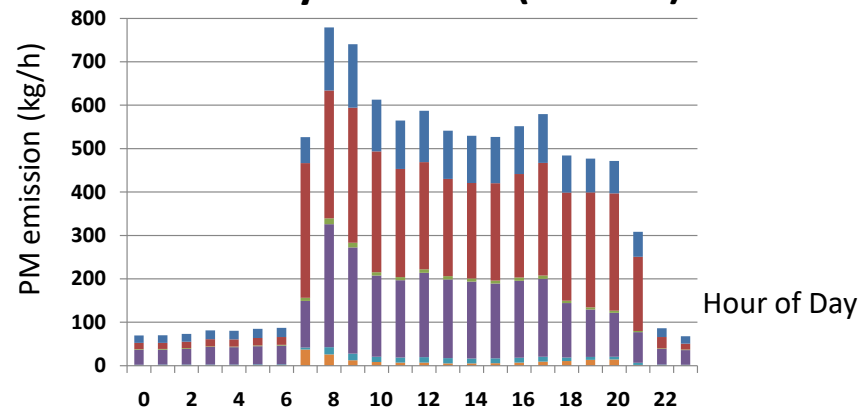
Reflecting operation results in emissions

Ratio to annual emissions — legend: Hokkaido, Tohoku, Tokyo, Hokuriku, Chubu, Kansai, Chugoku, Shikoku, Kyushu, Previous work

x-axis: 8/16 0:00, 8/17 0:00, 8/18 0:00

② Heat Supply Business for Office Use

Monthly emission

PM emission (t/Month) — Month: 4 5 6 7 8 9 10 11 12 1 2 3

Hourly emission（Summer）

PM emission (kg/h) — Hour of Day: 0 2 4 6 8 10 12 14 16 18 20 22

Legend: Heating Oil, Diesel Oil, Heavy Oil C, Heavy Oil A, LPG, City Gas

Hourly emission (Winter)

PM emission (kg/h) — Hour of Day: 0 2 4 6 8 10 12 14 16 18 20 22

Example of Emission from Other Small Sources ... Cigarettes

Emission Factor : Amount of pollutants released to the atmosphere per cigarette (μg/cigarette) by commercial brands.

Activity Rate : Sales number of cigarettes in Japan. 168,000,000,000 (as of the year 2016)

Geographical Resolution: Provincial tax on cigarettes

Temporal Resolution : People do not smoke in their sleep.

Japanese Waking Hours

Few people smoke in sleeping hours

People smoke in waking hours
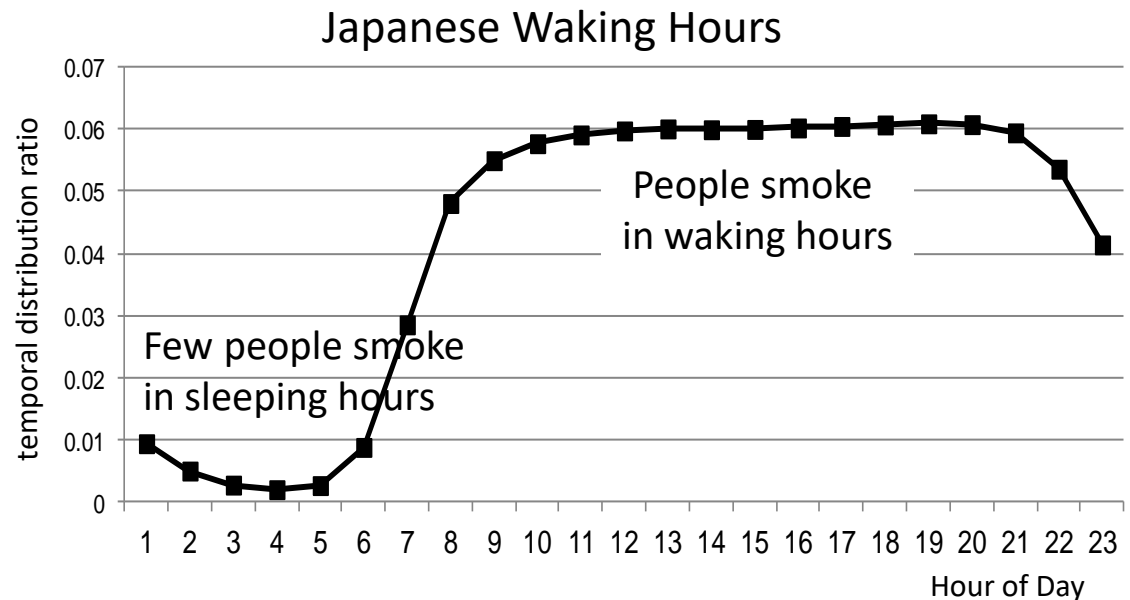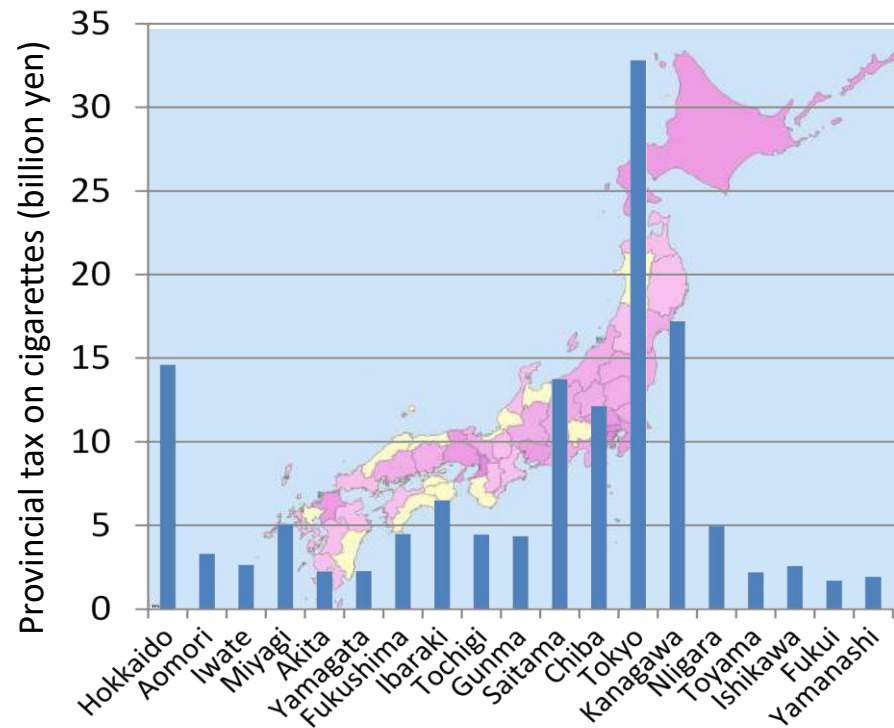
"Life style survey" by the Ministry of Health, Labour and Welfare

Characteristics of the Gasoline and Diesel Vehicles

	Gasoline Vehicle	Diesel Vehicle
Fuel and its characteristics	Gasoline, Flash point -40°C, ignition point 300°C, easy to evaporate and need to pay attention to evaporative emission.	Light Oil, Flash point +45~70°C, Ignition point 250°C. Low vapor pressure, no evaporative emission.
Combustion mechanism to extract power	Compress air/gasoline mixture and ignite with spark (Premixed combustion, 2000 °C).	Compresses only air and directly injects light oil to self-ignite (diffusion combustion, 800-1000 °C).
Characteristics of combustion and raw exhaust gas	Stoichiometric combustion, air:fuel = 1:1. O_2 is not included in the exhaust gas. Prone to incomplete combustion, high CO concentration. High NOx emissions due to high combustion temperature, but most are NO.	Lean burn, air is excess than fuel. O_2 is included in the exhaust gas. There is nonuniformity in the mixed state of fuel and air, and unburned fuel tends to be PM. CO is low. NOx emissions are lower than gasoline vehicles. Exhaust gas includes 10% NO_2 because O_2 is in the exhaust gas.
After treatment device	Three-way catalyst can be used because there is no O_2. CO and VOC → Using O of NOx, CO and VOC are oxidized to CO_2 and H_2O. NOx → NOx is reduced to N_2.	Three-way catalyst cannot be used because of O_2 included in exhaust gas. EGR is used to reduce O_2 in the air and reduce NOx production. Oxidation catalyst oxidizes VOC and PM. NOx is reduced by SCR and PM is collected by DPF.
Power	High speed, compact engine, easy to control, suitable for passenger cars.	Low speed torque is large and suitable for trucks.

Humidity correction factor for NOx (vehicle exhaust gas)

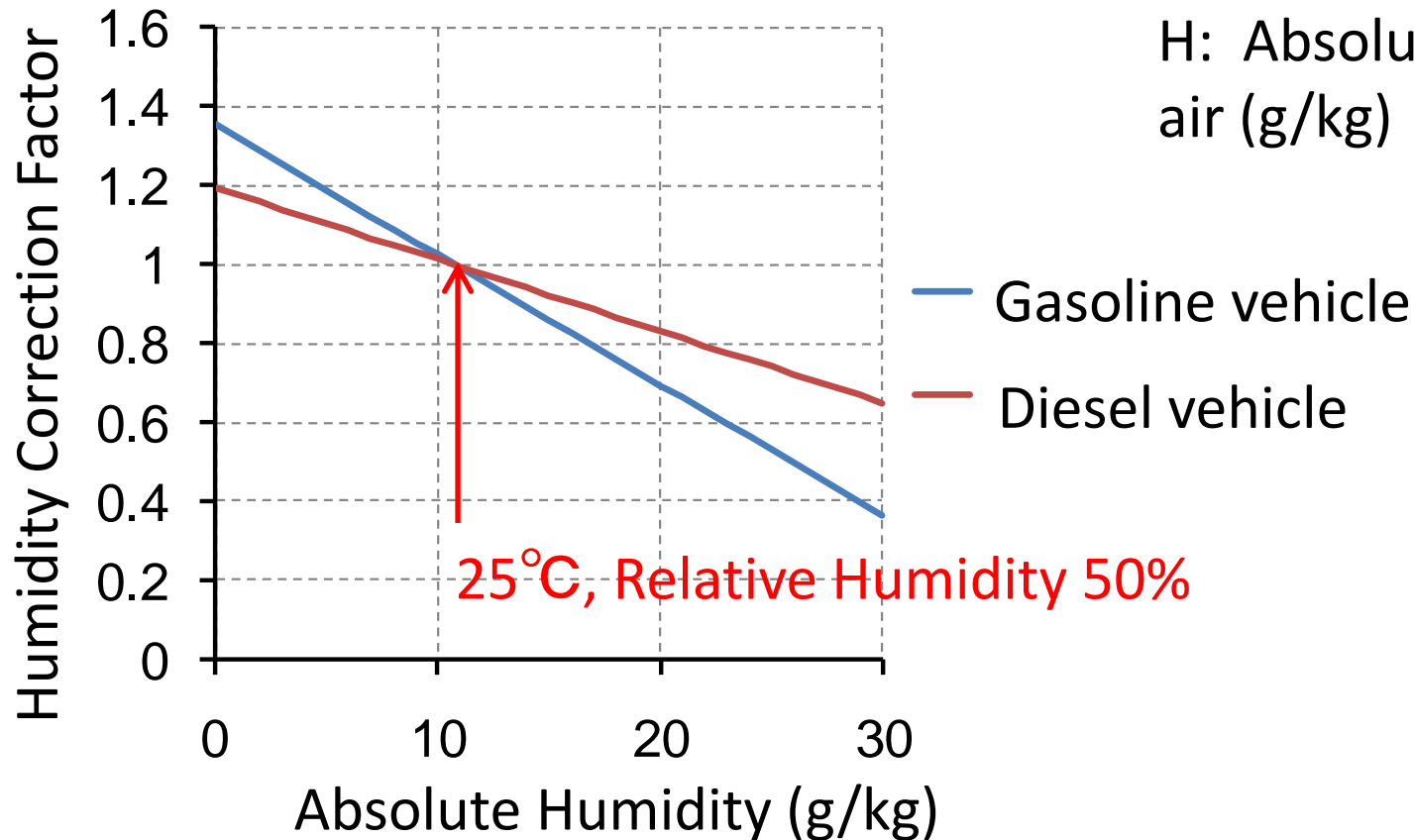*From "Automotive type approval test" method*
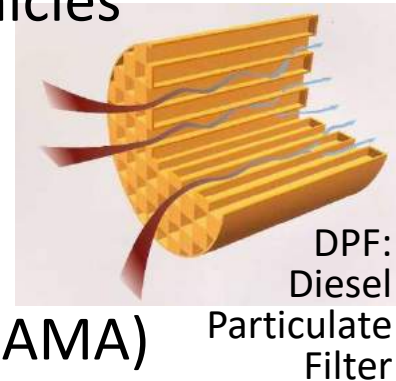
Hcf = 1 - 0.0047 (7H-75)   for Gasoline Vehicles
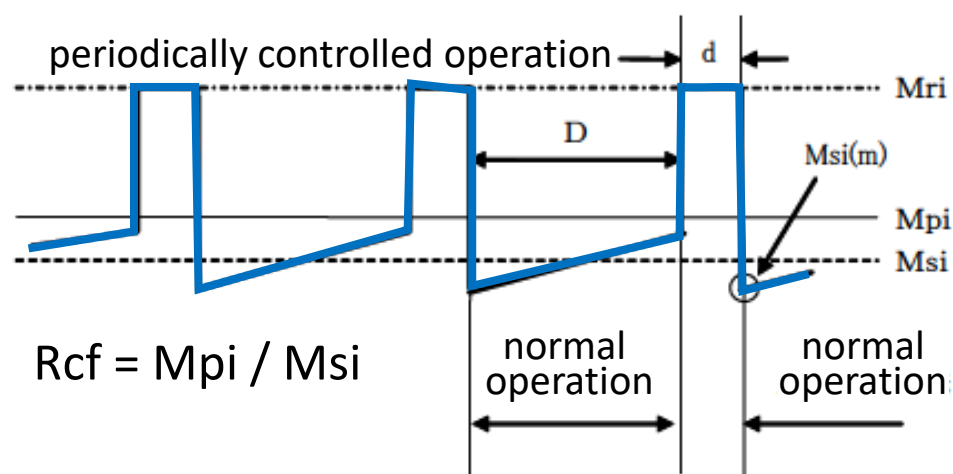
Hcf = 1 - 0.0182 (H-10.71)   for Diesel Vehicles

Hcf: Humidity correction Factor

H: Absolute humidity in intake air (g/kg)

— Gasoline vehicle

— Diesel vehicle

25°C, Relative Humidity 50%

Correction Factor for **regeneration of DPF:** for Diesel Vehicles

・Existing <u>DPF regeneration correction factor</u> (Rcf) is set from test results by repeated C/D tests in FY2008~2012.

・Data of the latest regulation (2009 reg.) diesel vehicles were obtained from Japan Automobile Manufactures Association (JAMA)

DPF: Diesel Particulate Filter

periodically controlled operation → d ←

$$Rcf = Mpi / Msi$$

normal operation   normal operation

**Mri** : Average emissions during periodically controlled operation

Mpi : Average emissions when forced regeneration is considered

Msi : Average emissions during normal operation

D: Total mileage during normal operation

d: Total mileage during periodic control operation

http://www.ngk.co.jp/product/automobile/diesel/index.html

DPF regeneration correction factor (Rcf)
(Diesel Heavy Duty Truck)

DPF regeneration correction factor

2.0

1.0

0

NOx   THC   CO   PM

■ Before 2003 reg.   ■ 2003 reg.   ■ 2005 reg.   ■ 2009 reg.
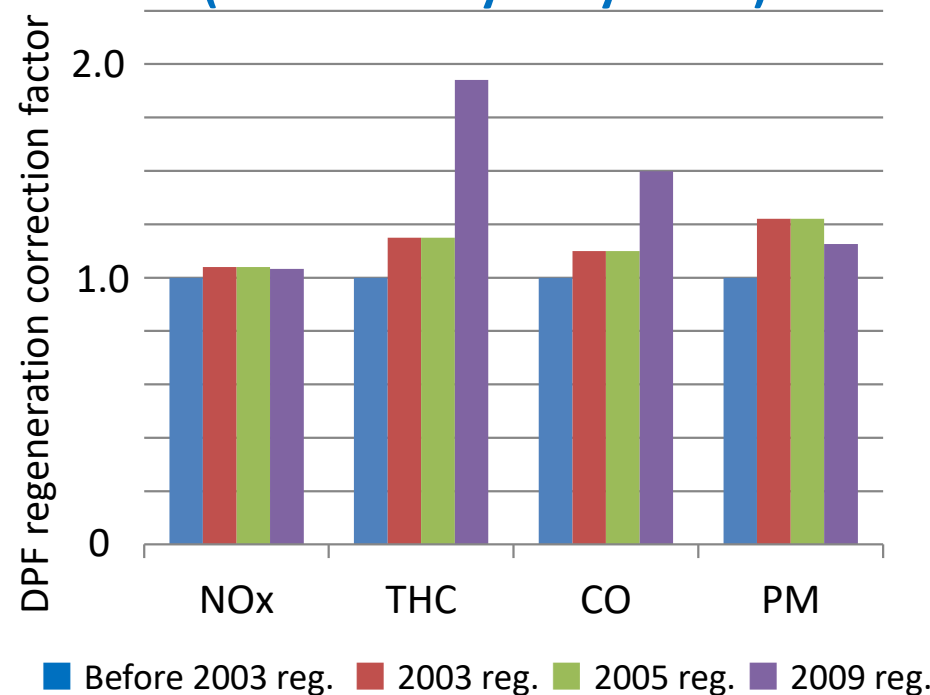
EMEP/EEA air pollutant emission inventory guidebook

The EMEP/EEA air pollutant emission inventory guidebook (formerly called the EMEP CORINAIR emission inventory guidebook) provides guidance on estimating emissions from both anthropogenic and natural emission sources.

1 Energy

1.A Combustion

1.A.1 Energy industries

1.A.2 Manufacturing industries and construction

1.A.3.a Aviation

1.A.3.b.i-iv Exhaust emissions from road transport

1.A.3.b.v Gasoline evaporation

1.A.3.b.vi-vii Road vehicle tyre and brake wear,
         road surface wear

1.A.3.c Railways

1.A.3.d Navigation (shipping)
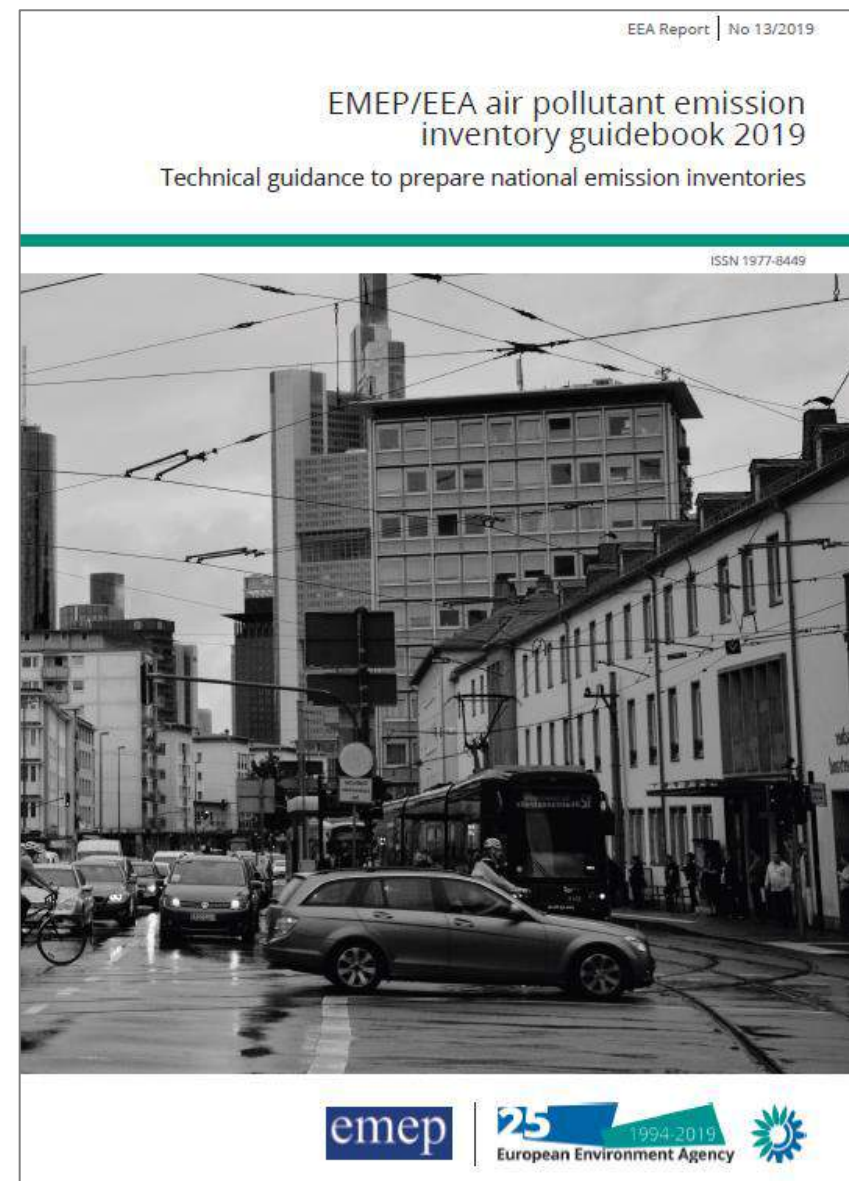
1.A.3.e.i Pipeline transport

1.A.4 Small combustion
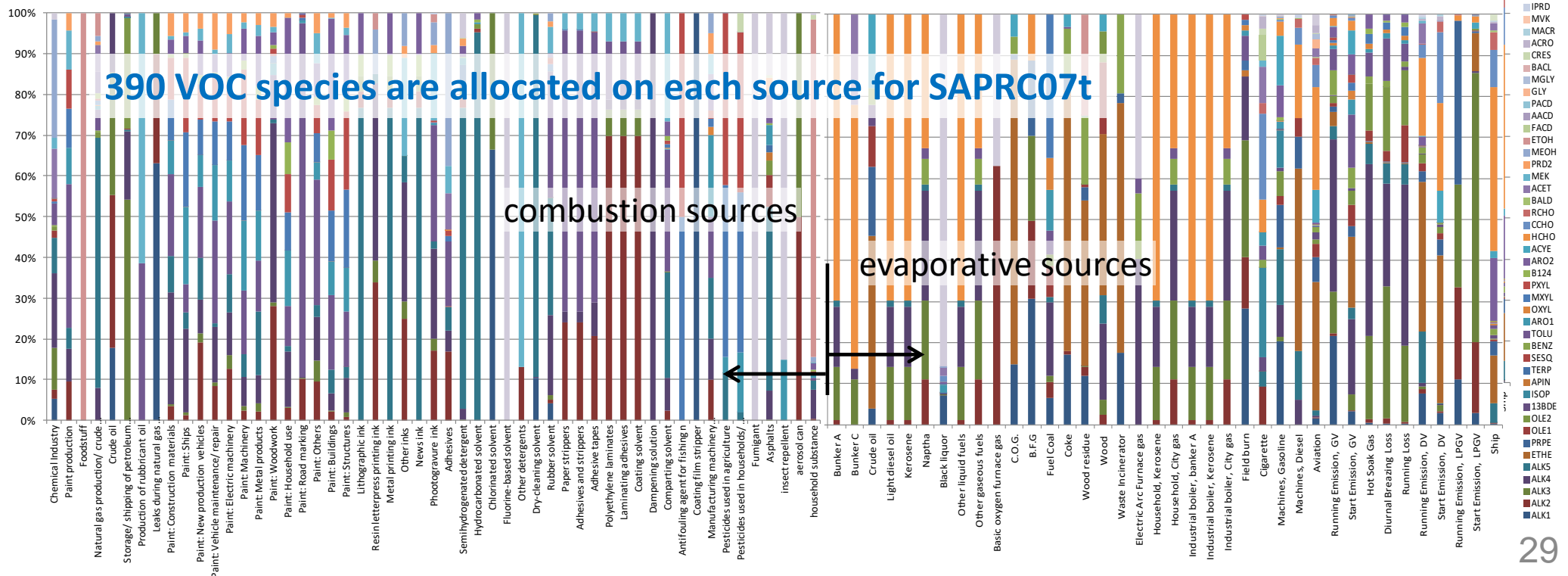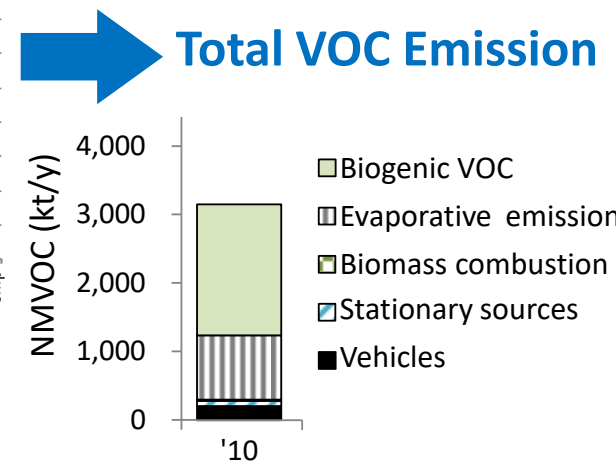
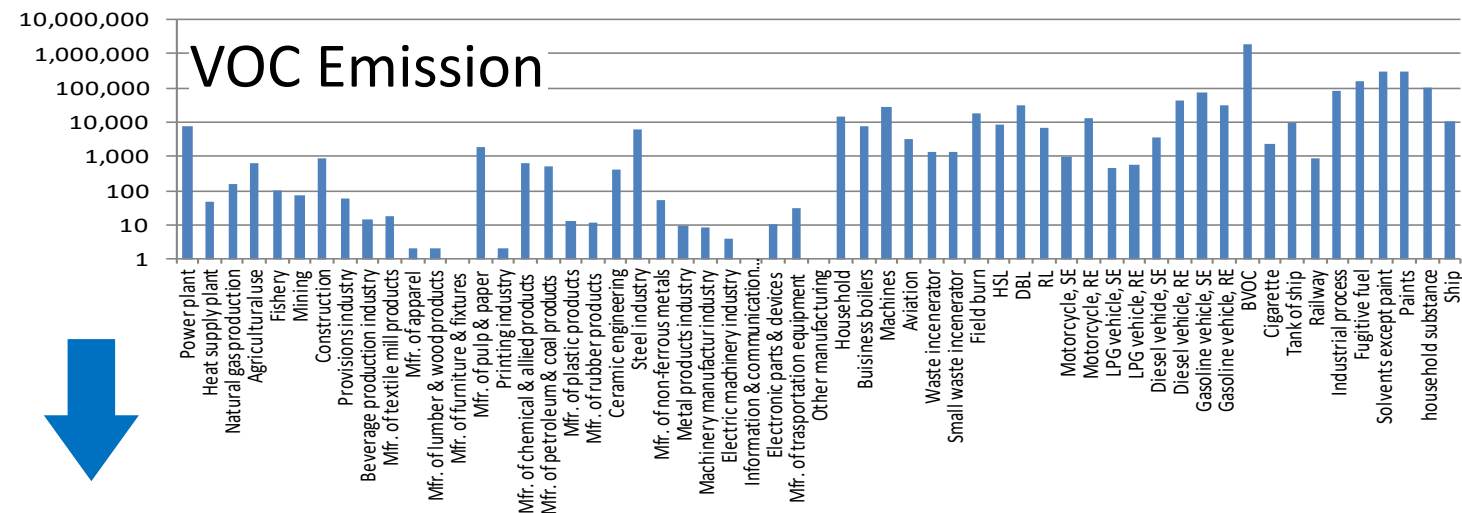1.A.4 Other non-road mobile sources and machinery

1.B Fugitive emissions from fuels……….

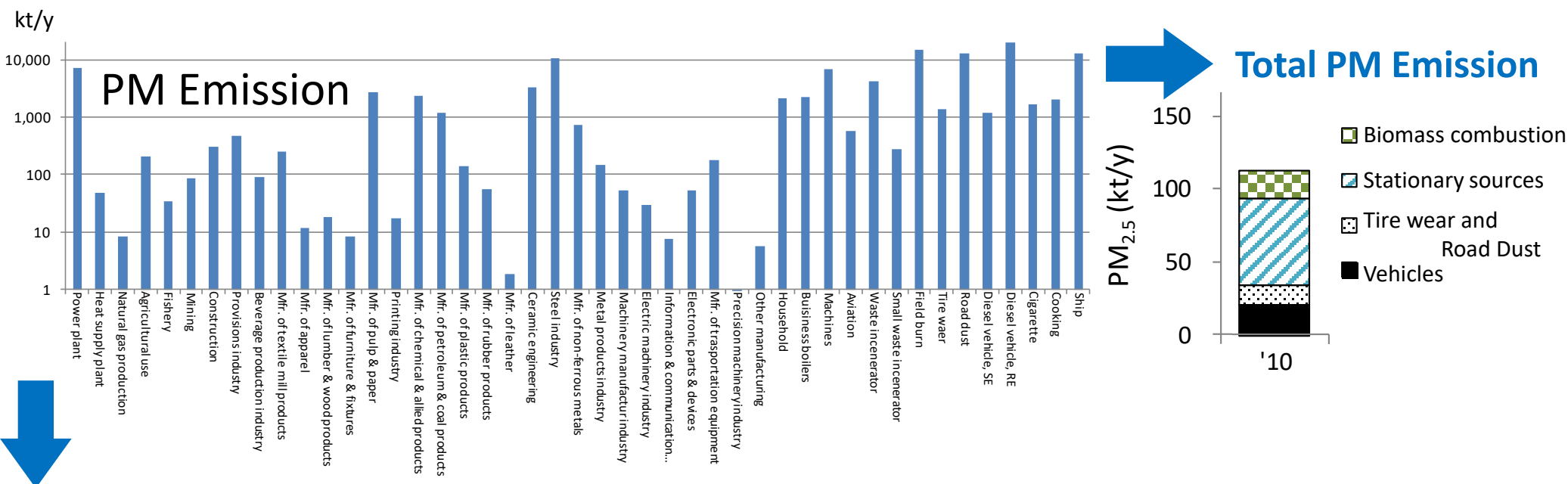## 2 Industrial processes and product use, 3 Agriculture

5 Waste, 6 Other sources, 11 Natural sources…

EEA Report | No 13/2019

EMEP/EEA air pollutant emission inventory guidebook 2019
Technical guidance to prepare national emission inventories

ISSN 1977-8449

emep | 25 1994-2019
European Environment Agency

VOC Profiles

VOC Emission

Total VOC Emission

390 VOC species are allocated on each source for SAPRC07t

combustion sources

evaporative sources

Primary PM₂.₅ Components

Primary PM₂.₅ Components chart showing PM Emission (kt/y) by source, Total PM Emission, and component breakdown. Caption text within figure: "EC, OC, Sulfate, Nitrate, Ammonium and 10 Metal components are allocated on each source for CMAQ's aero6"
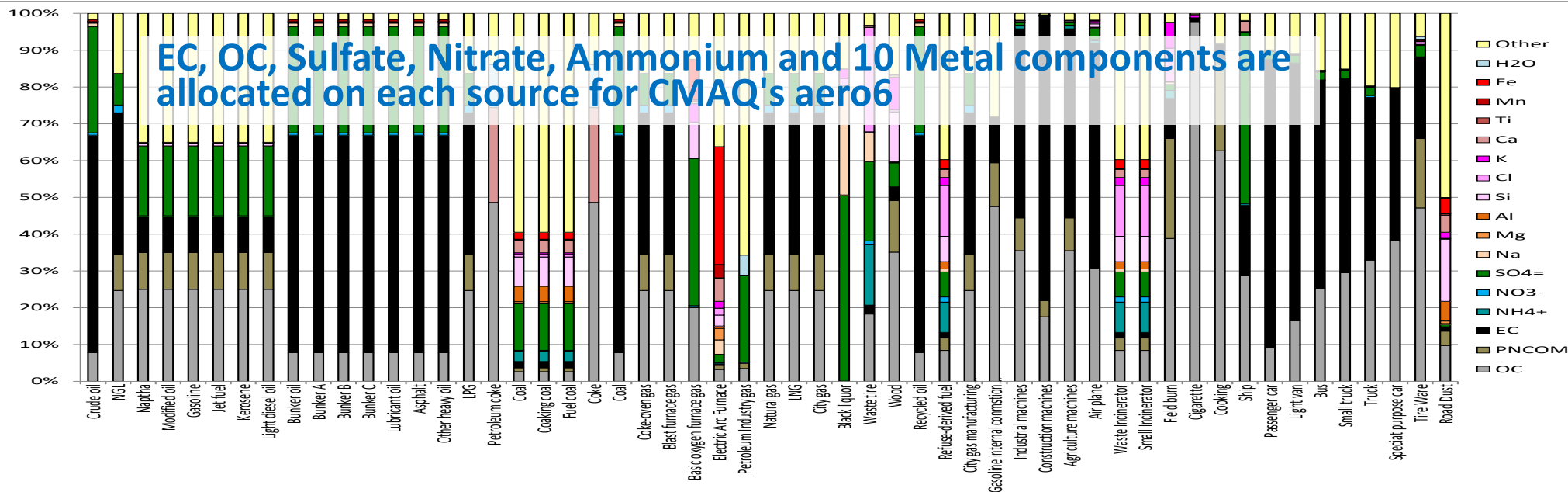
Japan's National GHG Inventory:

Institutional arrangement, data acquisition, QA/QC, compilation and reporting processes

EANET Emission Inventory Workshop
October 18th, 2021

Elsa Hatanaka
Greenhouse Gas Inventory Office of Japan (GIO)
National Institute for Environmental Studies (NIES)

0

United Nations Framework Convention on Climate Change (UNFCCC) Art 4

<u>All Parties</u>, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, <u>shall</u>:

(a) Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, <u>national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases</u> not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties

UNFCCC Art 12

In accordance with Article 4, paragraph 1, <u>each Party shall communicate to the Conference of the Parties</u>, through the secretariat, the following elements of information:

(a) <u>A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases</u> not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties

Obligations under the KP remain at present

Paris Agreement Art 13

Each Party shall regularly provide the following information:

(a) A national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Agreement

Year 1990 to X-2
National territory
Principles of Transparency,
Completeness, Consistency,
Comparability, Accuracy
in the IPCC GLs

GHGs:
CO_2, CH_4, N_2O, HFCs,
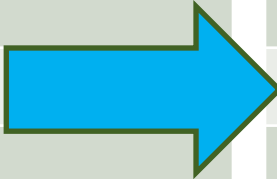PFCs, SF_6, NF_3

Act on Promotion of Global Warming Countermeasures Art 7

In order to prepare the inventory prescribed in Article 4.1 (a) of the United Nations Framework Convention on Climate Change and the annual inventory prescribed in Article 7.1 of the Kyoto Protocol, the national government is to calculate the amount of greenhouse gas emissions and absorption in Japan each year, and publicize the results as prescribed by Order of the Ministry of the Environment.

Annual Reporting

Gases: Changes from Convention to PA

AI party	NAI party
CO2	CO2
CH4	CH4
N2O	N2O
HFCs	HFCs
PFCs	PFCs
SF6	SF6
NF3	-
CO	CO
NOx	NOx
NMVOCs	NMVOCs
SOx	SOx

Developed country	Developing country
CO2	CO2
CH4	CH4
N2O	N2O
HFCs	HFCs
PFCs	PFCs
SF6	SF6
NF3	NF3
CO	CO
NOx	NOx
NMVOCs	NMVOCs
SOx	SOx

★*About GIO*

Establishment

First submission as GIO

July, 2002

August, 2002

GIO was established:

・ in the center for Global Environmental Research (CGER), **the National Institute for Environmental Studies (NIES)**

・ **to compile annual GHG inventories**

Annual **National GHG inventories**

NIR

CRF

National GHG Inventory

Greenhouse Gas Inventory Office of Japan (GIO)

4

★*Activities of GIO*

Domestic activities	- Preparing the annual national GHG inventory - Preparing the preliminary figures of the national GHG inventory - Providing support and assistance for the technical review of the national GHG inventory - Providing support and assistance for inventory related policies - Holding the meeting of the GHG inventory Quality Assurance Working Group (QAWG) - Disclosing information related to national GHG inventories on the GIO website
International activities	- Convening the Workshop on GHG Inventories in Asia (WGIA) - Providing support and assistance for the international negotiation on national GHG inventory related topics - Contributing to the technical review of national GHG inventories of other Parties as reviewers under the UNFCCC and the Kyoto Protocol

National inventory arrangements are required by…

Article 5, Paragraph 1 of the Kyoto Protocol
➢ Each Party…**shall** have in place…a **national system** for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases…

Decision 24/CP.19 (UNFCCC reporting guidelines on annual green house gas inventories)
➢ Each…Party **should** implement and maintain **national inventory arrangements** for the estimation of anthropogenic GHG emissions by sources and removals by sinks.

➢ **The national Inventory arrangements** include all **institutional, legal and procedural arrangements**…for estimating…, and for reporting and archiving inventory information.

Essentially the same for under the Paris Agreement

Japan's National System

Legal arrangement

1. Legal Basis for Japan's National Inventory Processes and System under Domestic Law

Institutional arrangement

2. Institutional Arrangements

2-1. Roles and responsibilities in the inventory preparation process

2-2. Other bodies involved in the national inventory processes and system

Procedural arrangement

3. Inventory Compilation Process

    3-1. Annual schedule for preparation

    3-2. Data collection process

    3-3. Calculation files

4. Quality Assurance and Quality Control (QA/QC) Procedures

    4-1. QC activity

    4-2. QA activity

5. Inventory Improvement Process

6. Documentation and Archive System

1. Legal Basis for Japan's National GHG Inventory Processes and System under Domestic Law
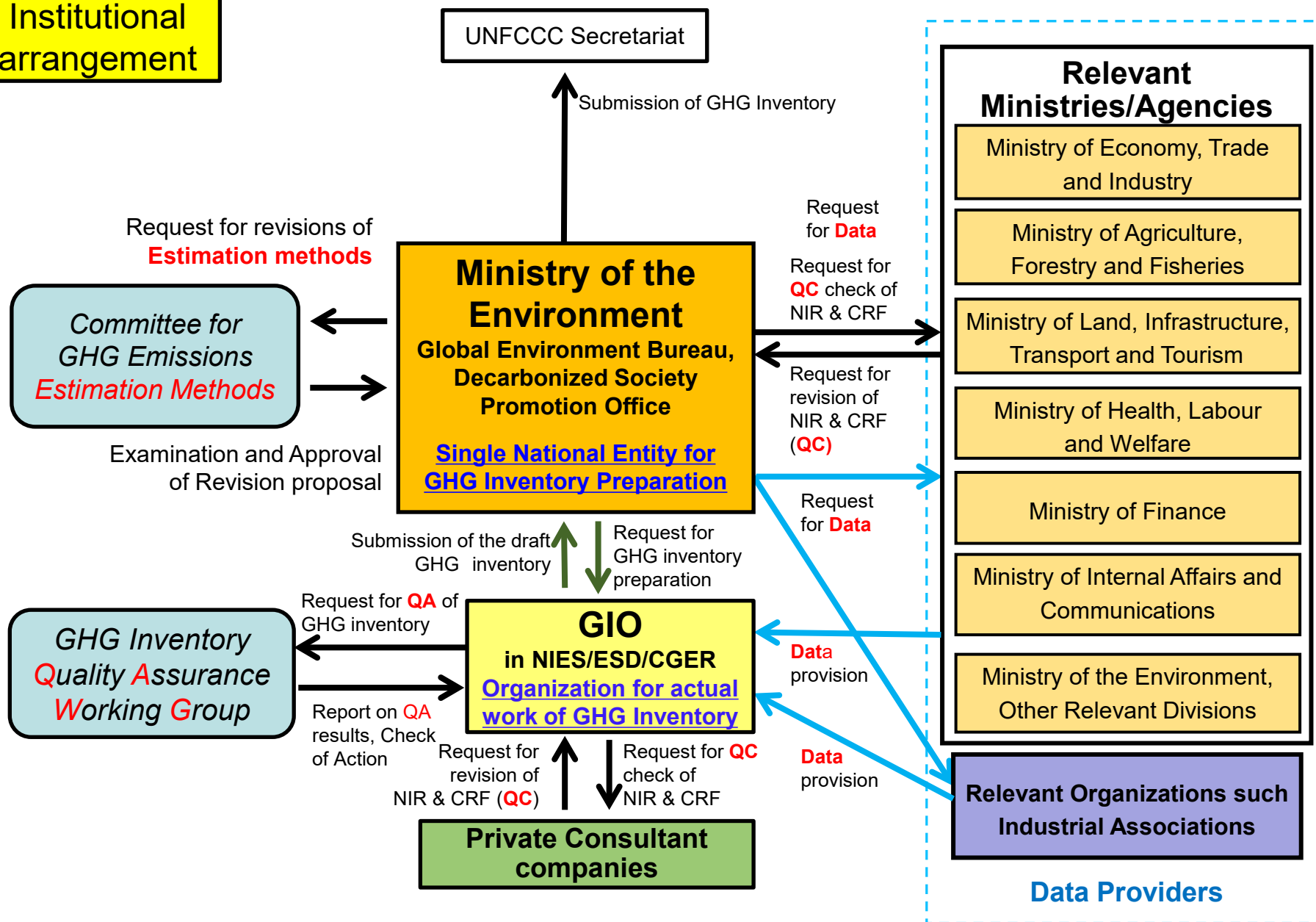
Legal arrangement

- ✓ **In accordance with _Article 7 of the Act on Promotion of Global Warming Countermeasures_** the national government shall calculate GHG emissions and removals for Japan and disclose the results every year.

Institutional arrangement

UNFCCC Secretariat

Submission of GHG Inventory

Relevant Ministries/Agencies

Ministry of Economy, Trade and Industry

Ministry of Agriculture, Forestry and Fisheries

Ministry of Land, Infrastructure, Transport and Tourism

Ministry of Health, Labour and Welfare

Ministry of Finance

Ministry of Internal Affairs and Communications

Ministry of the Environment, Other Relevant Divisions

Request for revisions of **Estimation methods**

Request for **Data**

Request for **QC** check of NIR & CRF

Request for revision of NIR & CRF (**QC**)

Request for **Data**

Ministry of the Environment
Global Environment Bureau, Decarbonized Society Promotion Office

Single National Entity for GHG Inventory Preparation

Committee for GHG Emissions Estimation Methods

Examination and Approval of Revision proposal

Submission of the draft GHG inventory

Request for GHG inventory preparation

Data provision

Request for **QA** of GHG inventory

GHG Inventory Quality Assurance Working Group

Report on QA results, Check of Action

Request for revision of NIR & CRF (**QC**)

GIO
in NIES/ESD/CGER
Organization for actual work of GHG Inventory

Request for **QC** check of NIR & CRF

Data provision

Data provision

Relevant Organizations such Industrial Associations

Private Consultant companies

Data Providers

9

2. *Institutional Arrangements (2)*

2-1 Roles and responsibilities in the inventory preparation process (1)

☐ **MOE** (Decarbonized Society Promotion Office, Global Environment Bureau, Ministry of the Environment)	• **The single national agency responsible for preparing Japan's inventory** • **Responsible for editing and submitting the inventory** • **Coordinates the QA/QC activities for the inventory** • **Checks and approves the QA/QC plan** • **Checks and approves the inventory improvement plan**

2. Institutional Arrangements (3)

2-1. Roles and responsibilities in the inventory preparation process (2)

GIO	- Performs the <u>actual work of inventory compilation</u> - Responsible for inventory calculations, editing, and the archiving and management of all data - Prepares the revised draft of the QA/QC plan - Prepares the draft of the inventory improvement plan

All tasks are carried out upon consultation with MOE as needed.

2. *Institutional Arrangements (4)*

2-1. Roles and responsibilities in the inventory preparation process (3)

☐ **Relevant ministries/agencies**	• **Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory** • **Confirmation of data provided for the preparation of the inventory** • **Confirmation of the inventory (CRF, NIR, JNGI files, and other information) prepared by the GIO (Category-specific QC).**
☐ **Relevant organizations (such as industrial associations)**	• **Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory** • **Confirmation of data provided for the preparation of the inventory**
☐ **Private consulting companies**	• **Quality control (QC) of inventory (CRF, NIR, JNGI files) compiled by the Ministry of the Environment and the GIO.**

2. Institutional Arrangements (5)

2-2. Other bodies involved in the national inventory processes and system (1) ～Committee for GHG Emissions Estimation Methods

♦ Created and run by the Ministry of the Environment

♦ Considers the methods for calculating inventory emissions and removals, and the selection of parameters such as activity data and emission factors

♦ The inventory WG and breakout groups comprise over 60 experts in various fields such as research institutes, universities, and industry organizations, and consider suggestions for inventory improvements

♦ Meetings are held once or twice annually to review issues to be addressed and approve solutions

♦ Private consultant companies perform technical surveys and administrative work as the secretariat of the breakout groups

Committee for GHG Emissions Estimation Methods

Inventory Working Group (Crosscutting Issues)

7 Breakout groups (by sector)

| Energy and Industrial Processes | Transport | Agriculture | Waste | F-gases | LULUCF | NMVOC |
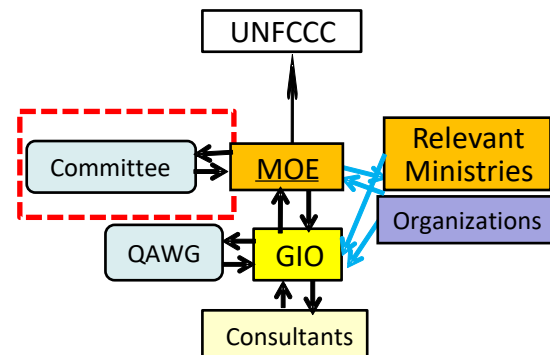
2-2. Other bodies related to the national inventory processes and system (2)～GHG Inventory Quality Assurance Working Group (QAWG)
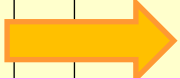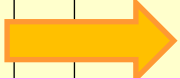
♦ The role is to assure inventory quality and to identify parts that need improvement by conducting detailed reviews of each emission source and sink in the inventory

♦ QAWG comprises experts who are NOT directly involved in inventory compilation

♦ GIO performs administrative work as the secretariat of the QAWG
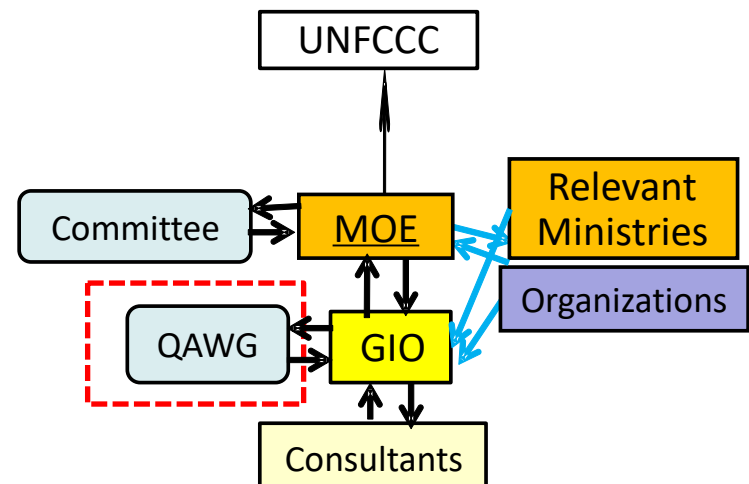
3. Inventory Compilation Process (1)

3-1. Annual schedule for preparation

Procedural arrangement

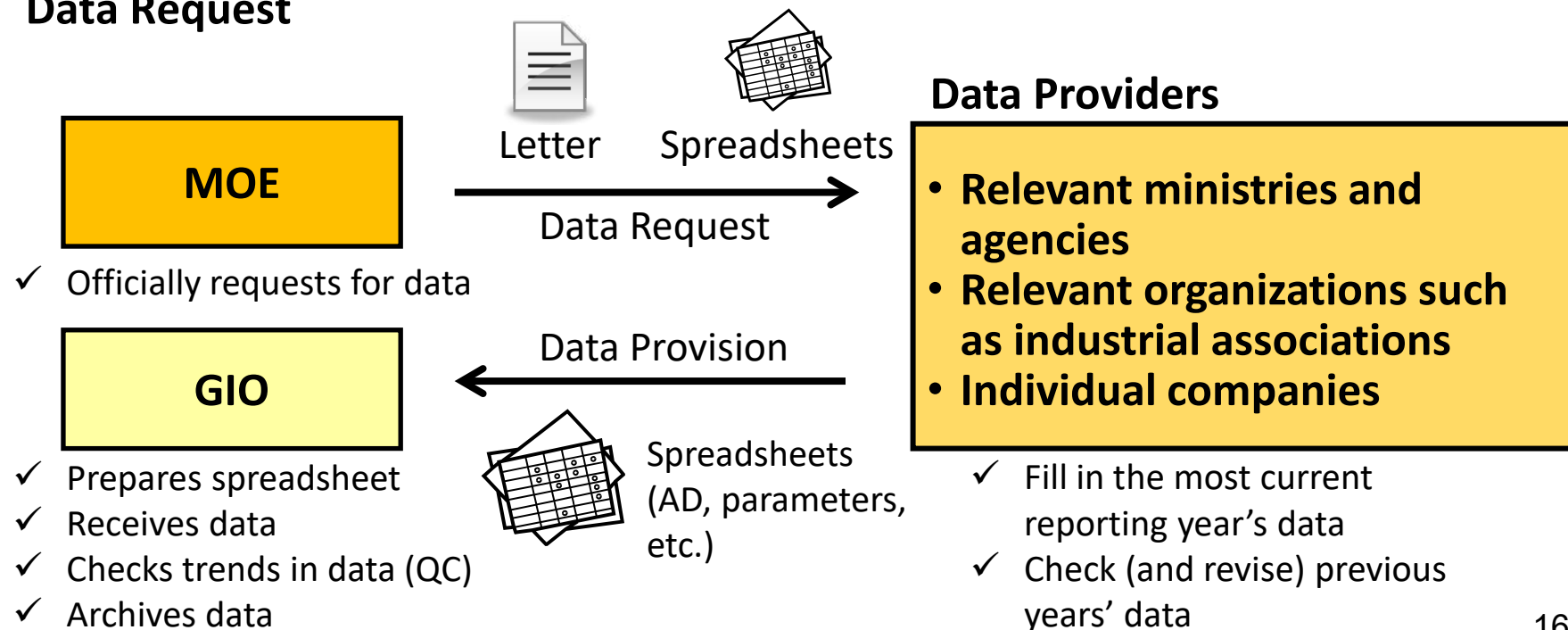|	Process	Relevant Entities	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Holding QAWG meeting	MOE, GIO	→											
2	Discussion on inventory improvement	MOE, GIO		→										
3	Consideration of inventory improvements & Holding the meetings of the Committee	MOE, (GIO, Private consultants)		→										
4	Data collection	MOE, GIO, Relevant Ministries/Organizations, Private consultants					**Preliminary** →			→		**Final**		→
5	Preparation of draft CRF and NIR	GIO, Private consultants											→	
6	Implementation of QC and coordination with relevant ministries	MOE, GIO, Relevant Ministries, Private consultants											→	
7	Finalizing draft CRF and NIR	MOE, GIO, Private consultants												→
8	Submission and official announcement	MOE, GIO												★

3-2. Data Collection Process (1)

➤ **Sources of Activity data (and parameters)**

- Published statistics
- Unpublished official data provided by relevant ministries/ agencies
- Unpublished data provided by relevant organizations such as industrial associations
- Unpublished data provided by individual companies

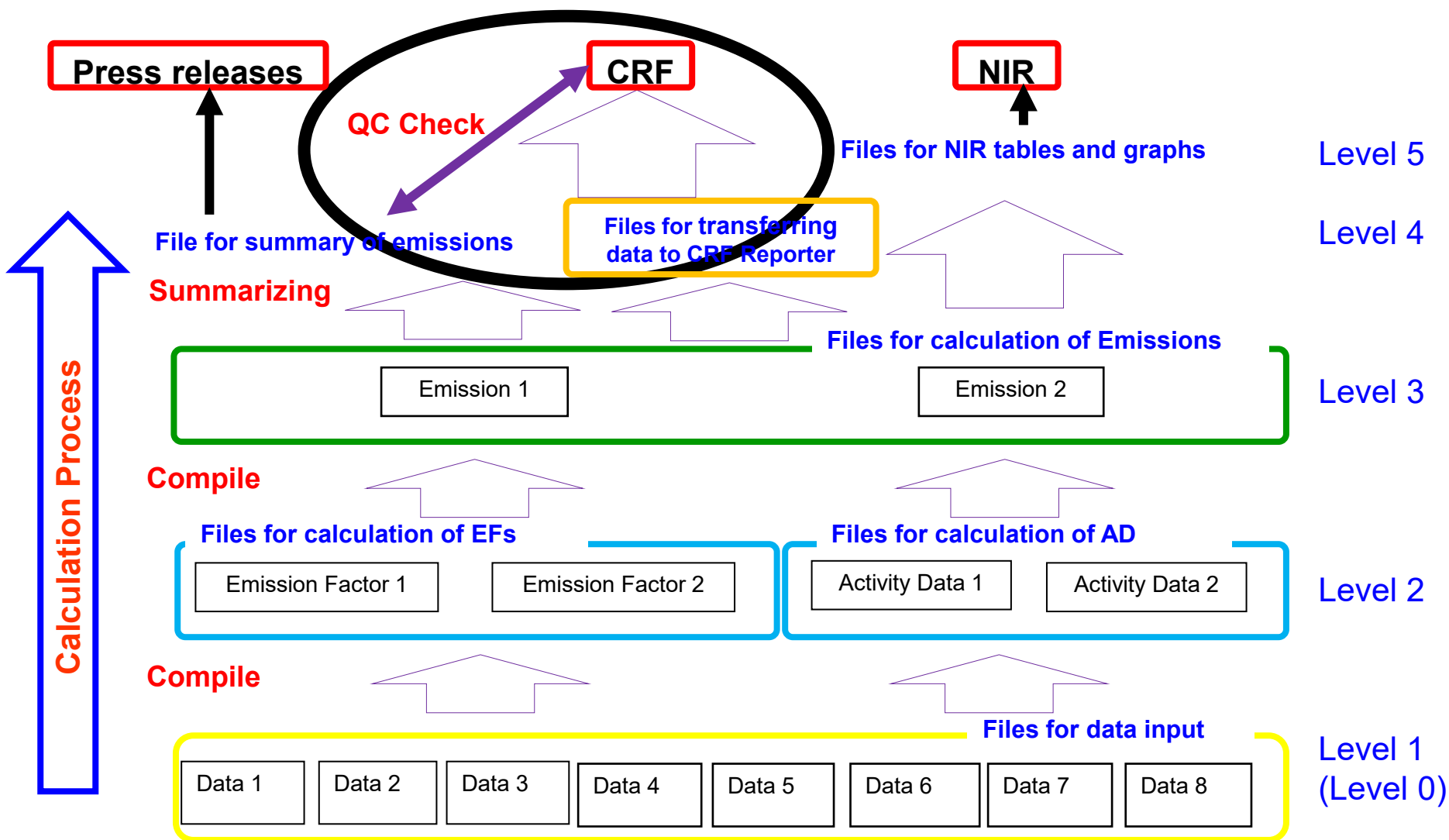Collected by Data Request

➤ **Data Request**

Letter   Spreadsheets

MOE

Data Request

✓ Officially requests for data

Data Provision

GIO

Spreadsheets (AD, parameters, etc.)

✓ Prepares spreadsheet
✓ Receives data
✓ Checks trends in data (QC)
✓ Archives data

Data Providers

- **Relevant ministries and agencies**
- **Relevant organizations such as industrial associations**
- **Individual companies**

✓ Fill in the most current reporting year's data
✓ Check (and revise) previous years' data

3. Inventory Compilation Process (3)

3-2. Data Collection Process (2)

■ Examples of Statistics and Data

Ministries/Organizations		Statistics or Data
Relevant Ministries	**Ministry of the Environment**	**Statistics for waste, etc.**
	Ministry of Economy, Trade and Industry	**General Energy Statistics, Yearbook of Chemical Industry Statistics , etc.**
	Ministry of Land, Infrastructure and Transportation	**Statistical Yearbook of Motor Vehicle Fuel Consumption, etc.**
	Ministry of Agriculture, Forestry and Fishery	**Livestock Statistics, National Forest Resources Database, etc.**
Relevant Organizations	**Federation of Electric Power Companies**	**Amount of Fuel Used by Pressurized Fluidized Bed Boilers**
	Japan Coal Energy Center	**Coal Production, etc.**
	Japan Cement Association	**Amount of clinker production, etc.**
Individual companies		**Confidential data**

Structure of the Excel File System

For details please see NIR Annex 6

Press releases

CRF

NIR

QC Check

Files for NIR tables and graphs — Level 5

File for summary of emissions

Files for transferring data to CRF Reporter — Level 4

Summarizing

Files for calculation of Emissions

| Emission 1 | | Emission 2 | — Level 3

Compile

Files for calculation of EFs | Files for calculation of AD

| Emission Factor 1 | Emission Factor 2 | Activity Data 1 | Activity Data 2 | — Level 2

Compile

Files for data input

| Data 1 | Data 2 | Data 3 | Data 4 | Data 5 | Data 6 | Data 7 | Data 8 | — Level 1 (Level 0)

Calculation Process

20

4. QA/QC Procedures (1)

4-1. QC activity

➢ *General QC procedures (in accordance with the 2006 IPCC Guidelines)*
  - ✓ QC check by Sectoral expert
    - • Checking for transcription errors in data entry and referencing, time series consistency, trends, etc.
  - ✓ QC check by National inventory compiler
    - • Confirming CRF reporter data, reasons for "NE" and "IE", key category analysis results, etc.

➢ *Category-Specific QC procedures*
  - ✓ QC by private consultant companies (External QC)
  - ✓ QC through coordination with the relevant ministries and agencies (External QC)
  - ✓ Committee for the GHG Emissions Estimation Methods

➢ *QC activities of the documentation and archiving of inventory information*

4-2. QA activity

GHG Inventory Quality Assurance Working Group (QAWG) is held as a QA activity, to assure inventory quality.

➢ **Summary**

The QAWG performs detailed reviews by experts not directly involved in inventory compilation in order to assure inventory quality and to identify parts that need improvement

➢ **Scope of review**

✓ Confirming the soundness of estimation methods, activity data, emission factors, and their items

✓ Confirming the soundness of content reported in the CRF and NIR

➢ **Outcome of review**

Review results will be reported to the Committee for the GHG Emissions Estimation Methods and considered/reflected in inventory

■ Continuous process to improve the quality of the inventory

Matters taken into account:
- ✓ Indication by UNFCCC inventory review and QAWG
- ✓ Progress of international negotiations
- ✓ Progress of scientific research and change in statistics
- ✓ Understanding of new information from the *Mandatory GHG Accounting and Reporting System*

Request of investigation and scientific research to research institutes and industrial organizations, and subsequent implementation

Revision of inventory improvement plan (Discussion of improvement principle and schedule)

Discussion and approval under the Committee for the GHG Emissions Estimation Methods

Detailed examination of the review reports

Reflection of new estimation methods to the inventory

Checking inventory

Inventory compilation

- ✓ UNFCCC inventory review
- ✓ QA

Inventory submission to the UNFCCC Secretariat

24

■ **Information needed for inventory compilation is documented and archived by the entity which compiles the inventory (GIO)**

➢ **Documenting and systematically archiving and organizing all** the information in electronic or printed form related to planning, preparation, and management of inventory development and activities including UNFCCC technical reviews and the Committee for GHG Emissions Estimation Methods.

➢ **Establishing archiving procedures for:**
  - Electronic information (e.g. Provided data, JNGI files and CRF- and NIR-related files) in Word, Excel, PDF, or other formats
  - Printed form (statistics, data, and other reference materials)

➢ **The server is automatically backed up** every day and access is restricted to limited ID holders

25

6. Documentation and Archiving System (2)

Electronic information:
All electronic information (e.g. provided data, JNGI files and CRF- and NIR-related files) in Word, Excel, PDF, or other formats are centrally archived at NIES (National Institute for Environmental Studies) computer servers.
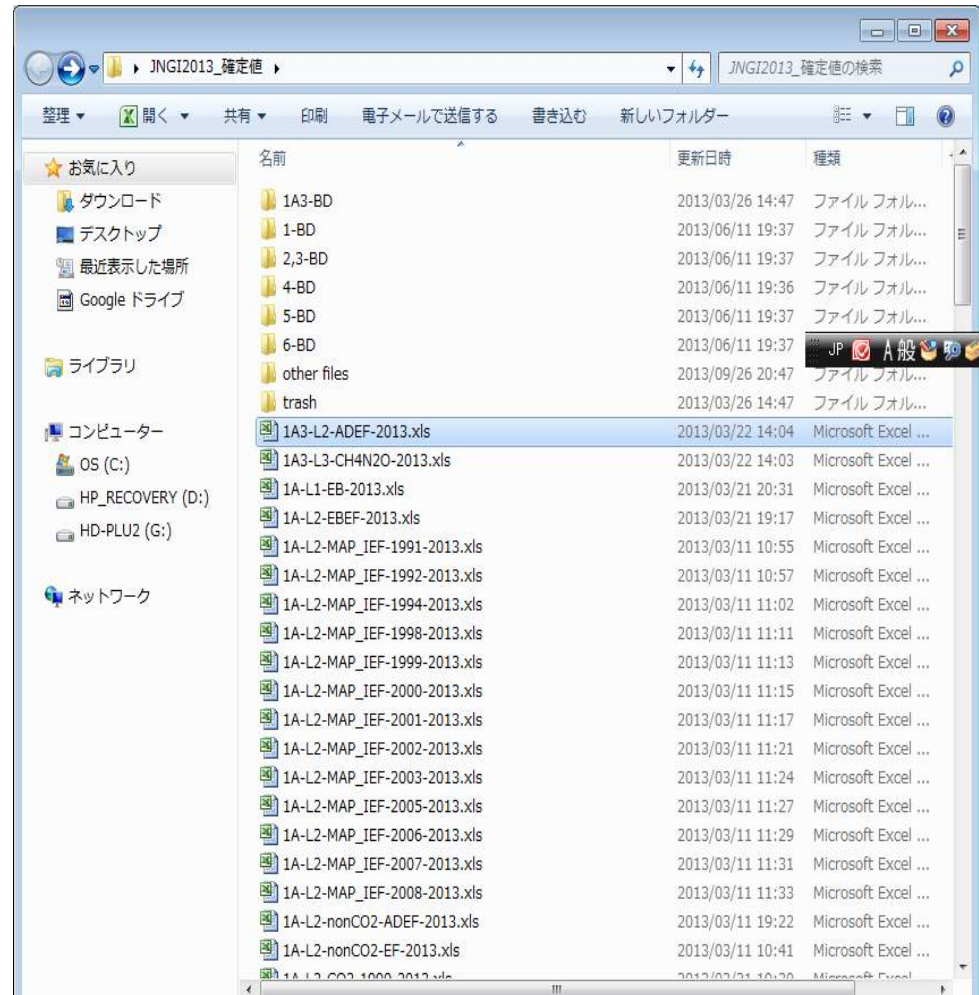
6. Documentation and Archiving System (3)

GIO's Bookshelf

Printed matter:
All related printed matter (statistics, data, and other reference materials) are centrally archived in GIO.

Main Research Building III, NIES where GIO is located in

Thank you very much

Greenhouse Gas Inventory Office of Japan (GIO)
National Institute for Environmental Studies (NIES)

Development of biomass open burning emission inventory for air quality management at national and regional levels in Thailand

Savitri GARIVAIT

Aerosols from Biomass Burning to the Atmosphere – Emission Inventory and Projection (ABBA – EIP)
The Joint Graduate School of Energy and Environment, Centre of Excellence on Energy Technology and Environment
King Mongkut's University of Technology Thonburi

The EANET Emission Inventory Workshop
18 October 2021, Web-based workshop in virtual meeting room
Organized by the Asia Center for Air Pollution Research (ACAP), the Network Center (NC) for the EANET

Biomass Open Burning Sources in Thailand

Biomass Open Burning

Solid Waste

Agricultural Residues

Forest Fires

Objectives of Biomass Open Burning Emission Inventory Development

❑ To establish a biomass open burning emission inventory database for supporting air quality modelling and management in Thailand

❑ To use as the baseline reference for biomass burning emission mitigation option development

General Principle of Emission Estimation

The emissions from biomass open burning can be estimated using the equation developed by Seiler, W. and Crutzen, P. J. (1980), which represents the relationship between the combustion process and its emission, as follows:

$$E_i = M \times EF_i$$

Where E_i is the emission of the air pollutant i(g); M is the mass of dry matter burned (kg of dry matter); and EF_i the emission factor of the air pollutant i (g/kg of dry matter burned).

M depends on three factors; burned areas (BA) (ha), biomass density (BL) (kg of dry matter/ha) and combustion efficiency (CF) (dimensionless), as follows:

$$M = BA \times BL \times CF$$

MODIS Monthly Burned Area Products
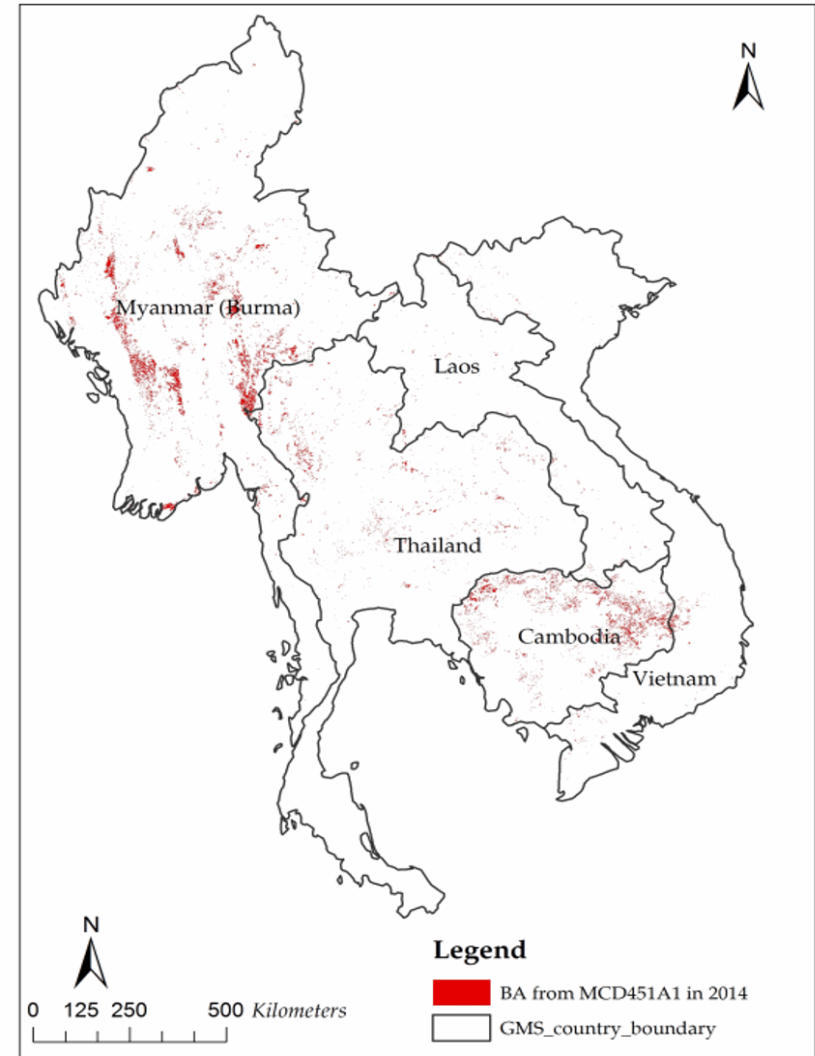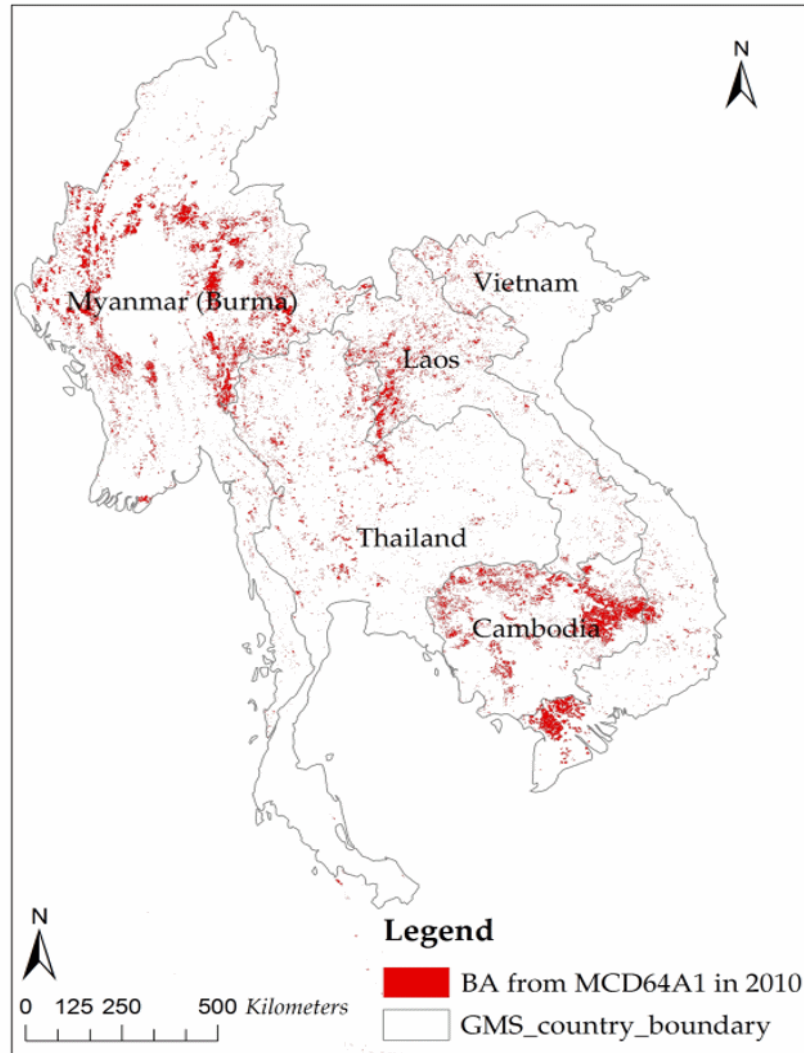
Land Use Map for Biomass Load Identification
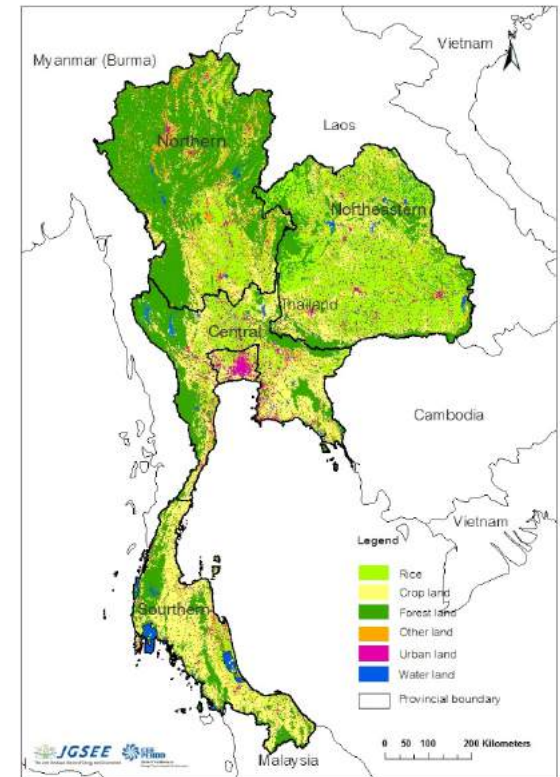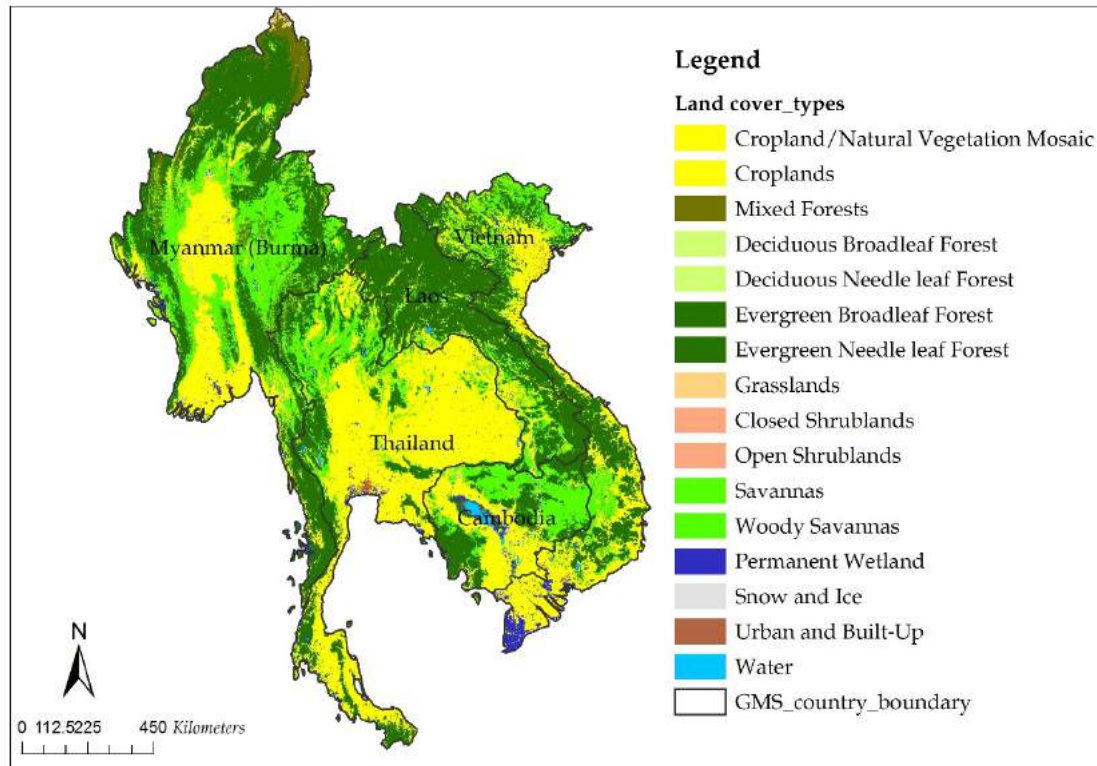
Land Cover Type Yearly L3 Global 500 m SIN Grid (MCD12Q1) Resolution 500 meters, 2013

Land use from LDD, Thailand, 2014

Source: https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1

Reference Fires for BA and BL Validation and Correction

- ❑ **We created the reference fires which occurred in the Northern part of Thailand during 2014-2016.**
- ❑ **The burn scars (reference fires) were created by using high spatial resolution, LANDSAT (OLI/TIRS surface reflectance data products through Earth-Explorer.**
- ❑ **LANDSAT imagery are available for acquisition free download from 2013 to present, using the Earth-Explorer tools to select scenes.**
- ❑ **The satellite imagery technique involved an analysis of pre-fire and post-fire selected conditions represented equations as Differenced Normalized Burn Ratio (ΔNBR) were derived from Howard et al. (2002)**

(Left) The pre-fire image is a Landsat 8 image (MIR, NIR, GREEN) acquired on November 24, 2015. (Right) The post-fire image (right) is a dark purple color Landsat 8 image (MIR, NIR, GREEN) acquired on March 16, 2015.
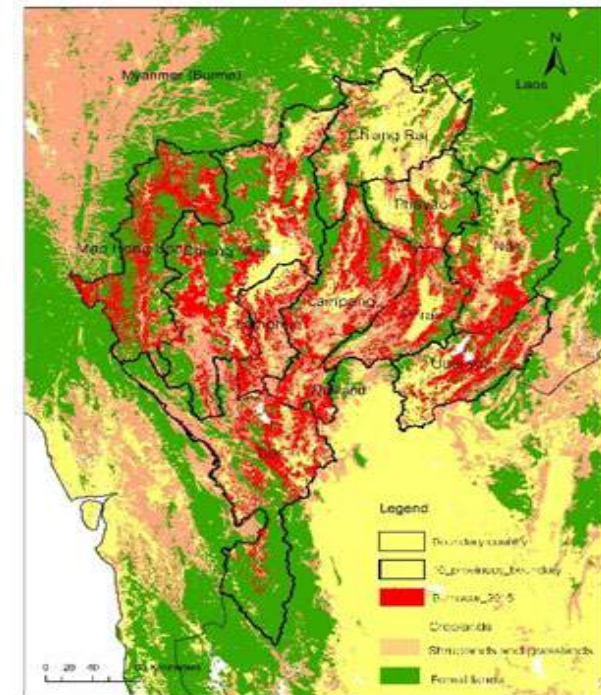
Spatial and Temporal Distribution of BA in 2015

Legend

Biomass open burning

Burned area, January 2015 (ha/grid)

- 0
- 1 - 250
- 251 - 500
- 501 - 750
- 751 - 1000
- 1,001 - 2,500
- 2,501 - 5,000
- 5,001 - 7,500
- 7,501 - 10,000
- 10,001 - 14,400
- GMS_country_boundary

Grid size 12 km x 12 km
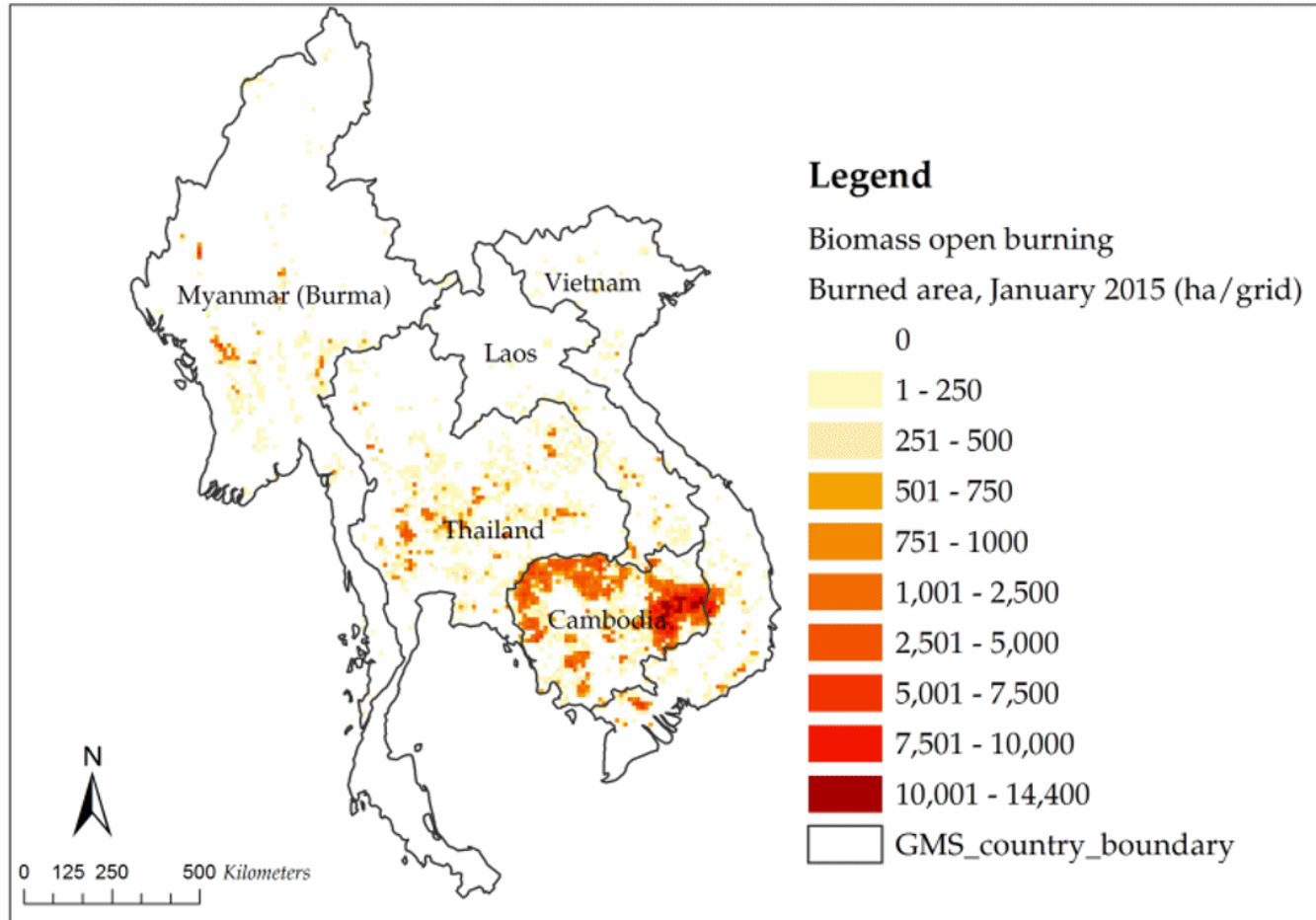
PM2.5 Emissions Trends in Thailand vs. GMS in 2010-2017

Country	PM2.5 emission from biomass open burning in GMS (kt)							
	2010	2011	2012	2013	2014	2015	2016	2017
Myanmar	784	540	789	598	1,104	541	373	448
Cambodia	315	384	307	317	358	336	312	331
Laos	328	60	142	178	130	143	215	79
Thailand	237	139	294	212	287	232	252	215
Vietnam	246	113	201	203	233	272	224	104
Total	1,904	1,237	1,738	1,508	2,115	1,529	1,377	1,177
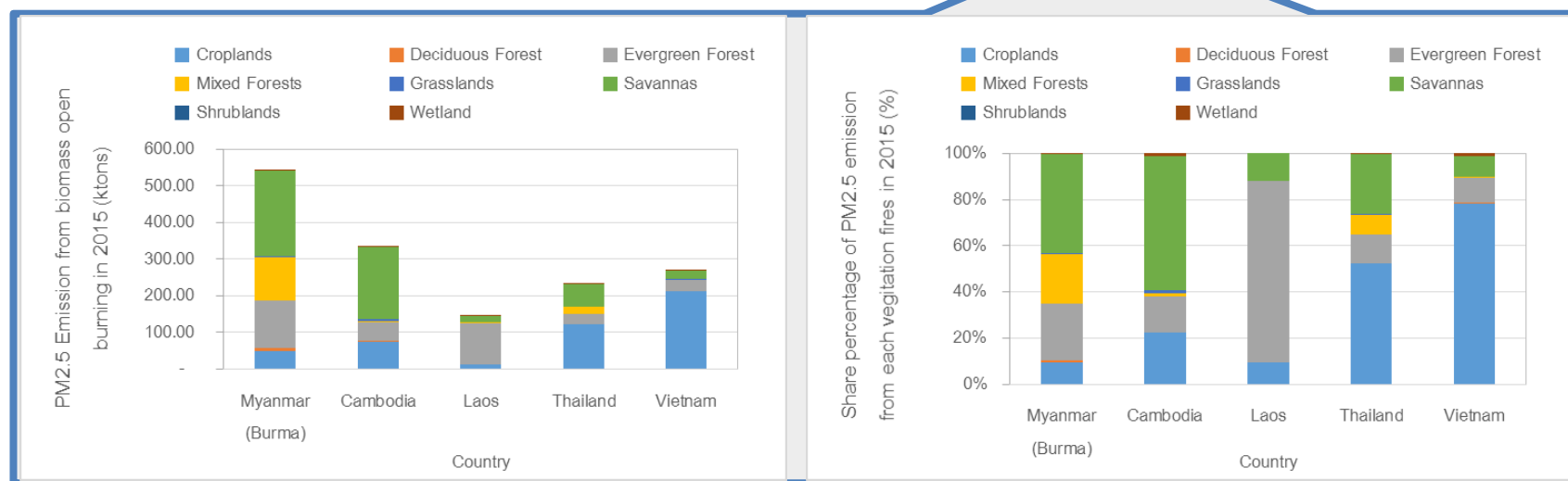
Spatial Distribution of PM2.5 from Forest Fires, Agricultural Burnings, and Grassland Burnings in GMS in 2015
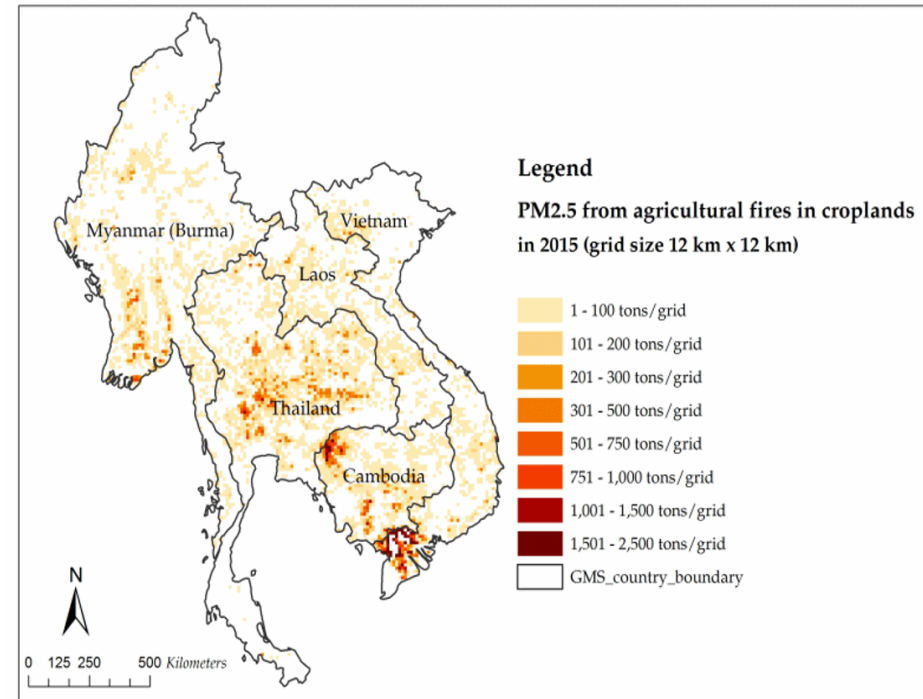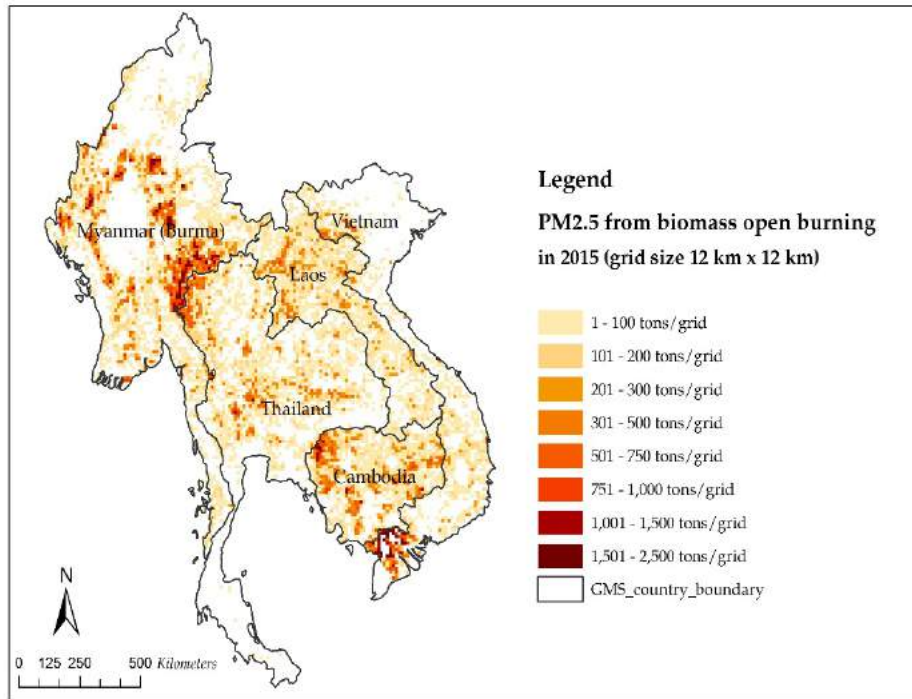
Air Quality Issues in Thailand & Bangkok Metropolitan Region (BMR)

Air Quality Situation in Thailand

- Two major problems: O_3 and $PM_{2.5}$
- The trend of annual average of O_3 during the past 15 years is increasing
- $PM_{2.5}$ has this year (2018) become the issue of concern for the public, especially in BMR and Northern part of Thailand
- $PM_{2.5}$ annually peaks during the dry season, but the annual average tends to decrease and became very close to the national standard value of 25 ug/m3 [Note: the 24h national standard being 50 ug/m3]
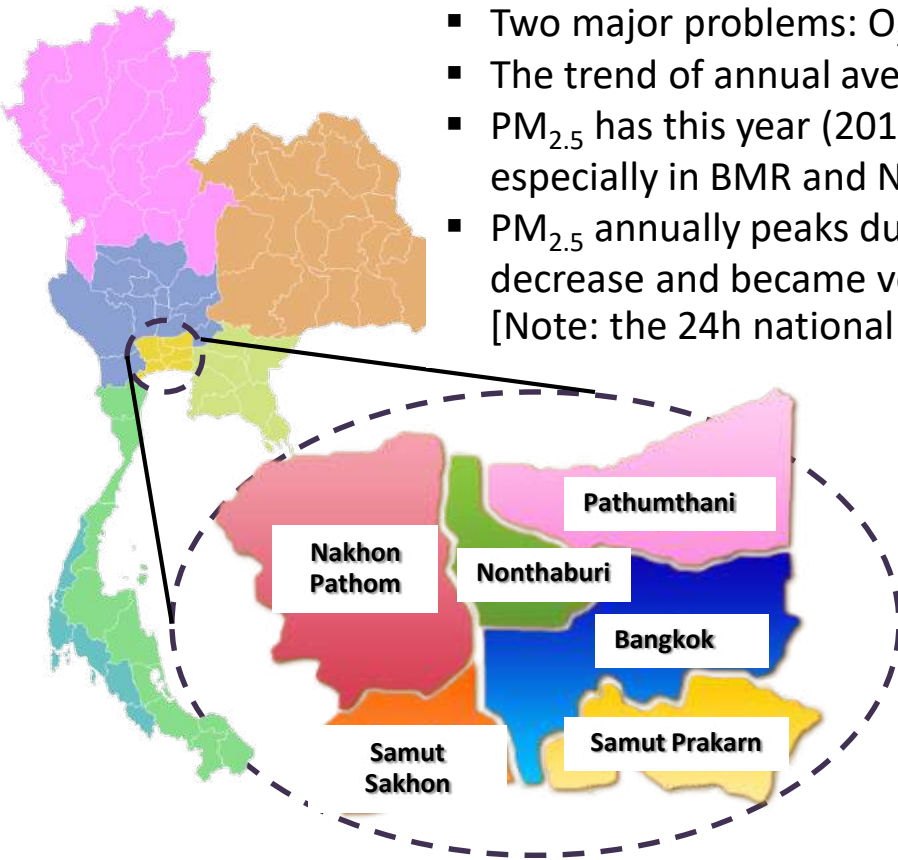
Bangkok Metropolitan Region (BMR)

- Cover 6 provinces: Bangkok, Pathumthani, Nonthaburi, Samut Prakarn, Samut Sakhon, and Nakhon Pathom
- Total area: 7,700 km^2 [a] (< 1.5% of total Thai area 554,000 km^2)
- Total population: 15 million (> 20% of total Thai population 69 million)
- Population density: 1,347.11 pp/km^2 [a]

Pathumthani

Nakhon Pathom

Nonthaburi

Bangkok

Samut Sakhon

Samut Prakarn

Source: [a]DOPA

Thailand's Anthropogenic Emission Inventory in 2015

PM2.5 emissions from biomass burning in 2015 =232 kt

Unit: kiloton (kt) (except CO_2, unit: million ton (Mt)

*CO_2	NO_x	CO	SO_2	CH_4	N_2O	OC	BC	$PM_{2.5}$	PM_{10}	TSP
316.5	917.1	1,844.8	376.2	3,653.3	127	88.6	40	362.3	424.5	539.4

Legend:
- 01:Energy sector
- 02:Domestic
- 03:Industrial combustion
- 04:Industrial processes
- 05:Fuel extraction
- 06:Solvents
- 07:Road transport
- 08:Off_road mobile
- 09:Waste management
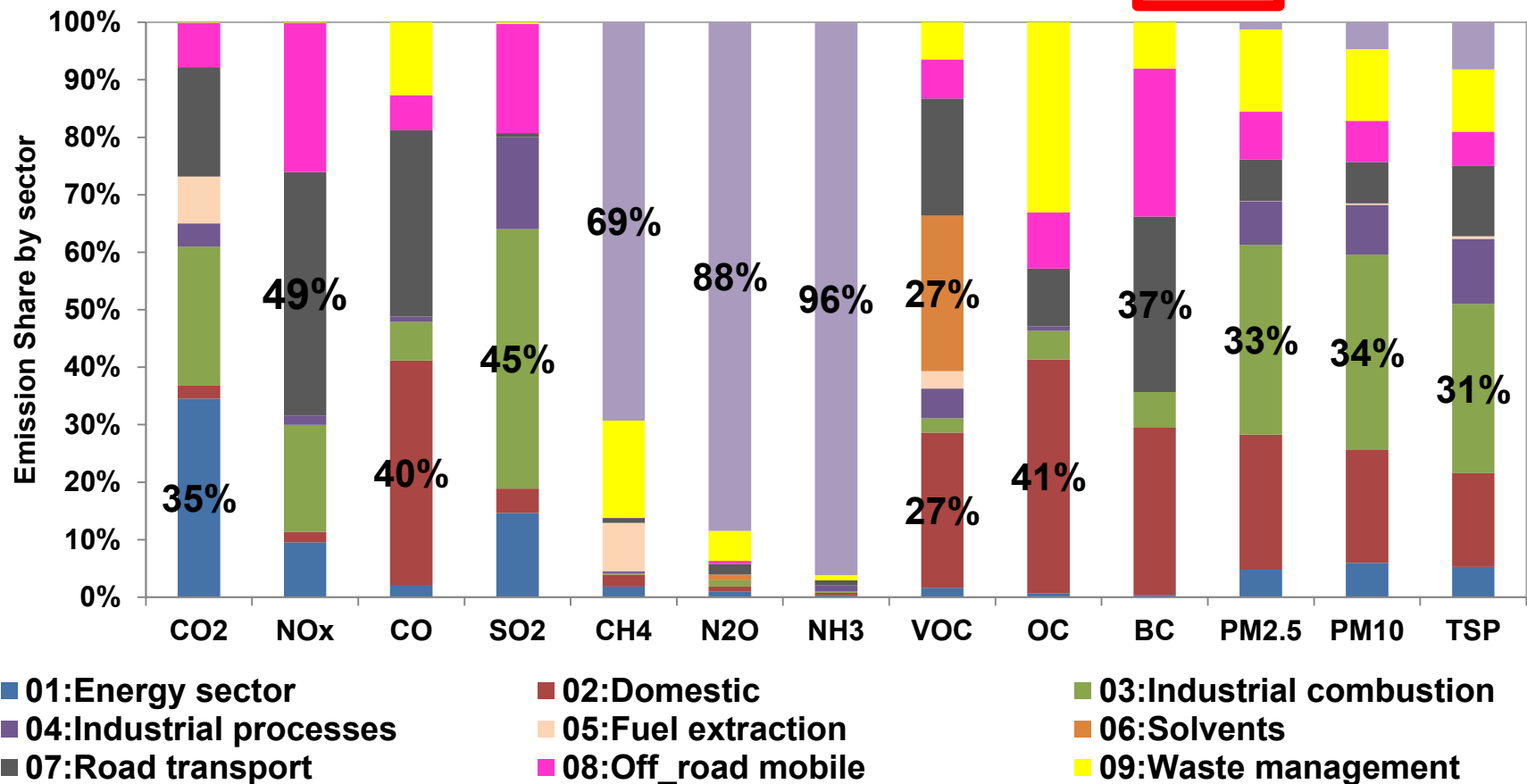
BMR's Biomass Burning and Air Quality
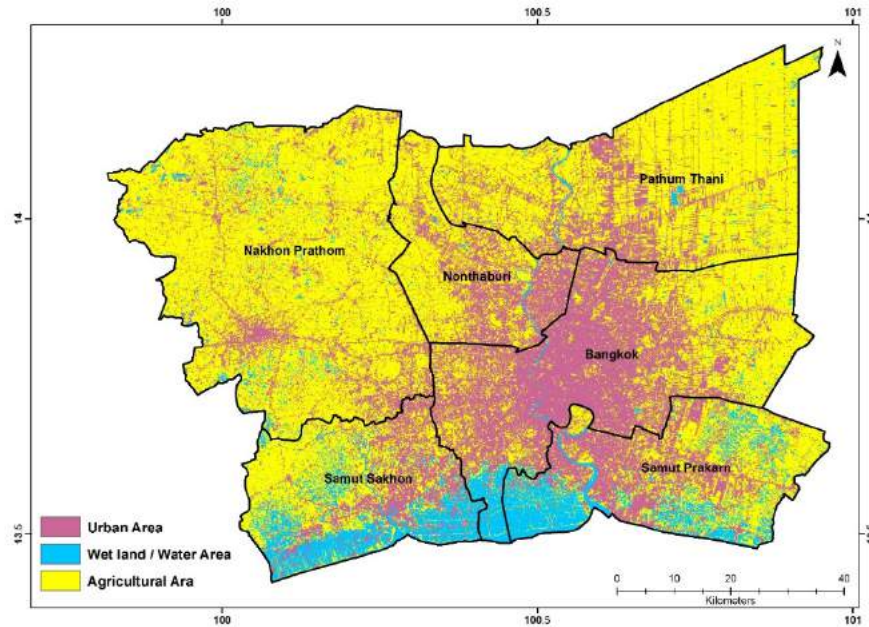
> ➢ **There are 60% of agricultural area in BMR**
> ➢ **BMR experiences intensive emissions from crop field residue burning, especially rice straw during the harvesting periods, in particular those conducted in December to March**

Courtesy of Dr. Supat Wangwongwatana

24h Average PM$_{2.5}$ Ambient Concentration in BMR (2011–2018)

National 24h Average Standard 50 $\mu g/m^3$
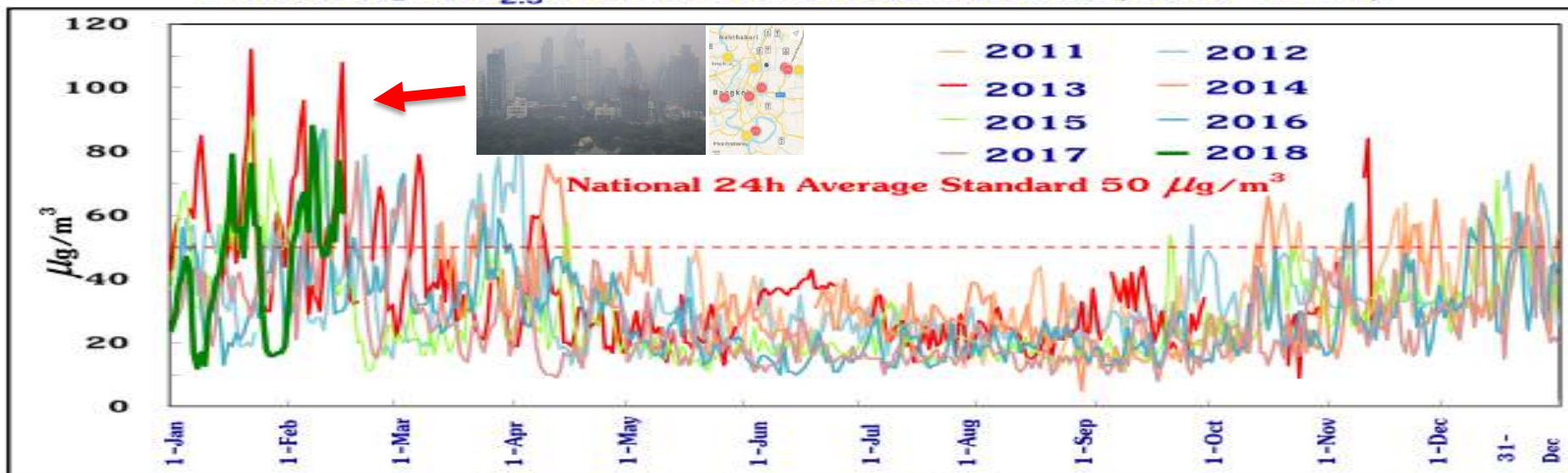
Difficulties in estimating emissions from biomass burning in BMR

Burned Area
3 ha   1 ha
2 ha

Photo taken 3 April 2019

➢ **In Bangkok Metropolitan Region (BMR), biomass open burning generally occurred in the form of "small fires" in paddy fields/plots, with an average size in the range of 0-5 ha during Jan – April each year.**

➢ **The burned area (BA) satellite products from the Moderate Resolution Imaging Spectro-radiometer (MODIS) detection are MCD45A1 and MCD64A1, which are used by global databases specialized in estimating emissions from biomass open burning, e.g. Global Fire Emissions Database (GFED4), to serve as input to air quality modeling simulations.**

➢ **BA from MODIS showed a very low number of burned scars in BMR**

➢ **In this study, we developed an algorithm for local small burned areas detection, based on Landsat images and active fires Visible Infrared Imaging Radiometer Suite (VIIRS) sensor's, we used the ground observations collected in March to April 2019, and especially questionnaire surveys for validation of burned areas and related emission.**

Fields Survey for Small Burned Area Estimation Validation

Field survey (Mar 2019) of burned area from Landsat 8 around BMR (n=223)
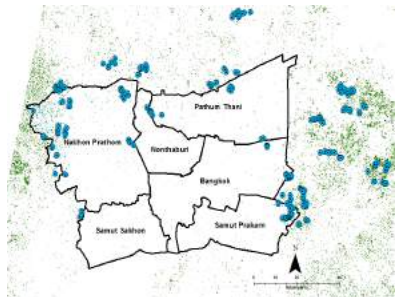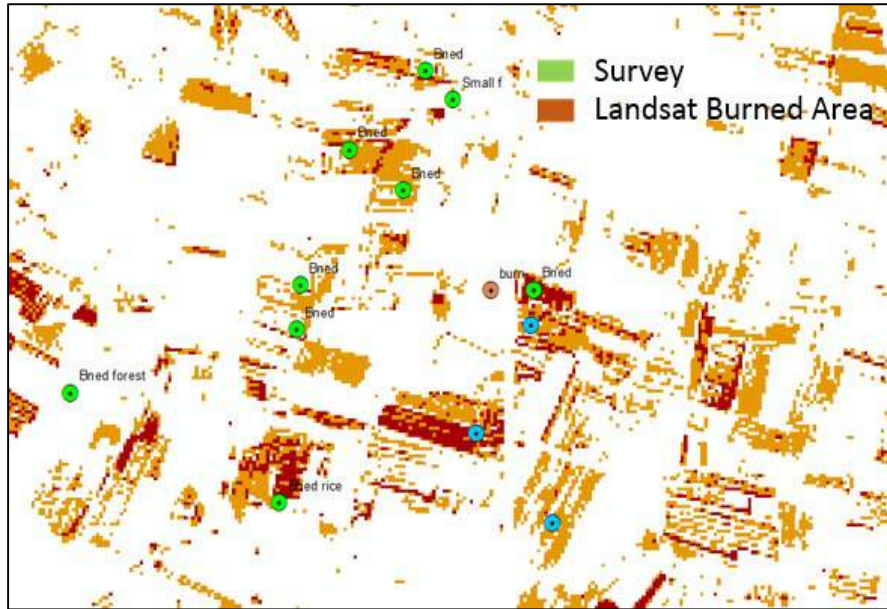
Sampling of 223 points
- **Not-burned: 72 points**
- **Burned: 151 points**

Biomass Burning Emission Inventory Quality Check Using Air Quality Modeling Platform WRF-CAMx with 2019 TH EI
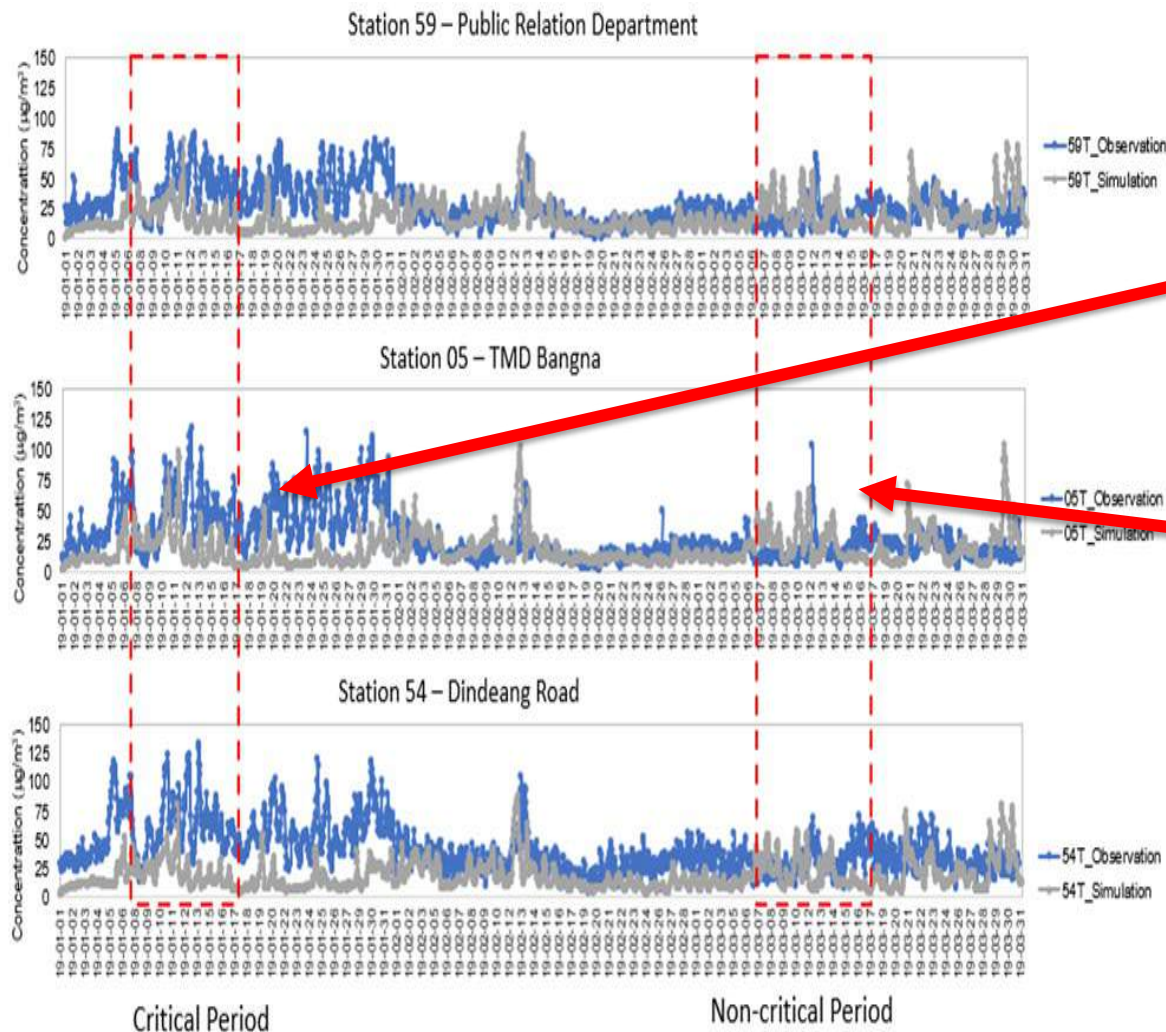
➢ **Significant differences in the peak intensity during the Critical Period, when agricultural residues burning activities are high in contrast to the Non-Critical Period when non-agricultural residues burnings were observed.**

Burned Area Validation Using Questionnaire Surveys

Burned area from Agricultural burning in Thailand, 2019 (ha)					
Month	**Satellite (MCD64A1)**		**Questionnaire Survey (QS)**		**Ratio (QS / MCD64A1)**	
	Paddy Field	**Field Crop**	**Paddy Field**	**Field Crop**	**Paddy Field**	**Field Crop**
Jan	65,310	81,135	83,496	560,306	1	7
Feb	44,335	41,203	146,234	298,038	3	7
Mar	77,332	42,783	349,267	314,507	5	7
Apr	50,787	28,904	274,091	96,551	5	3
May	9,275	6,365	146,725	8,000	16	1
Jun	670	-	58,659	492	88	-
Jul	1,149	-	59,260	4,573	52	-
Aug	11,143	92	249,705	11,883	22	130
Sep	8,370	576	301,690	66,442	36	115
Oct	3,065	868	282,596	80,774	92	93
Nov	112,268	3,591	1,811,244	116,587	16	32
Dec	23,235	28,694	291,607	67,157	13	2
Total	406,939	234,210	4,054,574	1,625,312	10	7

Burned Area Validation Using Agricultural Production Statistics

Month	Open burning in sugarcane fields (ha)						Ratio OSCB/MCD64A1		
	MCD64A1			OSCB					
	C	N	NE	C	N	NE	C	N	NE
Jan_2019	39,373	30,708	10,164	189,438	132,619	224,936	4.8	4.3	22.1
Feb_2019	14,207	17,918	8,979	110,048	68,831	113,686	7.7	3.8	12.7
Mar_2019	11,235	18,524	13,024	80,477	72,110	138,360	7.2	3.9	10.6
Apr_2019	298	24,774	3,832	1,993	10,535	49,635	6.7	0.4	13.0
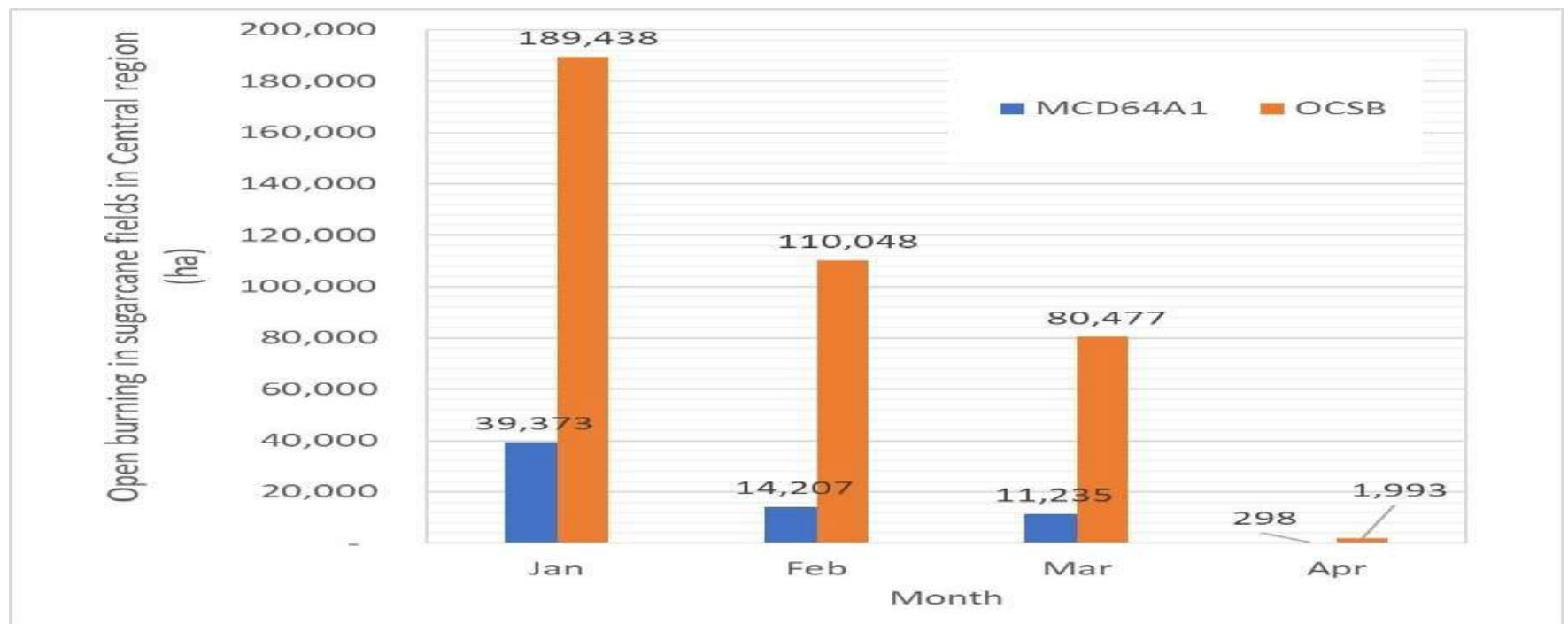
Comparison of PM2.5 Emission from Agricultural Burnings in Thailand

PM2.5 Emission from Agricultural Burnings in Thailand in 2019 (kt)

Regions	Rice	Sugarcane	Maize	Shifting cultivation	Total
BMR	0.3	0.0	0.0	0.0	0.3
C	9.3	13.1	0.9	0.0	23.3
N	24.2	9.7	10.2	1.3	45.4
NE	18.9	18.1	1.1	0.0	38.1
S	0.6	0.0	0.0	0.0	0.6
Total	53.3	40.9	12.2	1.3	107.7

Thailand's Anthropogenic vs. Biomass Burning Emission Inventory in 2019

Unit: kiloton (kt)

Sources	CH_4	N_2O	NH_3	NO_x	SO_2	NM VOC	PM2.5	PM10	OC	BC	CO
Anthropogenic (ANT)	4,145	113	428	979	423	506	230	301	61	42	2,279
Biomass Burning (BOB)	99	2	32	22	5	205	172	253	47	11	1,380
Total	4,243	115	459	1,001	428	710	402	555	108	54	3,659
ANT/BOB	42.0	53.8	13.5	45.0	79.1	2.5	1.3	1.2	1.3	3.7	1.7
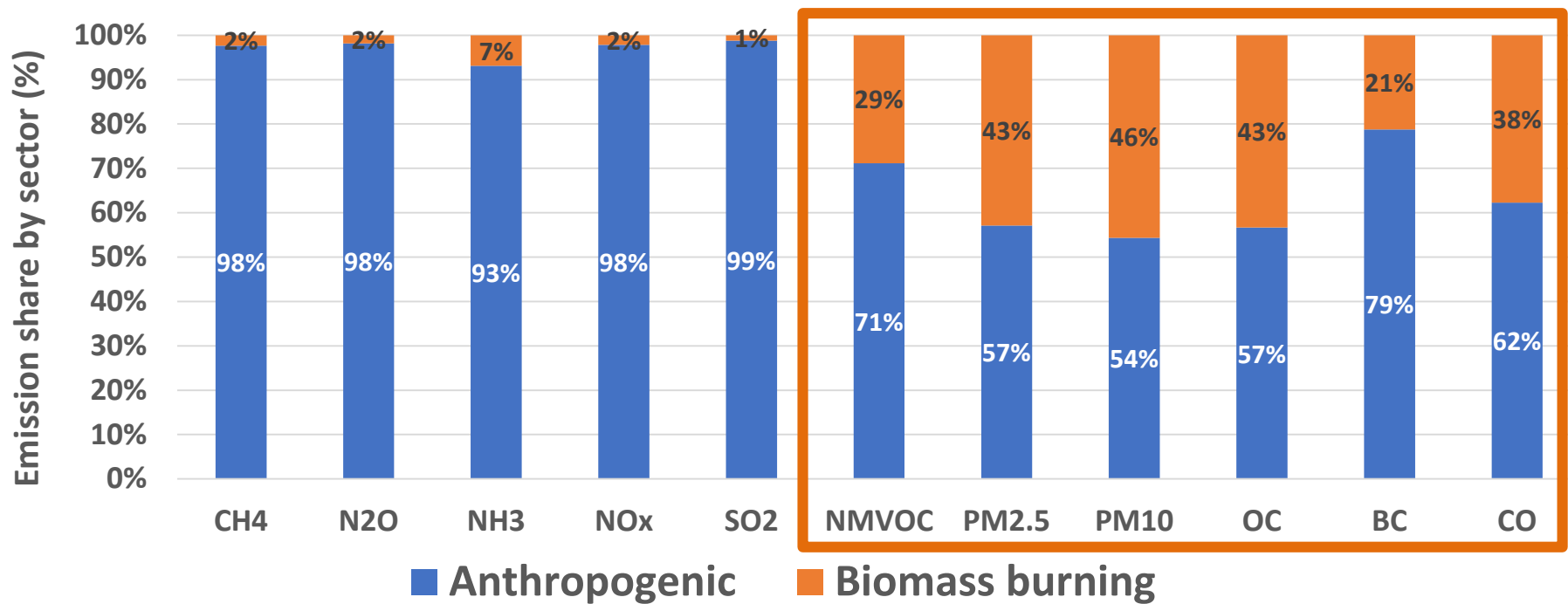
Comparison of PM2.5 and PM10 Emission from Biomass Burning vs. Anthropogenic Sources in Thailand
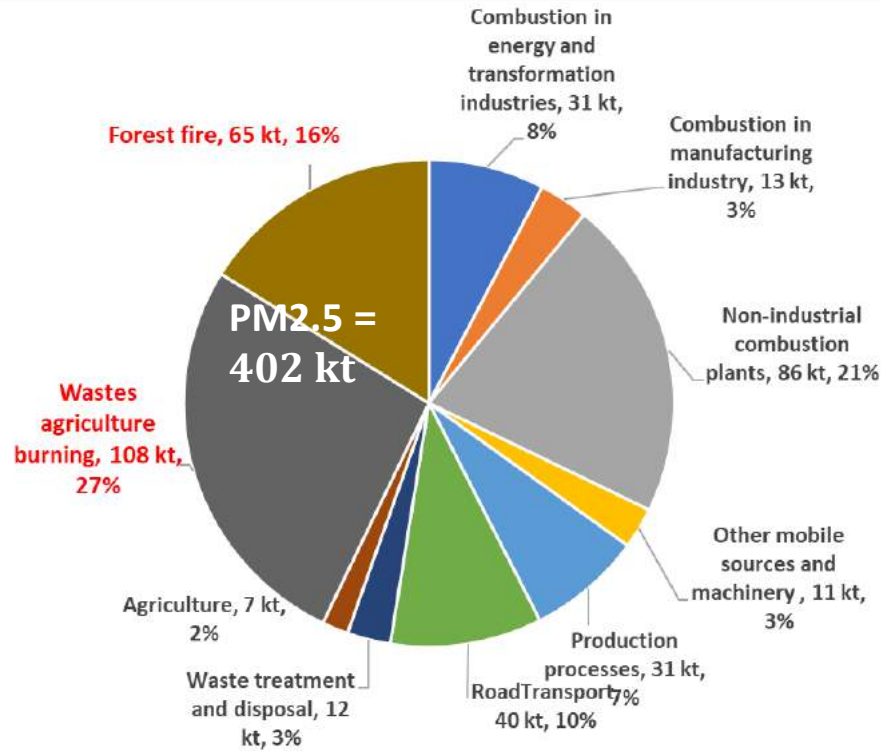
PM2.5
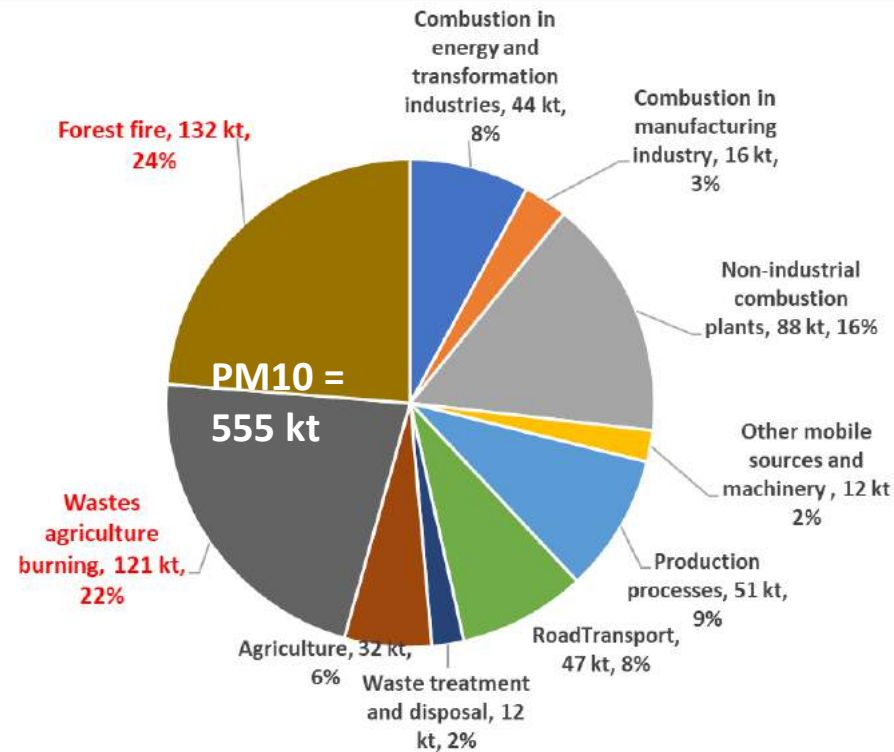
PM10

Comparison of PM2.5 and PM10 Emission from Biomass Burning vs. Anthropogenic Sources in Thailand – Temporal Variation
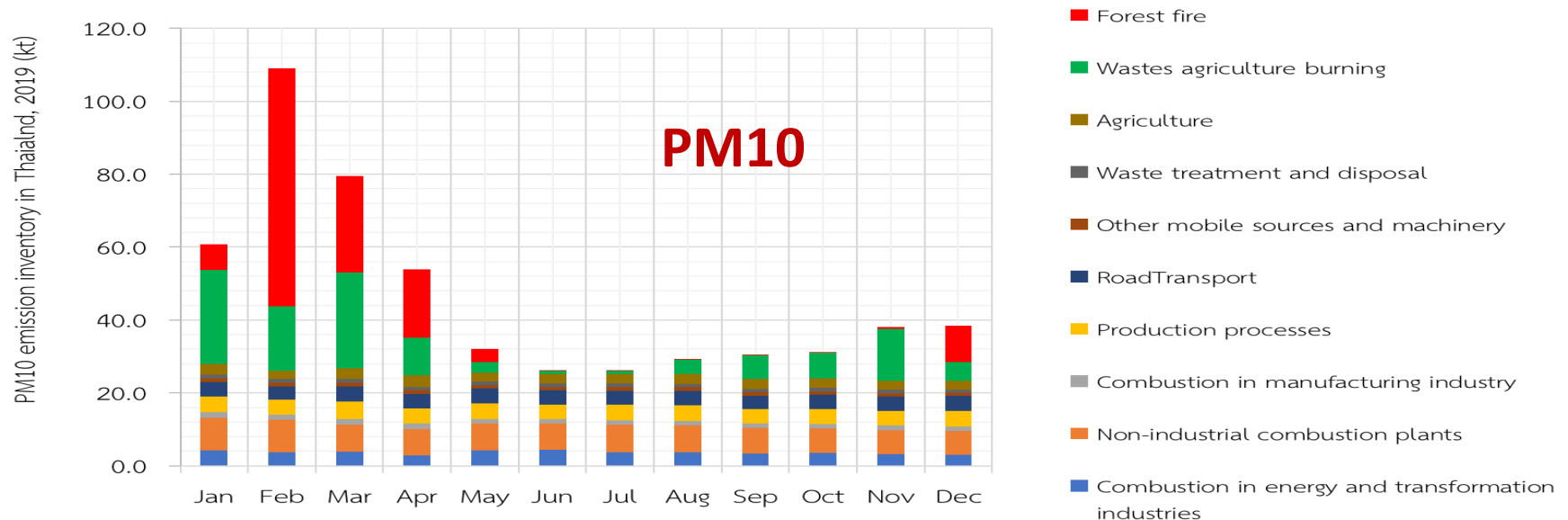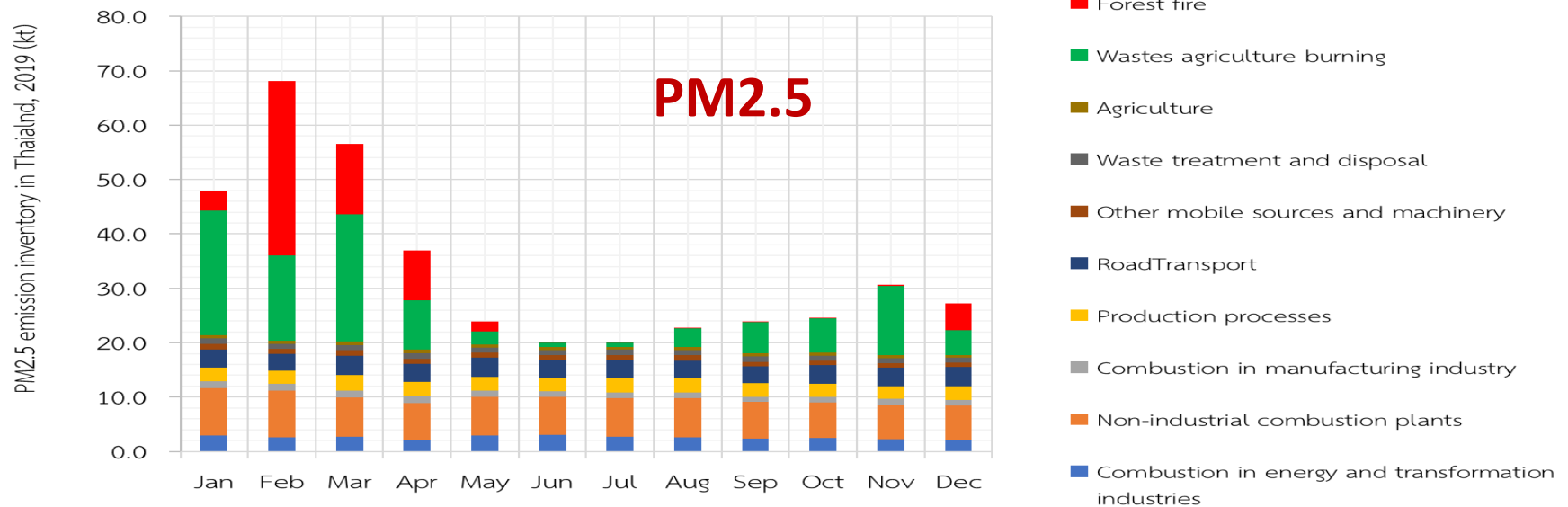
Comparison of PM2.5 Emission from Biomass Burning vs. Anthropogenic Sources in BMR and Central
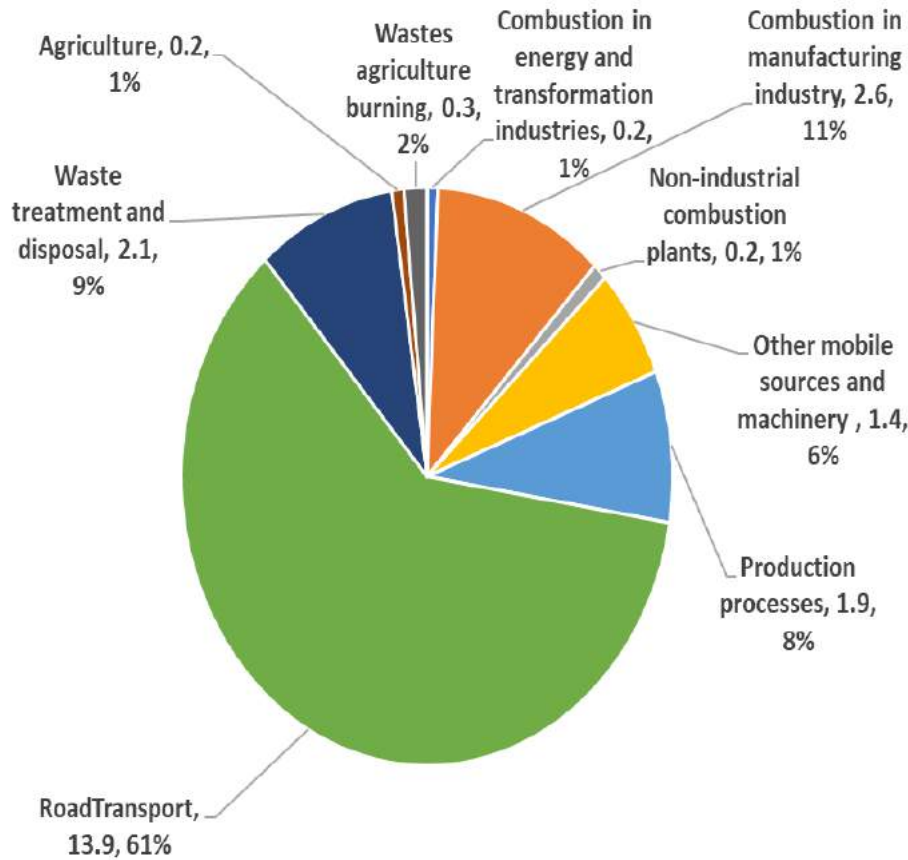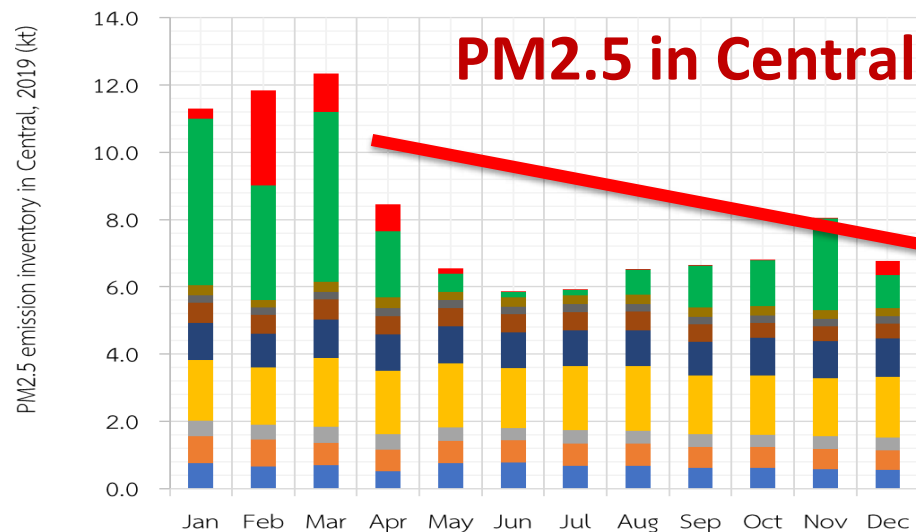

PM2.5 in BMR
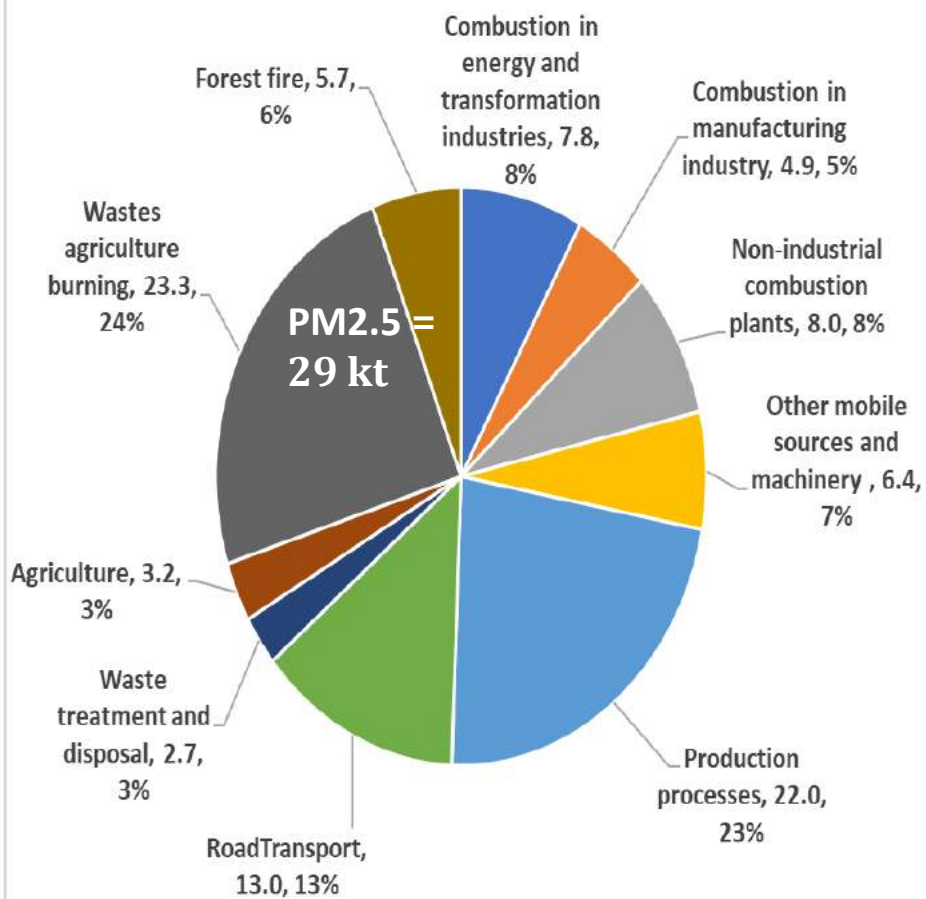
PM2.5 in Central

Comparison of PM2.5 Emission from Biomass Burning vs. Anthropogenic Sources in BMR and Central
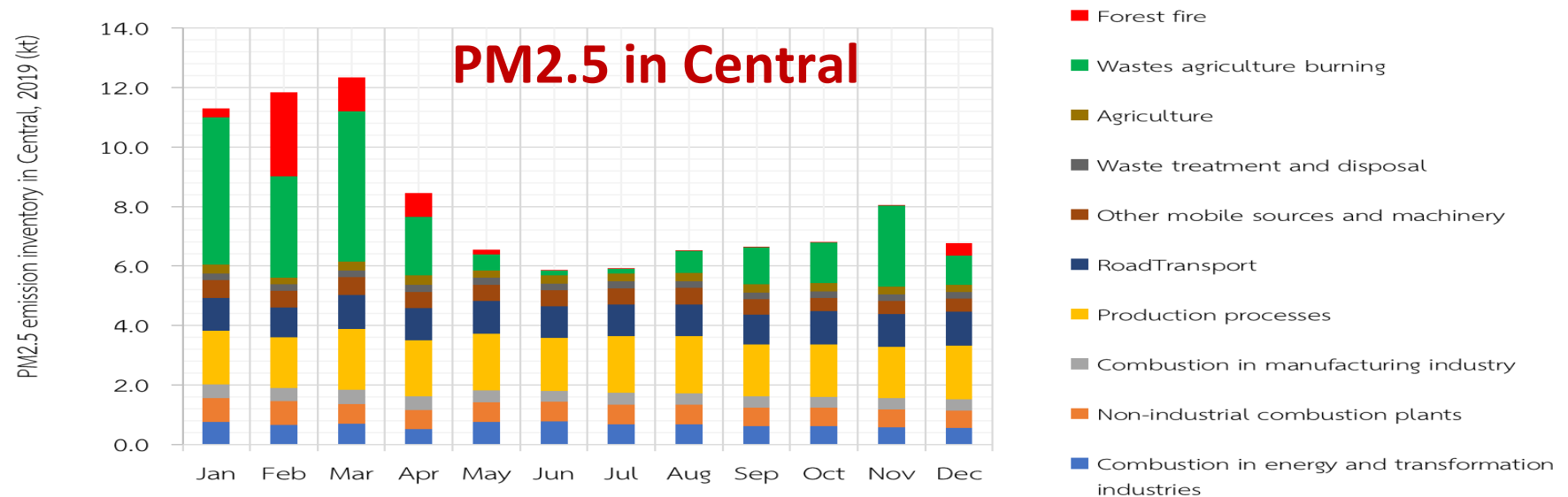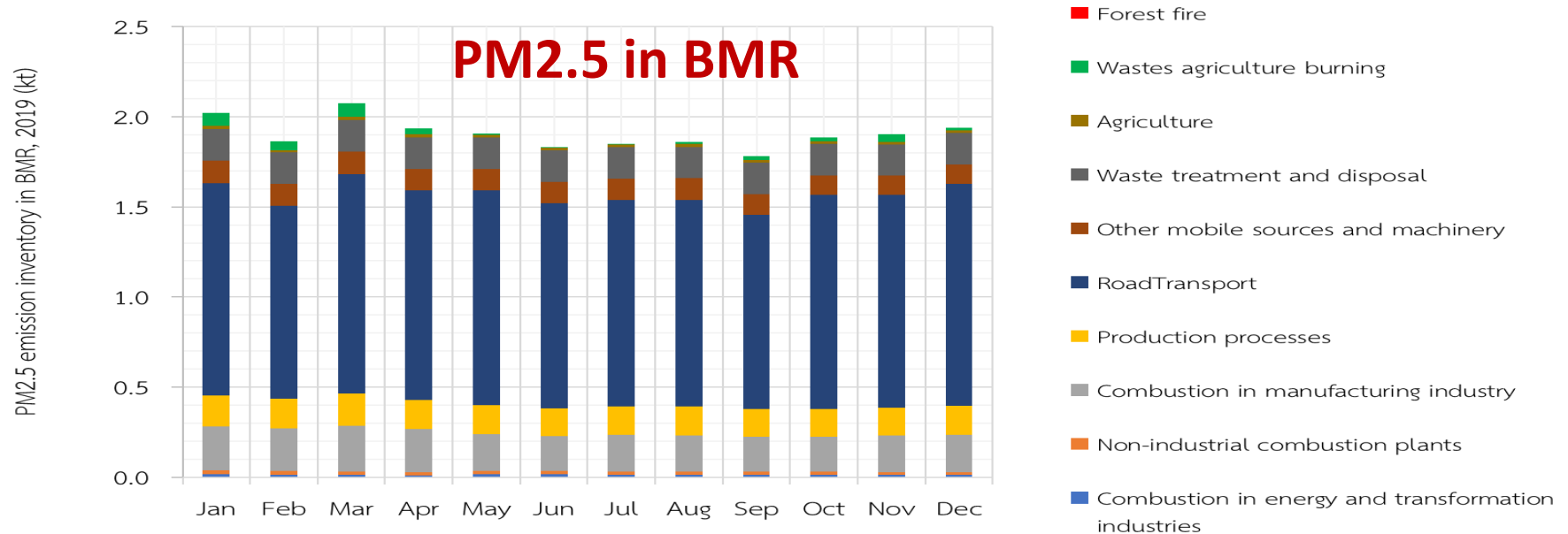
Comparison of PM2.5 Emission from Biomass Burning vs. Anthropogenic Sources in BMR and Central: What Contribution to AQ in BMR?
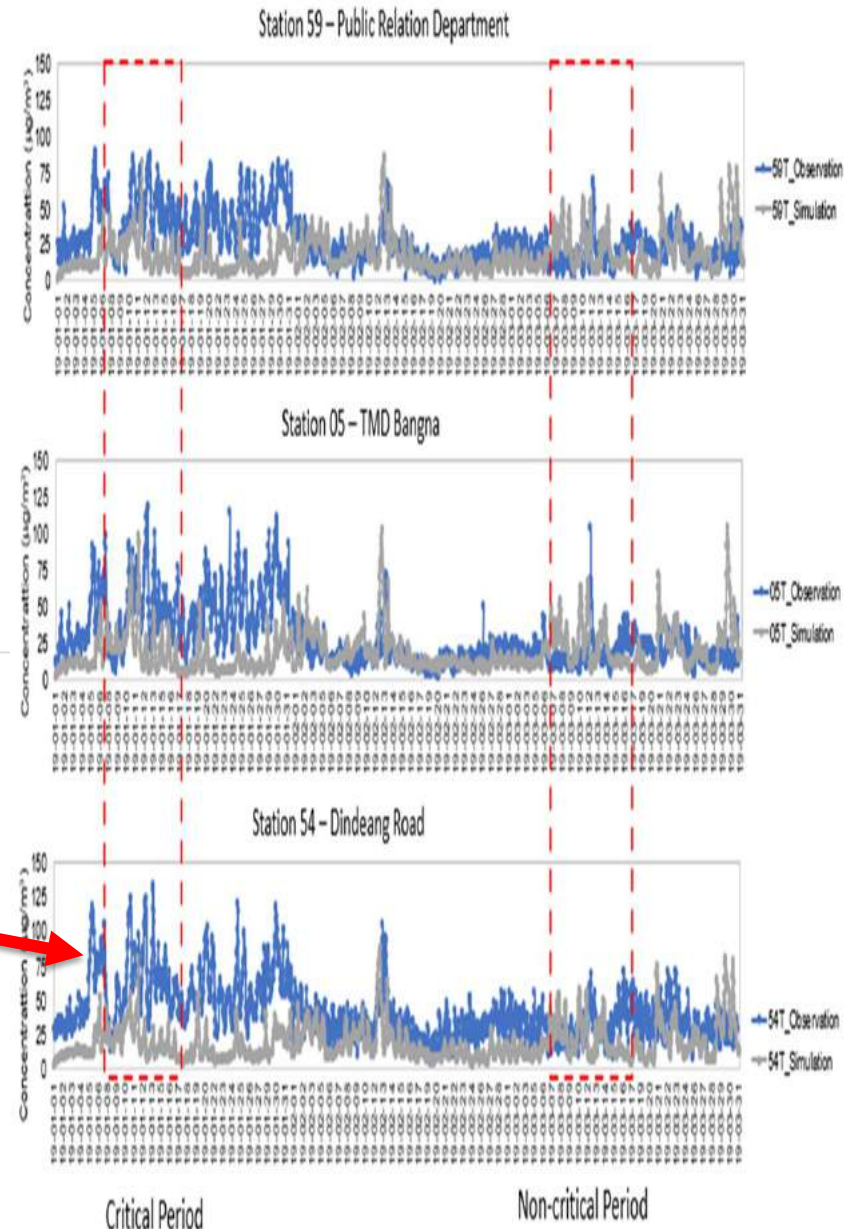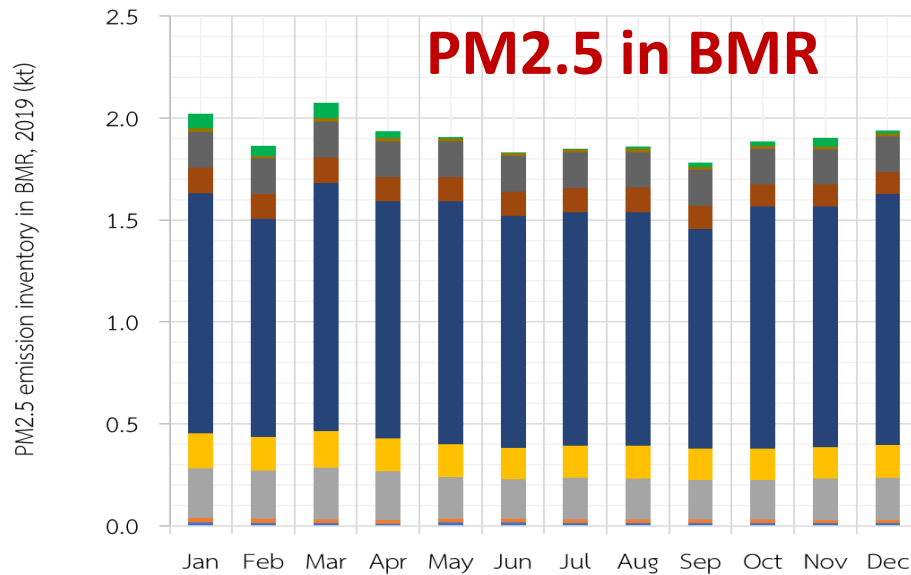
Summary and Future Work

➤ **Biomass open burning emission inventory was developed in Thailand since observations indicated that this source contributes significantly to air quality both at national and regional levels.**

➤ **For national and large region, e.g. GMS, hotspots, burned area, and land use-land cover resulted from satellite data using high resolution remote sensing are sufficient to support the estimation of emission from biomass open burning.**

➤ **For cities or megacities, validation of burned area using ground truthing and questionnaire surveys is required.**

➤ **Contribution of biomass burning is significant for PM10 (46%)>PM2.5 (43%)=OC (43%)>CO (38%)>NMVOC (29%)>BC (21%).**

➤ **Contribution of biomass burning may be the key source of PM for the period of January to April in Thailand, and Central region.**

➤ **Future work:**
  - ➤ **Quantify the contribution of biomass burning emissions in Central on PM2.5 ambient concentration in BMR**
  - ➤ **Monitor changes in emissions from biomass burning during the COVID-19 pandemic**

Thank You for Your Kind Attention

ขอบคุณค่ะ

Application of emission inventory to air quality simulation

Satoru Chatani

National Institute for Environmental Studies

国立研究開発法人
国立環境研究所
National Institute for Environmental Studies

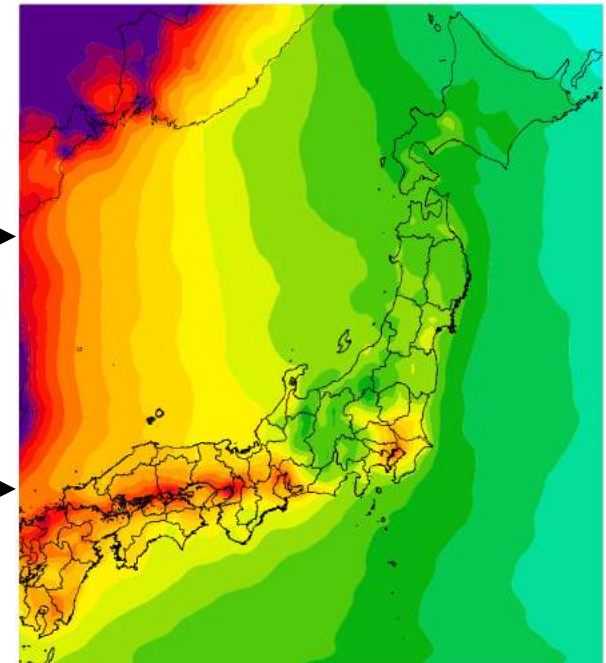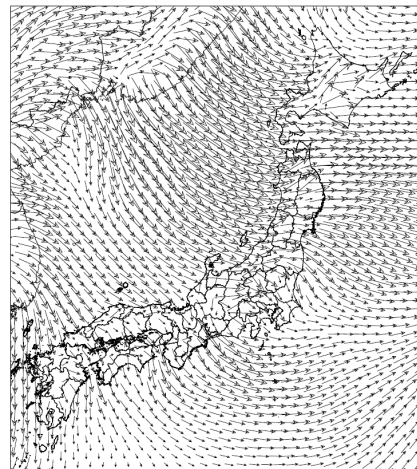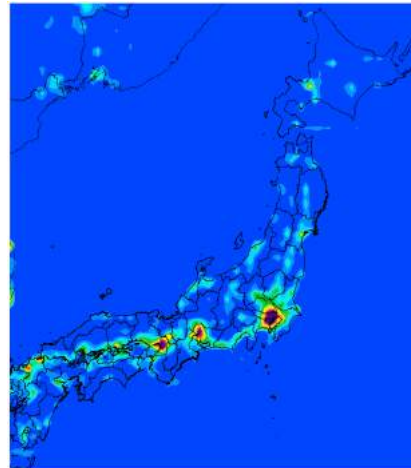# 3-D regional air quality simulation

☐ 3-D regional air quality simulation is useful to develop effective strategies for improving air quality.

Emission inventory

Compile amount of pollutants and precursors emitted from all sources.
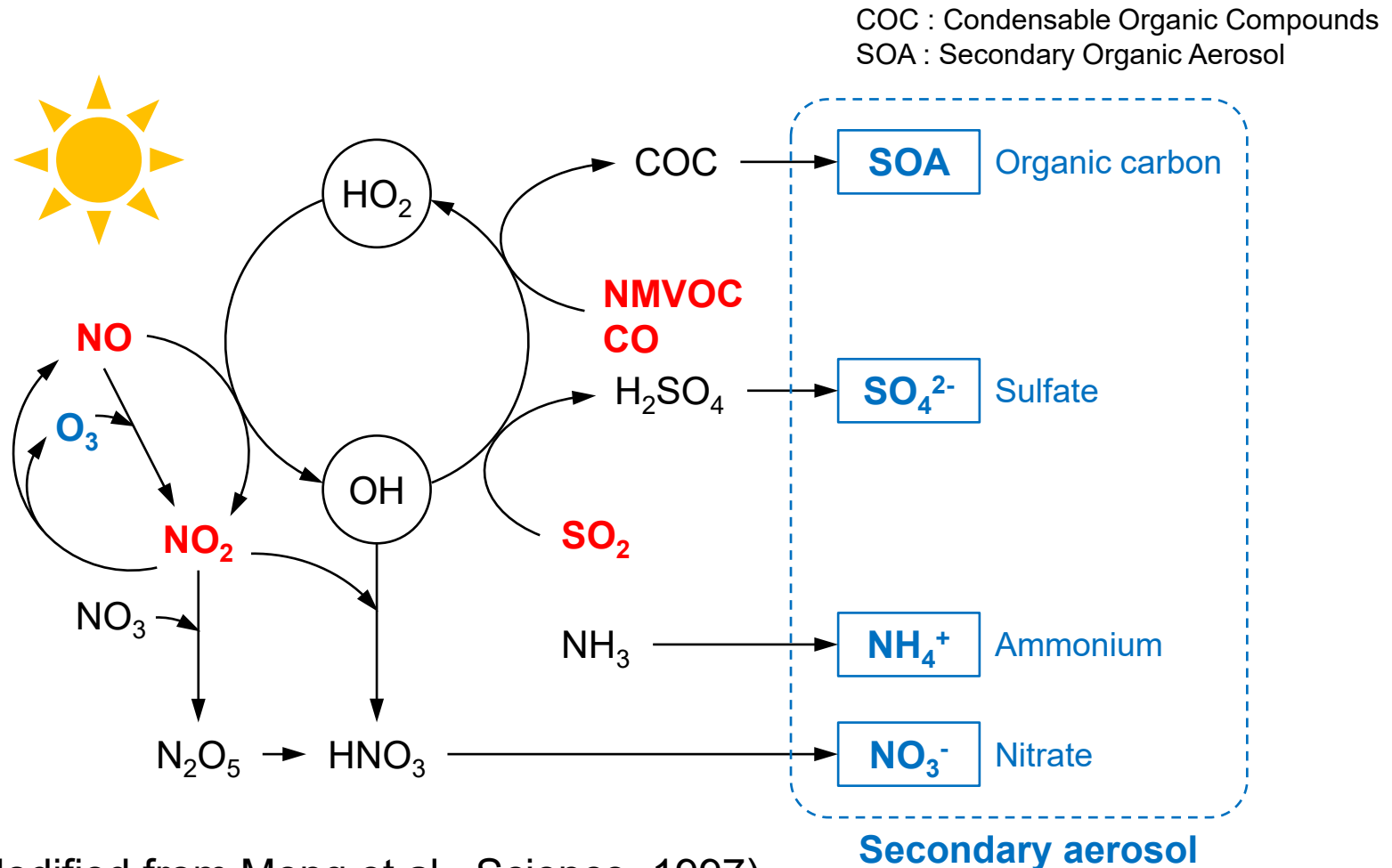
Regional meteorological model

Simulate temporal variation of meteorological fields.

Regional chemical transport model

Simulate temporal variation of pollutant concentrations.

Photochemical reaction cycle

COC : Condensable Organic Compounds
SOA : Secondary Organic Aerosol

(Modified from Meng et al., Science, 1997)

☐ Secondary pollutants are formed in the atmosphere via complex photochemical reactions.

Nonlinear relationships

□ Regional air quality simulations are required to represent nonlinear relationships between secondary pollutants and precursor emissions caused by complex photochemical cycles.
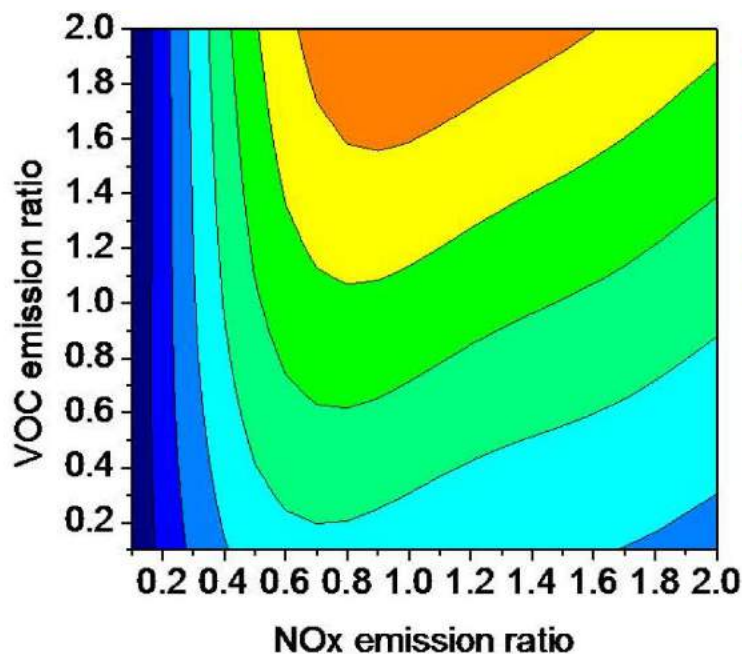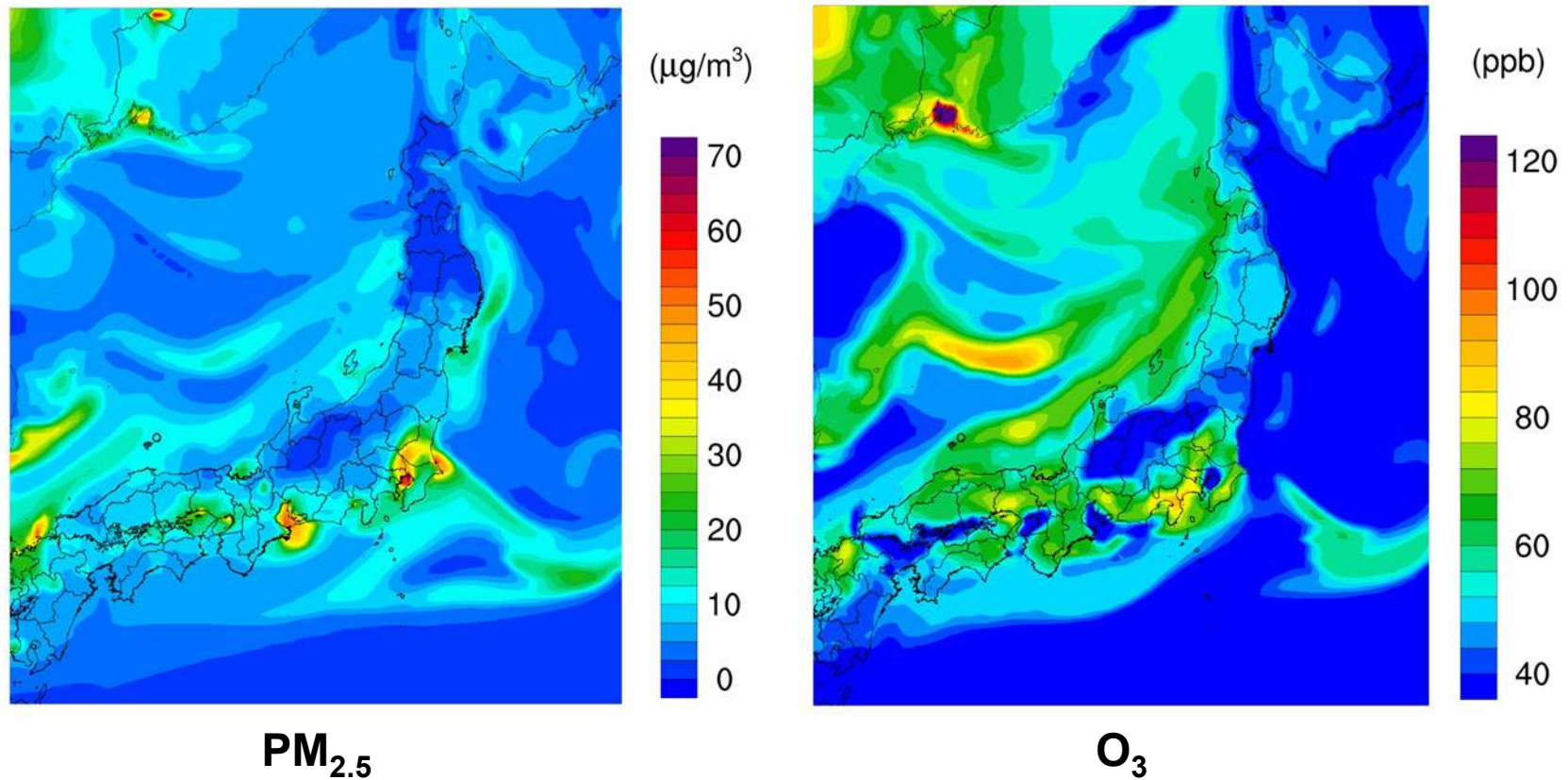

O$_3$ against NOx and VOC
(Xing et al., 2011)
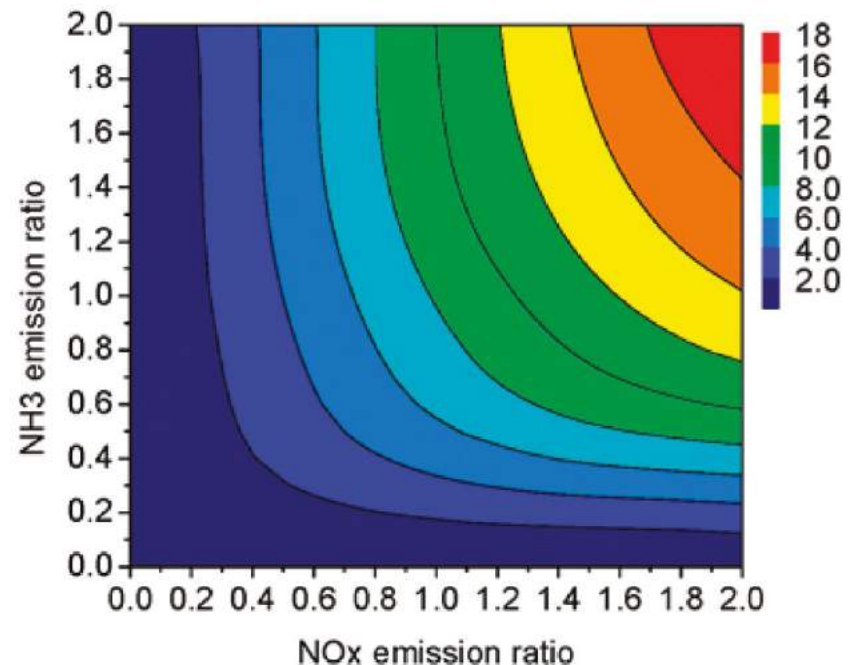
NO$_3^-$ against NO$_x$ and NH$_3$
(Wang et al., 2011)

Examples of simulated concentrations
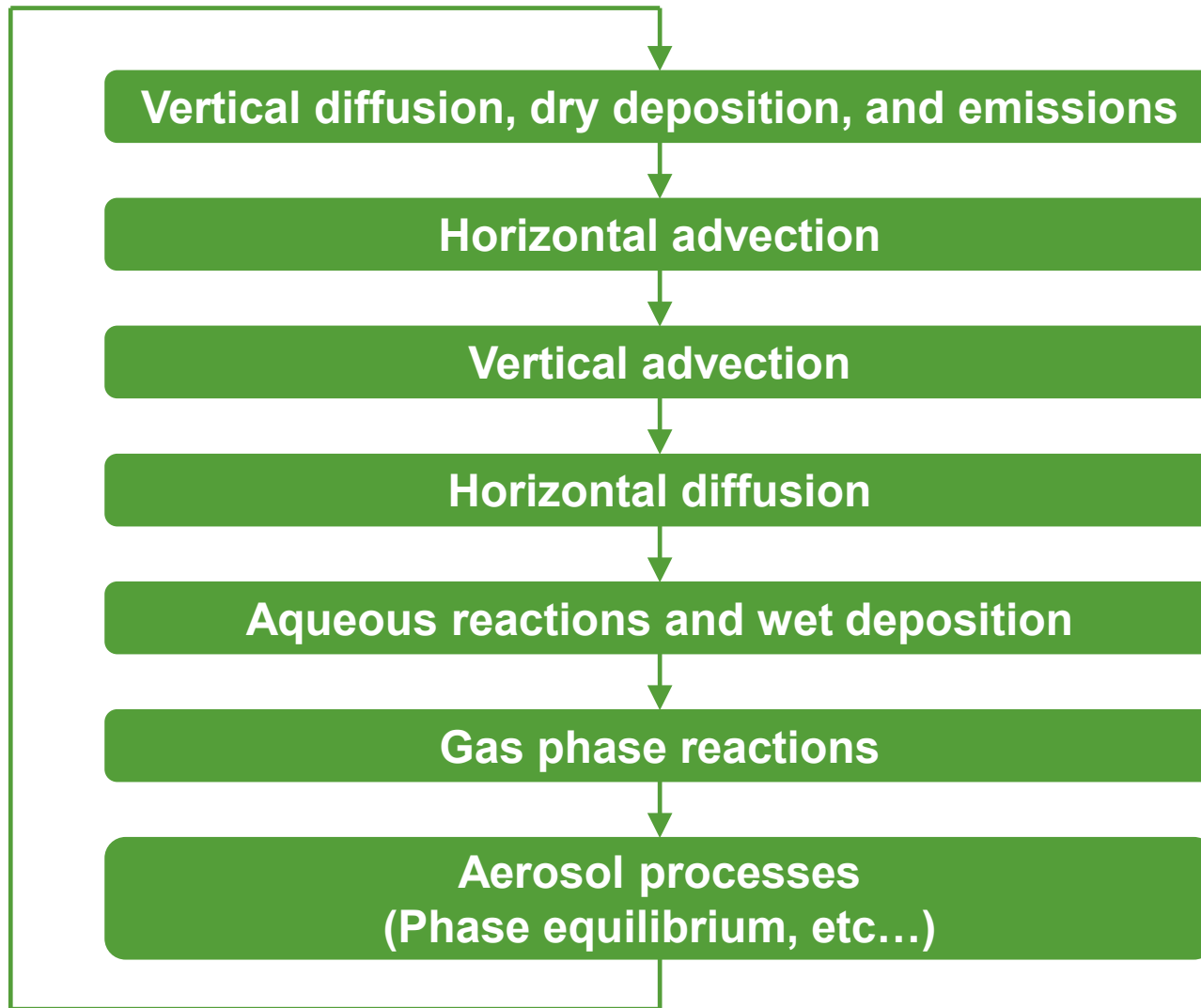
(July 25-29, 2012)

PM$_{2.5}$

O$_3$

Examples of applications

- Identify key process and sources for ambient pollutant concentrations.

- Evaluate source sensitivities of ambient pollutant concentrations to emissions.

- Predict future ambient pollutant concentrations based on emission scenarios.

- **Identify key process and sources for ambient pollutant concentrations.**

- Evaluate source sensitivities of ambient pollutant concentrations to emissions.

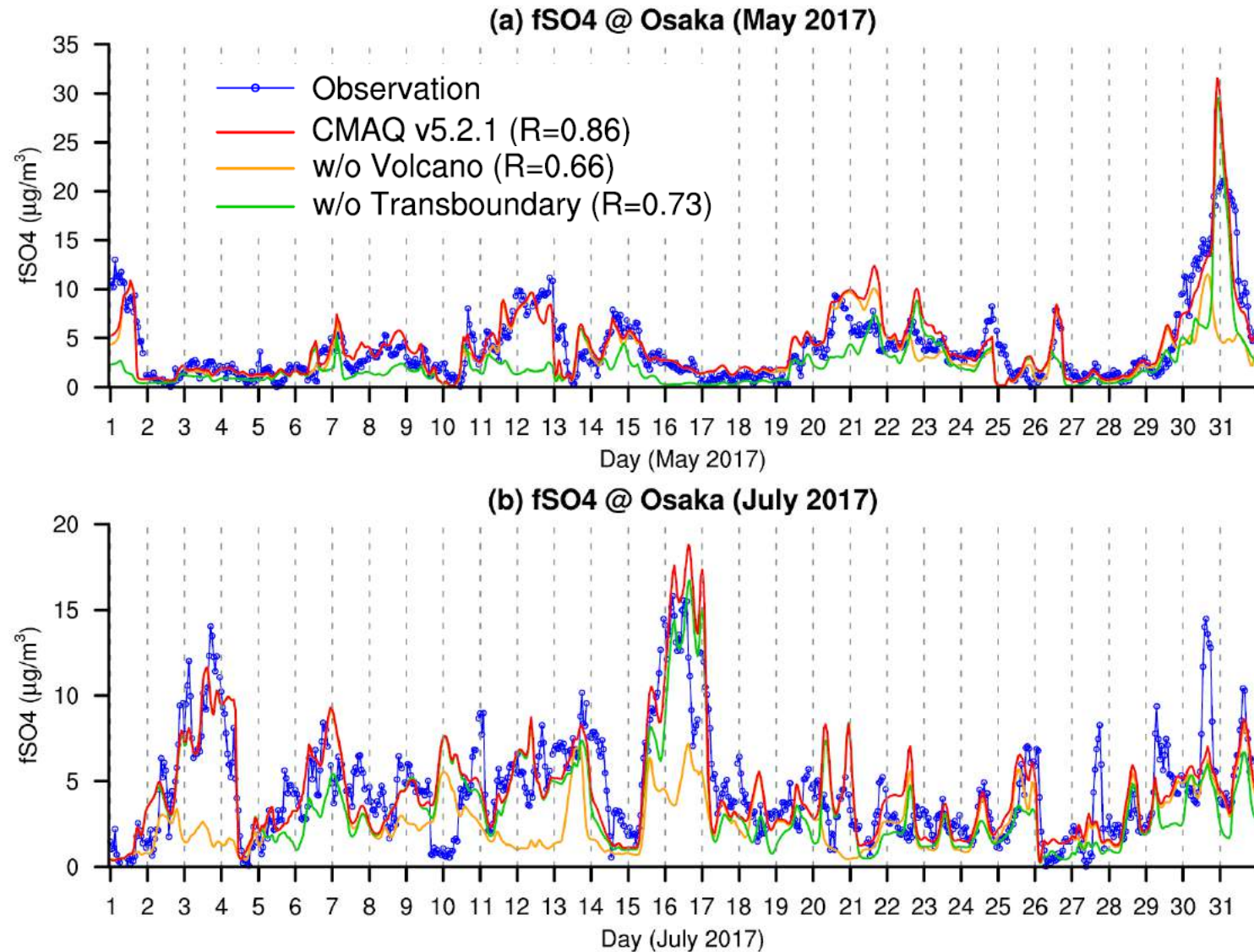- Predict future ambient pollutant concentrations based on emission scenarios.

Flow to simulate in models

☐ Influence of each process can be evaluated.

```
┌──────────────────────────────────────────────┐
│                    ↓                           │
│   Vertical diffusion, dry deposition, and      │
│                  emissions                     │
│                    ↓                           │
│            Horizontal advection                │
│                    ↓                           │
│             Vertical advection                 │
│                    ↓                           │
│            Horizontal diffusion                │
│                    ↓                           │
│     Aqueous reactions and wet deposition       │
│                    ↓                           │
│             Gas phase reactions                │
│                    ↓                           │
│             Aerosol processes                  │
│          (Phase equilibrium, etc…)             │
└──────────────────────────────────────────────┘
```

Influences on SO$_4^{2-}$ concentrations

(a) fSO4 @ Osaka (May 2017)

Observation
CMAQ v5.2.1 (R=0.86)
w/o Volcano (R=0.66)
w/o Transboundary (R=0.73)

fSO4 (µg/m³)

Day (May 2017)

(b) fSO4 @ Osaka (July 2017)

fSO4 (µg/m³)

Day (July 2017)

- Identify key process and sources for ambient pollutant concentrations.

- **Evaluate source sensitivities of ambient pollutant concentrations to emissions.**

- Predict future ambient pollutant concentrations based on emission scenarios.

Method to calculate source sensitivities

All emissions	→	Model	→	Concentration	↖
-20% emissions	→	Model	→	Concentration	↙

Source sensitivity
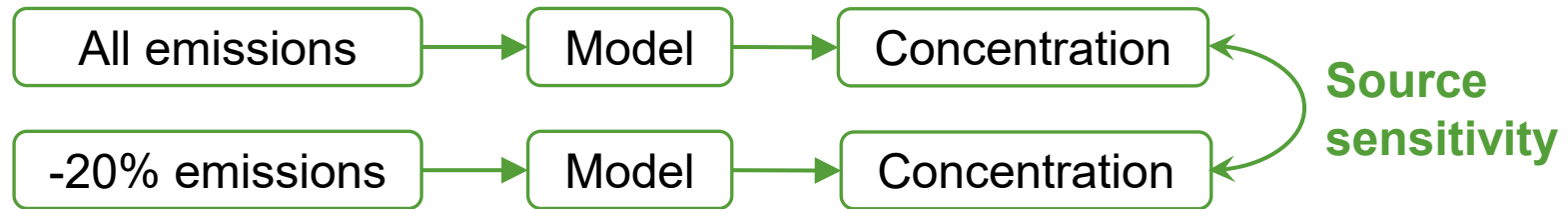
Group	Sector
s01	On-road vehicles
s02	Ships
s03	Non-road transport (machineries, railways, and airplanes)
s04	Stationary combustion (power plants, industries, and commercial)
s05	Biomass combustion (smoking, cooking, and agricultural residue burning)
s06	Residential
s07	Fugitive volatile organic compounds
s08	Agriculture (except for residue burning) and fugitive ammonia
s09	Natural (volcanoes, and biogenic)
s10	Other countries in d02
s11	Transport through boundaries of d02
s12	Sea salt

Source sensitivities of O$_3$ and PM$_{2.5}$

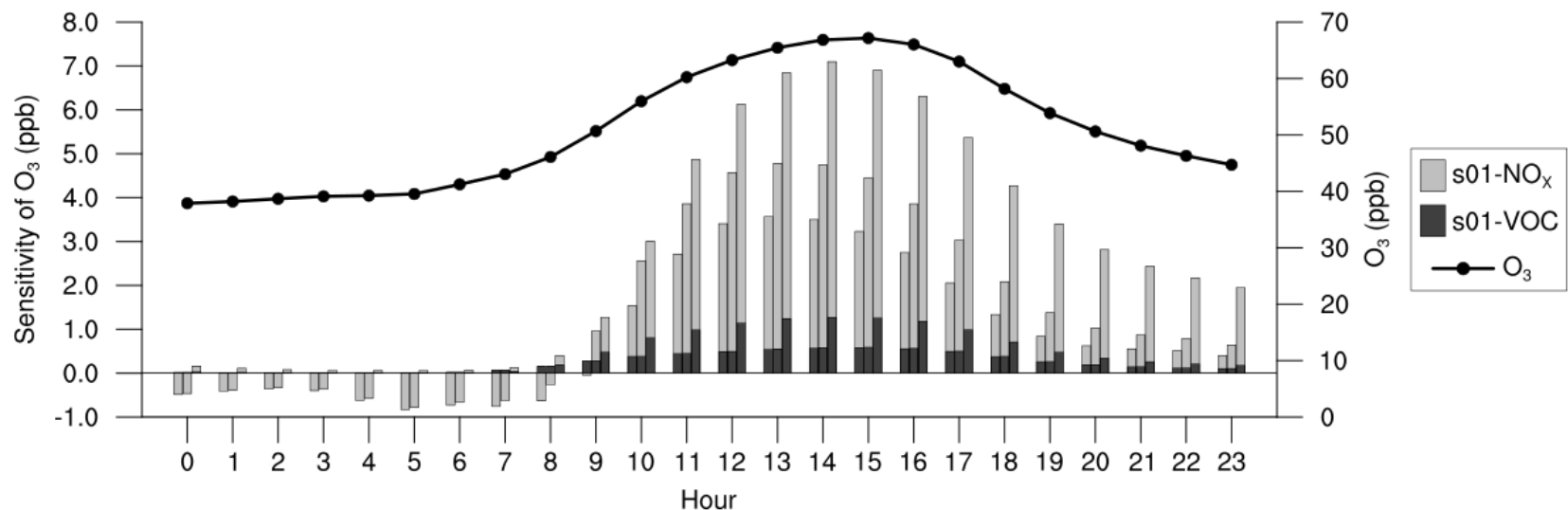□ Key emission sources affecting pollutant concentrations can be evaluated.
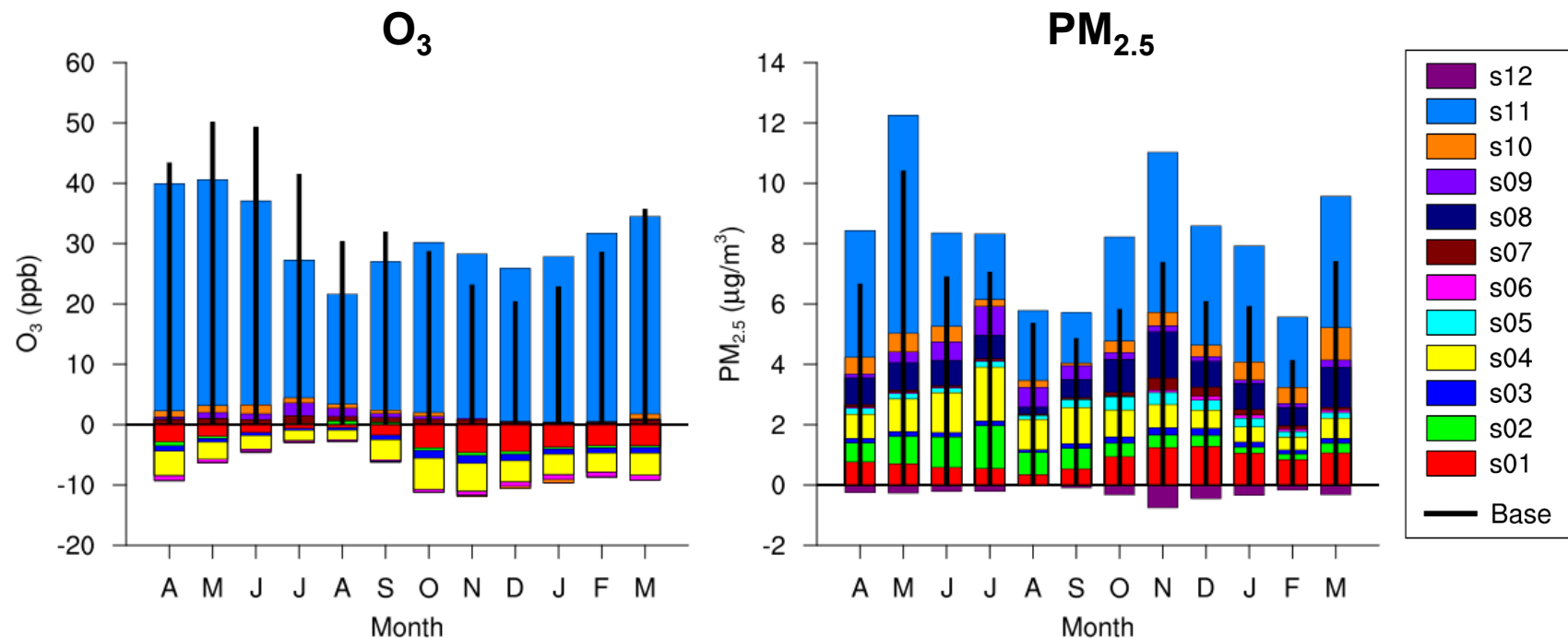
Simulated source sensitivities of monthly concentrations in Tokyo metropolitan area

(Chatani et al., 2020)

Source sensitivities of hourly O$_3$

- ☐ Dynamic variations in source sensitivities of hourly O$_3$ are evident.

Simulated source sensitivities of hourly O$_3$ concentrations in Tokyo metropolitan area

□ Identify key process and sources for ambient pollutant concentrations.

□ Evaluate source sensitivities of ambient pollutant concentrations to emissions.

□ **Predict future ambient pollutant concentrations based on emission scenarios.**

Assumptions of future scenarios

☐ Evaluate effects of possible future energy policies and environmental policies separately.

	Energy	Environment
BAU0	Future growth Existing policies	Future growth Existing policies
PC0	Additional energy policies	↑
PC1	↑	Additional environmental policies

(Chatani et al., 2014)

Future emissions in scenarios
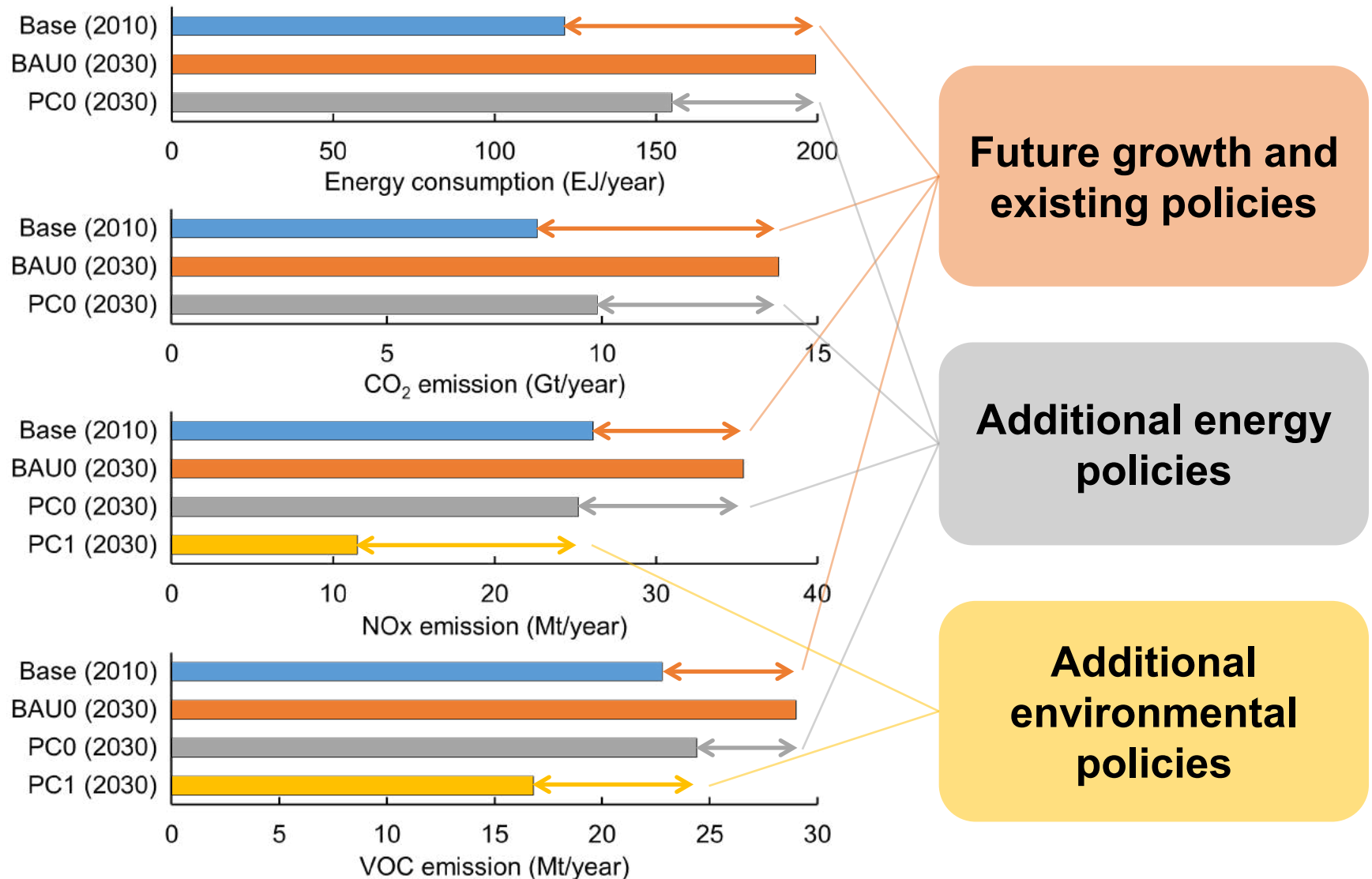
Energy consumption and emission in China

(Chatani et al., 2014)

Simulated future O$_3$ concentrations

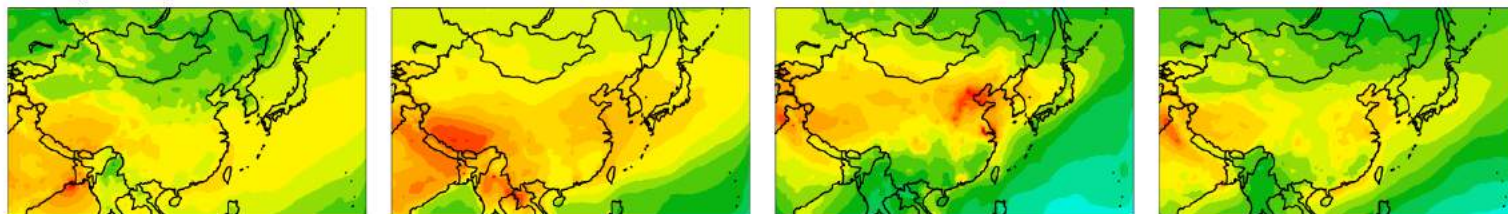- Additional energy and environmental policies are effective to reduce O$_3$ concentrations over East Asia.
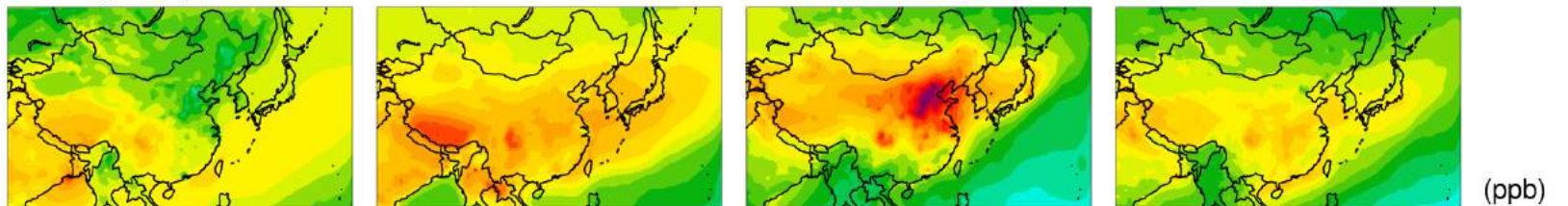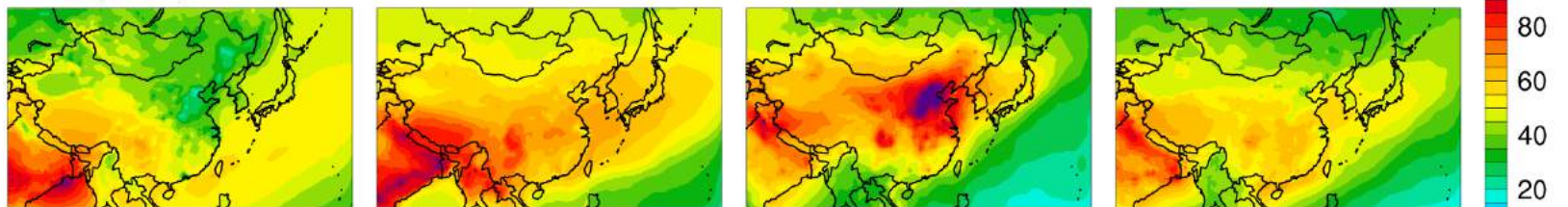
(Chatani et al., 2014)

Conclusion
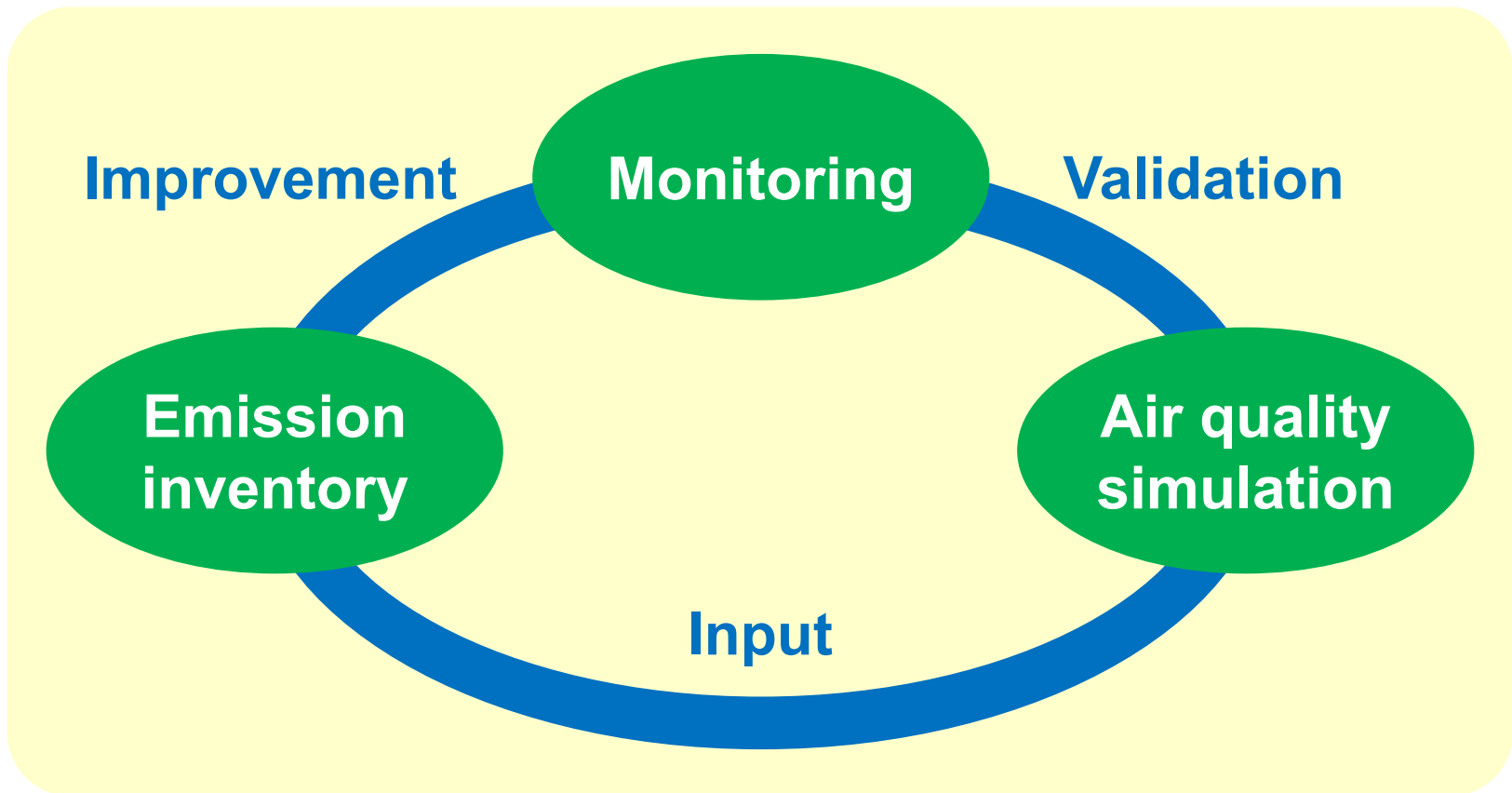
Prevent health damage
Support for effective strategy makings