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Co-benefits of LCS policies and air pollution abatement.

Gakuji KURATA, Chie YANAGI
Kyoto University

Contents

(1) Improvement of the downscaling method of air pollutants emission. (Country level to 1km-mesh)

(2) Implementation of Exposure Model, which can treat an indoor air pollution, in current model framework to estimate health impact.

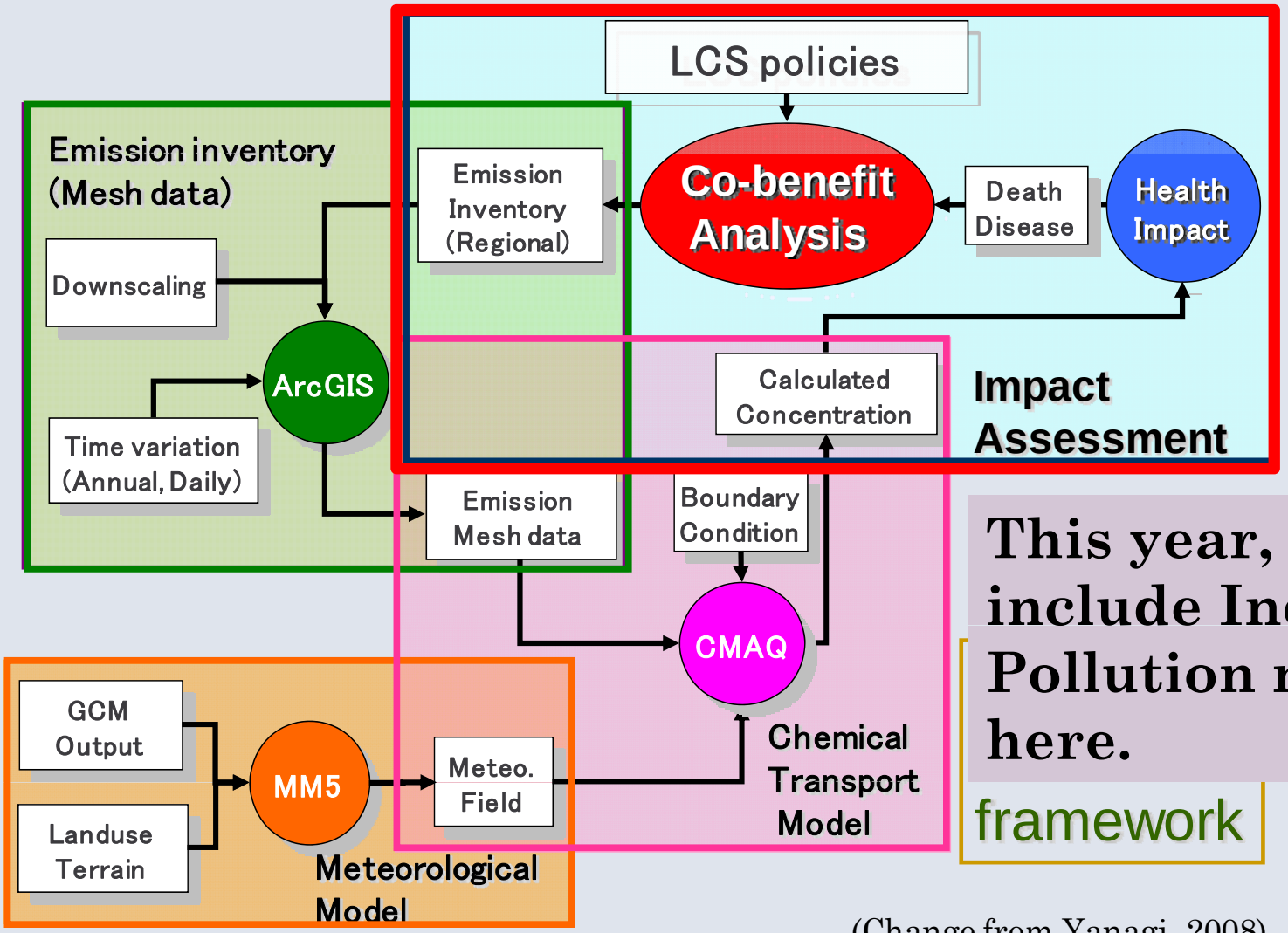
Objective

To evaluate a Co-benefit of LCS policies and air pollution abatement quantitatively.

Background

- Co-benefit is one of the most important factors to implement LCS policies to the developing countries.
- Co-benefits with air pollution abatement is large.
- Air pollution abatement has high priority in developing countries.
- WHO (2000) estimate that indoor air pollution is responsible for 2.8 million deaths per year.
- This is much larger than that from outdoor air pollution.
- (0.2 million deaths)

Model Framework presented at AIM WS, 2009

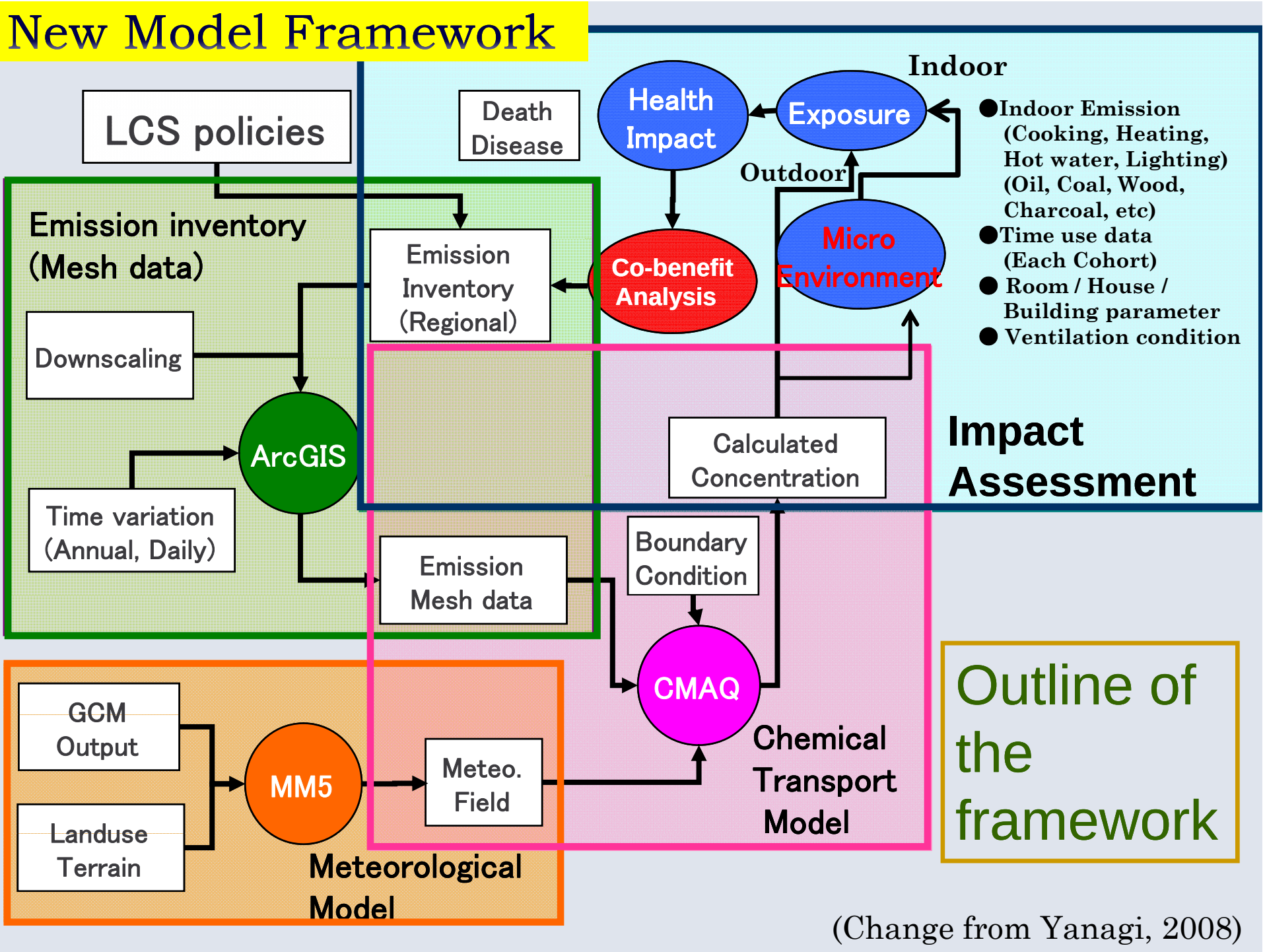


This year, we include Indoor Air Pollution model here.

framework

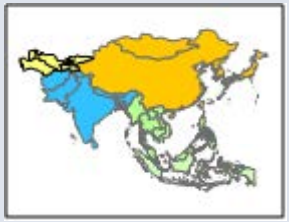
(Change from Yanagi, 2008)

New Model Framework



(Change from Yanagi, 2008)

Downscaling method of air pollutant emission



Country / Sector Energy Consumption

Emission Factor of Air Pollutants

Country Data

Pollutants Emission (Country / Sectoral)

Power Plant

Boundary Database

Local Government Data

Emission of State / Province level

LPS Database

GIS Area and Point (Population / Road / Railways)

Iron / Steel Mill

Downscalled Emission by LPS Data

Downscalled Emission by AREA Data

Road Network

Emission Map

(Nagayama,2009)

Country-level Emission of Air Pollutants

[Anthropogenic]

- For preliminary calculation:
  Country-level emission from EDGAR Fast Track 3.2 (Olivier *et al*., 2005)
  [CO_2 、 CH_4、N_2O、HFC、SF_6、CO 、 NO_x、NMVOC、 SO_2]
  [Biomass fuel, fossil fuel, industrial process, Agriculture]

- For Current Emission:
  IEA, UN energy statistics
  × Emission Factor (each Sector)

- For Current and Future Emission:
  AIM/Enduse energy use and Technology share
  × Emission Factor (each Technology)

not yet implemented

Natural Source

- Volcano SO_2 (Miyake Island) ← Japanese Meteorological Agency
- Volcano SO_2 (Other volcano) ← Streets *et al*.(2003), GEIA etc
- Biogenic VOC and Soil NOx ← GEIA

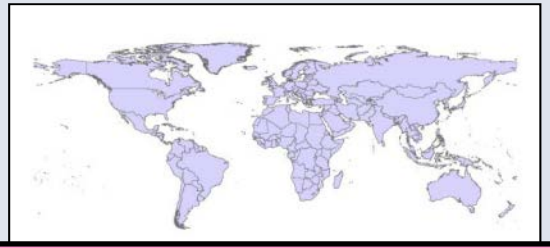
Biomass Burning

- GICC biomass burning inventory (Estimated from Satellite data and Land cover data)

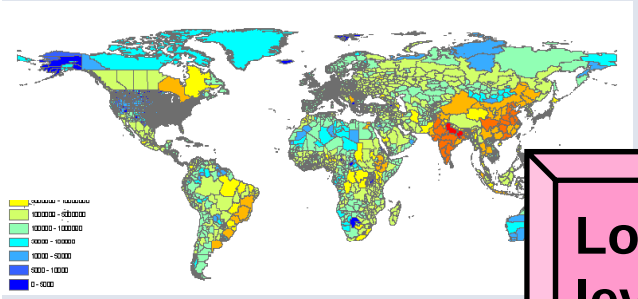
Outline of the Downscaling of Emission inventories

Air Pollutant Emission (Country-level / each Sector)

Industry | **Domestic** | **Transportation** | **Power Generation**



Boundary(polygon)Data

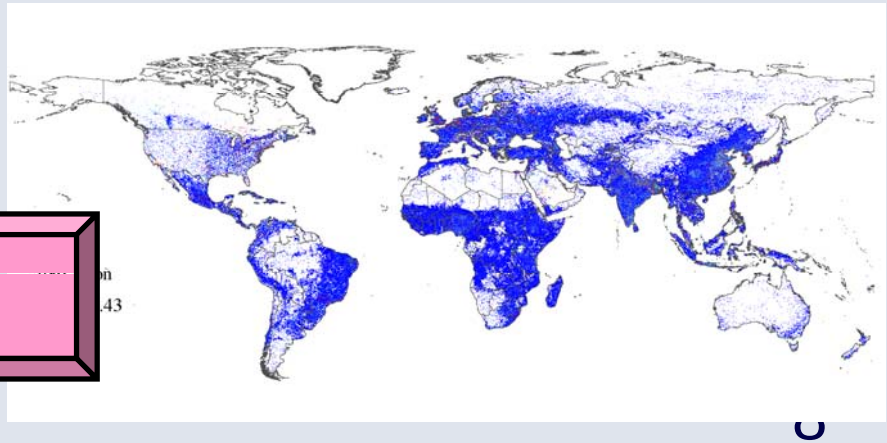


Local administration level emission data

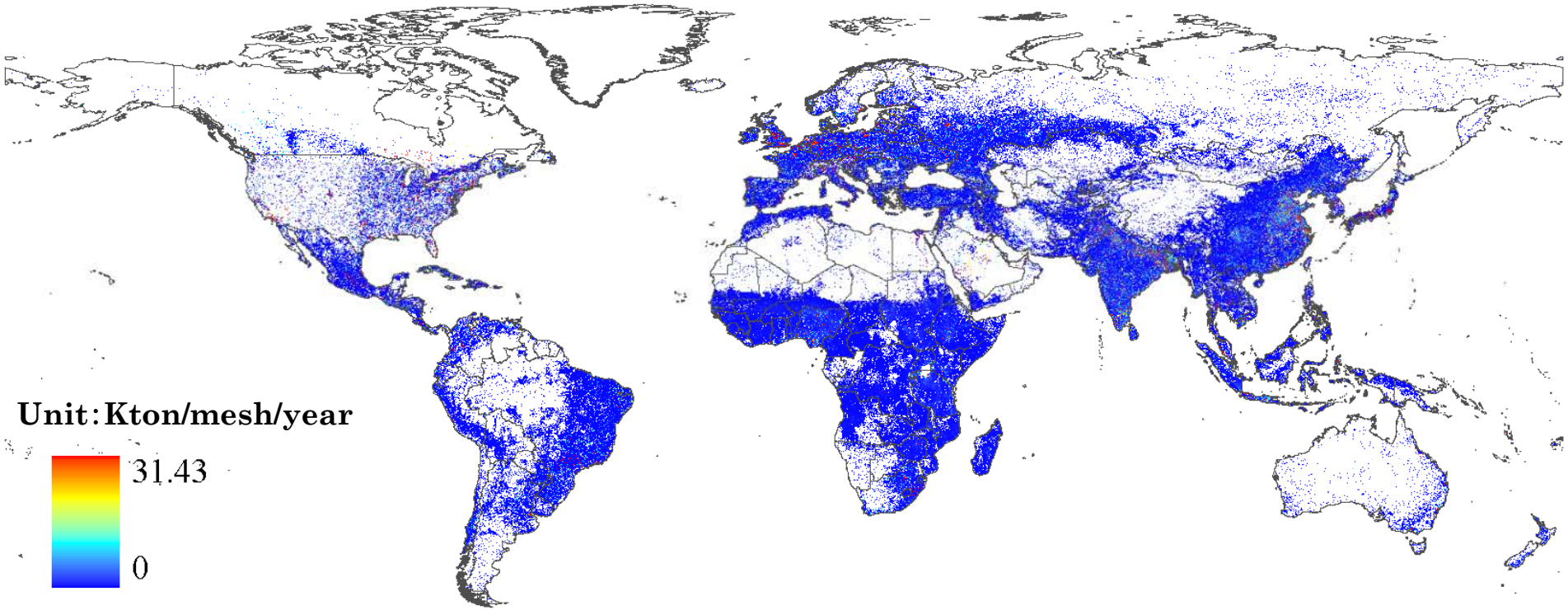
Allocation index for local administrative district level (Population, GRDP)

Population Mesh
Land use Mesh

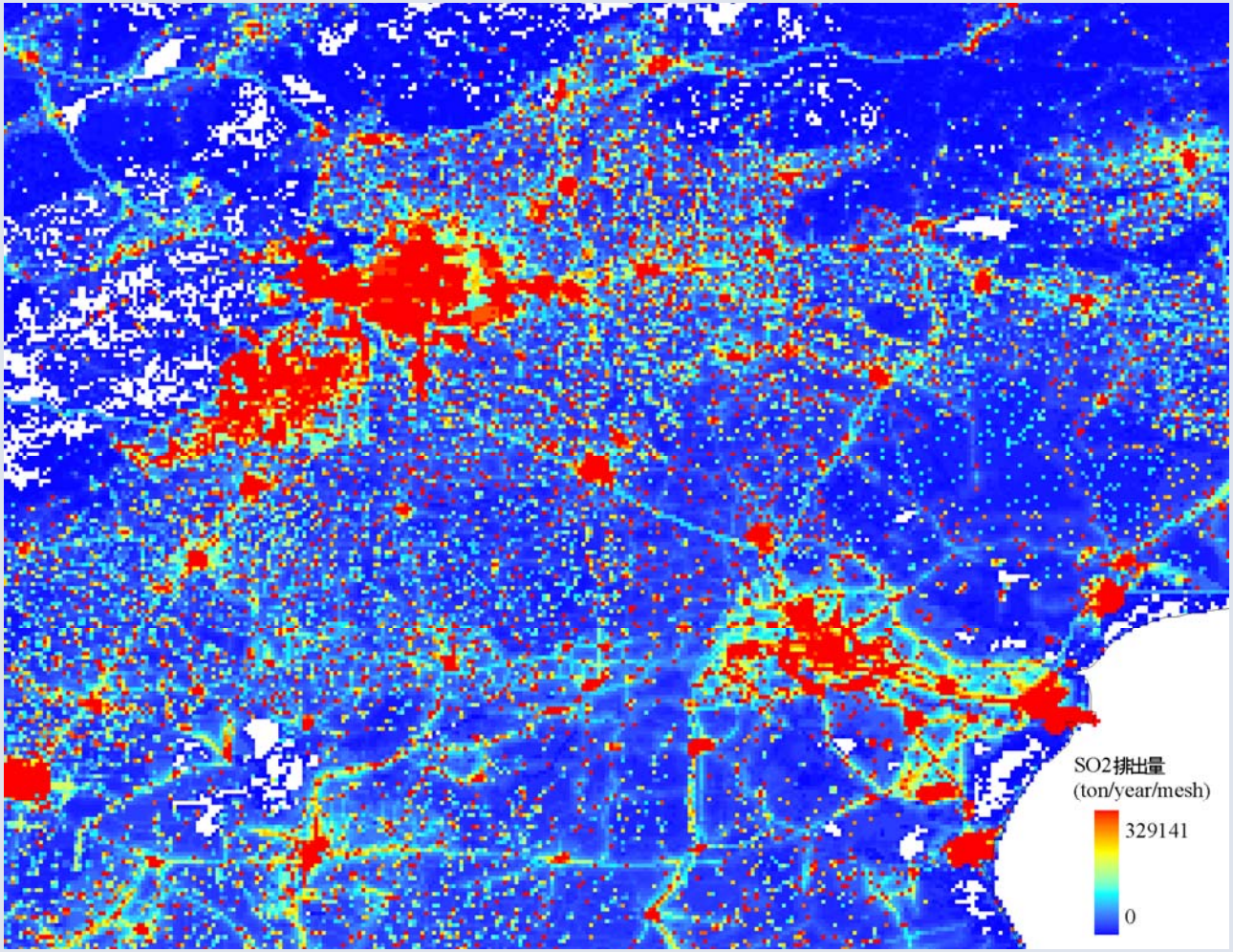
Emission Mesh Data



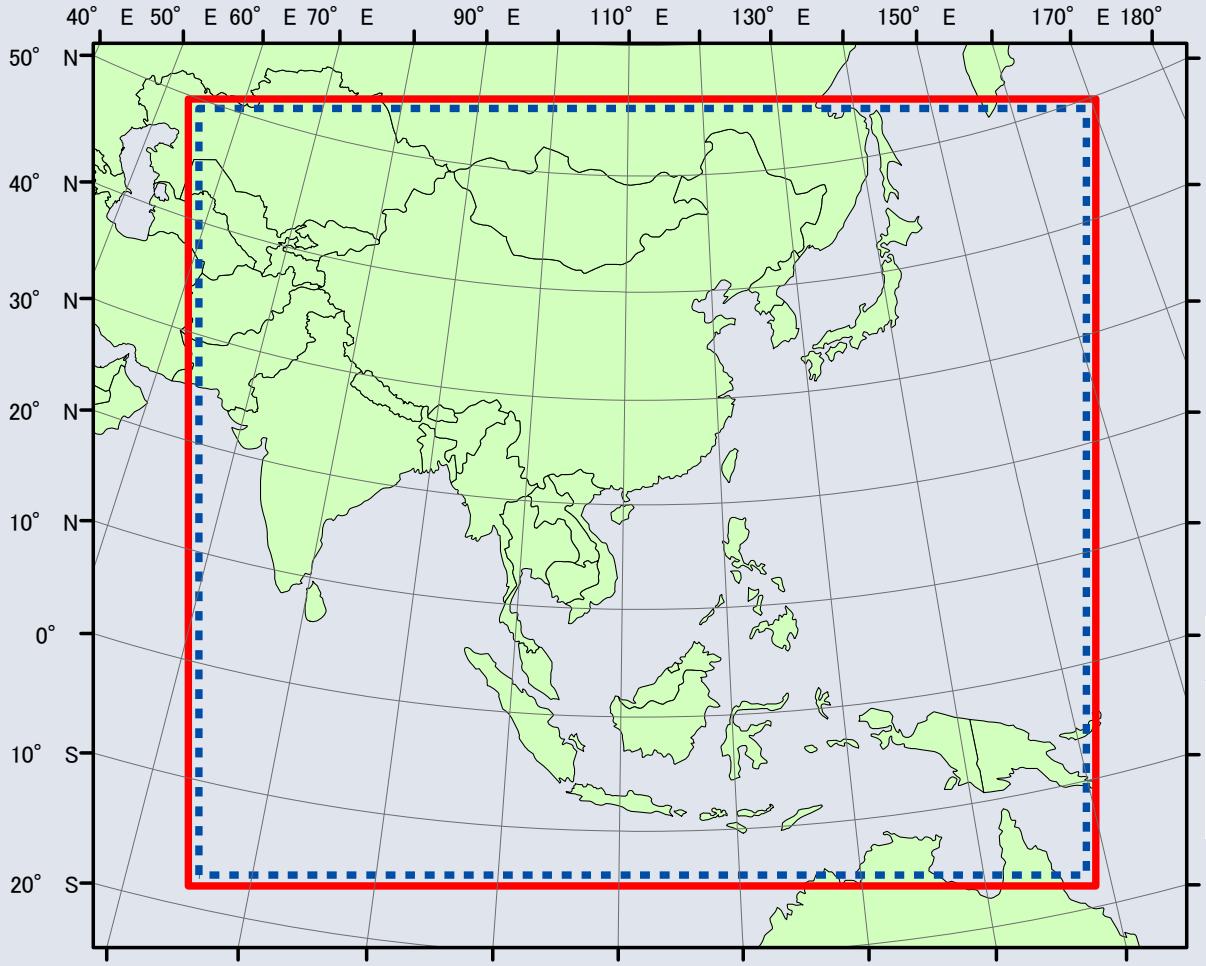
NOx emission (30″×30″)



NOx emission (30″×30″)



Chemical Transport Model



WRF

CMAQ

Target Area

Lambert Conformal
Center:112° E 21° N
Standard latitude :10° , 30°

	WRF	CMAQ
Grid Size	80km	80km
Number of Grids (East-West)	120	117
Number of Grids (North-South)	105	102

Calculation Term

1 Jan 2001 – 31 Dec 2001

WRF
(Weather and Forecasting Model)

- Meso-scale Meteorological Model developed by NCAR and Researchers community.
- WRF ARW(Advanced Research WRF) version 3.1.1
- Input Data
  - Terrain and Landuse data : USGS(U.S. Geological Survey)
  - Initial and Boundary Meteorological Data: JRA-25 (Re-Analysis by JMA)

CMAQ
(Community Multi-scale Air Quality Modeling System)

- Multi scale Chemical Transport Model developed by US EPA
- CMAQ version 4.7
- Input Data
  - Emission Mesh Data
- Chemical Reaction Mechanism
  - Gas Phase: CB05 (51 chemical Species, 156 Reactions)
  - Aerosol : AERO5

Exposure Model

- Developed an Exposure model considering micro environment
- Microenvironment in this study

Micro environment	Place	Source	Definition of Time Use
A	House	Cooking	Cooking Time
B	House	Hot Water	Cooking Time
C	House	Heating	Staying time at home (Except sleeping)
D	House	Lighting	Staying time at home (Except sleeping)
E	Indoor	none	Staying time at Indoor
F	Outdoor	–	Staying time at Outdoor

Cohort	Sex	Age	occupation
1	Man	0	–
2	Man	1–4	–
3	Man	5–9	–
4	Man	15–24	Y
5	Man	15–24	N
6	Man	25–34	Y
7	Man	25–34	N
8	Man	35–64	Y
9	Man	35–64	N
10	Man	65–	Y
11	Man	65–	N
12	Woman	0	–
13	Woman	1–4	–
14	Woman	5–9	–
15	Woman	15–24	Y
16	Woman	15–24	N
17	Woman	25–34	Y
18	Woman	25–34	N
19	Woman	35–64	Y
20	Woman	35–64	N
21	Woman	65–	Y
22	Woman	65–	N

Formulation for Exposure calculation

$$\overline{E^a} = \sum_m C_m \cdot T_m^a$$

$\overline{E^a}$: daily average exposure concentration for Cohort (a) (μg/m^3)

C_m : Pollution concentration in microenvironment (m)) (μg/m^3)

T_m^a : Staying time ratio at microenvironment (m) for Cohort (a) (--)

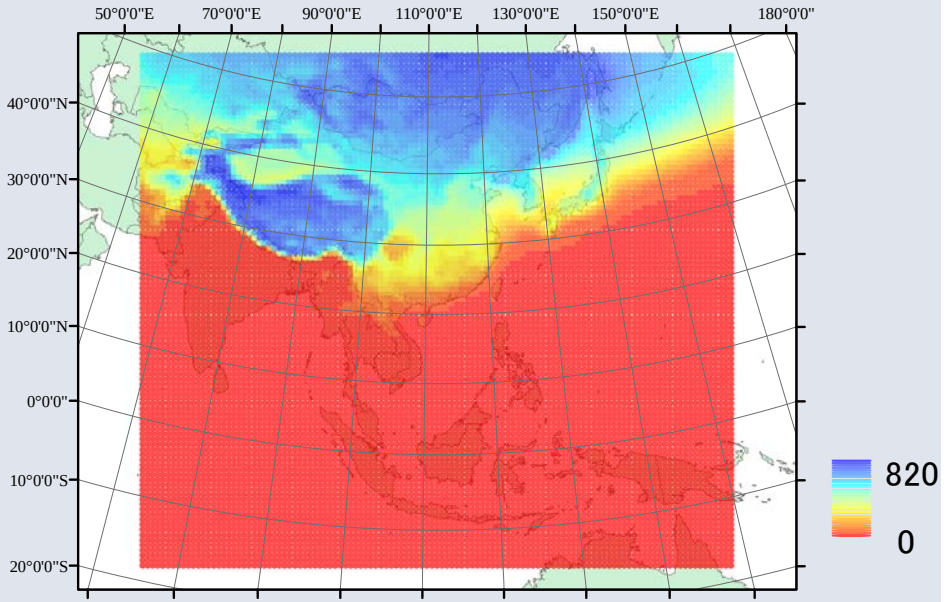
a : Cohort

Input Data to Micro Environment and Exposure Model

- Outdoor Pollutant concentration
  - 1 day average from CMAQ Calculation. (80km x 80km)
    → This may cause underestimate of the contribution of outdoor pollution.
- Emission Factor
  - Cooking and Heating by Gas, Liquid, Solid Fuel, Zhang *et al.*(2001)
  - EF of Biomass (Wood, Charcoal , Crop residue, Dung)
- Time use data
  - Shimada (2010)・・・Made from time-budget survey of each country and Calibrated by Cross Entropy method
- Volume of Microenvironment
  Average room size calculated by floor area and number of rooms of each country.
- Deposition rate, Penetration rate
  - from previous research.

Input Data to Exposure Model

- Energy consumption for household
  - Kanamori (2010)
    (each Household activity : Cooking, Heating, Hot water Supply, Lighting)
    (each Energy source: Coal, Oil, Natural Gag, Wood, Crop Residu
    For Heating …. Heating degree-day was used to estimate daily consumption.
- Air Exchange Rate
  - considering Heating degree-day and Existence of combustion source
- Heating degree-day
  - 10℃ (daily average temperature) was used for threshold for heating



Micro Environment Model

- Single-Compartment Mass Balance Model under steady-state assumption
- Micro Environment A, B, C, D

$$C_m = \frac{Se}{(v + F_d)V}$$

- Micro Environment E

$$C_m = \frac{F_p v}{v + F_d} C_o$$

- Micro Environment F

$$C_m = C_o$$

Micro environment	Place	Source	Definition of Time Use
A	House	Cooking	Cooking Time
B	House	Hot Water	Cooking Time
C	House	Heating	Staying time at home (Except sleeping)
D	House	Lighting	Staying time at home (Except sleeping)
E	Indoor	none	Staying time at Indoor
F	Outdoor	–	Staying time at Outdoor

C_m : Pollutant concentration at micro environment (m) (μg/m³)

C_o : Pollutant concentration at Outdoor (μg/m³)

F_p : Penetration Factor (-)

v : Air Exchange Rate (1/hr)

F_d : Deposition rate (1/hr)

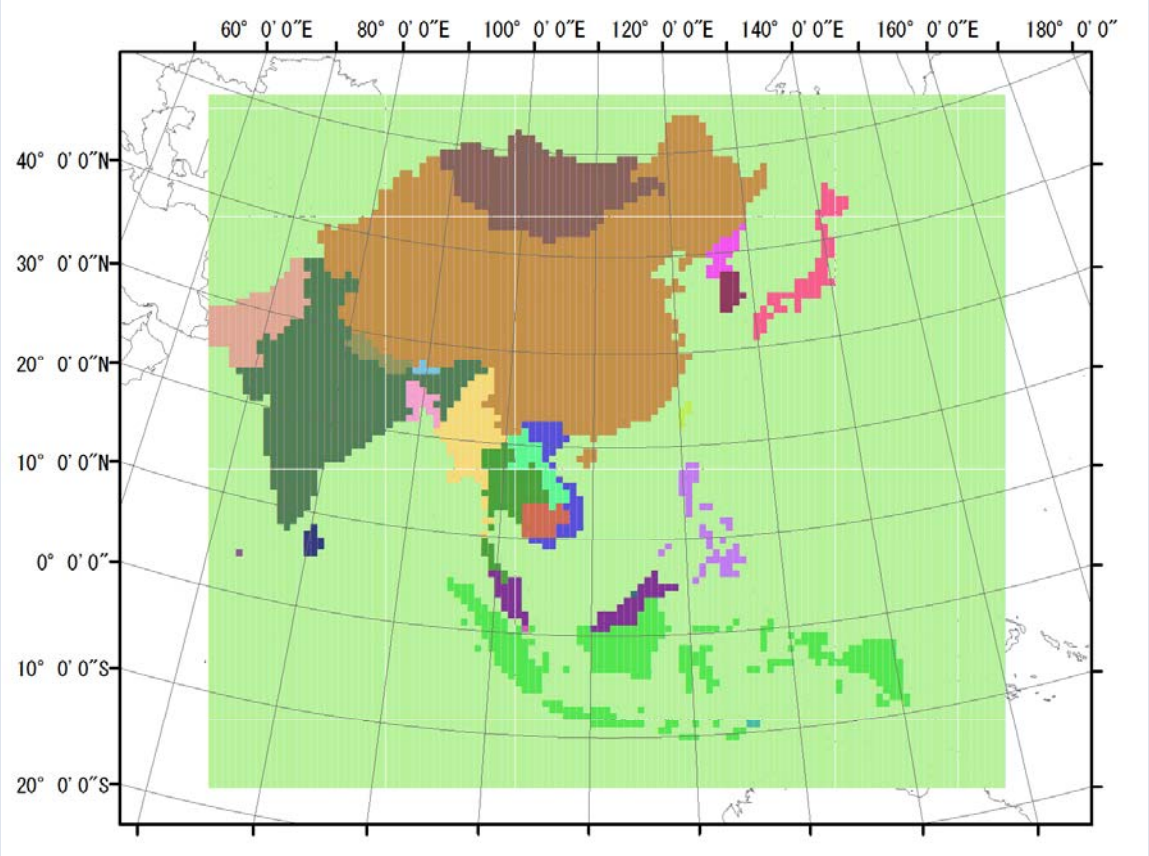
S : Energy consumption (KJ/hr)

e : Emission Factor (μg/KJ)

V : Volume of Micro Environment(m³)

Micro Environment Model and Exposure Model

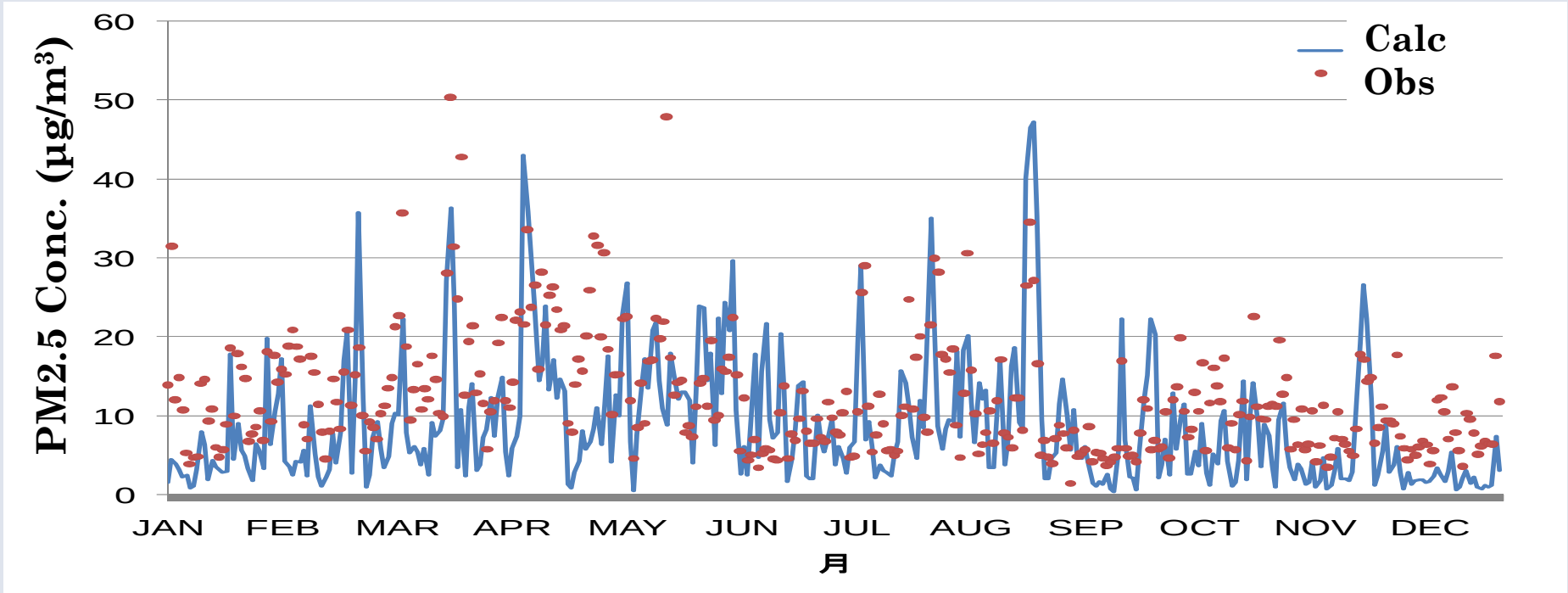
- Target: Asian 24 countries



- Calculation Period
  - 1 Jan 2001
    ～ 31 Dec 2001
- Time Step
  - 1 day
- Target Pollutants
  - $PM_{2.5}$
  - SO_2
  - NO_X
  - CO

Result (1) Chemical Transport Model

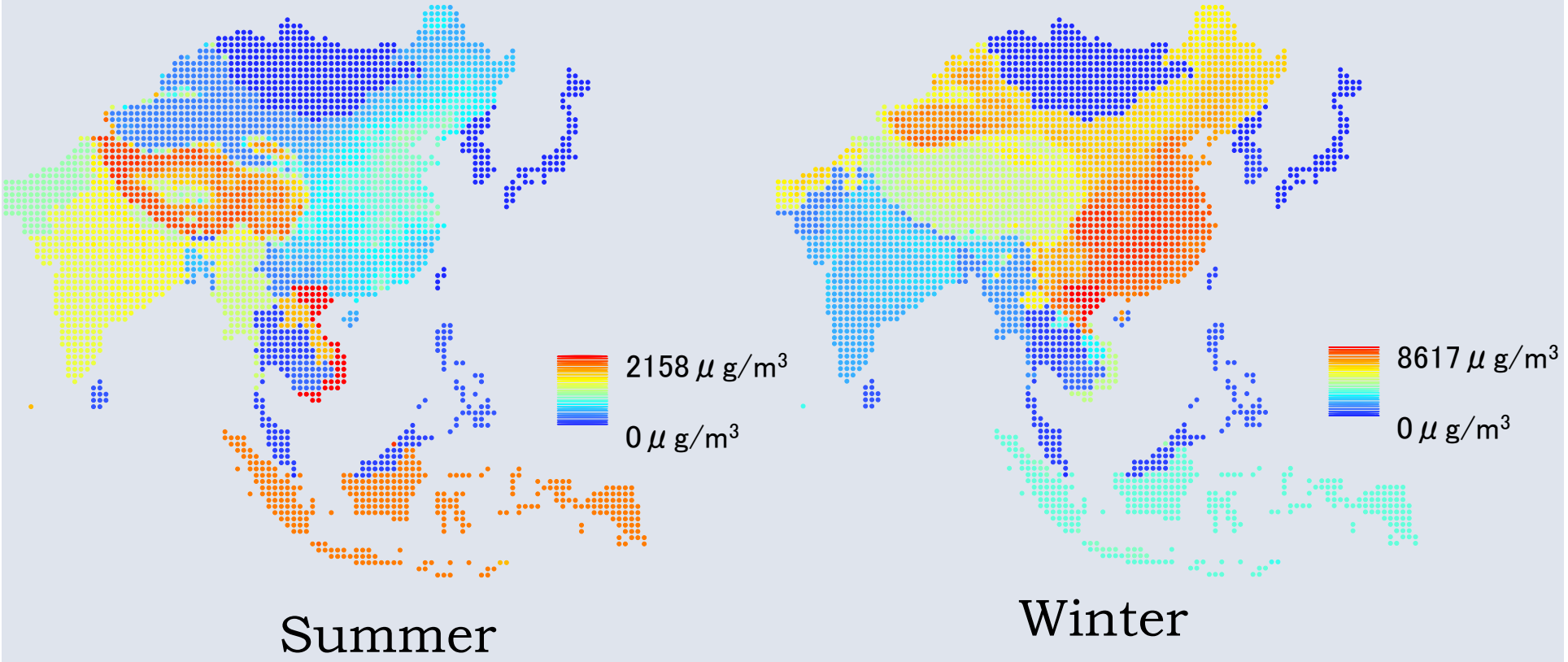
CMAQ vs. EANET Observation (2001)



at OKI Island (JAPAN) [Daily Average]

Result (Exposure Model) preliminary results

- Daily average exposure concentration of $PM_{2.5}$ for all grid, in winter and summer , Female age 35-64, non occupation.



Summer

Winter

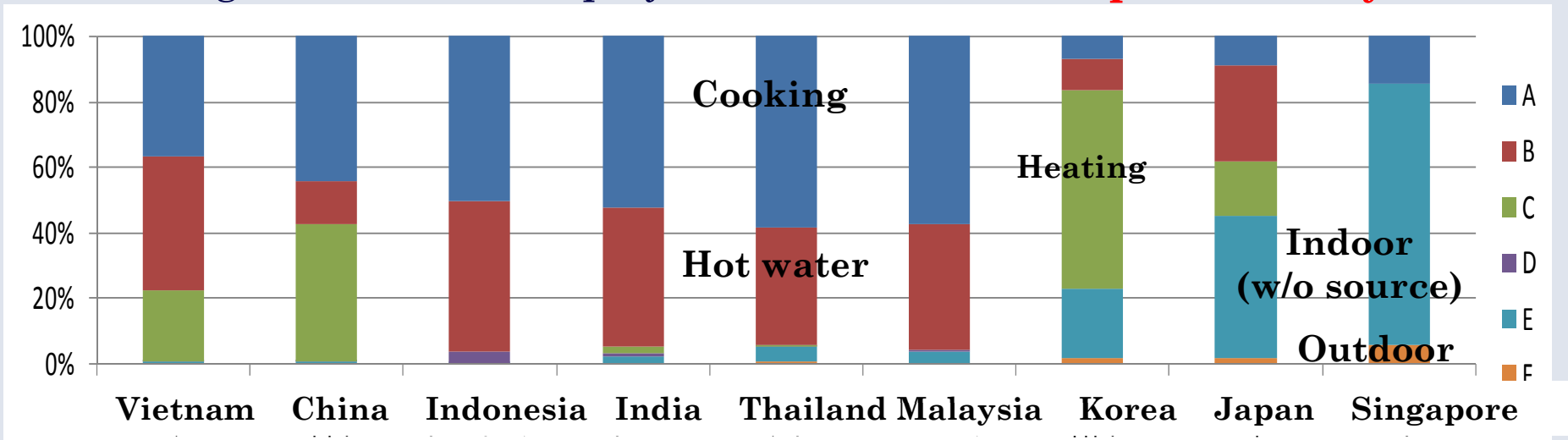
Contribution of Heating is very high in Winter season.

Result (Exposure Model) (Country)

Contribution to Exposure from each microenvironment :

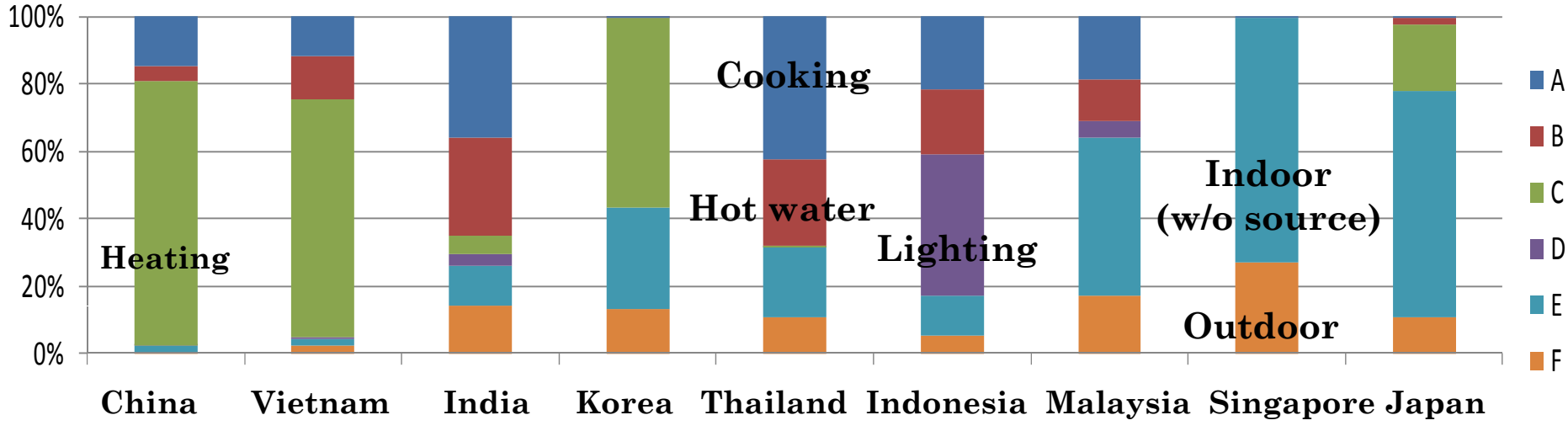
Woman age 35-64 : non-employed.

preliminary results



Man : age 35-64 : employed

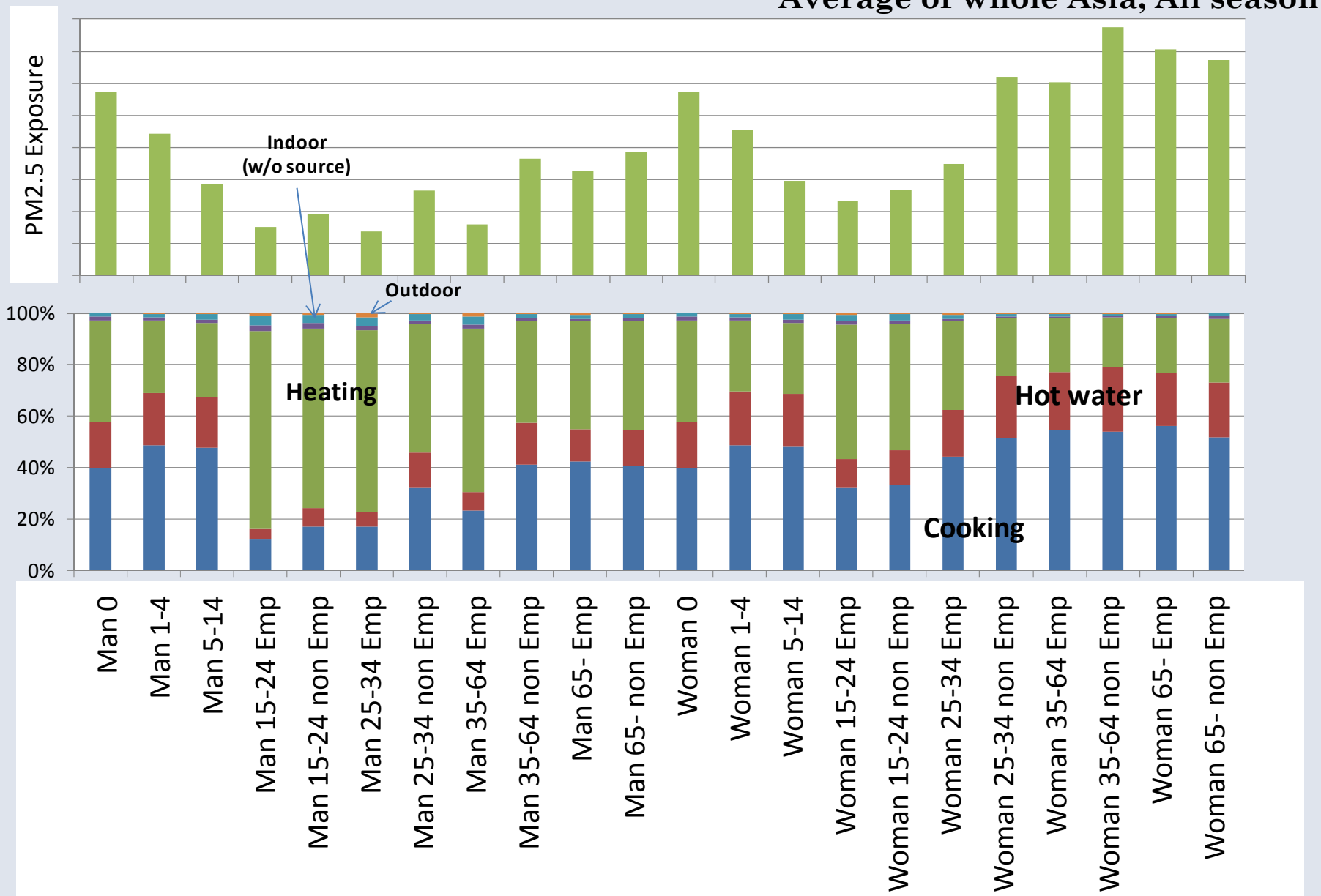
preliminary results



Exposure and contribution of each indoor source to each Cohort

preliminary results

Average of whole Asia, All season



Summary

- We developed the modeling framework to estimate the human exposure from both **indoor** and **outdoor** air pollution, using WRF, CMAQ and Exposure model.
- Concentration of $PM_{2.5}$ was slightly underestimated at remote site. (Oki Island). However, seasonal trend was reproduced.
- We developed the Exposure Model including an indoor air quality and micro environment, and calculated exposure for 15 Asian countries and 22 Cohorts.
- Preliminary results show the large difference of the impact of air pollutants between Countries and Cohorts.
- Indoor air pollution from Cooking and Heating is very large, especially when they use a biomass fuel.
- We can incorporate this model within LCS scenario development process for household sector.

Thank you for your attention