Further Challenge in
Automobile and Fuel Technologies
for Better Air Quality

Air Quality Simulation in Japan Clean Air Program II

October 28, 2005
Japan Petroleum Energy Center

http://www.pecj.or.jp/jcap/

JPEC
Japan Petroleum Energy Center

Content

1 . Outline of JCAP and Air Quality Model Research

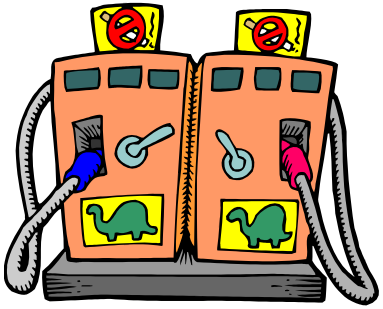
What is JCAP?

Japan Clean Air Program

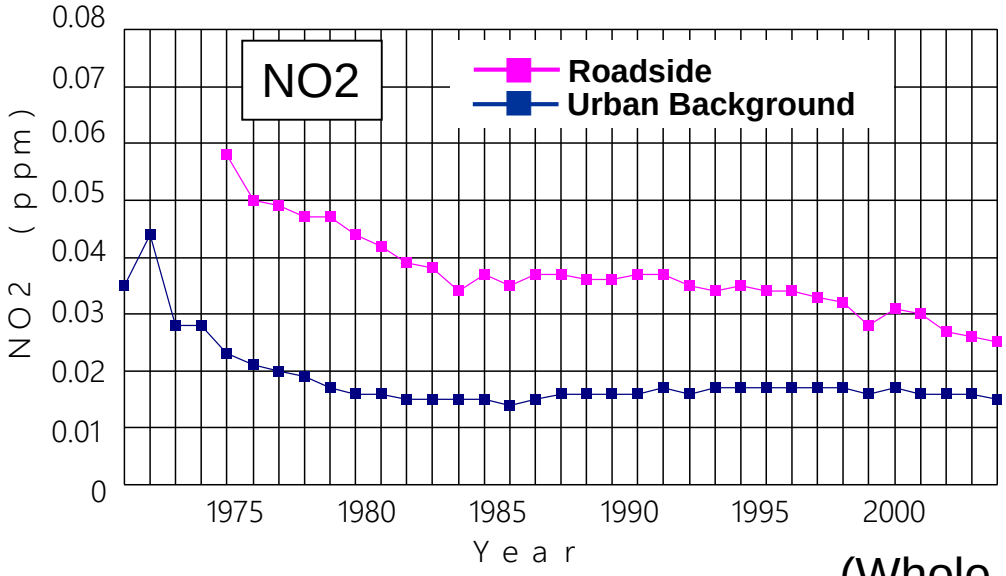
- Collaborative study by automobile and oil industries *to find* the best combination of automobile and fuel technologies to improve the air quality of Japan and *to provide* the government with rational technical data for policy making.
- Supported by Petroleum Energy Center, a subsidy of METI

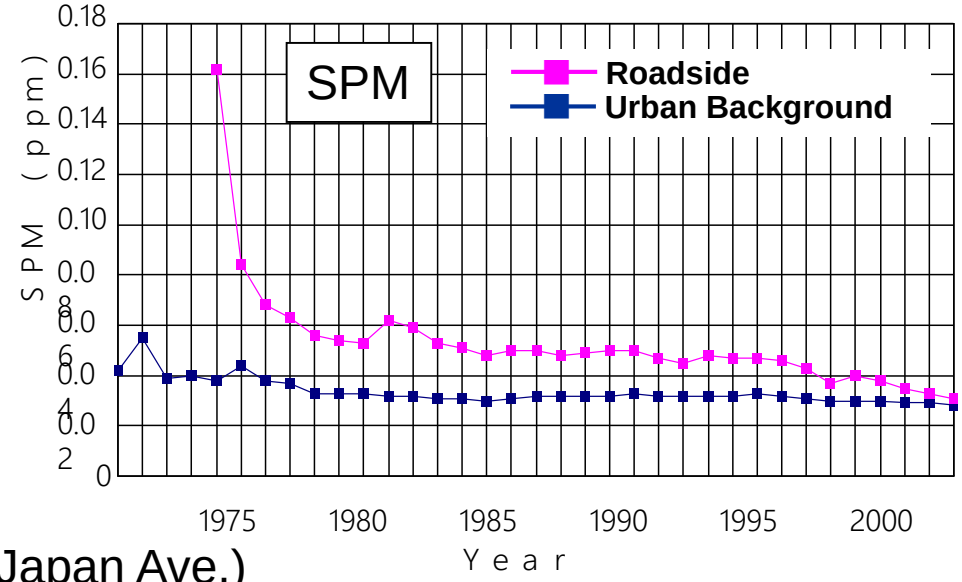
METI: Ministry of Economy, Trade and Industry

- **JCAP I** :1997 – 2001 (Budget: Approx. 5.4 billion yen, Numbers of staffs: over 100 members)
- **JCAP II**: 2002 – 2006 (Budget : Approx. 5.6 billion yen, Numbers of staffs: about 130 members)



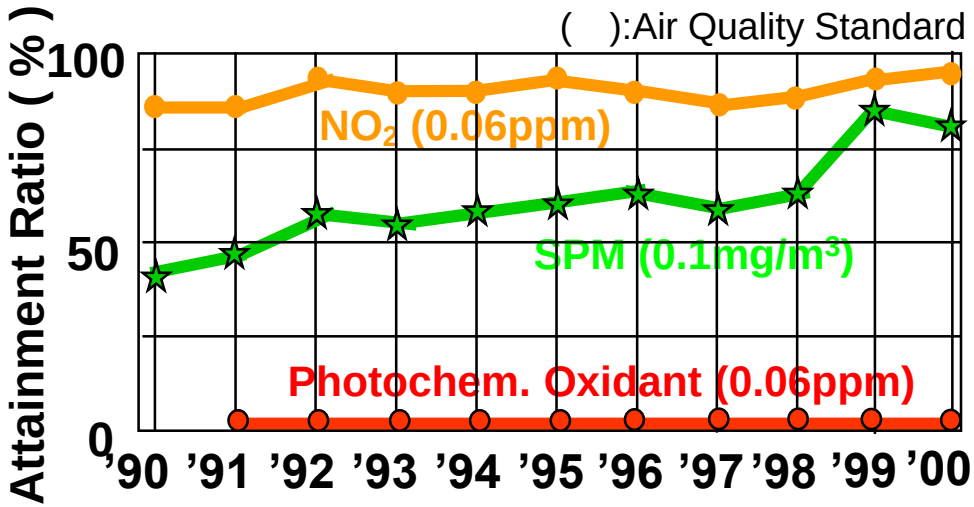
Motivation of JCAP -1-





(Whole Japan Ave.)

Air Quality:
-Not improved in early 1990's
-Attainment Ratio was poor at Urban Area

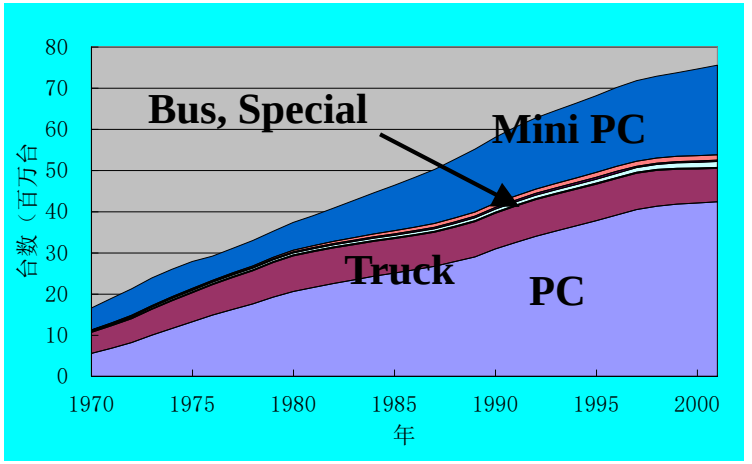


Motivation of JCAP -2-

Emission/Vehicle Reduction vs. Emission Inventory Increase

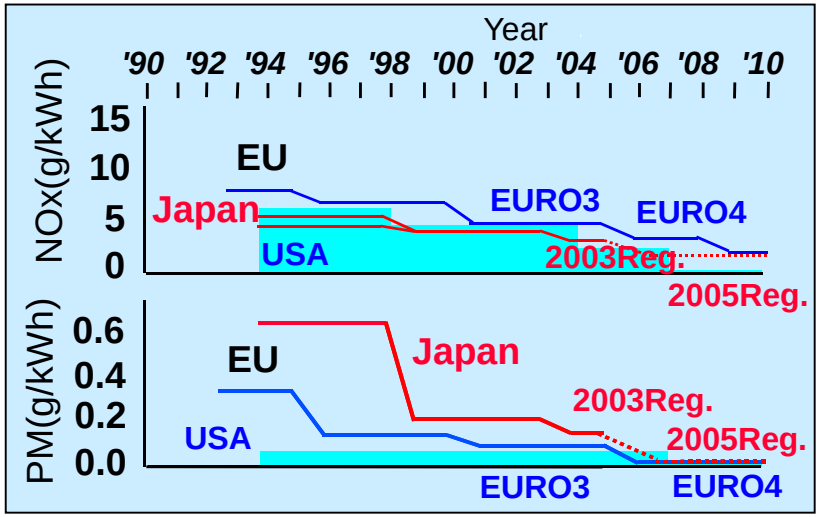
⇒ No. of Vehicles increase

⇒ Diesel Increase RV, Fuel Cost, etc.



Stringent Emission Regulation introduction

- -1989 Reg. Diesel NOx
- -1994 Reg. Diesel NOx
- -1998 Reg. Diesel NOx and PM
- -2003 Reg. (Under discussion)
- -2005 Reg. (Under discussion)

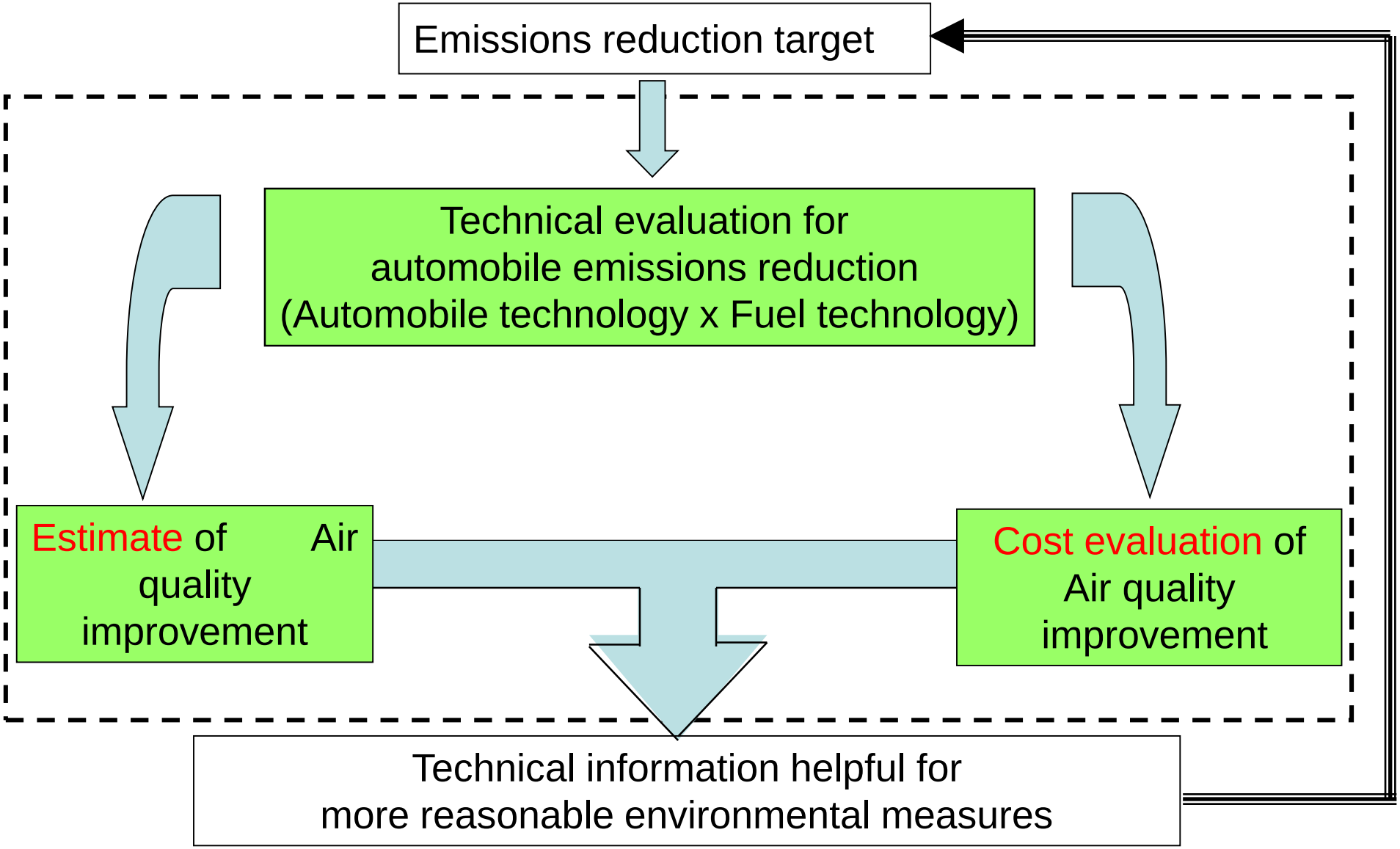


Combine fuel and automobile technology for further emission reduction

⇔

Develop of Air Quality Simulation Model and Evaluate future air quality improvement

Target of JCAP study



Example of JCAP Results Reflection in Environment and Energy Policies

1. Great effect of sulfur content in fuel on exhaust emissions.
   ⇒Reflected in fuel standard:
   50ppm S content; gasoline/diesel fuel from 2005.
   10ppm S content; gasoline/diesel from 2008/2007.

2. Great effect of Reid Vapor Pressure (RVP) of gasoline on evaporative emissions.
   ⇒Reflected in self-imposed control of gasoline RVP.

3. Diesel Particulate Filter (DPF) retrofitted to in-use vehicles is not sufficient, under urban driving conditions.
   ⇒Reflected in preparation of Tokyo Metropolitan Government's diesel vehicle emission regulations.

These are reflected through:

- **Experts Committee on Motor Vehicle Exhaust Emission,**
- **Petroleum Products Quality Sub-committee of Advisory Committee for Natural Resources and Energy,**
- **Evaluation Committee of Diesel vehicle Emission Control Technologies.**

Tasks of JCAP II

1. Pursuing the future automobile and fuel technologies aimed at realizing Zero Emissions and improving fuel consumption, based on the latest technologies and overall energy efficiency.

2. Developing Air Quality models with high accuracy to predict real world.

3. Study of un-regulated emissions and nanoparticles from the vehicles.

JCAP II Study Subject Outline

(1) Automobile and Fuel Technology Study

- Evaluate high technology for gasoline/diesel vehicles aiming at near Zero Emissions and fuel/oil properties
- Evaluate emissions and CO_2 reduction potential
- Examine fine particle measurement method and evaluate high technology through high measurement methods

Key Word: Zero Emissions, CO_2 reduction, Octane Number of Gasoline, Bio fuel, Nanoparticle, Oil properties (Ash, P,S)

(2) Air Quality Model Study

- Build Real-world Emission Inventory Simulation Model
- Build Integrated Air Quality Model of Urban Air Quality Model and Roadside Air Quality Model
- Evaluate Integrated Air Quality Model and Case Study

Key Word: Real world, High accurate model, Roadside, Nanoparticle

Role of JCAP II to Regulatory Affairs

Contribution to environment and energy policies through Fair Data

Environmental policies ⇔ Energy policies

Forecast for petroleum quality, supply and demand

Prospects of Air Quality improvement effects such as automobile emission reduction

Direction of future automobile technologies and the required fuel quality

Emission inventory estimate in real world in the future

Researches on Air Quality Modeling with high-grade accuracy and database establishment enabling to evaluate policies

Researches on automobile and fuel technologies aimed at realizing Zero emission (compatible with CO_2 emission control measures)

JCAP II results and incorporation into policy-making

- Fuel economy improvement due to fuel sulfur content reduction (from 50 to 10ppm) has been verified.
  - **Reported to the Petroleum Products Quality Subcommittee of Advisory Committee for Natural Resources and Energy.**

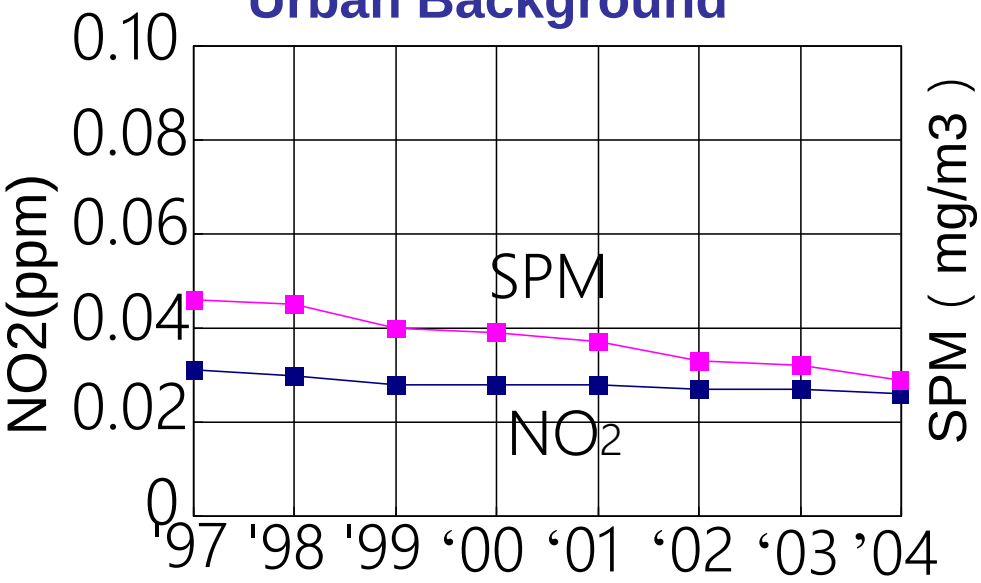
    ・The report has been incorporated into the Subcommittee report, **"Fuel sulfur content should be reduced to 10ppm or less from 2007 for diesel fuel and 2008 for gasoline, respectively."**
- Air quality improvement effect due to new emission control technologies has been simulated.
  - **Reported to a hearing of Experts Committee on Motor Vehicle Exhaust Emissions of the Central Environment Council.**
    - The results were used for the 8th report of the Central Environment Council of the Ministry of the Environment as data predicting the air quality improvement effect due to enforcement of stricter emission regulations quantitatively.

Air Quality Improvement in Japan(Tokyo)

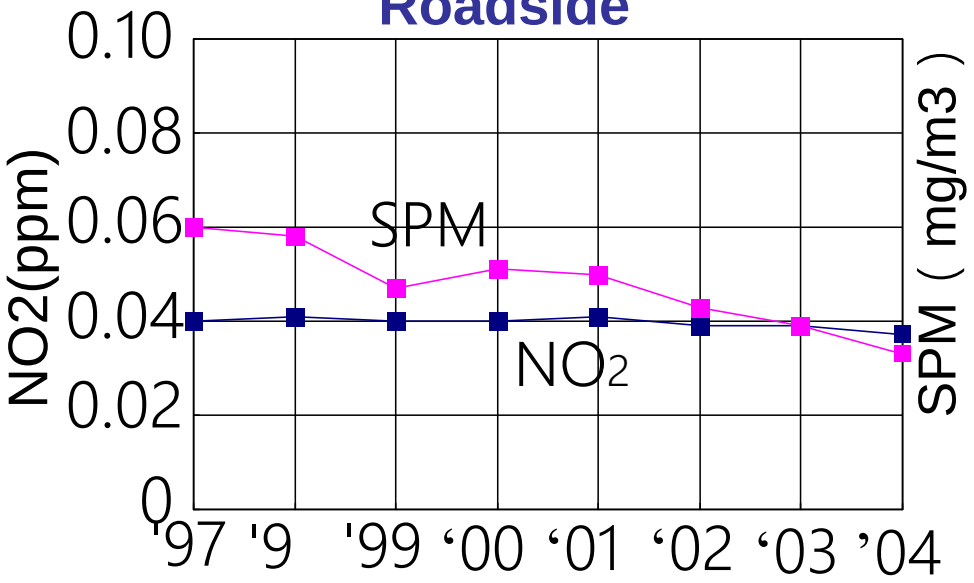
Average NO_2/SPM concentrations decreased, and the attainment of the environmental standards is low on the roadside.

Annual Ave. Conc.

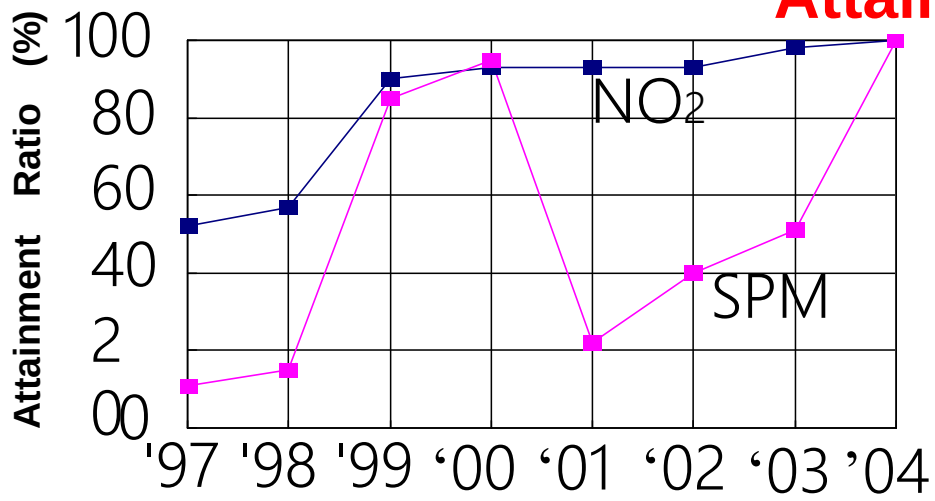
Urban Background

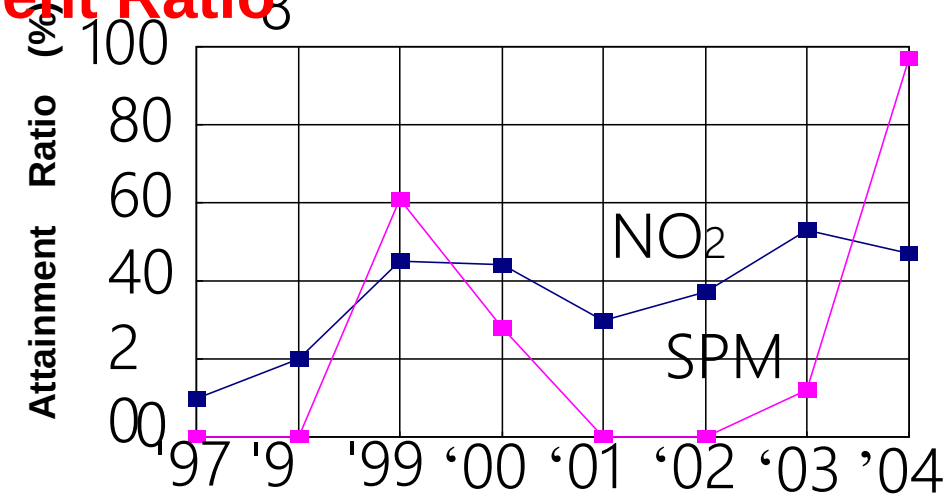


Roadside



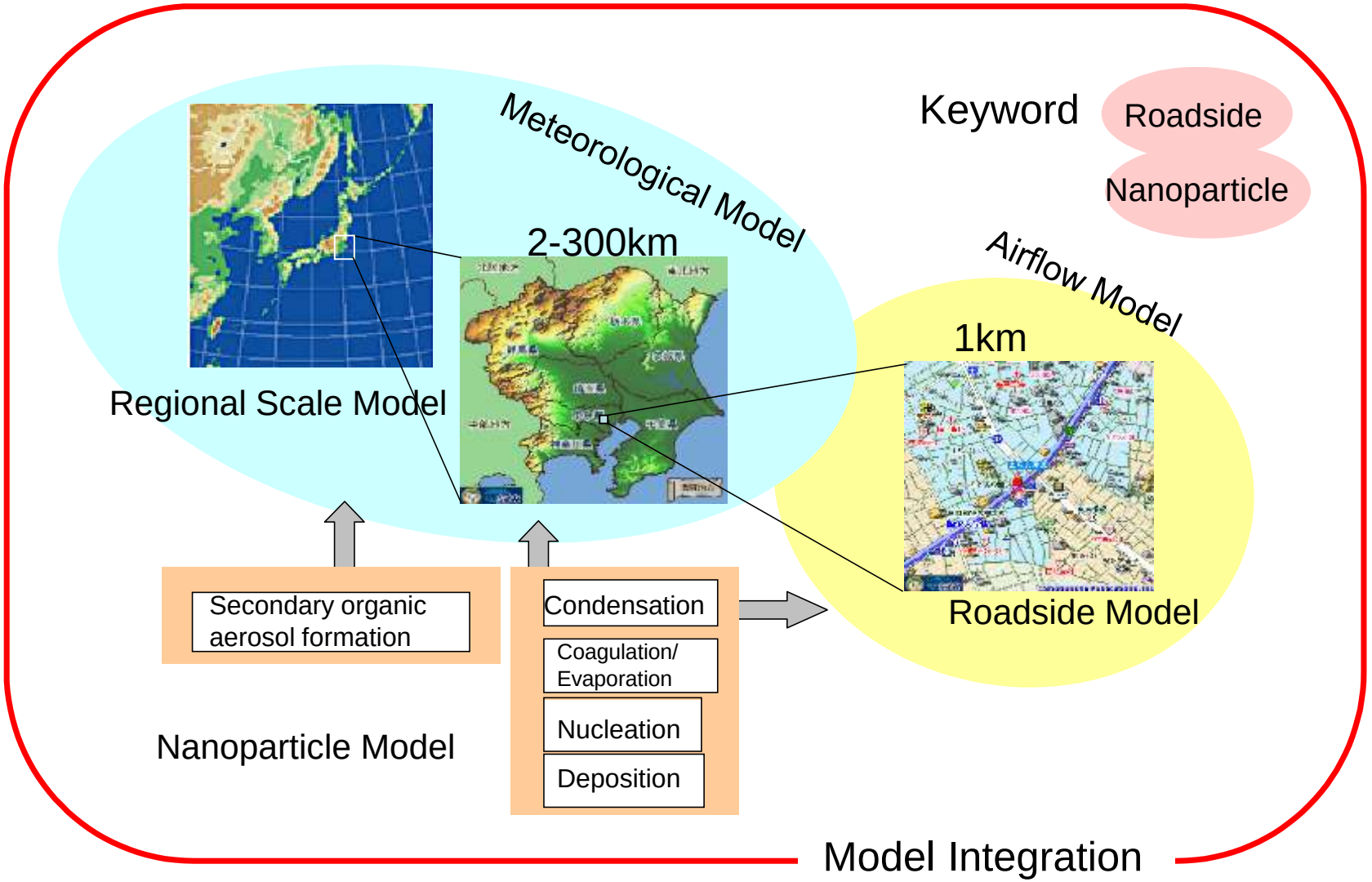
Attainment Ratio



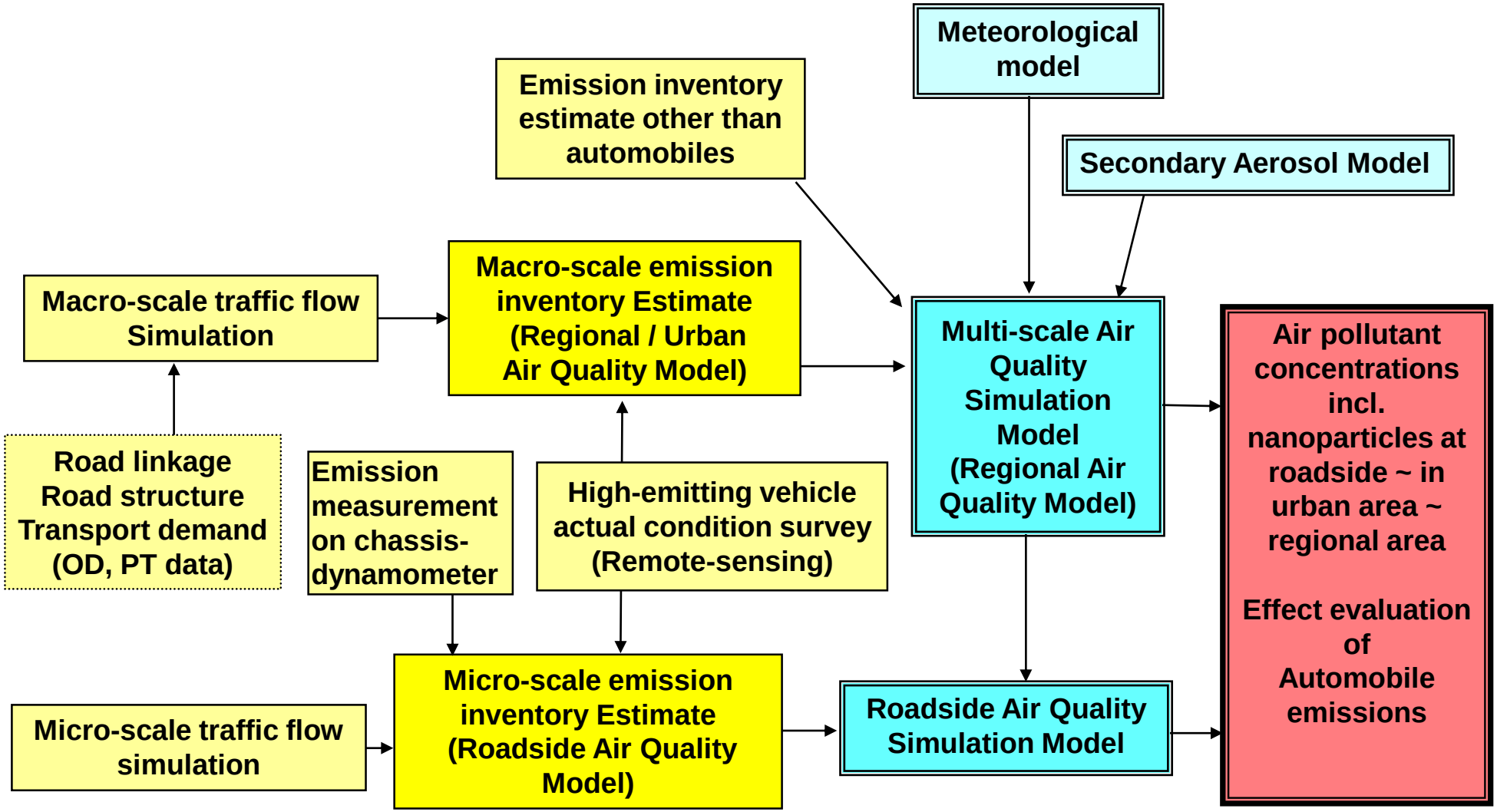


2 JCAP II Air Quality Simulation Model Development Concept

General Formation of Air Quality Models



(1) Air Quality Model Data Flow



(2) Sensitivity Analysis Method Outline

Sensitivity analysis method in URM

-> Decoupled Direct Method (DDM)

(What is DDM?)

Parameter $p = \varepsilon P$

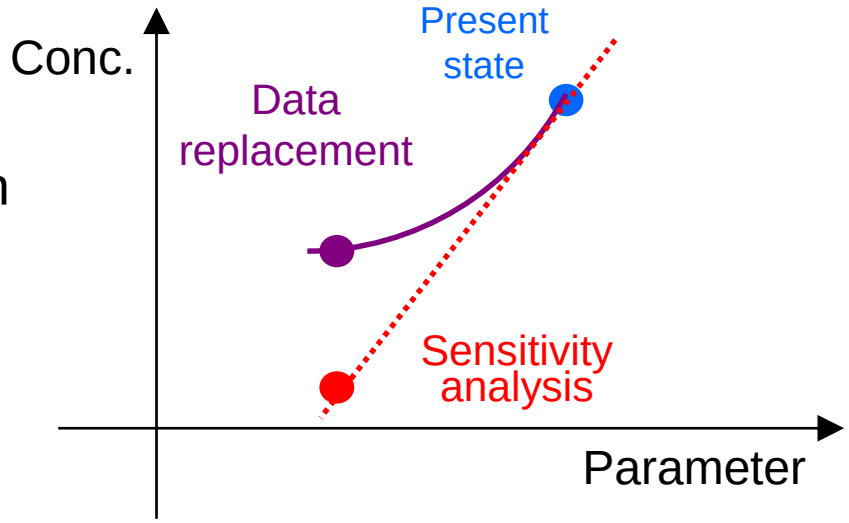
(Initial condition, boundary condition, emission inventory, wind speed, diffusion coefficient, etc.)

Transportation / reaction equation for $\dfrac{\partial c}{\partial \varepsilon}$

Analogous with concentration equation

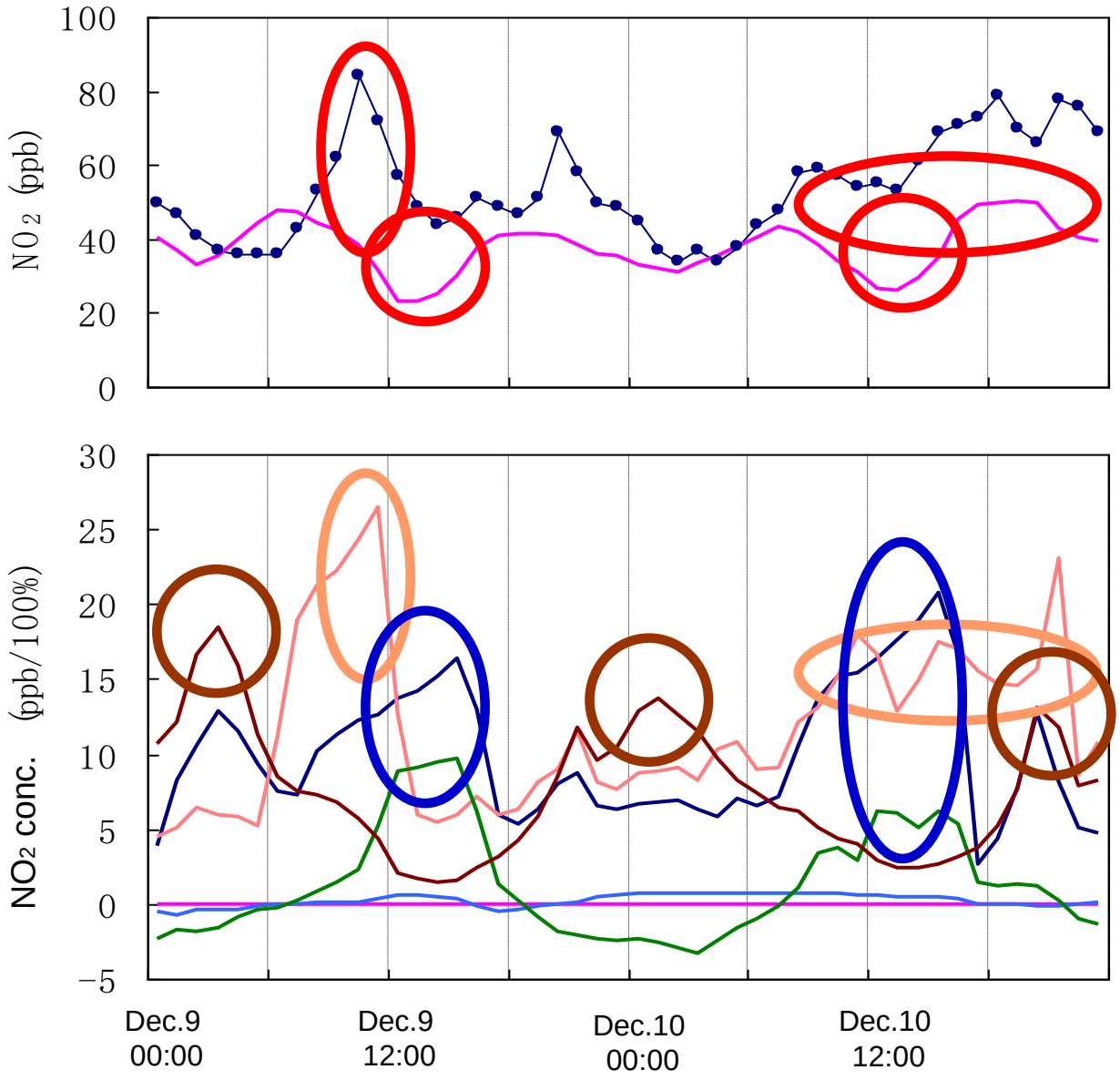
Solve in parallel with concentration c

For emission inventory simulation, simulation target place can be appointed.



Sensitivity to NO_2

(Time-series analysis at Kanda-Central of Tokyo)



Observed value

Calculated value

High sensitivity to wind speed in the morning while calculated values are underestimated

High sensitivity to emission inventory while calculated values are small

High sensitivity to deposition rate at night

NOx emissions

Wind speed

Initial conc.

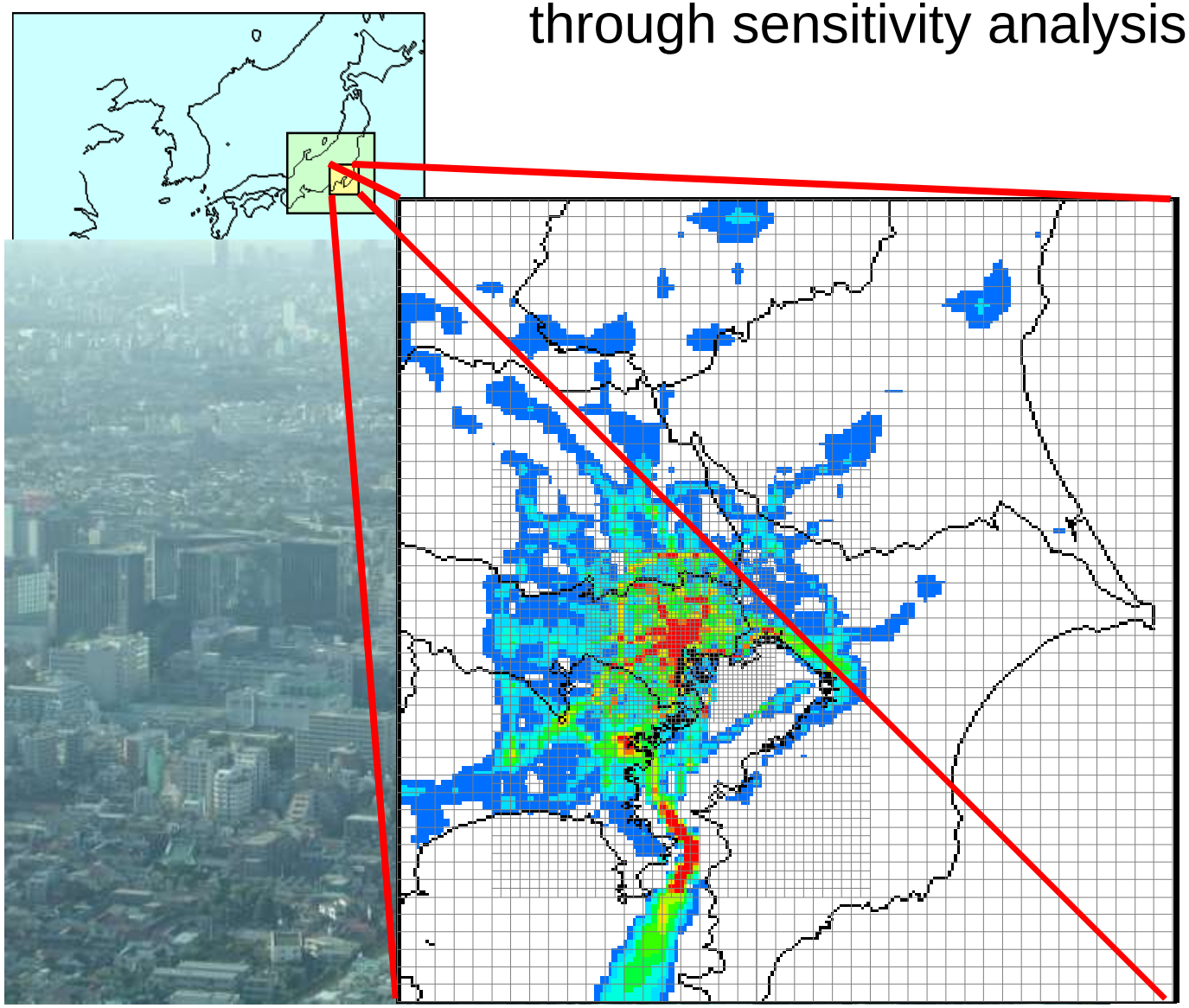
Diffusion coefficient

Boundary conc.

Deposition rate

(3) Key Points in Air Quality Model development

- Measures for simulation precision improvement through sensitivity analysis -



i) Establish Multi-scale model

ii) Reproduce complex weather condition at city center

iii) Consider trans-boundary air pollution

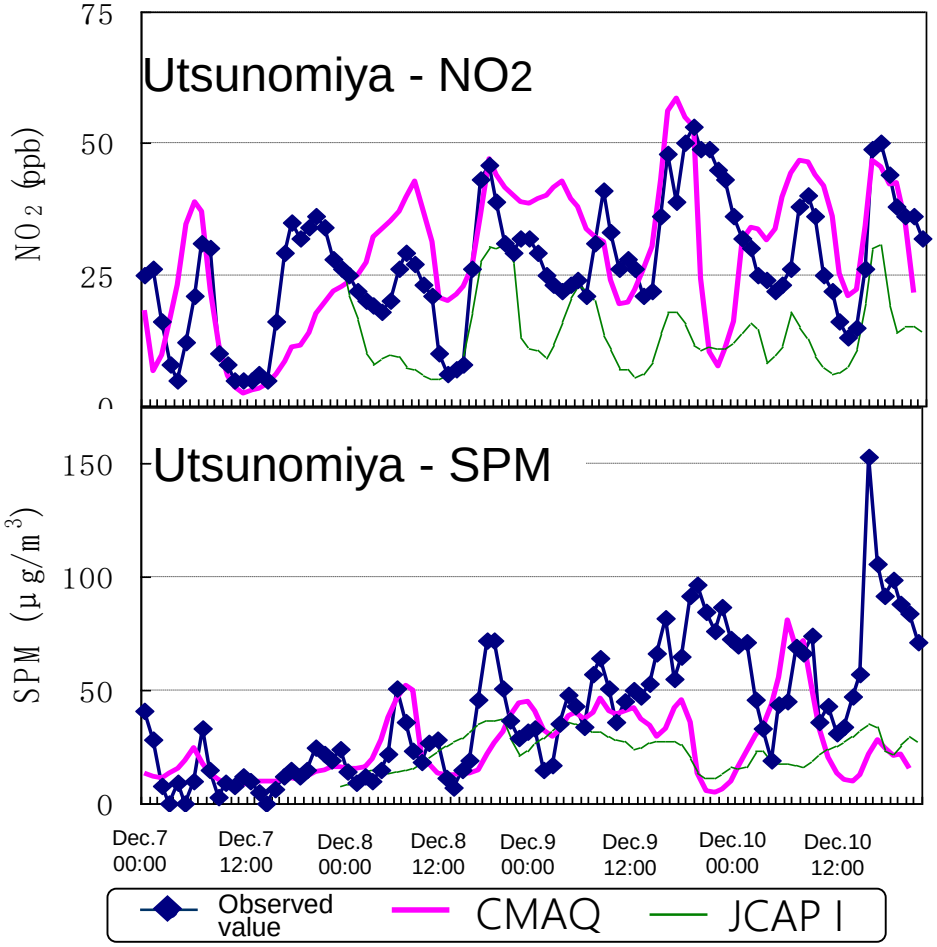
iv) Establish tertiary grid cell emission source data

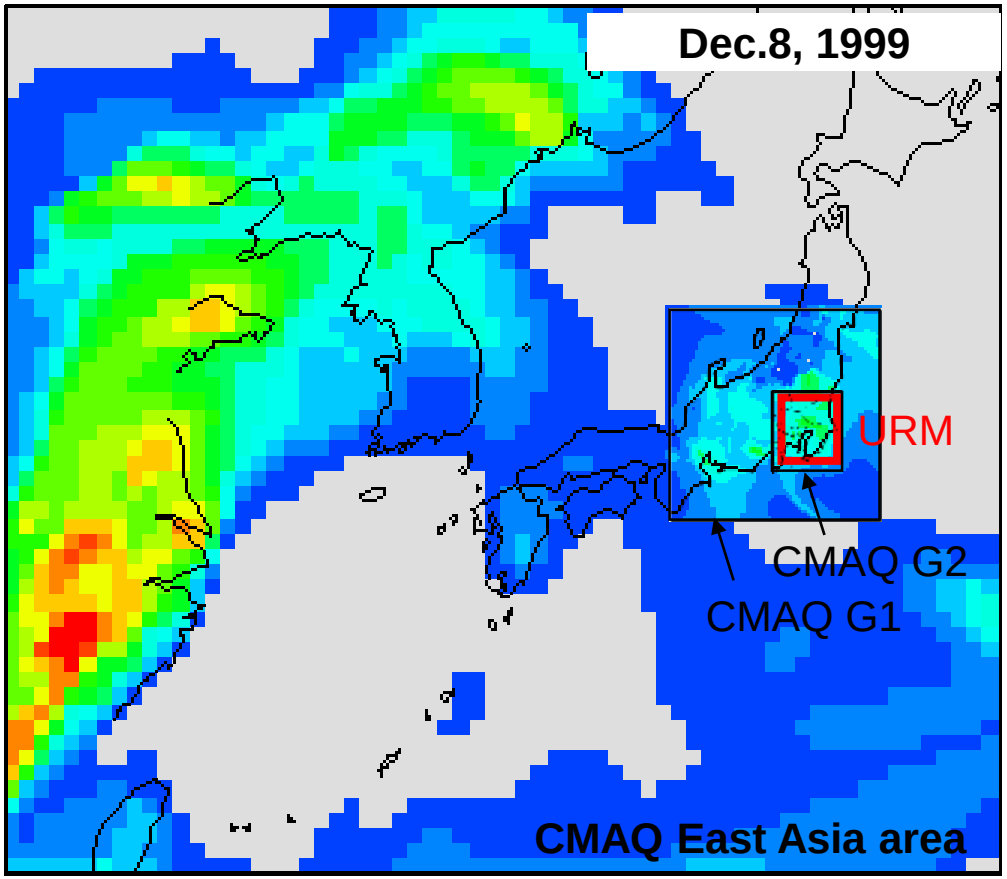
(3)-1 Integration of long range air pollution transportation effect

Boundary condition: Apply CMAQ simulation results of grid cells ranging from 10 to 4 km square

CMAQ boundary is set based on East Asia area simulation results

Initial condition: Start the simulation 8 days before the evaluation target day

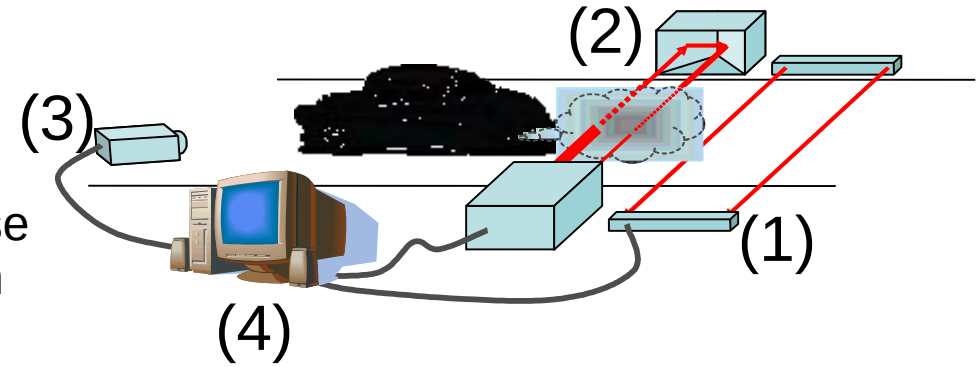




(3)-2 Remote-Sensing Device

(1) Speed-Acceleration Detector

- Comprehend test vehicle driving conditions
- Exclude inaccurate analysis results because of exceeding acceleration and deceleration



(2) Emissions Detector

- CO，CO2，HC*： Measurement using Infrared rays (IR)
- NO，PM**： Measurement using Ultraviolet rays (UV)
  - * Conversion into propane (C3H8)
  - ** Conversion into PM weight per 100g of fuel (smoke factor) instead of Opacity

(3) Automatic License Plate Reader

- Test vehicle information such as vehicle type, applicable regulations, GVW, fuel type, etc. is obtained from license plate. Information is used for emission test result analysis.

(4) Data Processing Equipment

- Speed-Acceleration, emission measured values, imagery of test vehicles are recorded in real time. Number plate information is input separately.

High-emitting vehicle emission inventory estimate method (Gasoline vehicles only)

RSD Emission inventory measurement

⇓

Limit speed/acceleration range, and set Cut Point for high-emitting vehicles (Ex. NO: 1250ppm, corresponding to level of US I/M test Cut Point * 2)

⇓

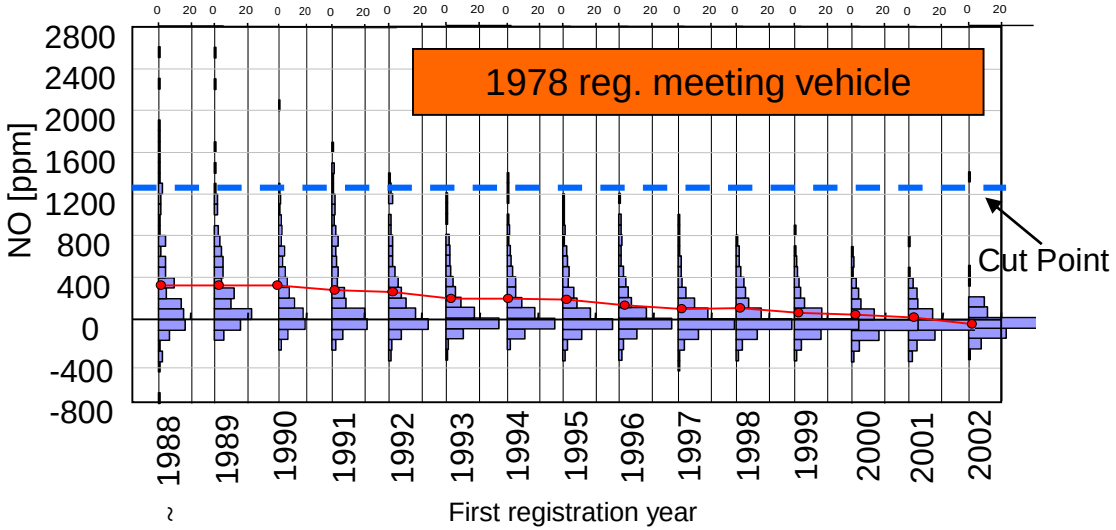
Ratio estimate in number of high-emitting vehicles by model year

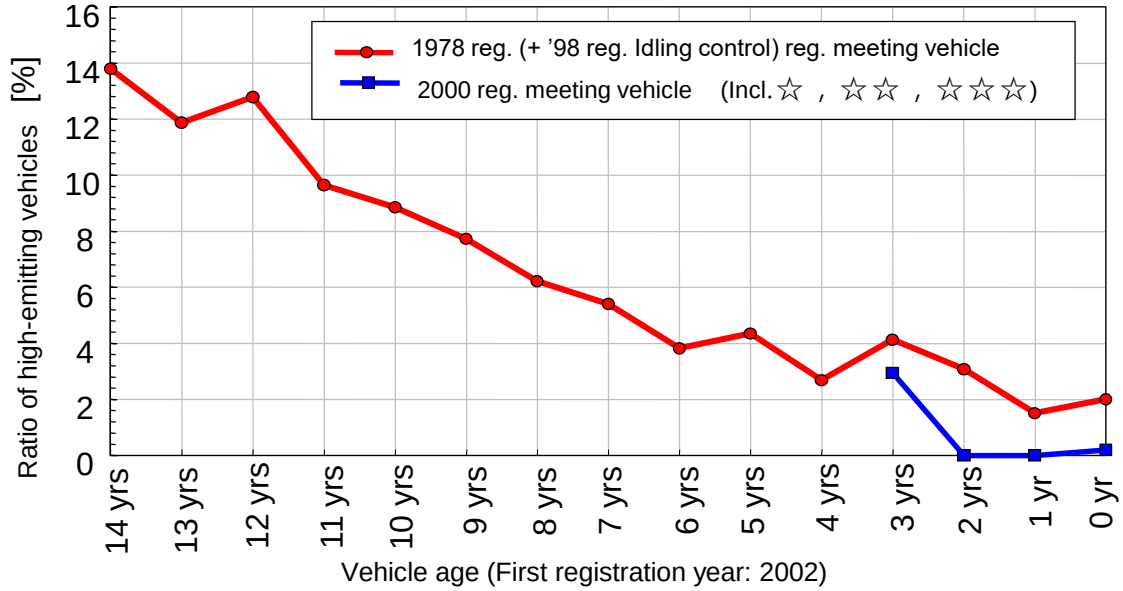
⇓

Set emission factor for high-emitting vehicles (Basis: ’78 reg. meeting vehicle w/o catalyst)

⇓

High-emitting vehicle emission inventory estimate

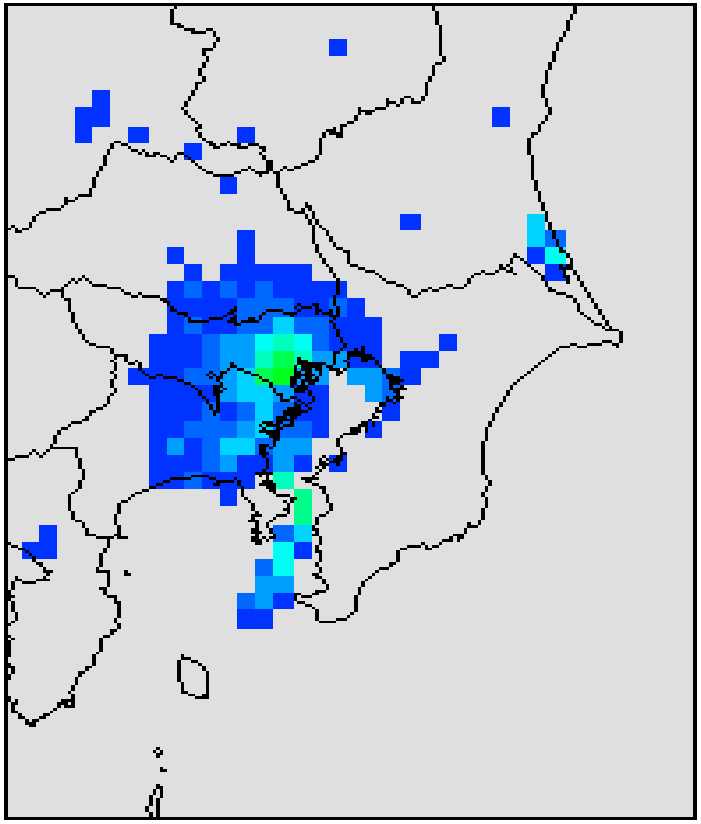




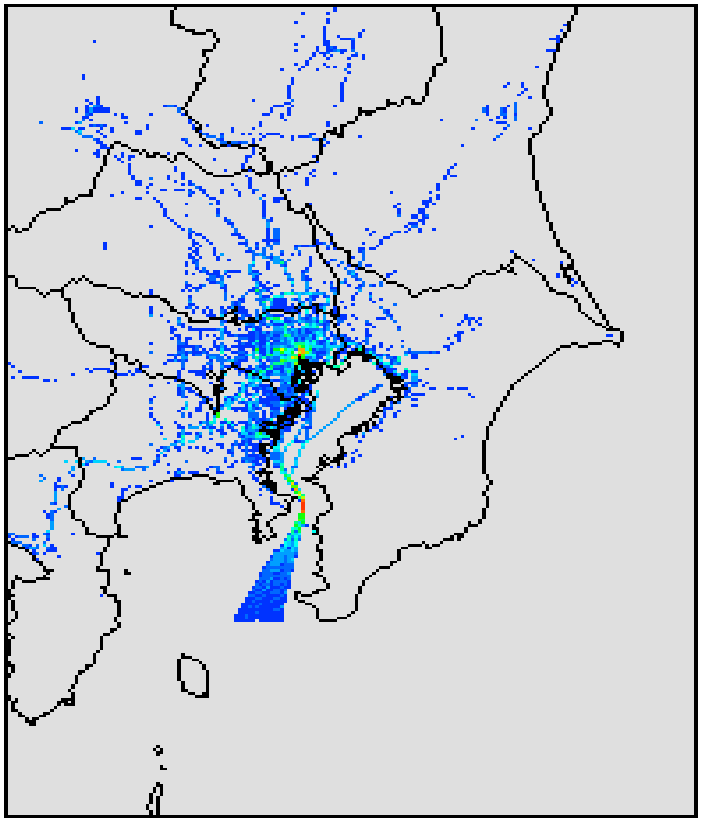
(3)-3 Emission inventory estimate from all emission sources

Example of emission inventory distribution (NOx)

JCAP Ⅰ Grid cell size: about 5km



JCAP Ⅱ Grid cell size: about 1km



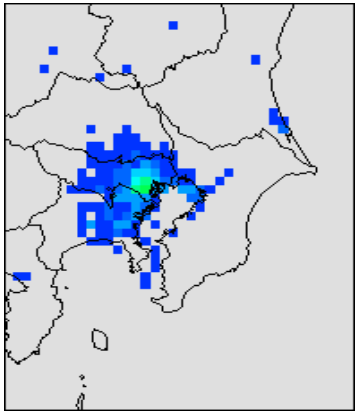
Add other emission sources which had been excluded from consideration:

Construction, industrial and agricultural machinery, open burning, etc.

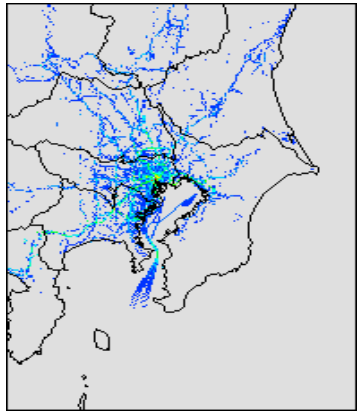
3. Air Pollution Concentration Simulation Precision

SPM Concentration Distribution (Dec. 10, 18:00)

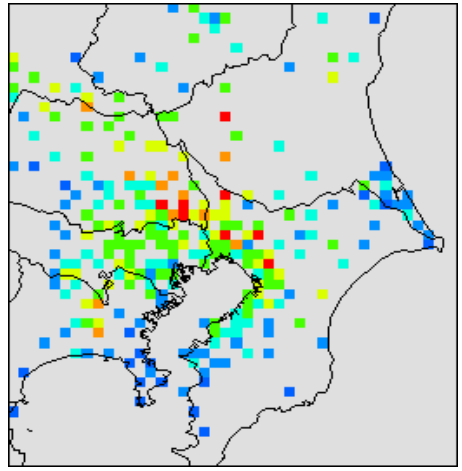
JCAP I ⟷ JCAP II



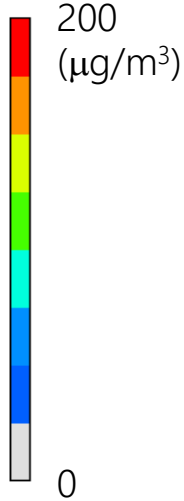
JCAP I
Emission
inventory data

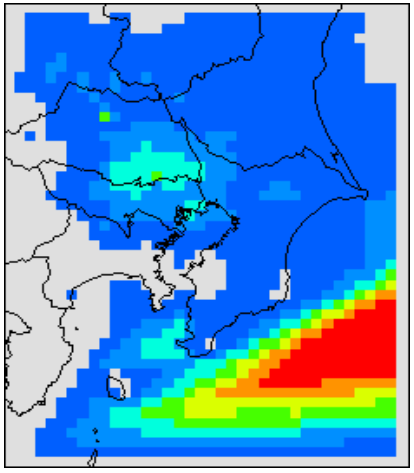


Latest emission
inventory data

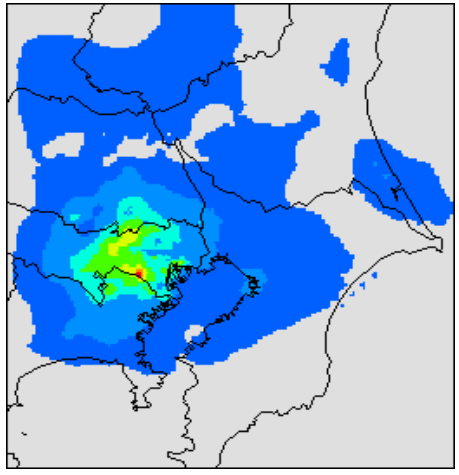


Air pollution monitoring
station observation data

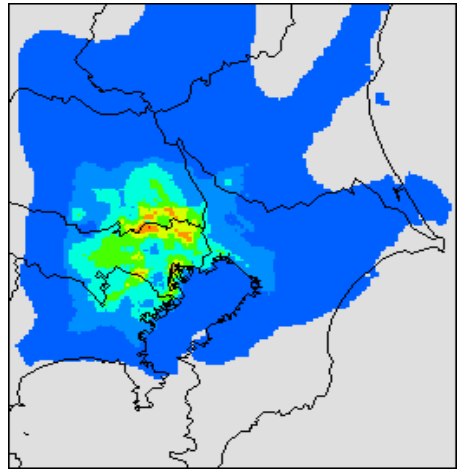




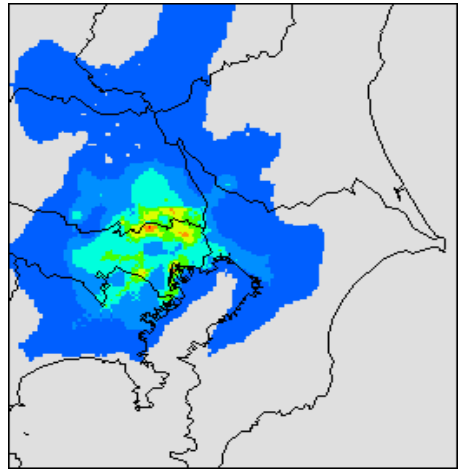
JCAP I



Update of model /
meteorological condition

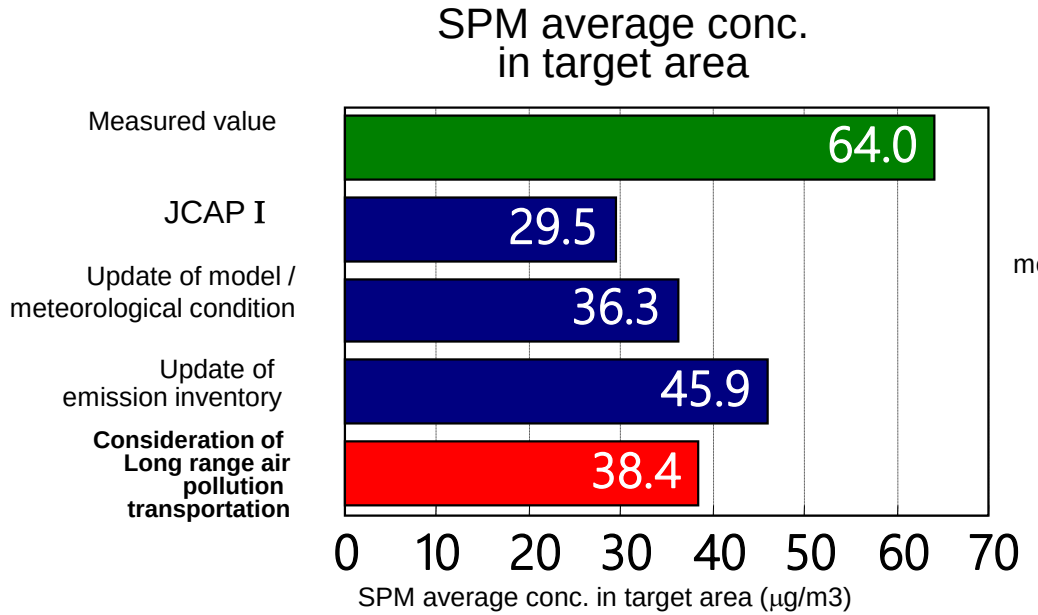


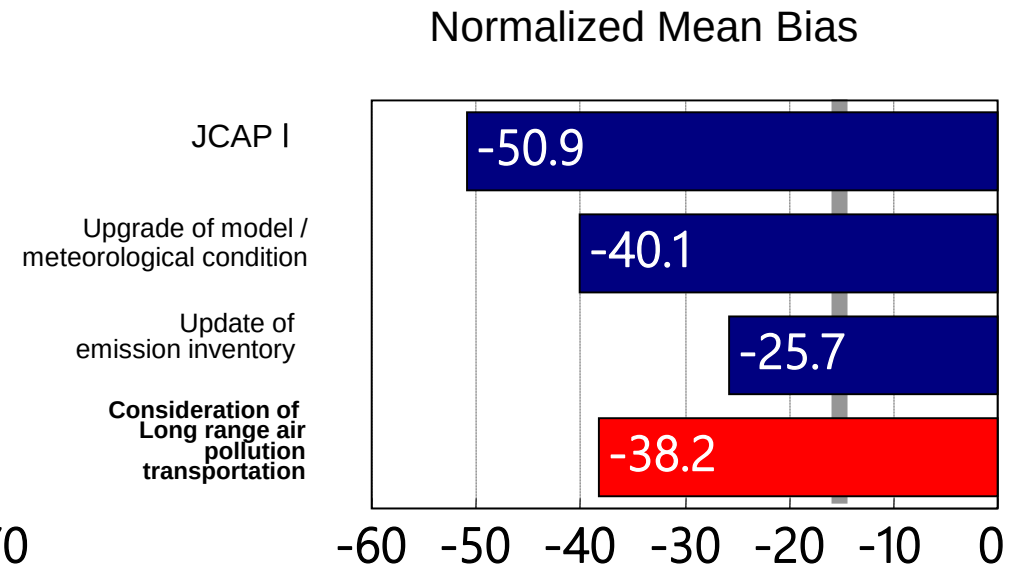
Update of emission
inventory

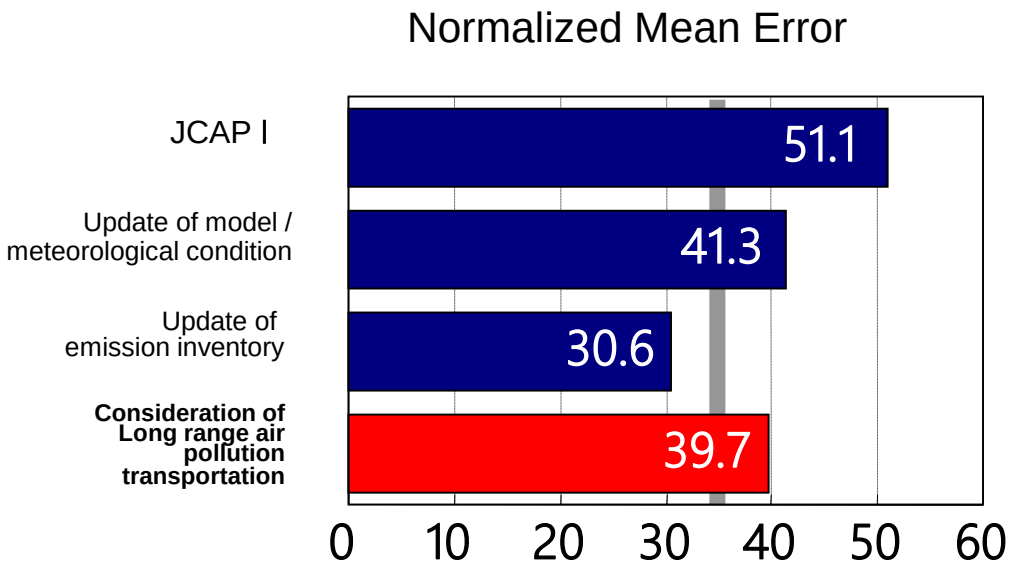


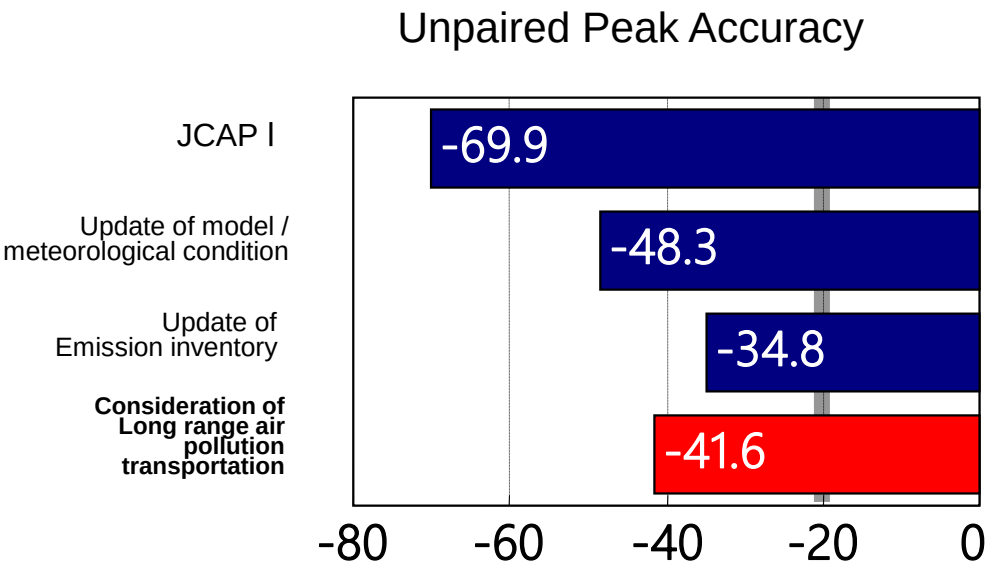
Consideration of long range
air pollution transportation

SPM Simulation precision





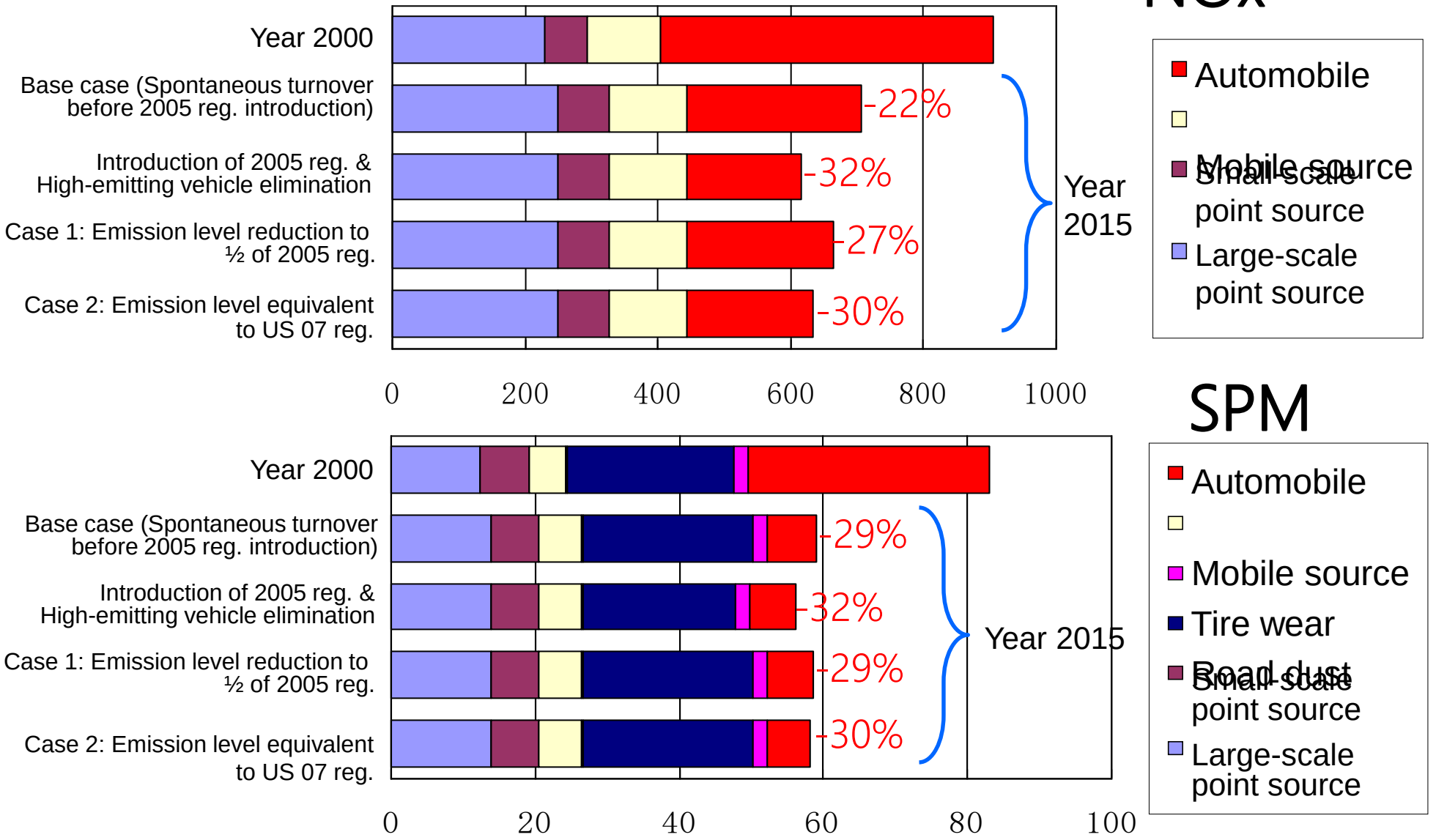




4. Future Air Quality Prediction Results

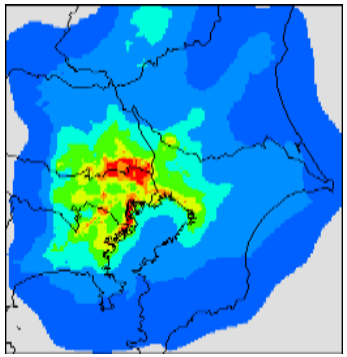
Total Emission Inventory Estimate

Total emission inventory in the specified area for Automobile NOx/PM Laws in Kanto bloc (t/day)

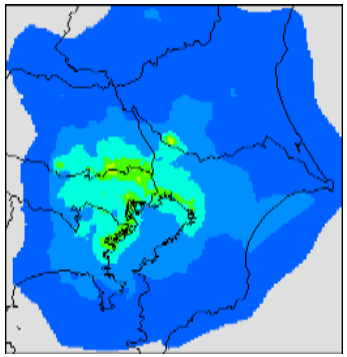


SPM concentrations

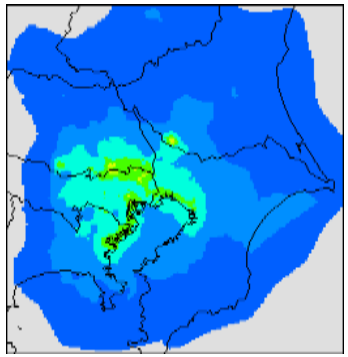
Daily average SPM conc. distribution



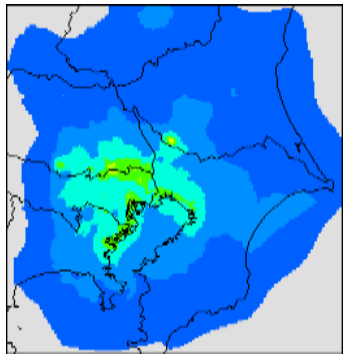
Year 2000
(with HE / ME emission factor)



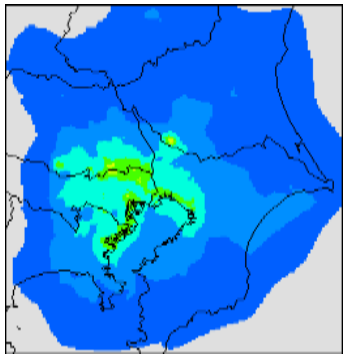
Year 2015
(with HE / ME emission factor)



Year 2015
(w/o HE, with ME emission factor)

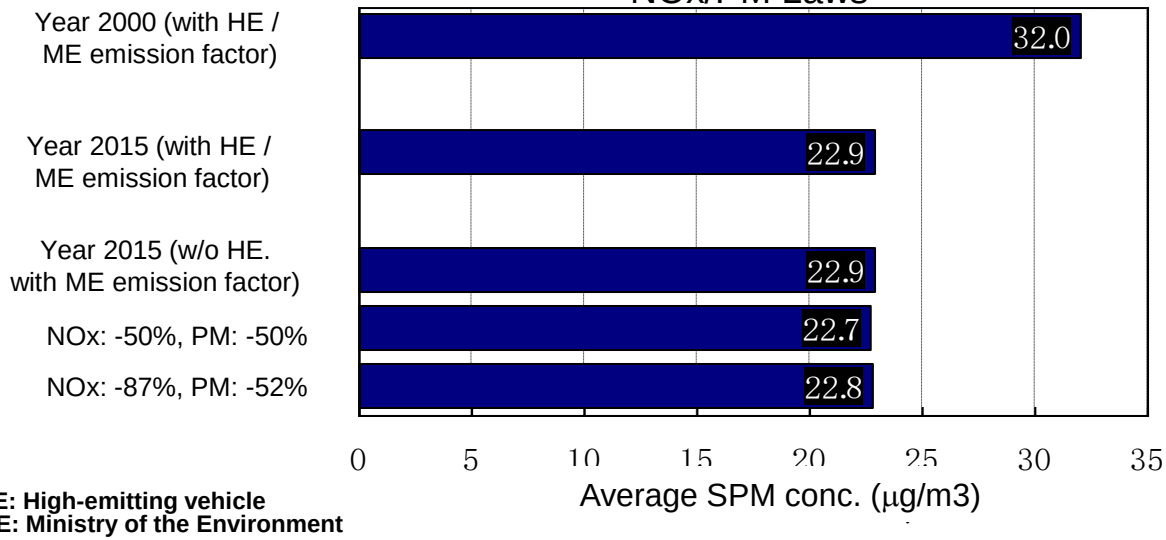


NOx: -50%
PM: -50%

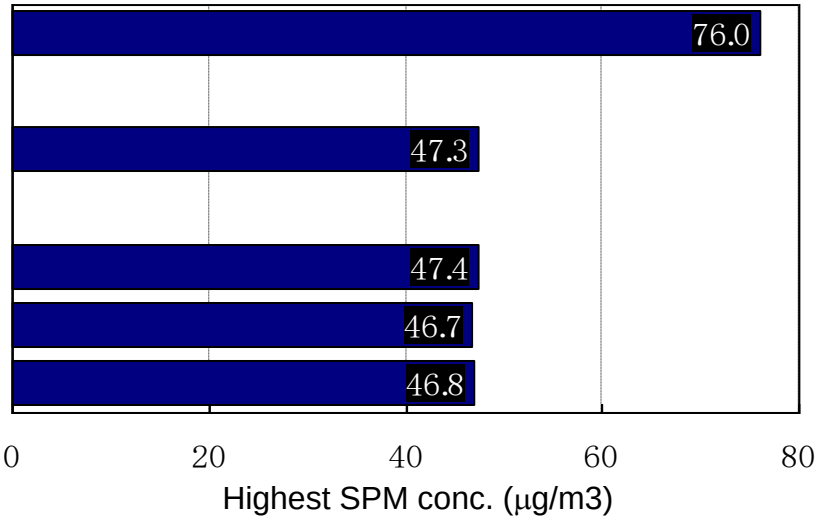


NOx: -87%
PM: -52%

Average conc. in the specified area for NOx/PM Laws



Highest conc. in the specified area for NOx/PM Laws



HE: High-emitting vehicle
ME: Ministry of the Environment

5.Summary

JCAP II Air Quality Model Study are summarized as follows:

- Sensitivity Analysis method was introduced for prediction accuracy improvement
- Multi-scale model, Emission data accuracy and precise meteorological data in central metropolis. are key points for simulation accuracy improvement
- Air quality simulation is an effective way for policy making to improve future air quality
- JCAP Model will be opened to the public widely when the JCAP II finished

End of Presentation