AIM workshop in Feb., 2007

AIM/Air: Approach to local air quality modeling ~ Emission from outside ~

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Background

- Recent years, according to increase of energy consumption in developing countries, emission and deposition of air pollutants（SO_2, NO_x PM） become serious problem of heath risk.
- Air pollution problem comes out mainly in the city with high population density.
- However, it was found not only emission from the city but also emission from surrounding area and outside of the country are high level.
- In order to figure out movement and chemical transform of air pollutants, several chemical transport models have been developed.

Research outline **(1)**

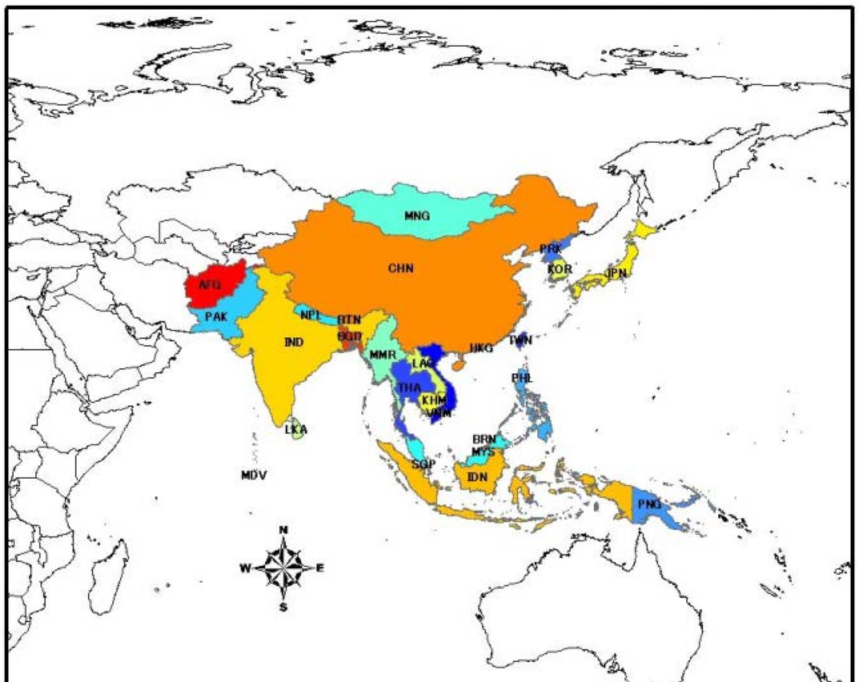
- In the AIM workshop in the last year, we presented application of multi-scale air quality model, MM5 and CMAQ to estimate background concentration of SO_2 and NOx in Beijing and Tianjin.
- In this research, more detailed study on background analysis and source-receptor relationship by using MM5 and CMAQ.
- Source-receptor relationship means affection by emission among (neighboring) regions.
- In this presentation, the affection is evaluated as ratio of emission contribution by source region.
- Source-receptor relationship among local regions in China and Japan were evaluated in this study.

Research outline (2)

- Another purpose is to project future air quality by using econometric model and AIM/Enduse model.
- Econometric model estimates the energy demanded by the future world from socio-economic condition, such as population growth, economic growth, industrial structure, unemployment ratio, and so on.
- SO_2 and NO_x concentration in 2020 were estimated by using output of AIM/Enduse model with BAU condition.

Regions and targets (1)

- Target area
  1. Whole Asia
  2. China
  3. Beijing, Chongqing
  4. Kansai area

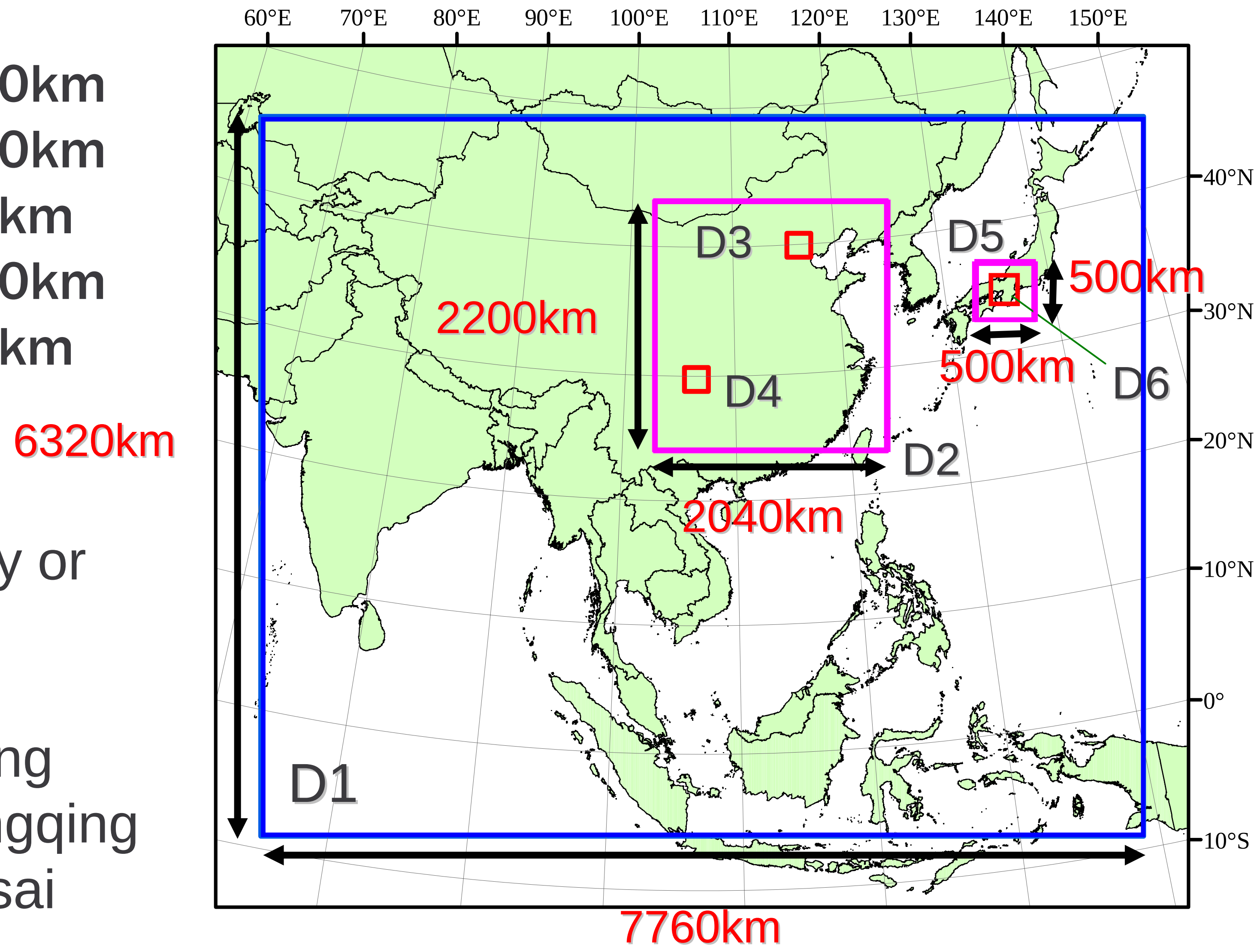


- Target period
  - 2001
- Target pollutants
  - Sulfur oxides（SO_2, SO_4^{2-}）
    Nitrogen oxides（NO_2, NO, NO_3^-）
    NH_3
    O_3
    CO
    PM
    NMVOC

Regions and Targets (2)

Grid size

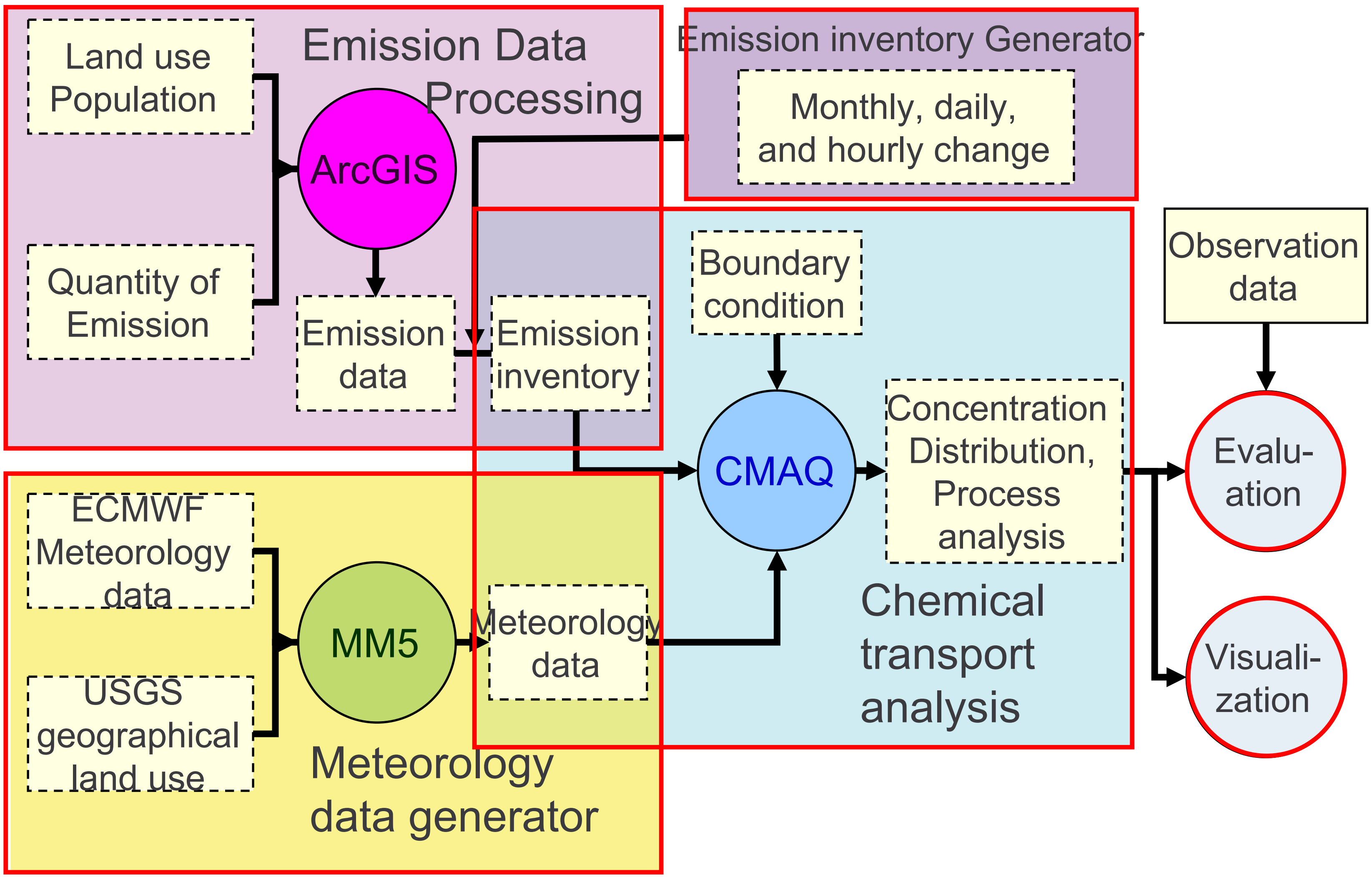
D1	80km
D2	20km
D3,D4	5km
D5	20km
D6	5km



Major city or area in regions
D3: Beijing
D4:Chongqing
D6: Kansai

Integrated Computational System

- Outline of process flow

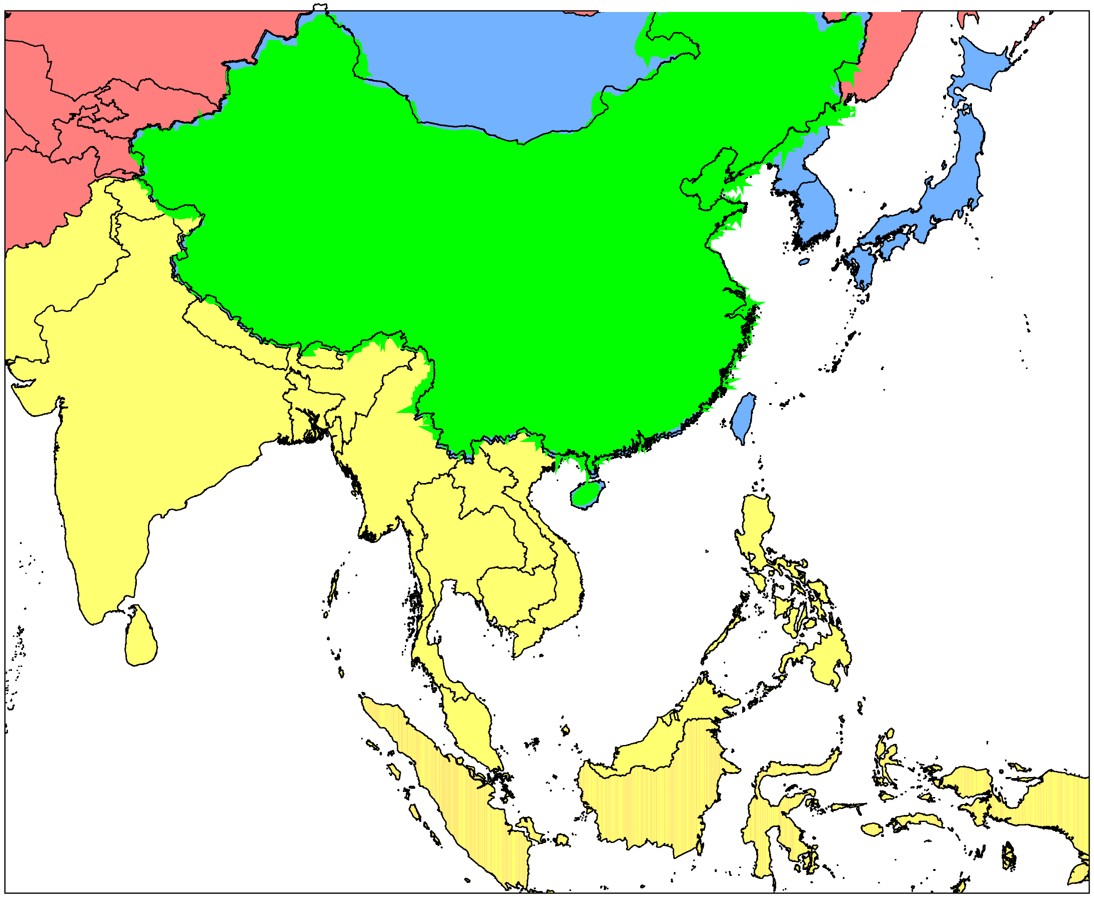


Emission data (1)

Annual emission data of anthropogenic source

- China
  Estimated result by AIM/Enduse model
- Japan, Korea, South and North Korea, Mongolia
  EAGrid2000(Kaminari *et al,* 2005)
- South～East Asia
  Streets *et al*.(2003)
- Other countries
  EDGAR3.2FT2000(Olivier *et al*, 2005)

Emission data (2)



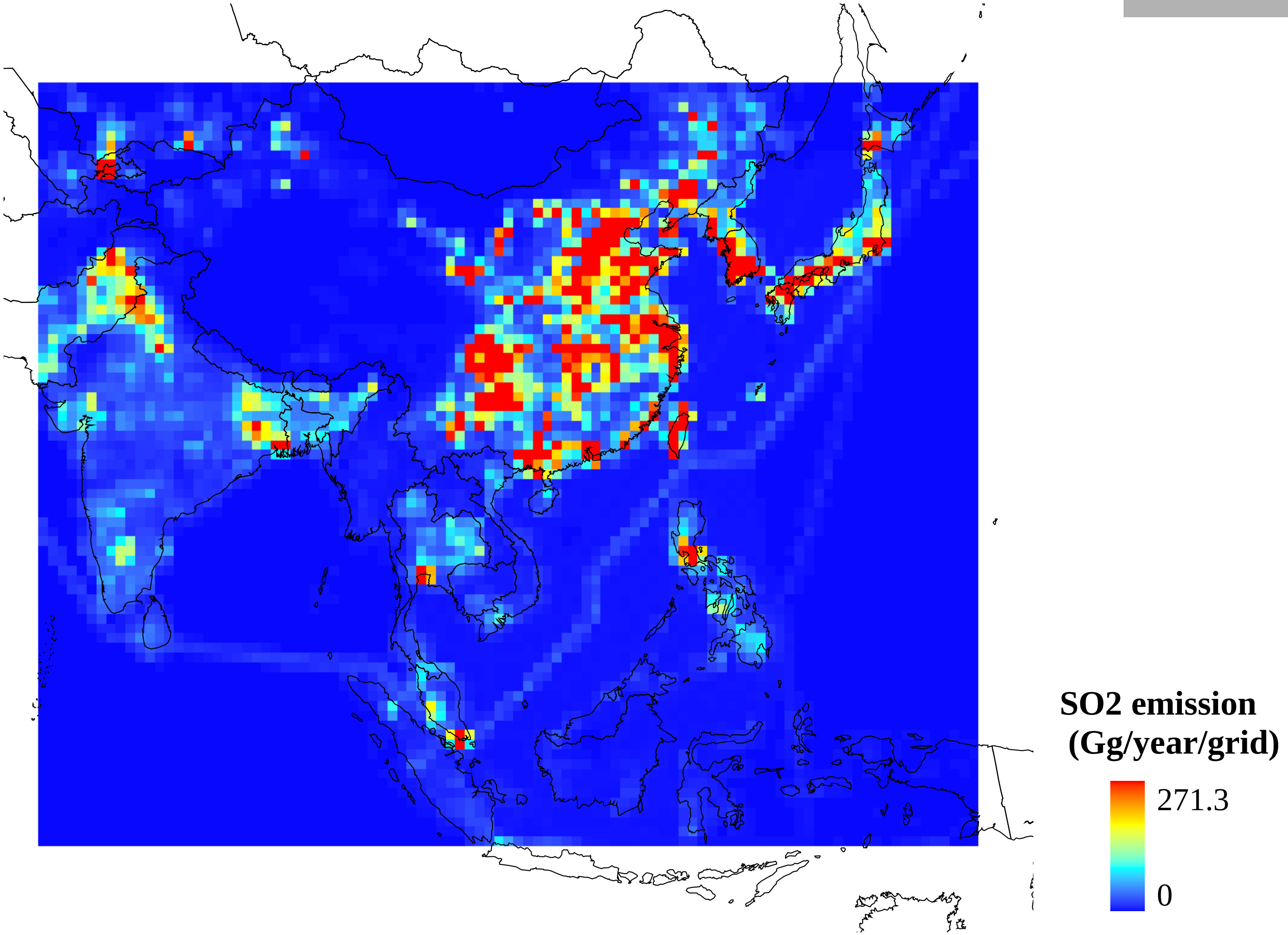
AIM/Enduse

EAGrid2000

Streets *et al.*(2003)

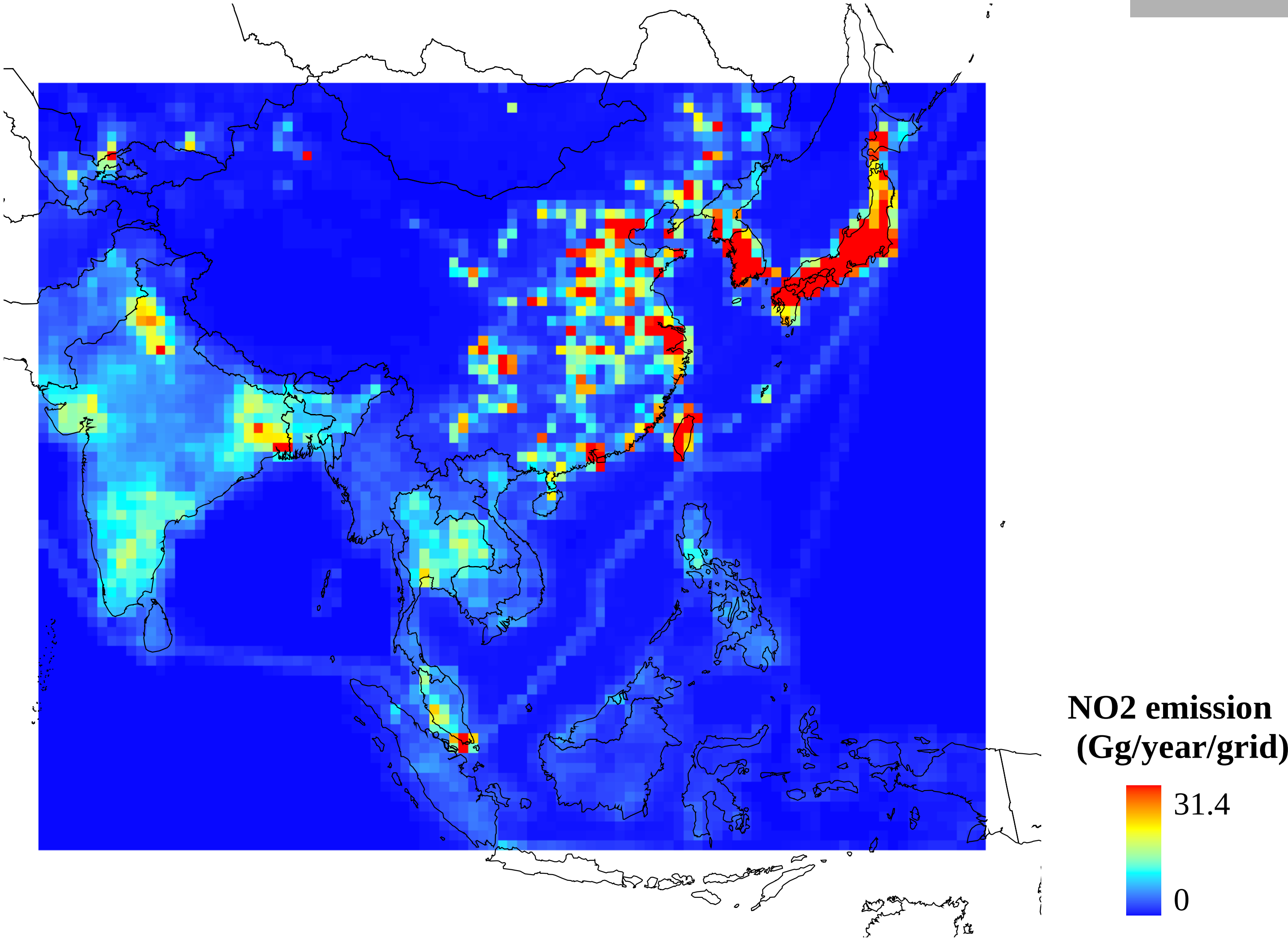
EDGAR3.2FT2000

SO_2 emission data



SO_2 emission

NO_2 emission data



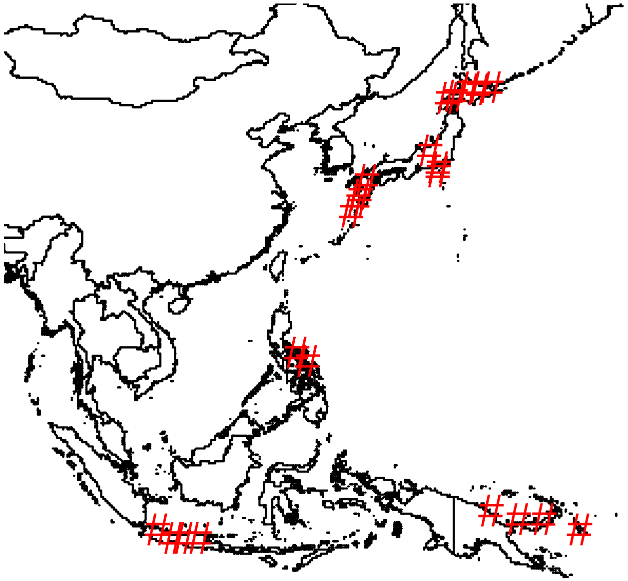
NO_2 Emission

Generation of emission inventory

- Monthly, daily, and hourly change in emission by each of industrial, commercial, public, and transport sectors was considered.
- For countries except China, monthly and hourly change by each sector was considered.
- Time lag between local time and world standard time was considered

Emission data from natural source

- Volcano source O_2
  - Central Research Institute of Electric Power Industry /GEIA,
  - Japan Meteorological Agency (Miyake island)
- Soil source NO_x
  - Yienger *et al.*(1995)
- Biological source NMVOC
  - Guenther *et al.*(1995)



Position of volcano

Air Quality Model

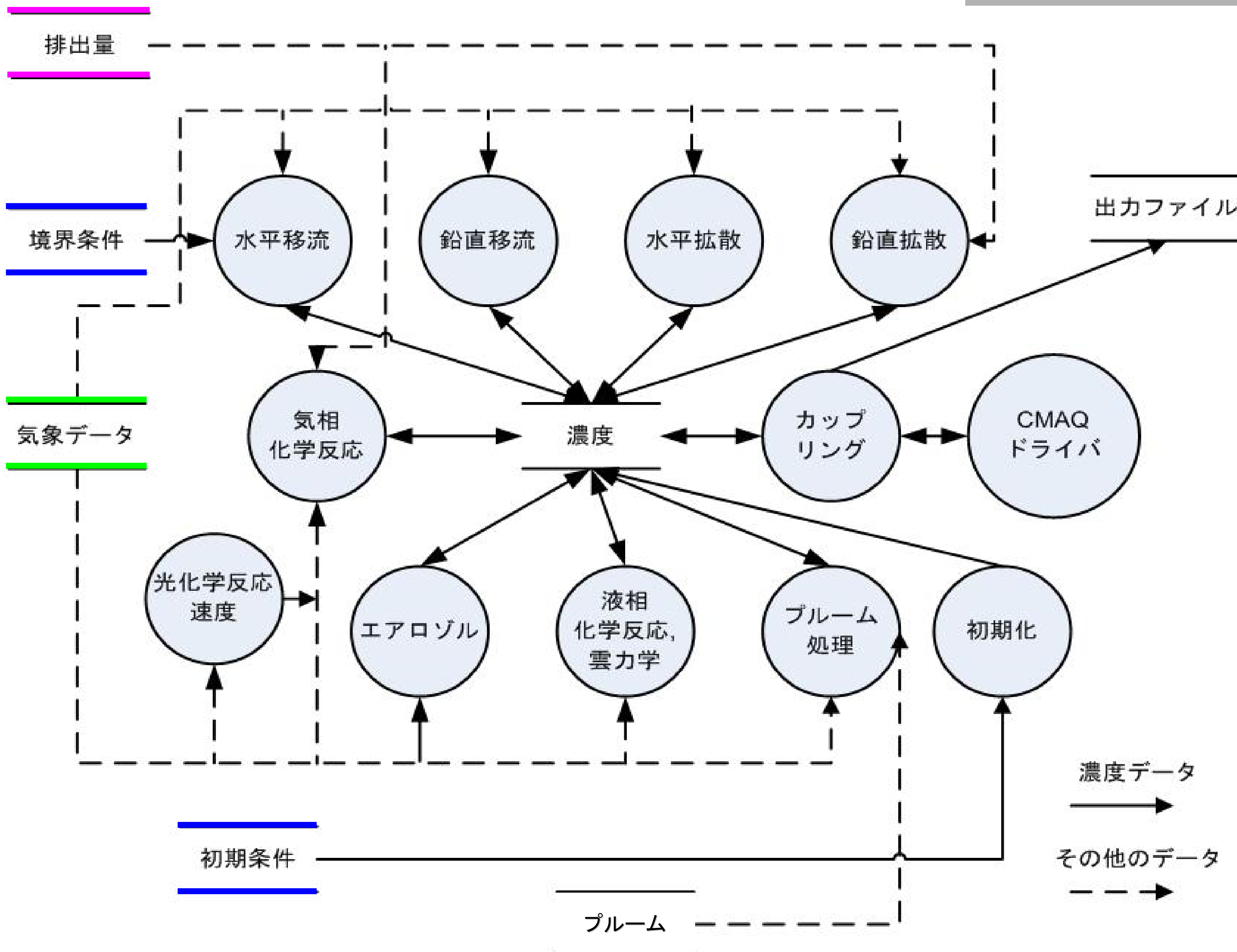
MM5 : 5th Generation Meso-scale Model

- Meso-scale meteorological model developed by Pennsylvania State University (PSU) and National Center for Atmospheric Research (NCAR)

CMAQ : Community Multi-scale Air Quality Model

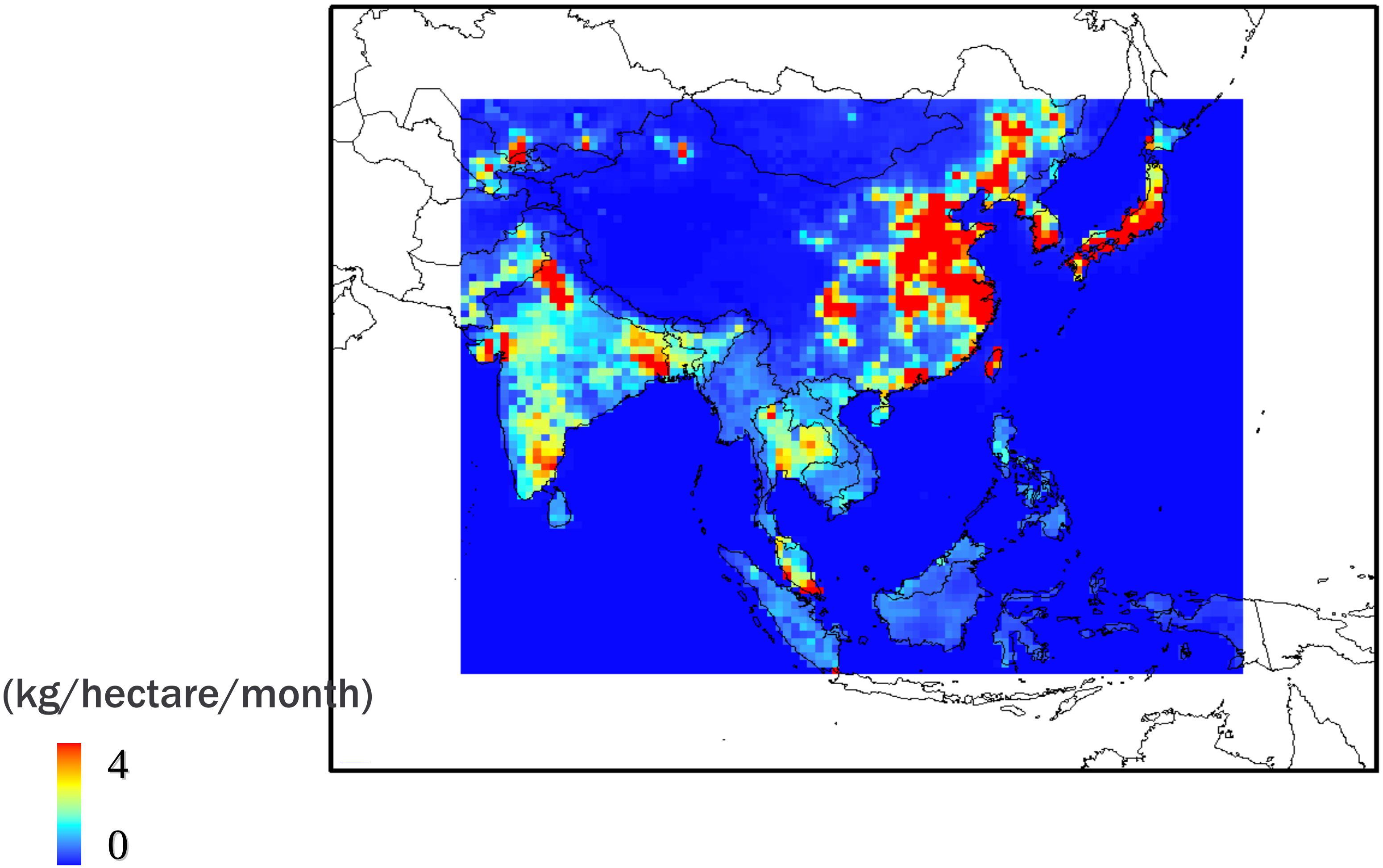
- Three dimensional Euler-type chemical reaction & transportation model developed by US EPA
- As chemical reaction in gas phase, B4(Gery et al., 1989) or SAPRC99(Carter, 2000) is available.

CMAQ : Community Multiscale Air Quality Model

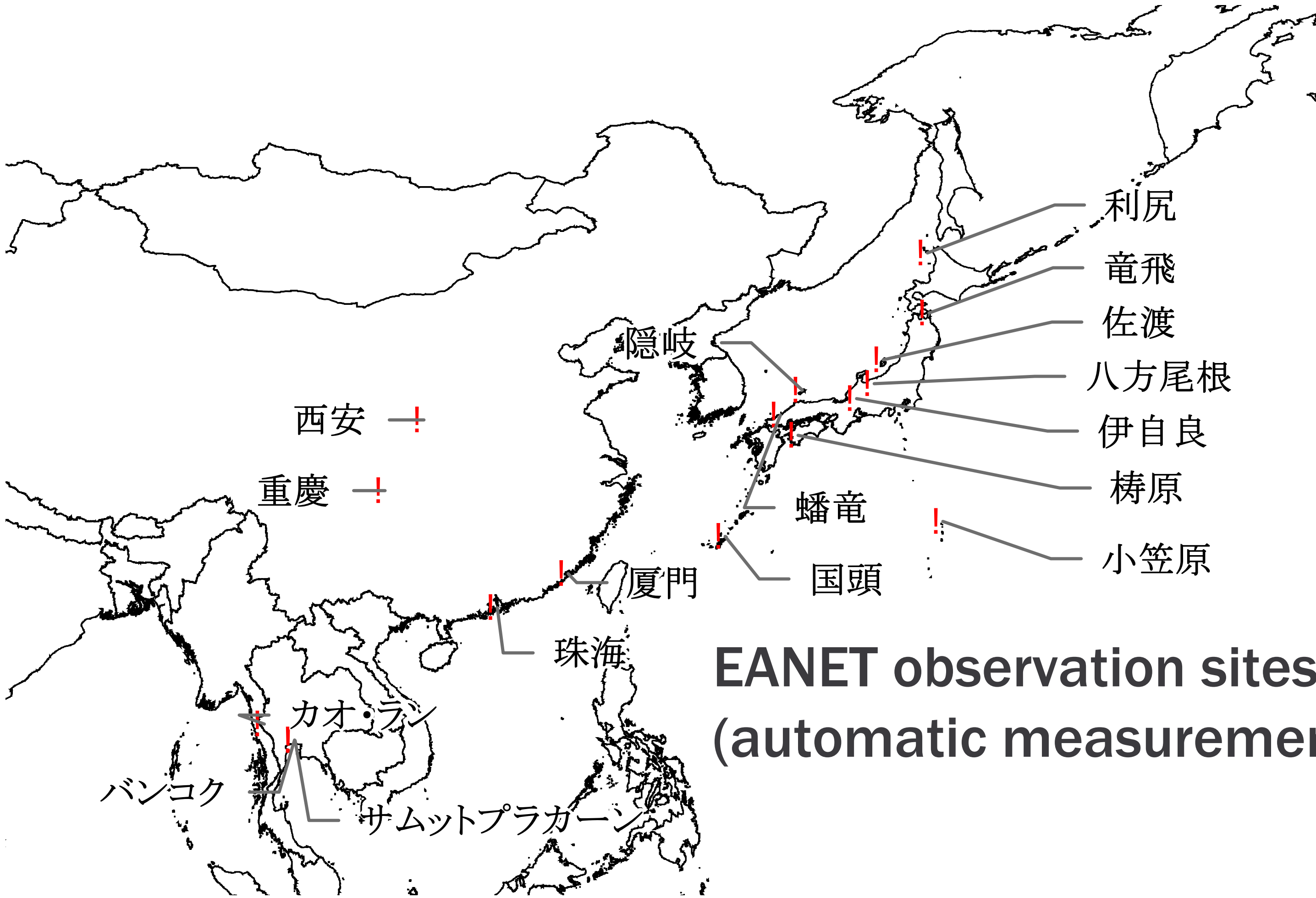


Result of calculation

- Dry deposition of NO_2 in September, 2001

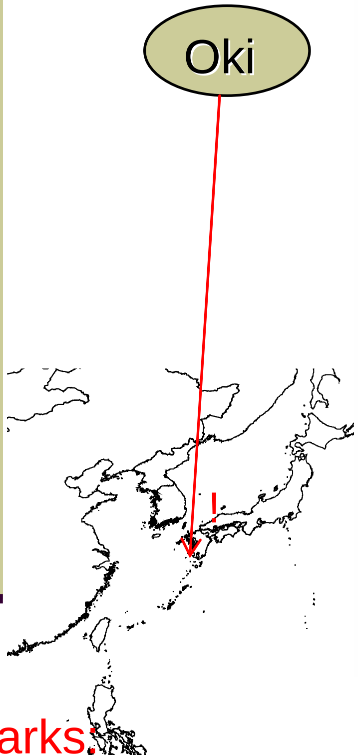


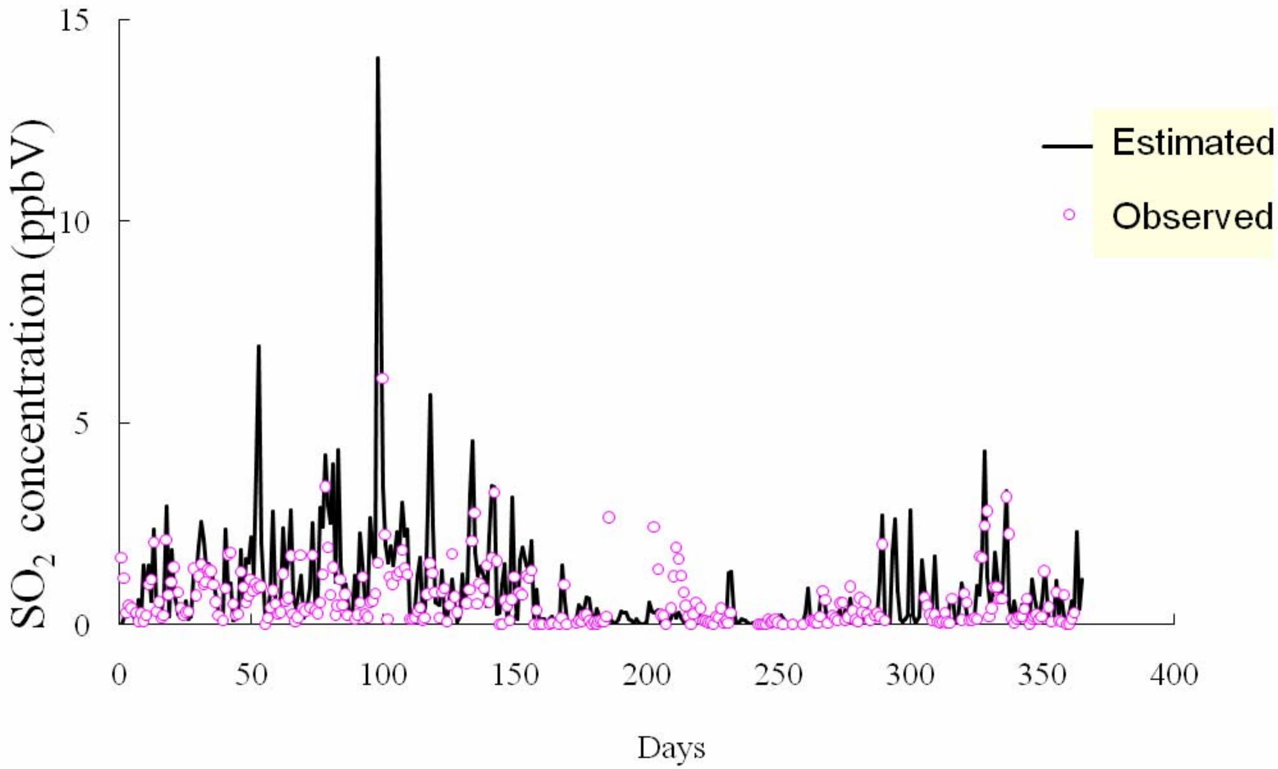
Comparison to EANET observations (1)



EANET observation sites
(automatic measurement facility)

Comparison to EANET observations (2)





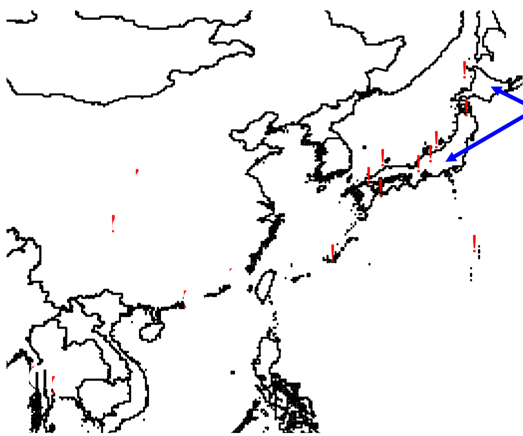
Day average SO_2 concentration at ‘Oki’

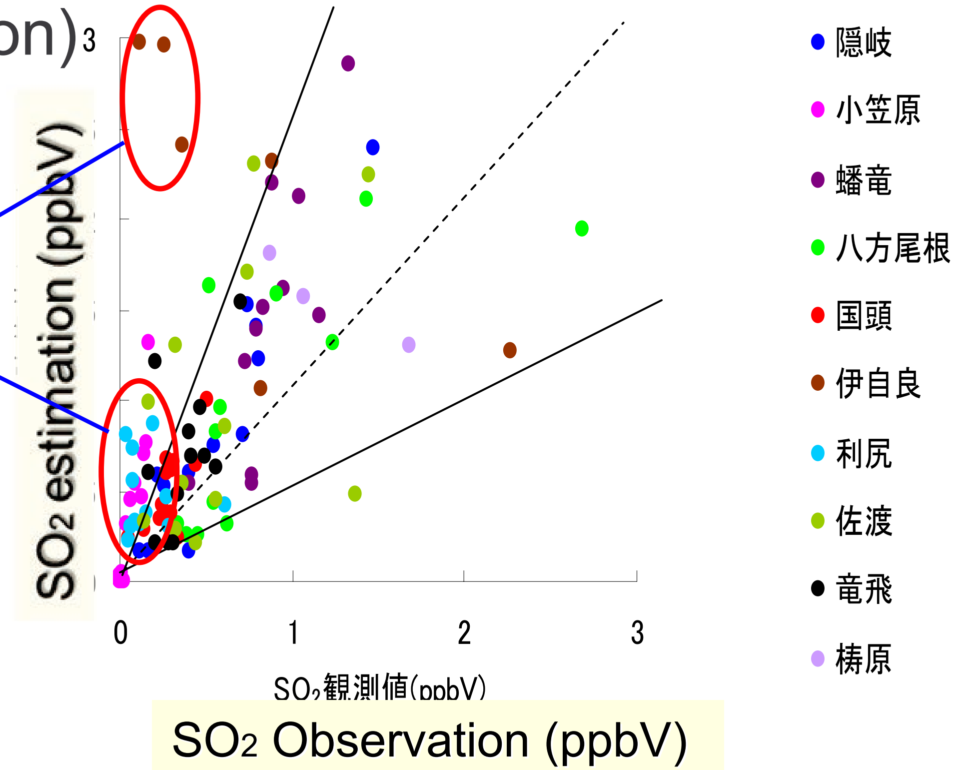
Remarks:

- ◆Tendency of concentration is represented.
- ◆Estimated values tend to be higher than observed values.
- ◆There exist peaks around 200 days which can not be expressed.

Comparison to EANET observations (3)

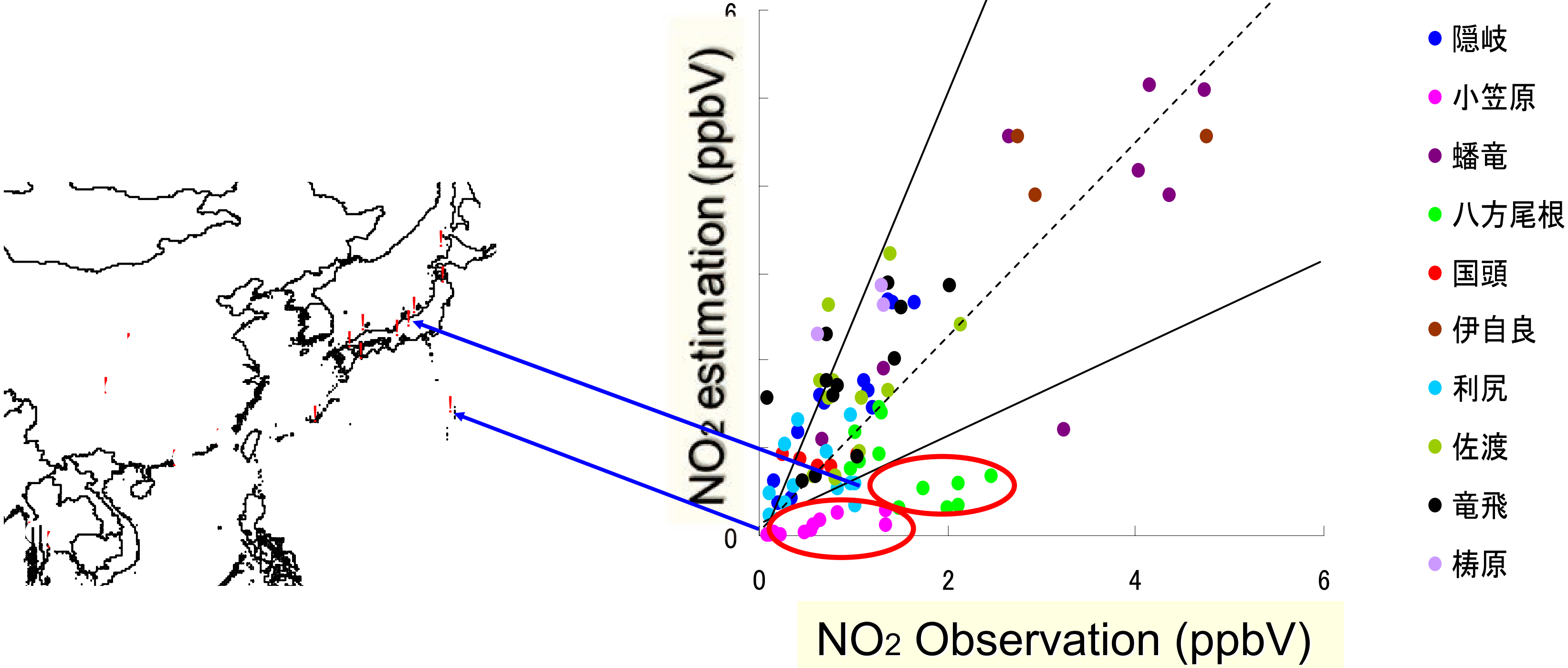
Plot of month average SO_2 concentration (observation vs. estimation)



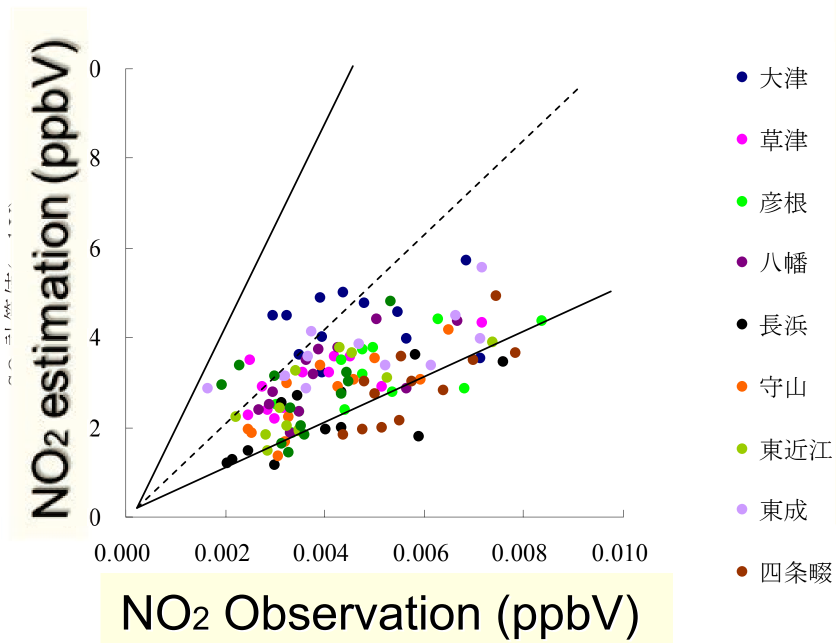


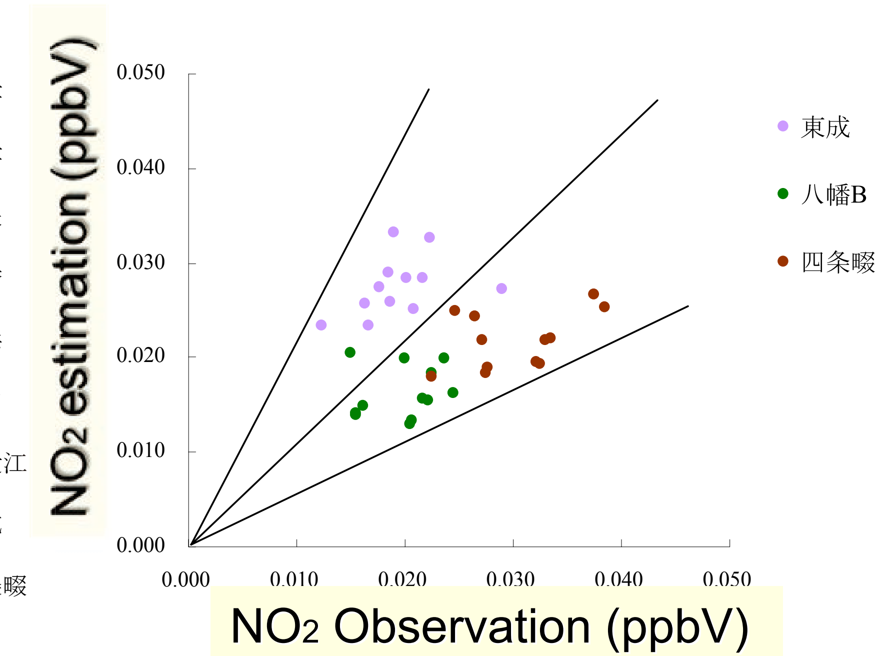
Comparison to EANET observations (4)

Plot of month average NO_2 concentration (observation vs. estimation)



Comparison to Kansai observations





Approach to estimation of emission contribution

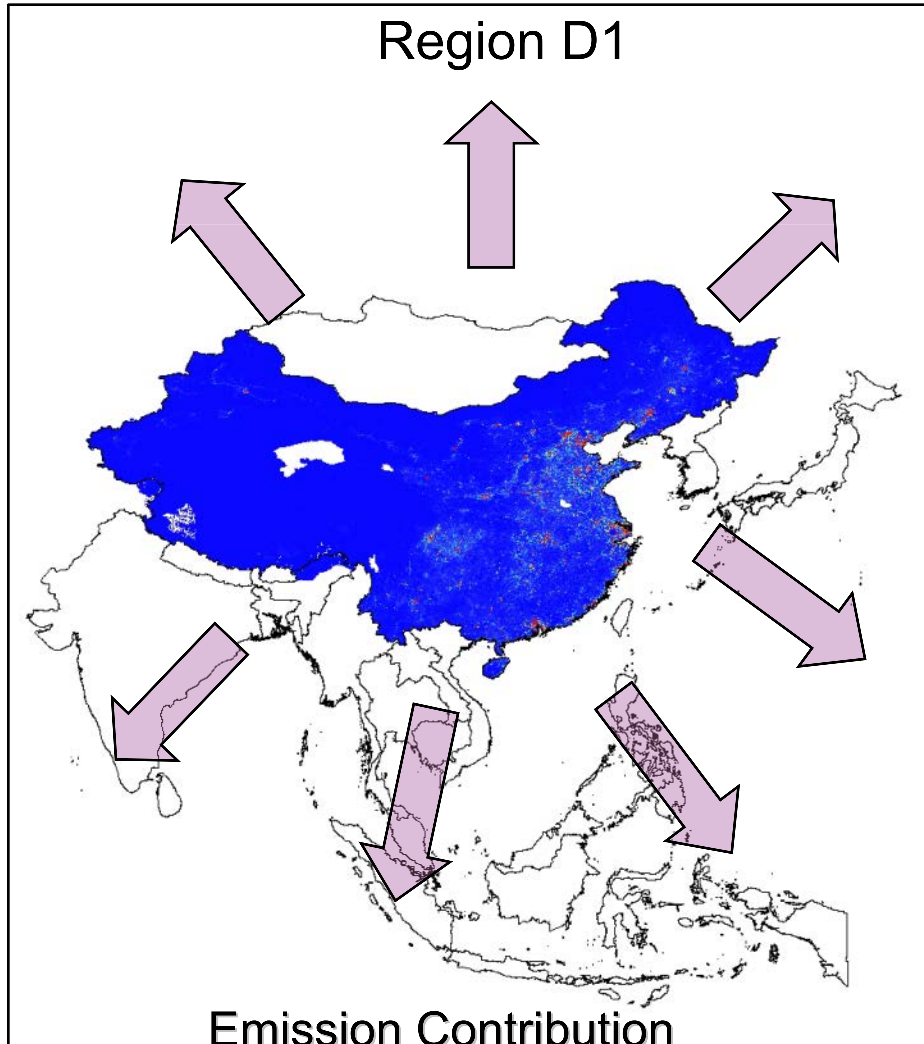
Region :D1

(Asian countries)

The difference between emissions of case 1 and 2 is regarded as emission contribution from China:

Case 1. Asian countries have SO_2 emission.

Case 2. Only emission from China is set to be zero.



Emission contribution from China (1)

$$\textbf{\textit{Contribution}} = \frac{\text{difference of } \textbf{\textit{sulfur deposition}} \text{ between Case 1 and 2}}{\text{total } \textbf{\textit{sulfur deposition}} \text{ in Case 1}} \times 100$$

$$\textbf{\textit{sulfur deposition}} : \text{amount of sulfur deposition in a year}$$

Country	Contribution(%)	
	Sulfur oxide	Nitrogen oxide
China	80	68
South Korea	23	14
Japan	8	8
Mongolia	81	66
Indian	6	16
Indonesian	36	40
Cambodian	25	32
Kyrgyzstan	30	64
Laos	42	39
Macao	65	55
Malaysian	11	17
Thai	15	26
Vietnam	64	58
Myanmar	25	31

Emission contribution from China (2)

Country	Contribution(%)	
	Sulfur oxide	Nitrogen oxide
China	80	68
South Korea	23	14
Japan	8	8
Mongolia	81	66
Indian	6	16
Indonesian	36	40
Cambodian	25	32
Kyrgyzstan	30	64
Laos	42	39
Macao	65	55
Malaysian	11	17
Thai	15	26
Vietnam	64	58
Myanmar	25	31

Contribution from City to City (1)

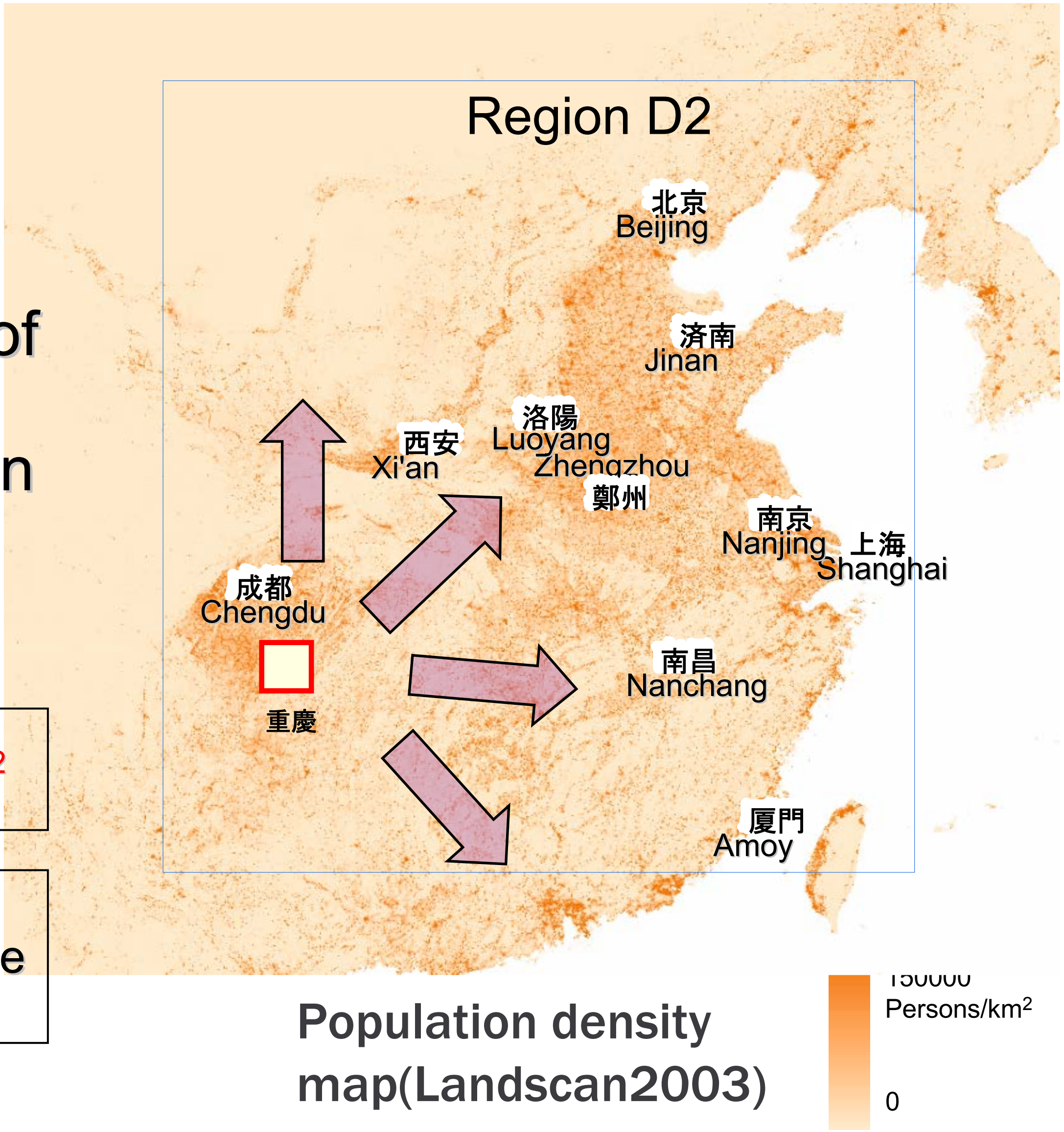
Region :D2

(China)

The difference between emissions of case 1 and 2 is regarded as emission contribution from Chongqing area:

Case 1. D2 area have SO_2 emission.

Case 2. Only emission from Chongqing is set to be zero.



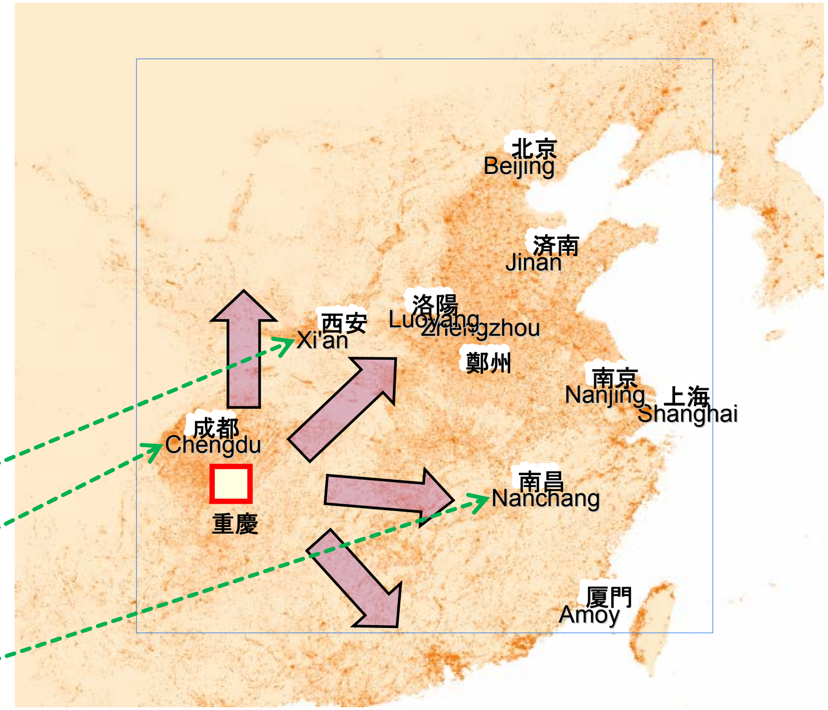
Population density map(Landscan2003)

Contribution from City to City (2)

$$\textbf{\textit{Contribution}} = \frac{\text{difference of } \textbf{\textit{sulfur deposition}} \text{ between Case 1 and 2}}{\text{total } \textbf{\textit{sulfur deposition}} \text{ in Case 1}} \times 100$$

sulfur deposition : amount of sulfur deposition in a year

City	Province	Contribution (%)
Beijing	Beijing	3.6
Amoy	Fujian	6.7
Jinan	Shandong	6.3
Zhengzhou	Henan	5.1
Luoyang	Henan	5.1
Shanghai	Shanghai	2.7
Xi'an	Shanxi	7.2
Chengdu	Sichuan	7.5
Nanjing	Jiangsu	6.3
Nanchang	Jiangxi	7.5



Remarks:

Deposition amount in cities near Chongqing is larger than others

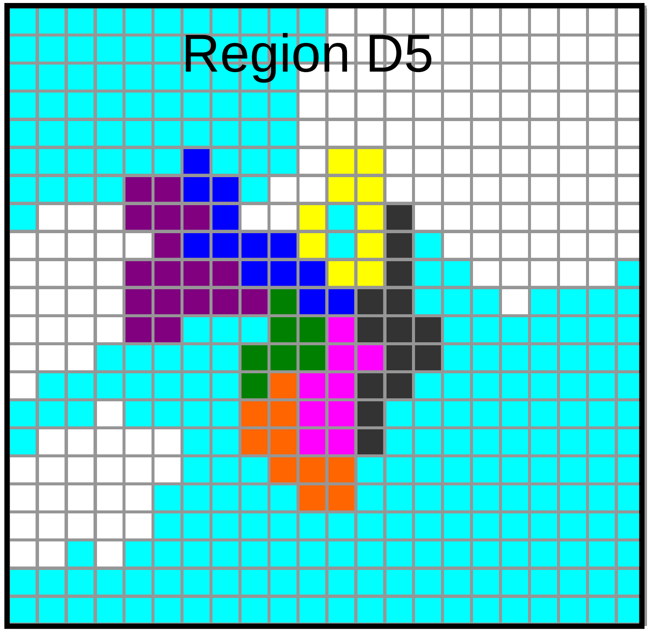
Deposition contribution among neighboring regions (1)

Region :D5

（Kansai district in Japan）

Source-receptor relationship among regions is analyzed

The difference between emissions of case 1 and 2 is regarded as emission contribution from target prefecture:



Green :Osaka prefecture
Blue: Kyoto prefecture
Yellow: Shiga prefecture
Violet: Hyogo prefecture
Pink: Nara prefecture
Orange: Wakayama prefecture
Black: Mie prefecture

Case 1. Asian countries have SO_2 emission.

Case 2. Only emission from the prefecture is set to be zero.

Deposition contribution from source to receptor (Sulfur oxides)

- Source to receptor matrix of sulfur oxides deposition (%)

		Receptor								
		Osaka	Kyoto	Shiga	Hyogo	Nara	Wakayama	Mie	Other places in D5	Kansai region
Source	Osaka	25.3	4.6	1.8	2.4	4.5	2.9	1.6	0.6	2.0
	Kyoto	5.3	11.6	2.6	1.6	2.0	0.8	1.6	0.5	1.5
	Shiga	0.6	1.1	4.9	0.2	0.4	0.2	0.7	0.3	0.6
	Hyogo	2.3	3.1	0.6	10.5	0.7	0.5	0.4	0.4	1.2
	Nara	1.7	0.8	0.4	0.3	5.1	0.6	1.4	0.1	0.6
	Wakayama	1.6	0.2	0.1	0.2	1.0	3.5	0.1	0.1	0.3
	Mie	0.3	0.4	2.1	0.2	0.4	0.2	3.8	0.5	0.8
	Other places in D5	7.1	6.1	8.8	8.9	3.0	3.5	4.5	13.2	10.6
	China	13.2	11.8	11.8	11.8	11.8	17.7	11.8	11.8	12.1
	Others	42.6	60.4	66.9	64.0	71.2	70.2	74.1	72.6	70.3
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Remarks:

◆For Osaka prefecture, which is the largest industrial city in Kansai region, deposition to itself is largest.

◆ Deposition from outside Kansai region is relatively significant.

◆Contribution to Osaka from others is smaller than contribution to other prefectures

Deposition contribution from source to receptor (Nitrogen oxides)

- Source to receptor matrix of nitrogen oxides deposition (%)

		Receptor								
		Osaka	Kyoto	Shiga	Hyogo	Nara	Wakayama	Mie	Other places in D5	Kansai region
Source	Osaka	26.9	6.9	4.1	4.4	7.2	6.2	4.2	2.1	4.3
	Kyoto	7.3	20.8	5.8	4.5	3.8	2.0	4.2	1.7	3.9
	Shiga	2.0	2.9	15.6	0.8	1.4	0.7	3.8	1.1	2.2
	Hyogo	3.1	6.4	1.9	21.1	1.9	1.5	1.1	1.9	3.7
	Nara	3.7	1.7	1.2	1.1	13.7	3.8	4.6	0.6	1.8
	Wakayama	4.0	0.7	0.5	0.8	3.3	13.8	1.0	0.5	1.4
	Mie	1.5	1.7	4.5	0.8	2.0	1.2	14.4	1.2	2.1
	Other places in D5	11.1	12.6	20.4	15.3	7.6	9.2	14.8	26.5	21.6
	China	10.4	9.7	9.3	10.8	9.4	18.0	12.8	11.8	11.6
	Others	30.0	36.7	36.7	40.4	49.7	43.6	39.2	52.4	47.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Remarks:

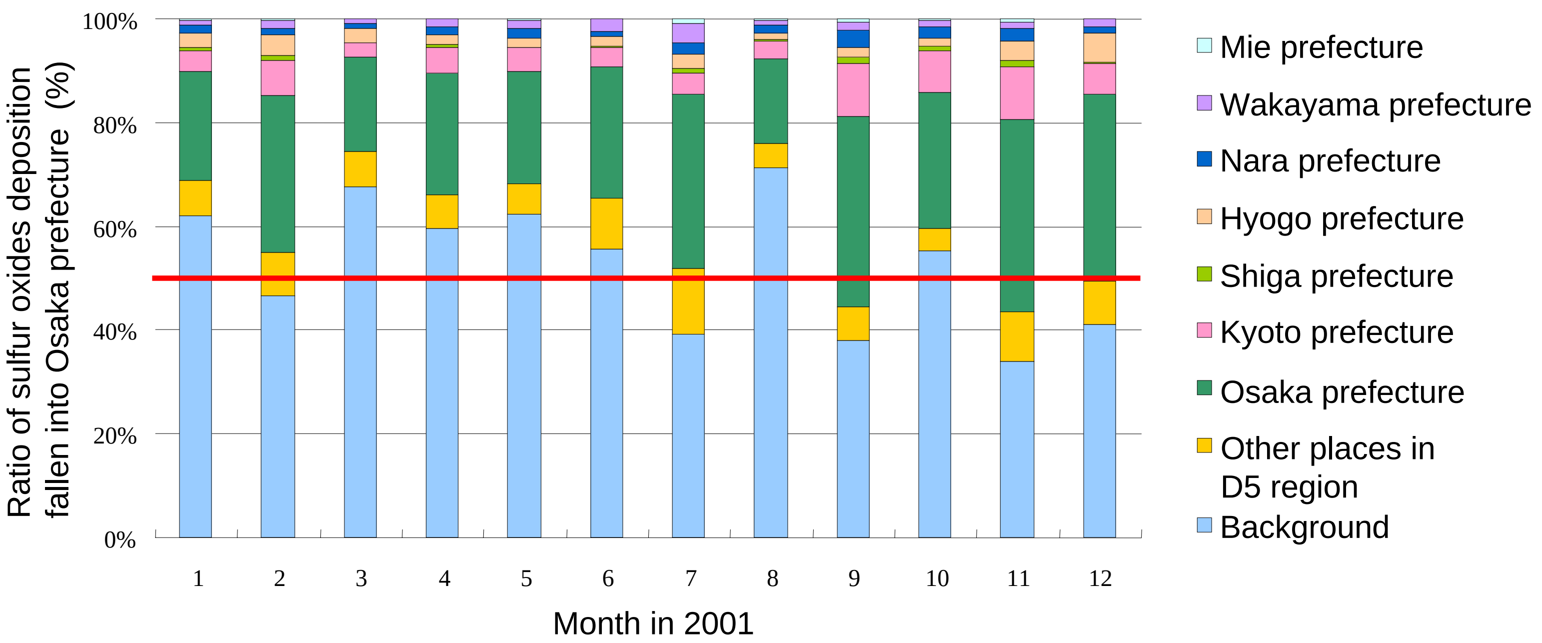
◆For Osaka prefecture, which is the largest industrial city in Kansai region, deposition to itself is largest.

◆ Deposition from outside Kansai region is significant.

◆Contribution from other place in region D5 is larger than sulfur oxides deposition.

Ratio of nitrogen oxides deposition (Osaka)

■ Ratio by emission source of sulfur oxides deposition fallen into Osaka.

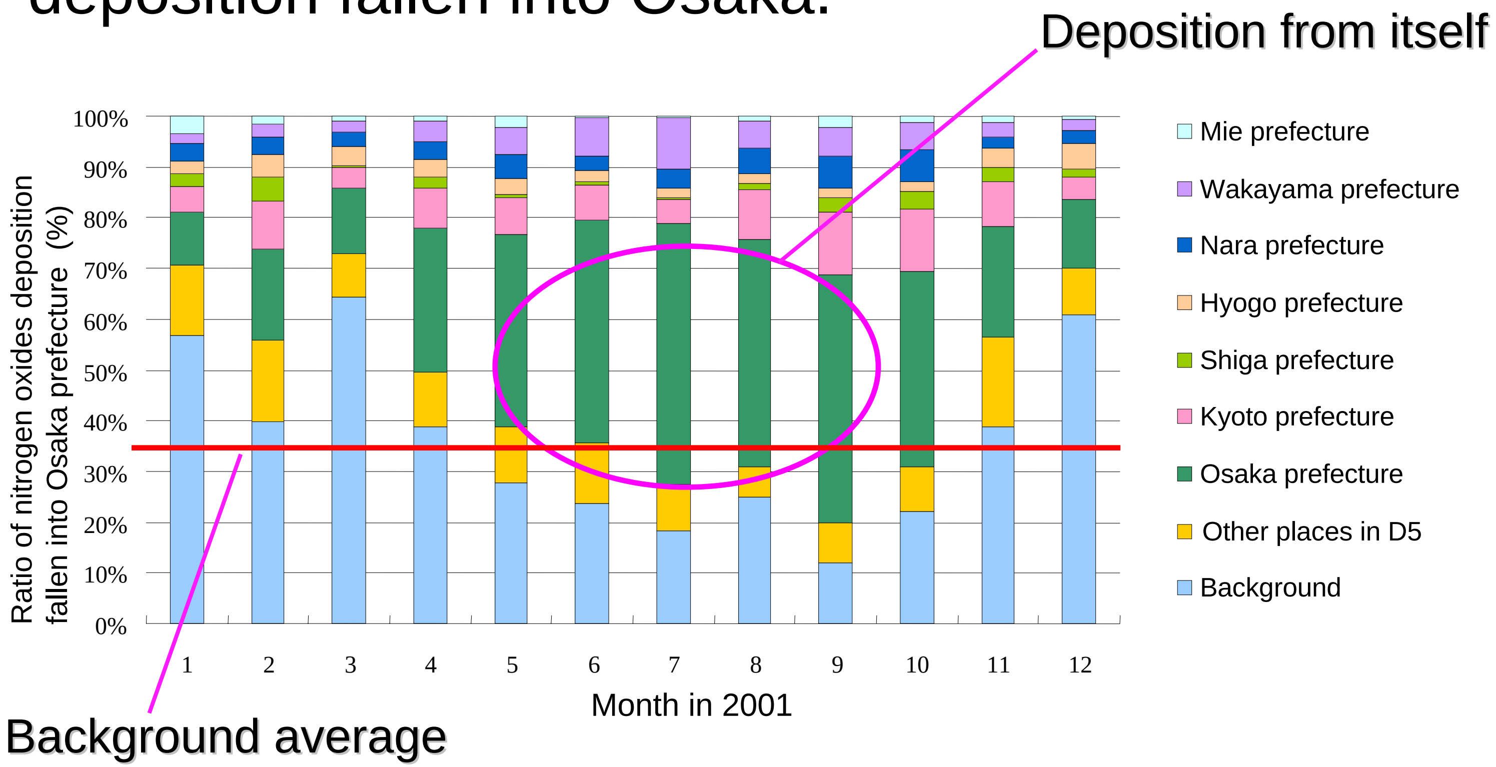


Remarks:

- ◆Year average ratio of background deposition is about 50%.
- ◆Deposition to emission source itself (Osaka) is 20 ～ 30% in the year.
- ◆In summer, self-deposition is weak in March and August.

Ratio of nitrogen oxides deposition (Osaka)

■ Ratio by emission source of nitrogen oxides deposition fallen into Osaka.



Remarks:

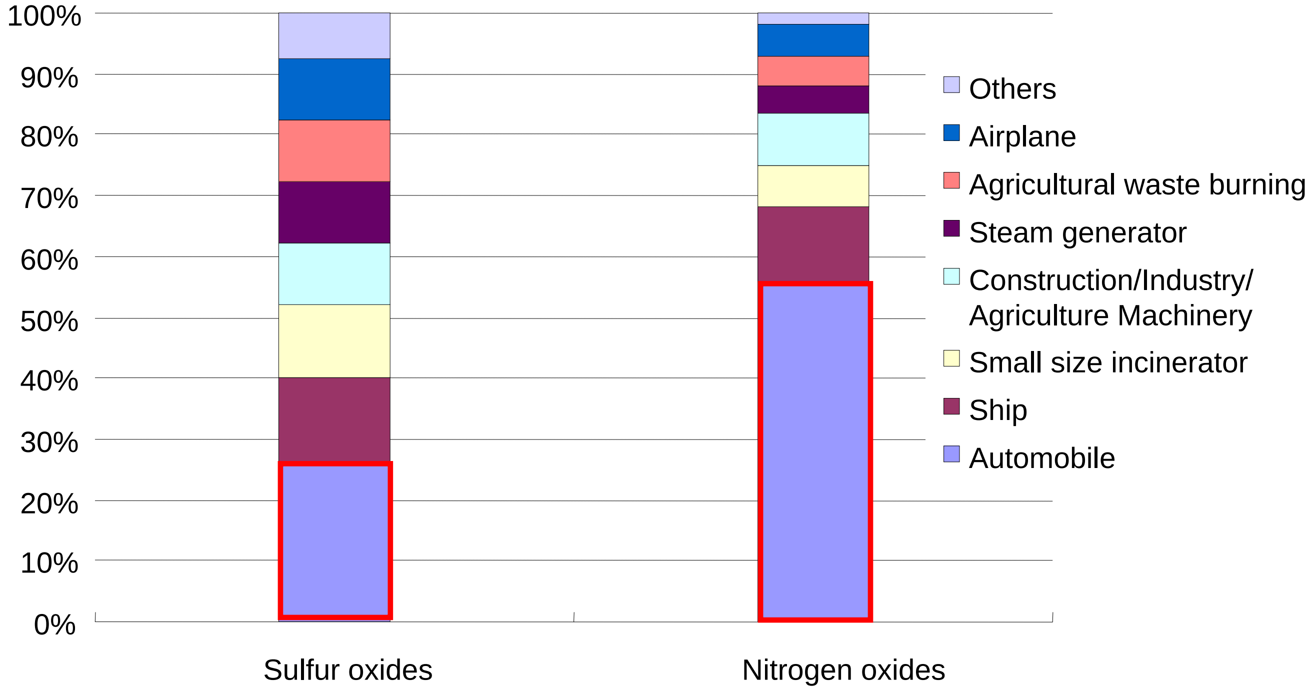
◆Year average ratio of background deposition is about 40%

◆Deposition to emission source itself (Osaka) is larger in summer.

◆In summer, self-deposition is a little weak in August.

Emission contribution from sector
(Sulfur oxides and Nitrogen oxides)

The difference in amount of deposition between emission and zero emission from target sector is regarded as emission contribution from the sector.

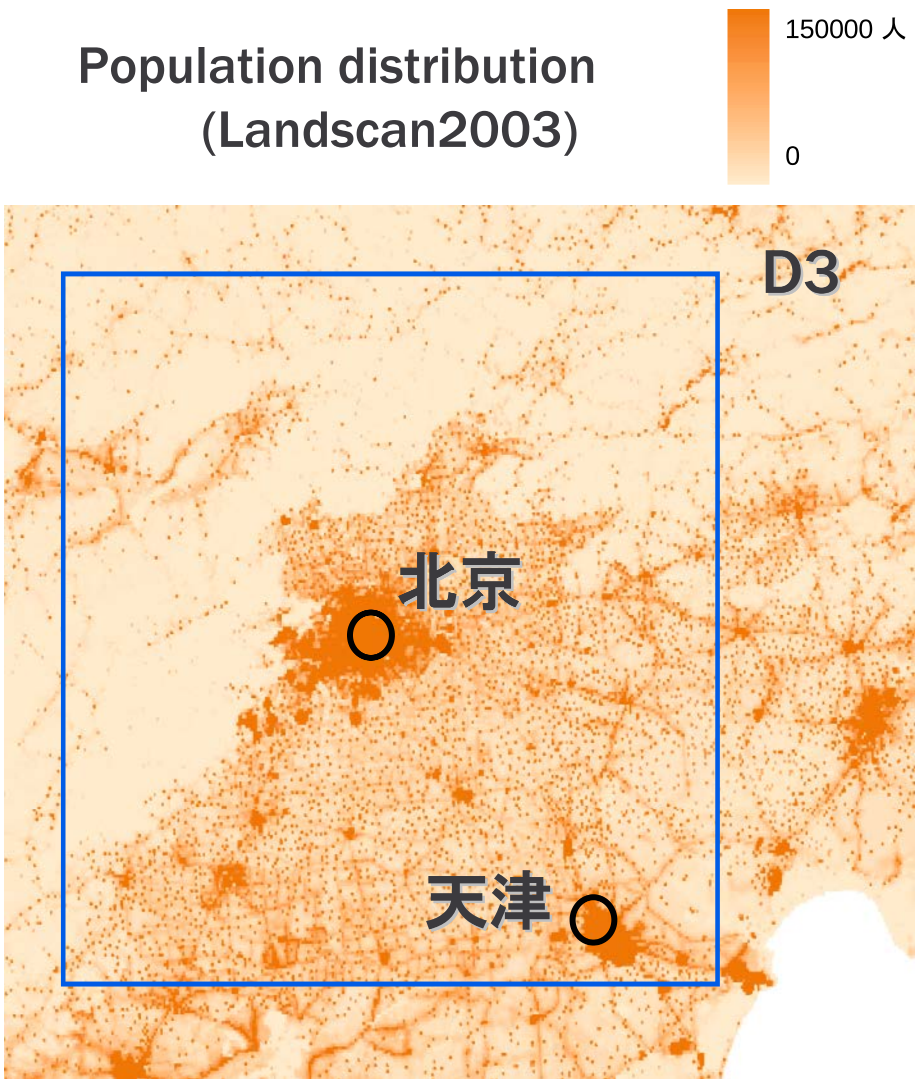


Remarks:

◆ Emission from automobiles strongly affects on deposition of nitrogen oxides.

Future projection of air pollution

- Comparison of SO_2 and NO_2 concentration in Beijing and Tenjing, between year 2001 and 2020, under BaU condition without any countermeasure for air pollution.

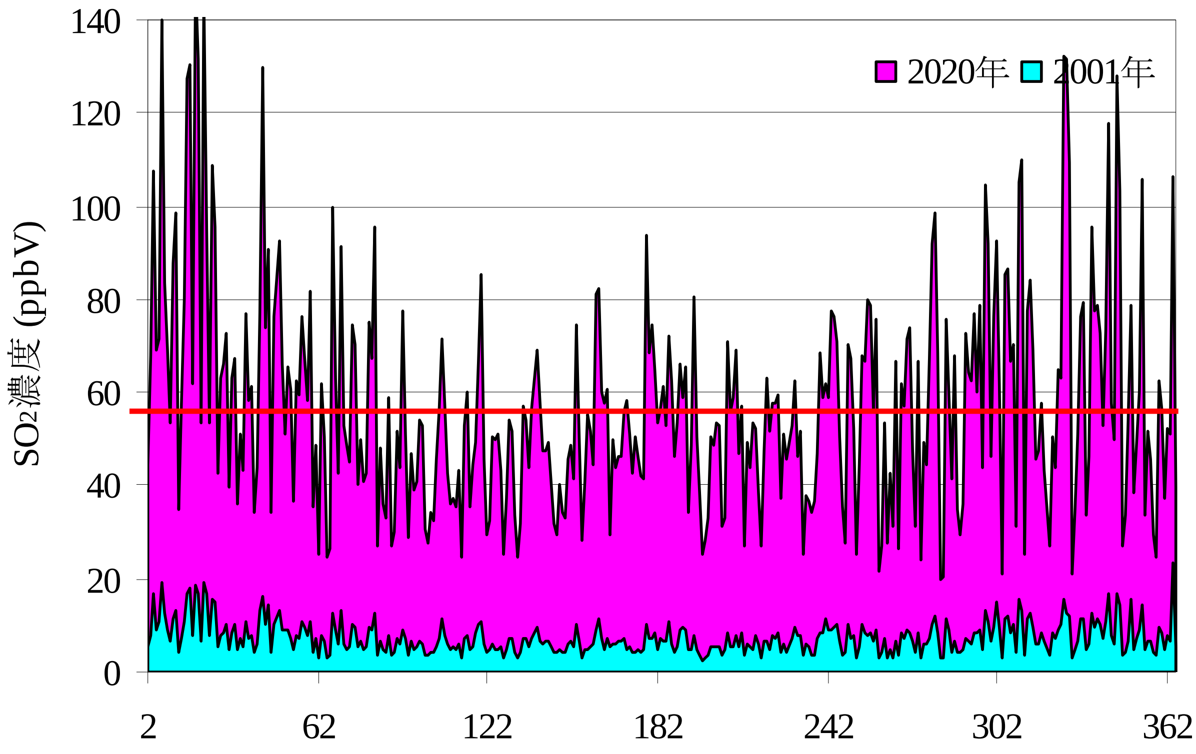


Future projection of SO_2 concentration (Beijing)

Year average SO_2 concentration of Beijing	year 2001		2020
	7ppb	→	56ppb

Chinese 2nd level environmental standard:

Day average SO_2: 150 μ g/m^3
~56ppb



Remarks:

Year average SO_2 concentration in 2020 is 8 times larger than 2001's.

Concentration level excesses so often the 2nd standard level in the year.

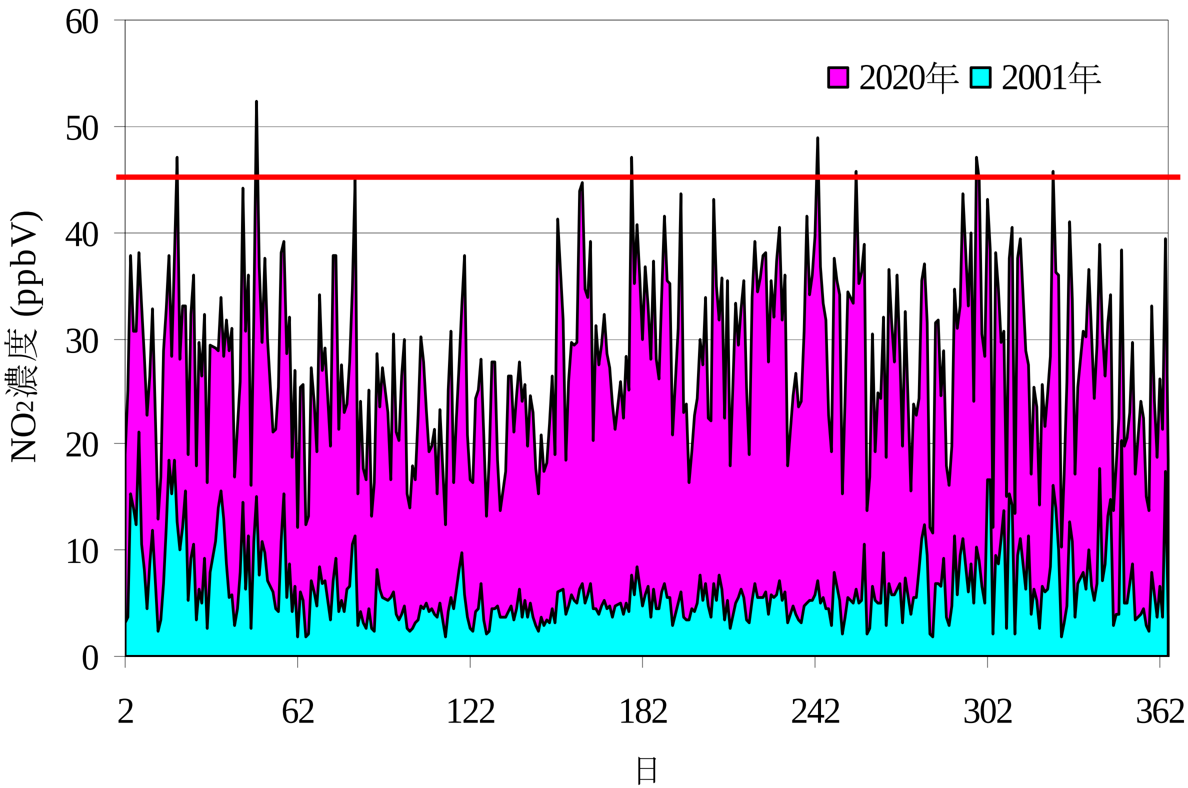
Future projection of NO_2 concentration (Beijing)

Year average NO_2 concentration of Beijing

	year 2001		2020
	6ppb	→	27ppb

Chinese 2nd level environmental standard:

Day average NO_2: 120 μ g/m³ ~46ppb



Remarks:

Year average NO_2 concentration in 2020 is 4.5 times larger than2001's.

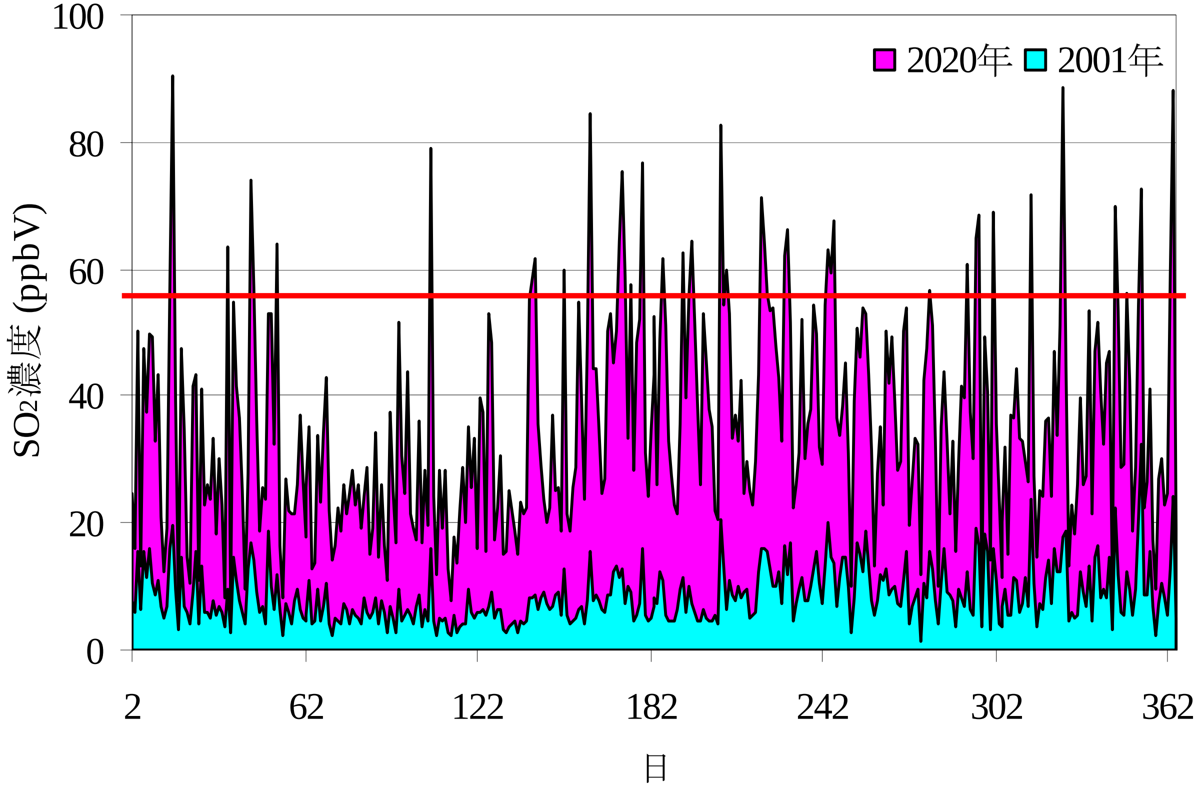
Concentration level sometimes excesses the 2nd standard level.

Future projection of SO_2 concentration (Tenjing)

Year average	year 2001		2020
SO_2 concentration of Tenjing	9ppb	→	35ppb

Chinese 2nd level environmental standard:

Day average SO_2: 150 μ g/m³ ~56ppb



Remarks:

High concentration exists during summer to winter season in 2020.

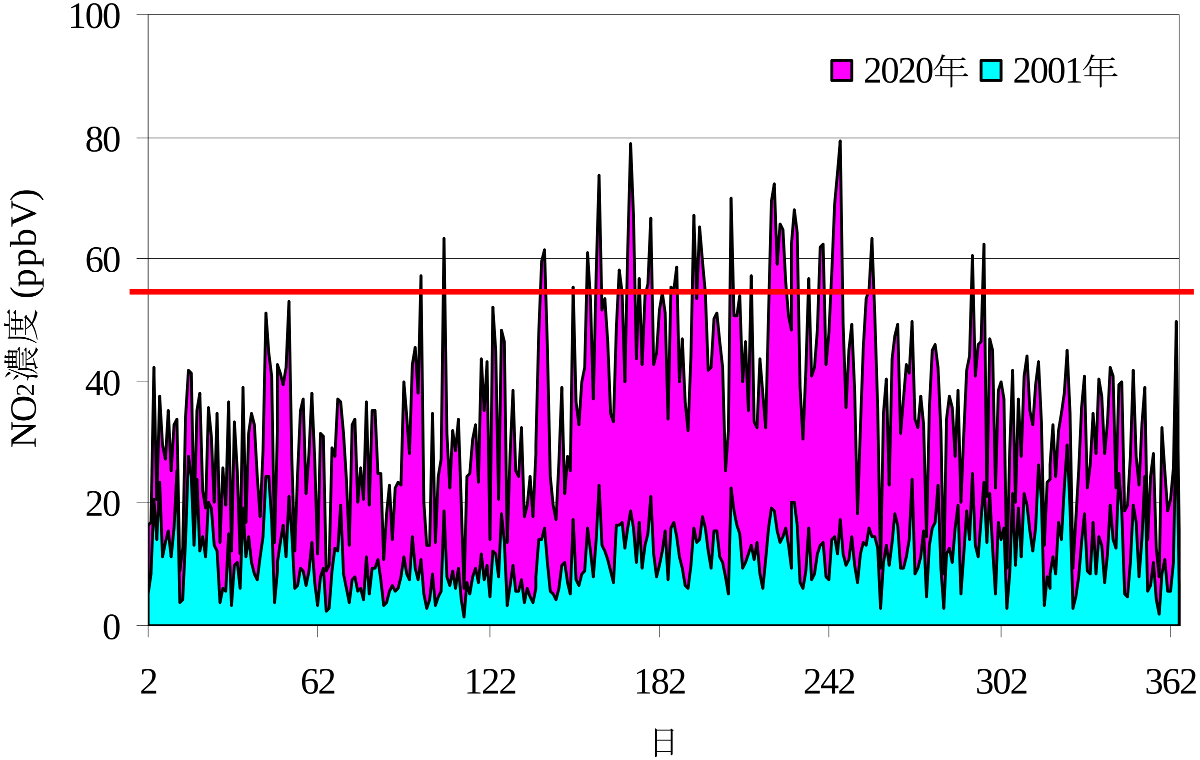
Concentration level often excesses the 2nd standard level.

Future projection of NO_2 concentration (Tenjing)

Year average NO_2 concentration of Tenjing	year 2001		2020
	11ppb	→	36ppb

Chinese 2nd level environmental standard:

Day average NO_2: 120 μ g/m^3 ~46ppb



Remarks: High concentration exists in summer season in 2020.
Concentration level often excesses the 2nd standard level.

Conclusion

- Estimation of background concentration was estimated.
- Source and receptor relationship was estimated.
- Future air quality was projected.