Local Air Quality Modeling, AIM/Air

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Outline of AIM/Air

+ AIM/Air is a program package to calculate the pollutant concentration based on plume and puff diffusion models.
+ Area source (AS) and Large Point Source (LPS) can be dealt with. The emission data from “AIM/Local” are directly available by using converter “A-GIS”.
+ Target size is from city to country.
+ AIM/Air has friendly user interface and runs on both PC’s Windows and Linux.

Characteristics of AIM/Air

+ Properties of emission, such as amount per year, gas temperature, and gas flow, are definable by each LPS or cell of AS.
+ Emission profile is definable. Not only change of emission in a day, in a week and in year but also special terms (such as holiday and off-time in equipment maintenance) are considered.
+ Standard meteorological data (ECMWF) is available. Use of the meteorological data locally measured is effective to increase accuracy of diffusion analysis.
+ An effective algorithm to reduce computational time is adopted.

Model Equations

Plume model (Wind velocity >= 1 m/s)

$$C(x,y,z)=\frac{Q_p}{2\pi\sigma_y\sigma_z u}\cdot\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\cdot\left[\exp\left\{-\frac{(z-He)^2}{2\sigma_z^2}\right\}+\exp\left\{-\frac{(z+He)^2}{2\sigma_z^2}\right\}\right]$$

Puff model (Wind velocity < 1 m/s)

$$C(x,y,z)=\frac{Q_p}{(\sqrt{2\pi})^3\gamma}\cdot\exp\left(-\frac{u^2}{2\alpha^2}\right)\cdot\left[\frac{1}{\eta_-^2}\left\{1+\frac{\sqrt{2\pi}ux}{\alpha\eta_-}\cdot\exp\left(\frac{u^2x^2}{2\alpha^2\eta_-^2}\right)\cdot erfc\left(-\frac{ux}{\sqrt{2}\alpha\eta_-}\right)\right\}\right.$$

$$\left.+\frac{1}{\eta_+^2}\left\{1+\frac{\sqrt{2\pi}ux}{\alpha\eta_+}\cdot\exp\left(\frac{u^2x^2}{2\alpha^2\eta_+^2}\right)\cdot erfc\left(-\frac{ux}{\sqrt{2}\alpha\eta_+}\right)\right\}\right]$$

$$\eta_-^2=R^2+\frac{\alpha^2}{\gamma^2}(z-He)^2 \qquad \eta_+^2=R^2+\frac{\alpha^2}{\gamma^2}(z+He)^2 \qquad erfc(W)=\frac{2}{\sqrt{\pi}}\int_W^\infty\exp(-t^2)dt$$

AIM/Air General Data Flow Diagram

Emission projection

AIM/Local

A-GIS

Grid data by raster format

AGIS.rst

convAGIS

agis.air

Emission patterns

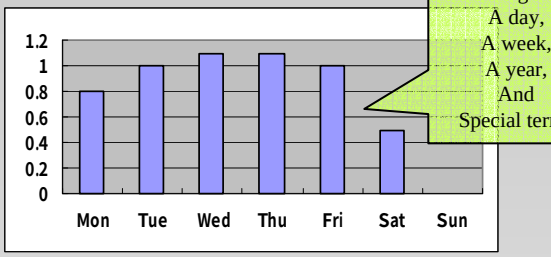
editEpat

epat.air

Target area

editGmap

gmap.air



Meteorological data

ECMWF

readGRBX

u.air

Local measurement

local.air

LPS

AS

Integration of LPS emission data

editLPS

emitLPS.air

editAS

emitAS.air

Integration of AS emission data

Stability calculation for LPS

stabLPS

stabLPS.air

stabAS

stabAS.air

Stability calculation for AS

Diffusion calculation

diffB

diff.air

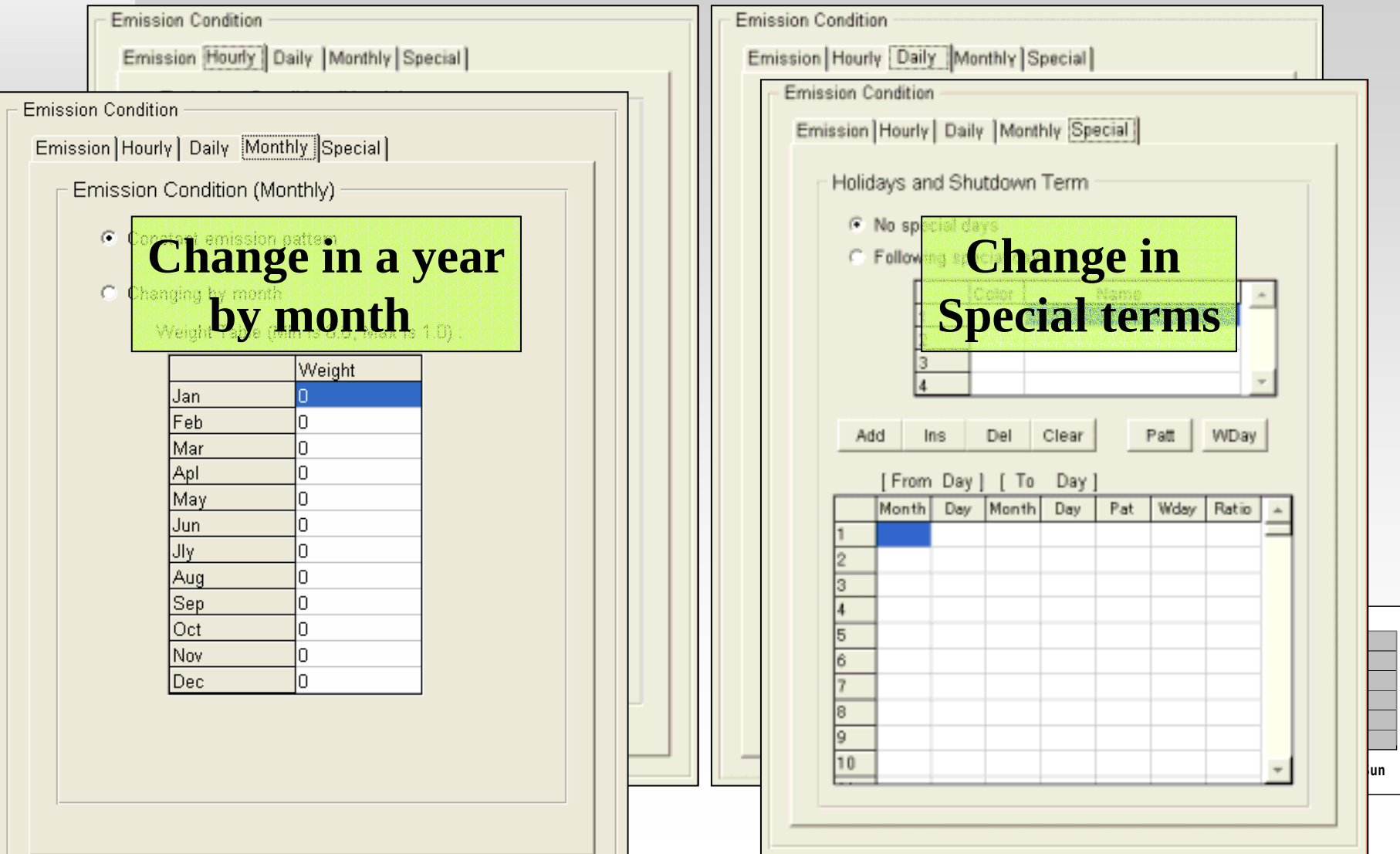
viewCont

Viewer

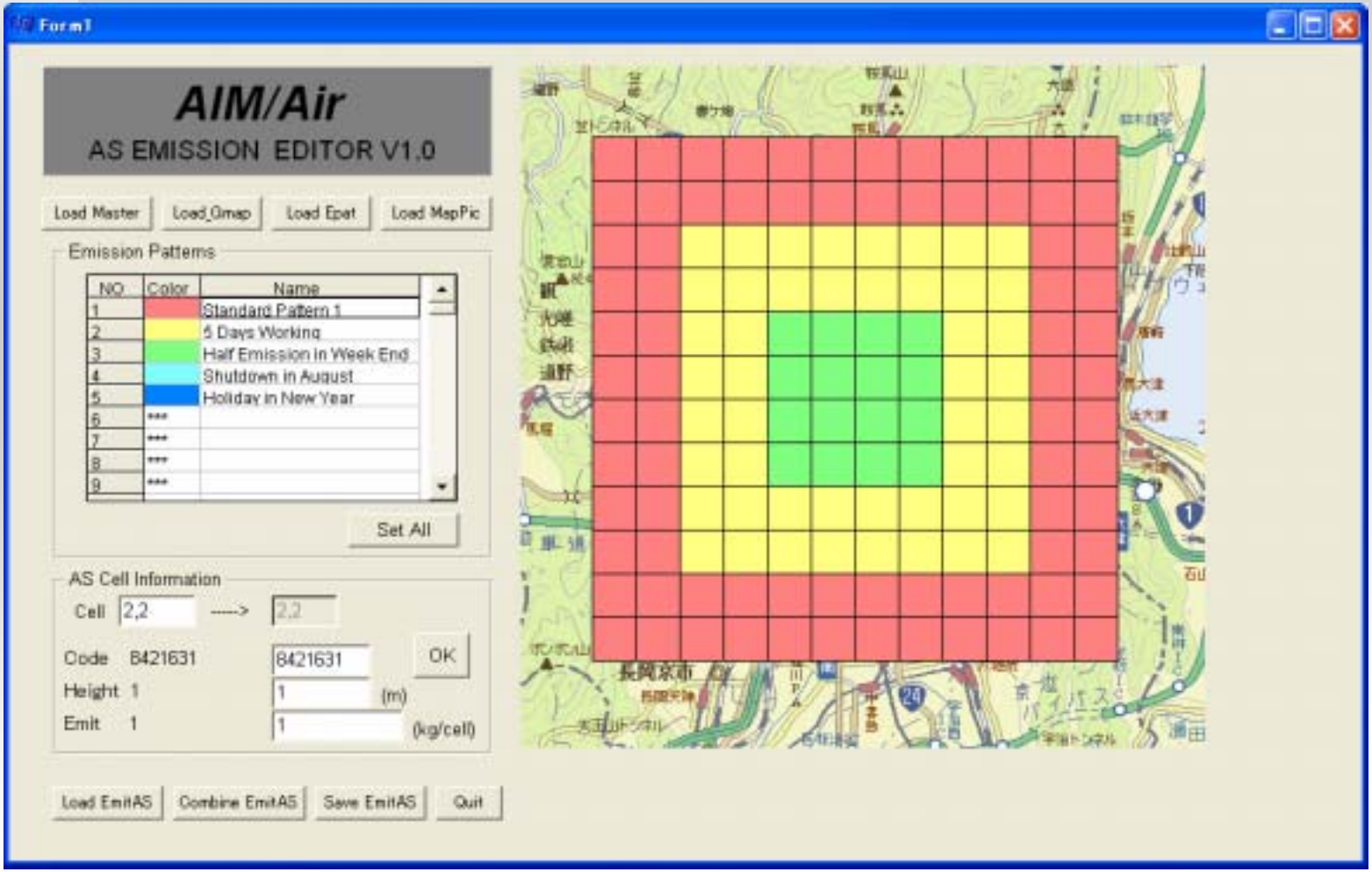
Concentration

(Connect to health impact assessment module)

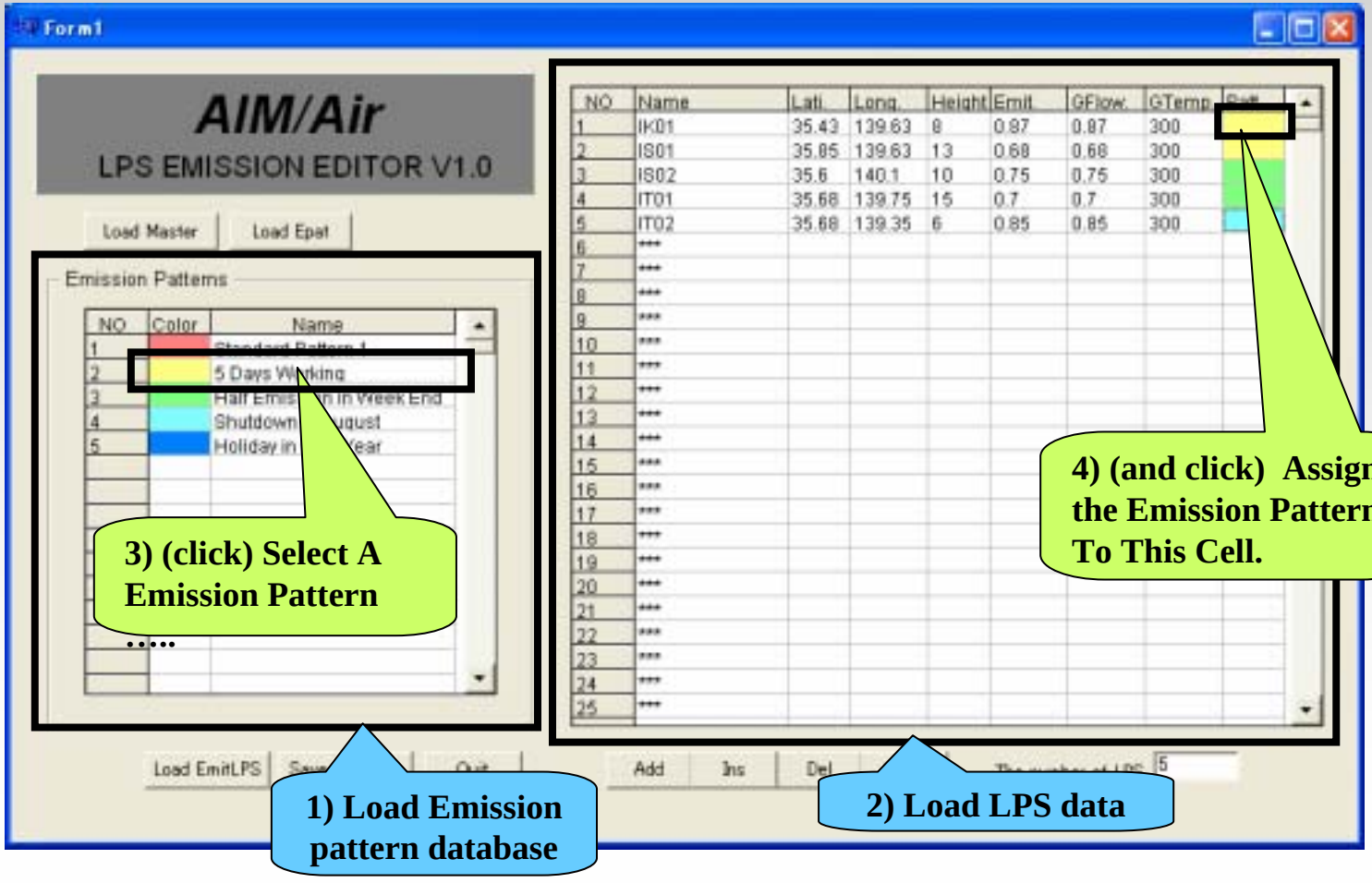
Emission Pattern Editor



AS Emission Editor



LPS Emission Editor



Application

- AIM/Air was applied to assess health impact of SO_2 in Beijing.

Air Quality Level in China

The 1st level: Nature protection zone, scenic zone. Day-averaged SO_2 concentration: 50 μg/m³

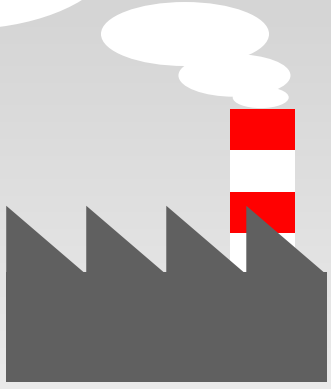
The 2nd level：Residential area, the area mixed with commercial, transportation and residential area, cultural area , usual industrial area, and agricultural area

Day-averaged SO_2 concentration： 150 μg/m³

The 3rd level：Specified industrial area. Day-averaged SO_2 concentration：250 μg/m³

Pollution Level of cities in China

Because of drastic development of economics in China to identify the health impact caused by SO_2 is significantly important.



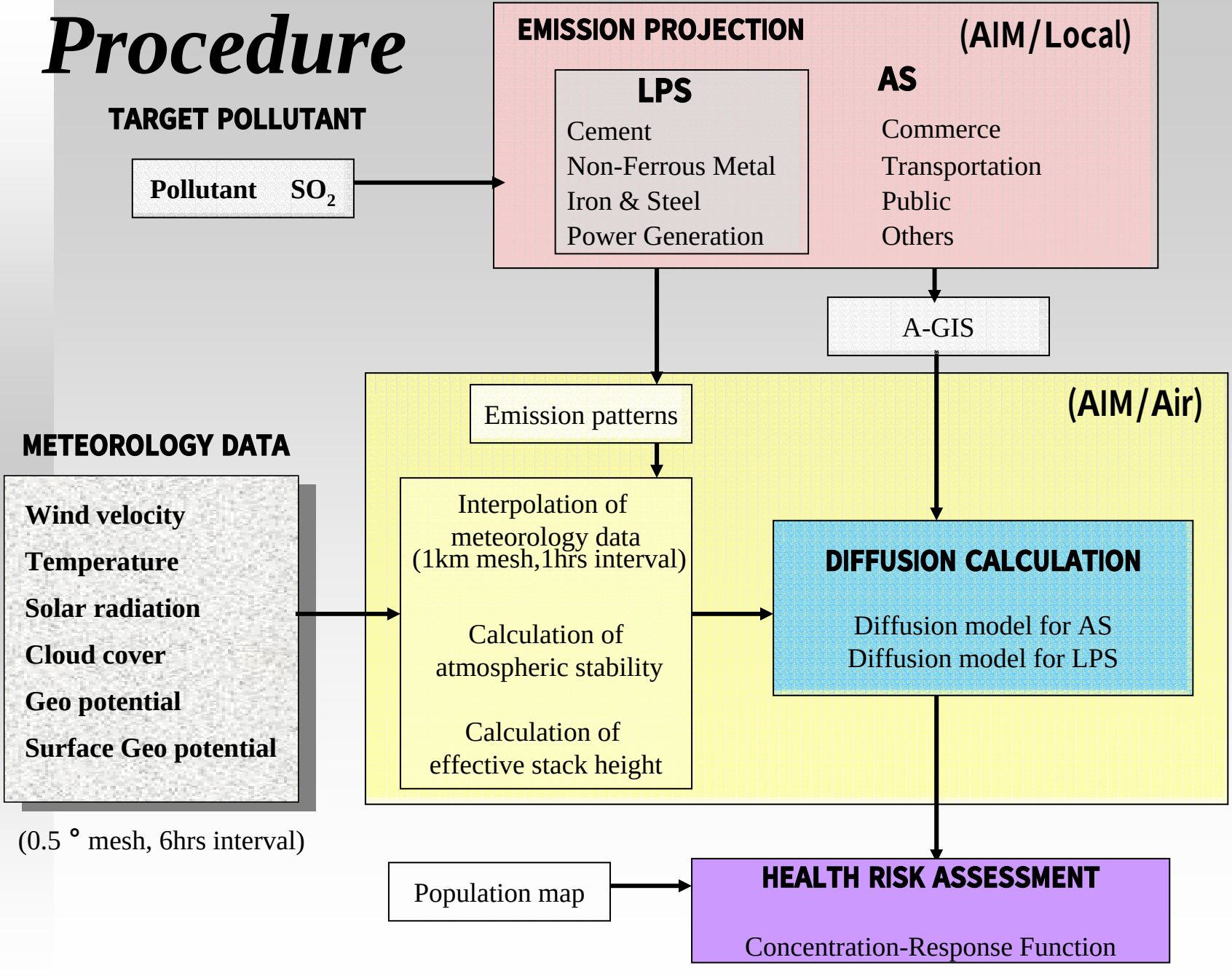
In 343 cities researched in China,

The number of cities where SO_2 concentration is above the standard value of the 3rd level air quality：107 cities(31.2%)

Above the 2nd level and below the 3rd level ：120cities(35.0%)

If the 2nd air quality level is achieved 178,000 of death will be avoided (World Bank)

Procedure


TARGET POLLUTANT
Pollutant SO2
EMISSION PROJECTION
(AIM/Local)
LPS
Cement
Non-Ferrous Metal
Iron & Steel
Power Generation
AS
Commerce
Transportation
Public
Others
A-GIS
(AIM/Air)
Emission patterns
METEOROLOGY DATA
Wind velocity
Temperature
Solar radiation
Cloud cover
Geo potential
Surface Geo potential
(0.5 ° mesh, 6hrs interval)
Interpolation of meteorology data (1km mesh,1hrs interval)
Calculation of atmospheric stability
Calculation of effective stack height
DIFFUSION CALCULATION
Diffusion model for AS
Diffusion model for LPS
Population map
HEALTH RISK ASSESSMENT
Concentration-Response Function

Target Area

Beijing(China)

1,600km^2

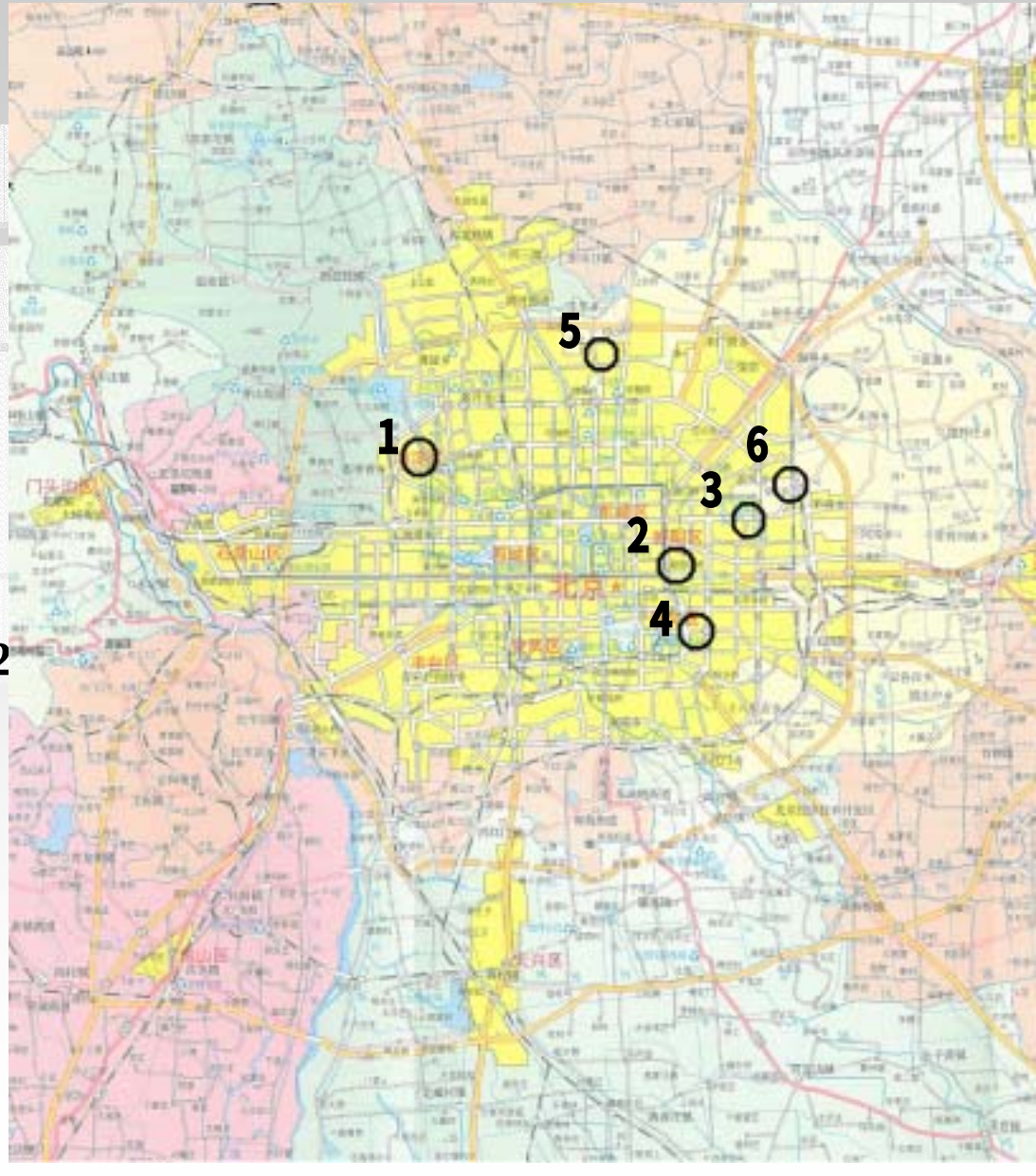
Target time extent:

Jan 1, ~Dec. 31, 2000

Target pollutant: SO_2

○ Measurement points

1	Che Gong Zhuang
2	Qian Men
3	Dong Si
4	The Temple of Hea
5	Olympic Center
6	Agricultural Museu



Emission Source (AIM/Local)

AS(Area Source)

LPS(Large Point Source)

- **Cement sector**
- **Steel and iron sector**
- **Non-ferrous metal sector**
- **Power generation sector**

GDP by secondary industry section in each district

Population density in each 30 seconds mesh

- **Commerce sector**
- **Transportation sector**

GDP by third industry section in each district

Population density in each 30 seconds mesh.

- **Public sector**
- **Other sector**

Population density

Emission pattern (1)

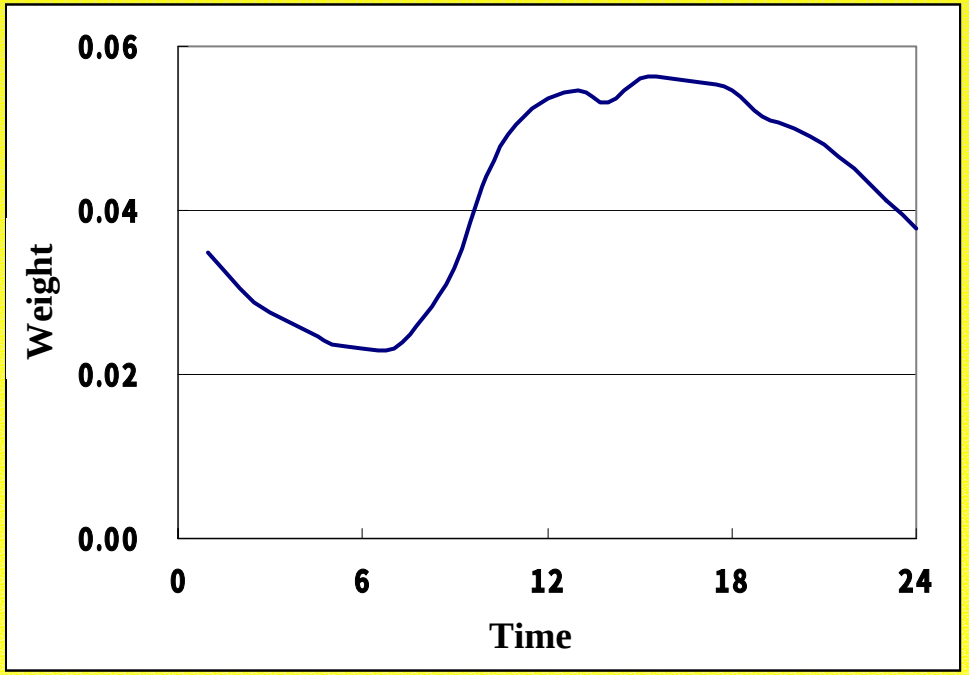
Change in day

Industry and commerce sectors

Constant during 9:00～19:00

Zero during 19:00～8:00

Power generation and public sectors



Change in week

Industry sector：constant during Mon. to Fri. and zero on Sat. and Sun.

Emission Pattern (2)

Change in year

Commerce and public sectors (frequent use of heater)

$$\frac{\textit{Emission from heater}}{\textit{Emission from every equipment}}$$

=39%(public sector)

=89%(commercial sector)

Month	Emission rate by sector	
	Commerce	Public
Jan.	0.447	0.243
Feb.	0.169	0.121
Mar.	0.066	0.076
Apr.	0.011	0.052
May	0.009	0.051
Jun.	0.009	0.051
Jul.	0.009	0.051
Aug.	0.009	0.051
Sep.	0.009	0.051
Oct.	0.013	0.052
Nov.	0.071	0.078
Dec.	0.178	0.125

Special terms

- 新年 ：Jan. 1
- 労働祭：Apr. 29～May 5

春節　：Feb. 5～7

国慶祭：Sep. 29～Oct. 3.

Health Impact Assessment

The relationship between SO_2 concentration averaged in 48 hrs and daily mortality

$$Daily\ Mortality = \left[y_0 \cdot \left(\exp\left(-\beta \cdot \Delta SO_2 \right) - 1 \right) \right] \cdot pop$$

y_0 : rate of death caused by any events except accident

β : SO_2 coefficient

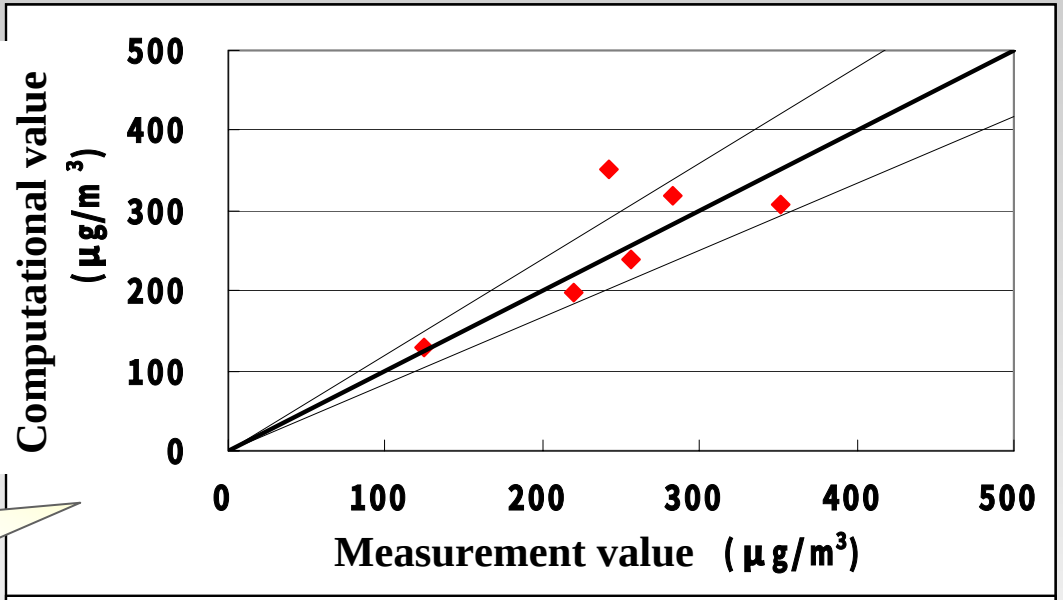
ΔSO_2 : The difference between projected SO_2 concentration which is averaged in 48 hrs and the regulation value of the 2nd grade standard.

Using the daily mortality how many death can be avoided if the concentration is regulated under the standard value of the 2nd level air quality is calculated.

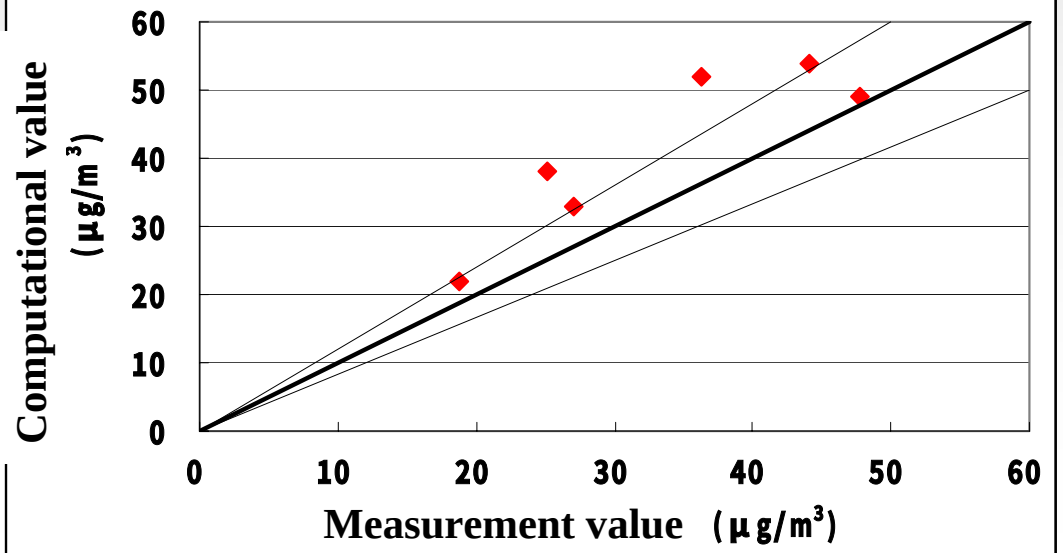
Result from diffusion simulation (1)

Comparison between measurement and computation of day-averaged concentration.

Winter season
Relation coefficient: 0.769



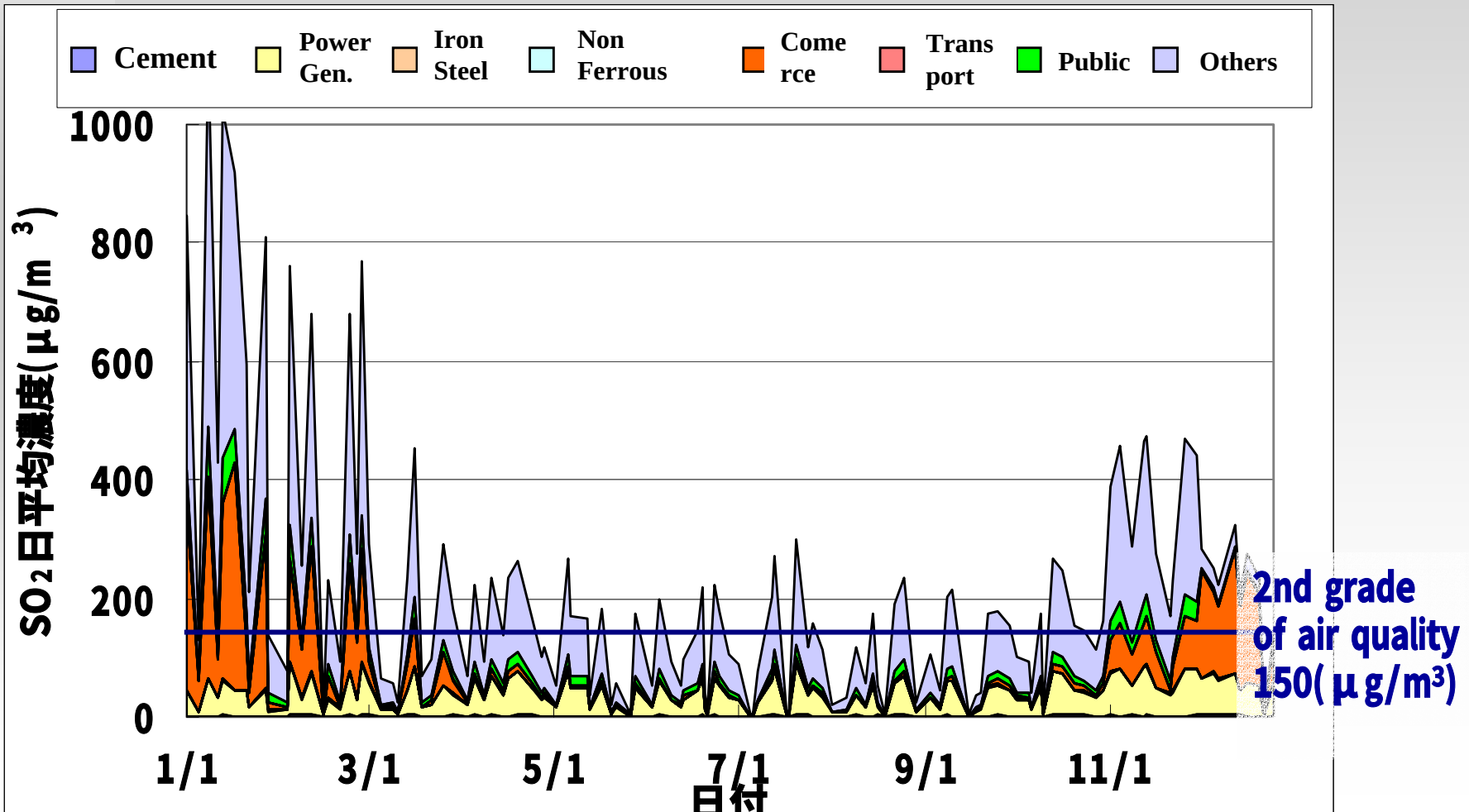
Summer season
Relation coefficient 0.892



(environmental annual report of 1998)

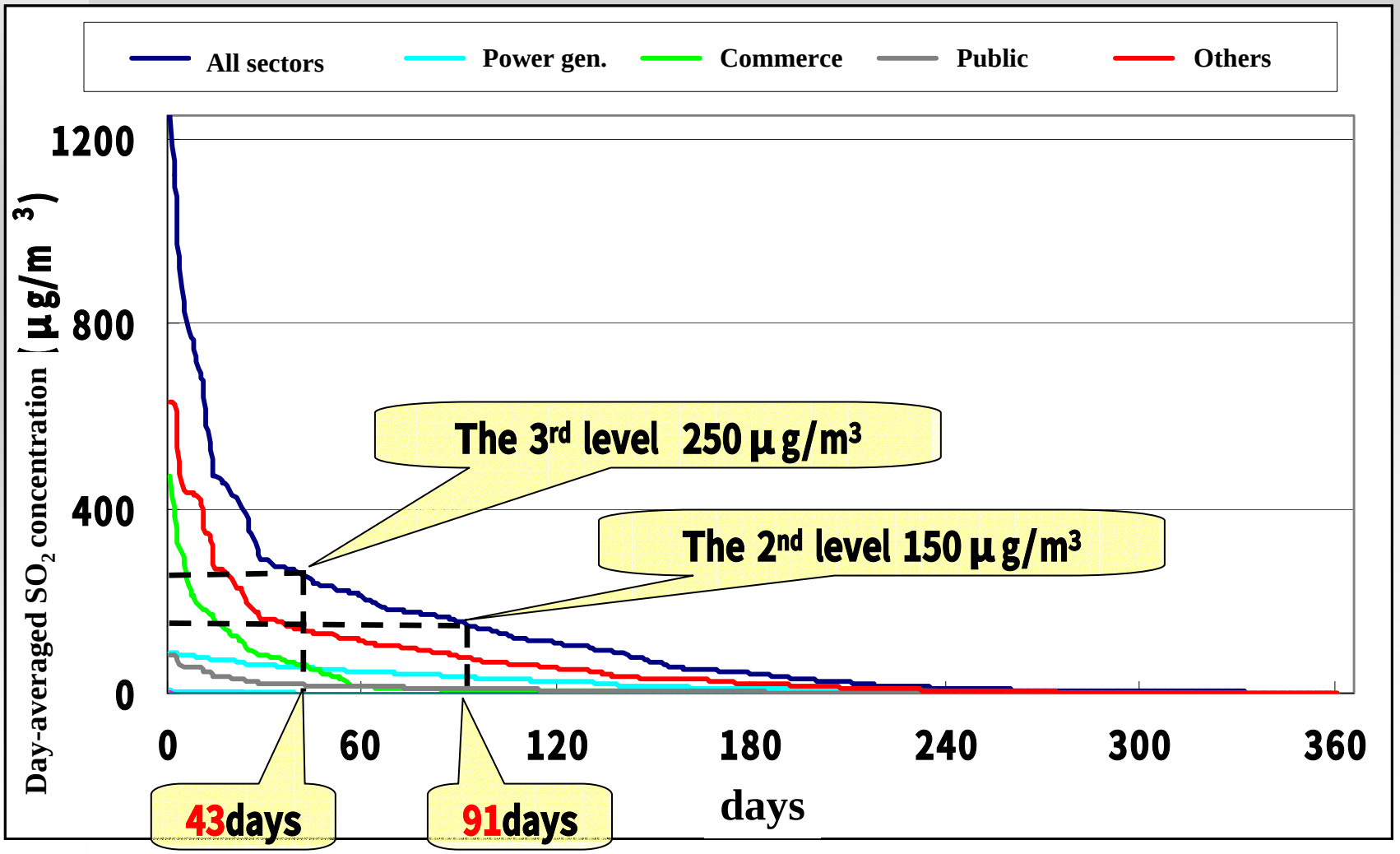
Result from diffusion simulation (2)

Contribution of the day-averaged SO_2 concentration by sector at a cite of high population density



Result from Diffusion Simulation (3)

Histogram of day-averaged SO_2 concentration



Result from Diffusion Simulation (4)

The number of days which day-averaged SO_2 concentration is above the standard value of the 2nd level air quality

# of days above standard	Month											
	Jan.	Feb.	Mar.	Apl.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
0	86.09	97.09	99.25	99.84	99.78	99.81	99.75	99.91	99.69	99.75	99.37	99.5
1	8.054	1.88	0.501	0.063	0.157	0.063	0.157	0.031	0.219	0.157	0.439	0.345
2	3.322	0.282	0.094	0	0	0.031	0	0.031	0.031	0.031	0.031	0.031
3	0.721	0.188	0	0.031	0	0.063	0	0	0	0	0	0.031
4	0.407	0.157	0	0	0.031	0.031	0.031	0.031	0.031	0	0	0
5	0.501	0.125	0	0	0.031	0	0.031	0	0	0	0.063	0.031
6	0.094	0.031	0.094	0.031	0	0	0.031	0	0.031	0	0	0
7	0.094	0.031	0.031	0	0	0	0	0	0	0.031	0.031	0.031
8	0.251	0.063	0	0	0	0	0	0	0	0.031	0	0
9	0.125	0	0	0	0	0	0	0	0	0	0	0
10	0.063	0.031	0	0.031	0	0	0	0	0	0	0.031	0
11	0.031	0	0	0	0	0	0	0	0	0	0	0.031
12	0.063	0	0	0	0	0	0	0	0	0	0	0
13	0.031	0.063	0.031	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0.031	0
15	0.031	0.031	0	0	0	0	0	0	0	0	0	0
17	0.031	0	0	0	0	0	0	0	0	0	0	0
18	0.031	0.031	0	0	0	0	0	0	0	0	0	0
21	0.031	0	0	0	0	0	0	0	0	0	0	0
29	0.031	0	0	0	0	0	0	0	0	0	0	0

The maximum number of days which is above the 2nd standard is 104 days.

Result from Impact assessment

The total number of avoidable death in the target area and the maximum number of the avoidable death in whole cells, by month

Month	Total	The maximum in cells
Jan.	587.14	206.78
Feb.	22.09	11.17
Mar.	3.57	2.09
Apr.	0.72	0.72
May	0.39	0.39
Jun.	0.79	0.41
Jul.	2.28	1.38
Aug.	0.31	0.31
Sep.	1.15	0.73
Oct.	0.82	0.82
Nov.	6.6	6.02
Dec.	1.79	1.77

Unit: person's death

If SO_2 concentration in Beijing is regulated under the standard value of the 2nd grade of air quality in China, the total number of avoidable death in year 2000 is approximately **626.9**

Conclusion

- **Air quality modeling and simulation tool AIM/Air was developed.**
- **By using this tool concentration of air pollutant can be calculated from the information of emission source that is resulted from AIM/Local.**
- **Proposed algorithm for quick calculation and user interface enables to run diffusion calculation both on PC's Windows and Linux.**
- **This tool was applied to project air quality of Beijing. Moreover, daily mortality was assessed.**

Thank you