Local Air Pollution Modelling, AIM/Air

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Topics

- Calculation of impact of traffic sector on air quality
  - By using traffic volume data measured in traffic census, emission from traffic sector was disaggregated into line source of road networks.
- Improvement of AIM/Air: inclusion of land use information
  - Based on land use information, total emission of each sector was disaggregated to a set of area which is used by the sector.

[The 1st topic]
Calculation of impact of Traffic Sector on Air Quality

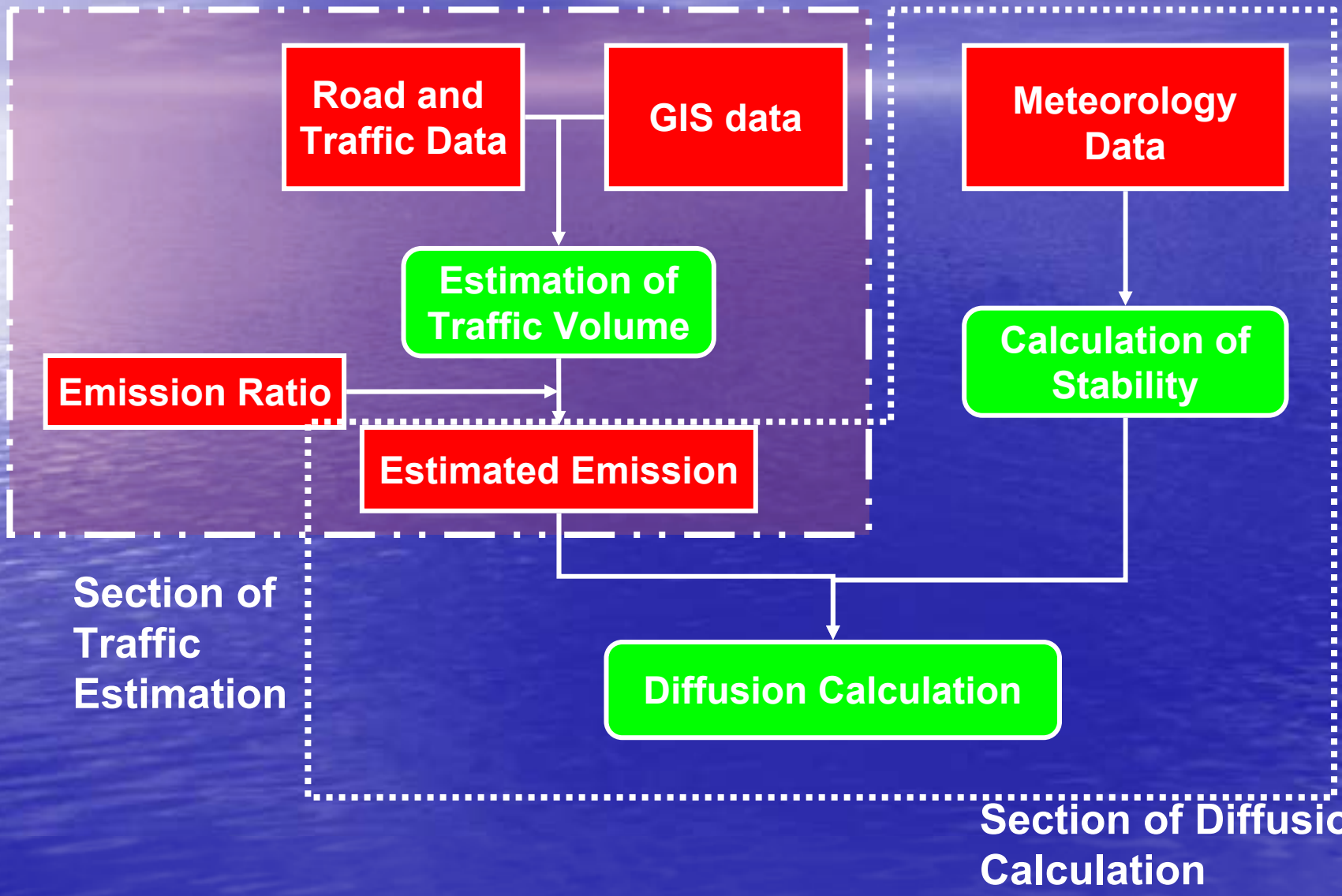
Outline

- The method of estimating traffic volume on road networks by using limited number of measurement data are applied.
- Diffusion of emission gas and particles (NOx、SOx、PM) from automobiles was calculated.
- Line emission source was regarded as a series of point sources.

Back ground

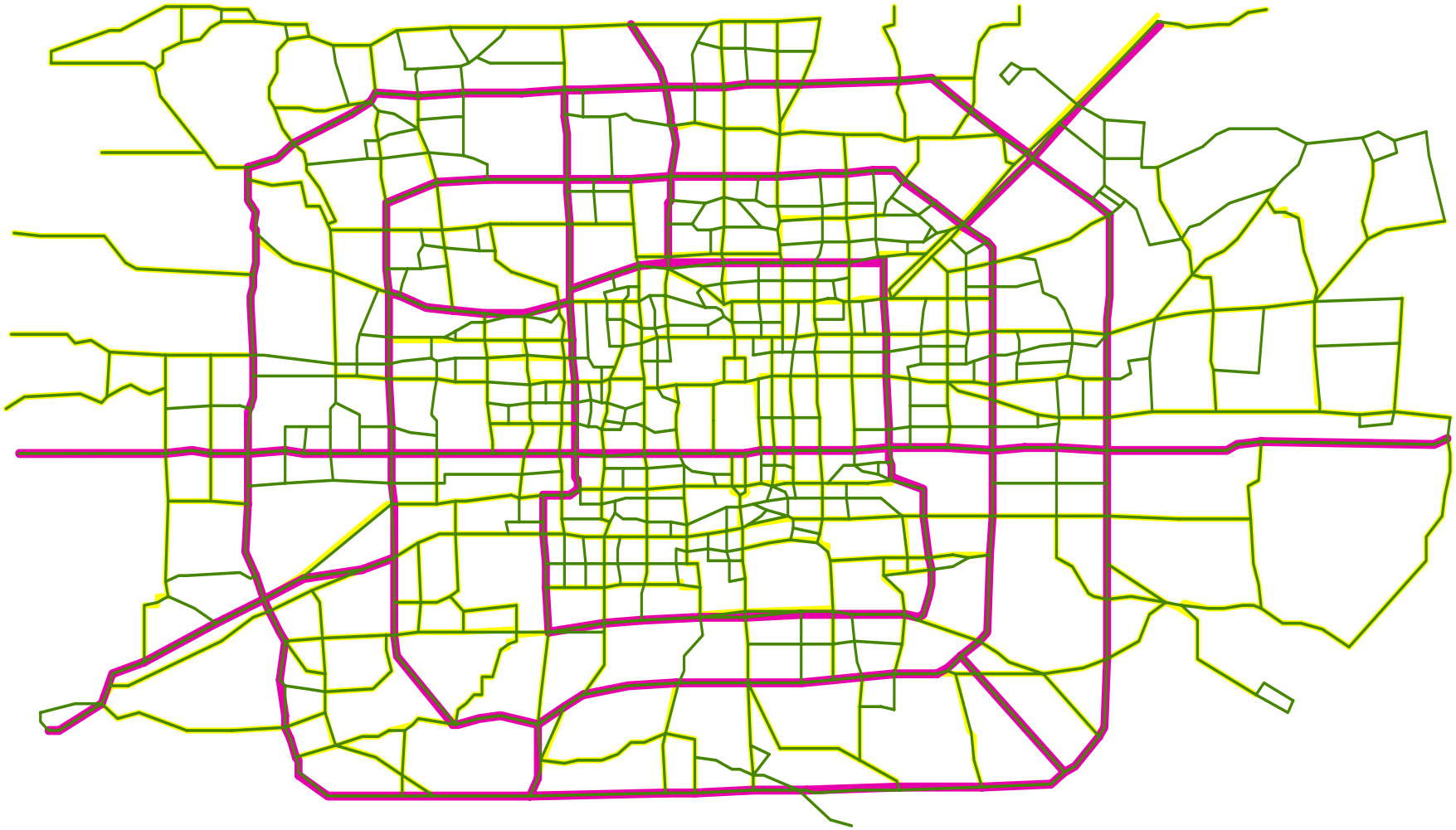
- Research on emission from automobiles by Dr. Hao et. al., which had been published as a book「城市机动车排放污染控制」
- Hao's group have already calculated emission diffusion from automobiles in Beijing.
- Emission condition of automobiles, such as emission coefficient for each type of car, was assumed based on MOBLIE 5 model.

Flow Diagram of Calculating Concentration Related with Transport Sector



Traffic Data Required

- Road data and traffic volume data measured
  - Road length, width, connection.
  - Measured flow rate of automobile.
- Traffic volume
  - How many automobiles pass over per hour.
- Emission ratio of automobile
  - NOx emission ratio of each type of automobiles is used.



Traffic volume estimation

- Using road network, land use, and actual traffic volume data, traffic volume of each road was estimated.
- OD traffic volume estimation method based on link flow was applied.
- To accelerate computation speed cluster computer system was used.

Traffic Volume Estimation

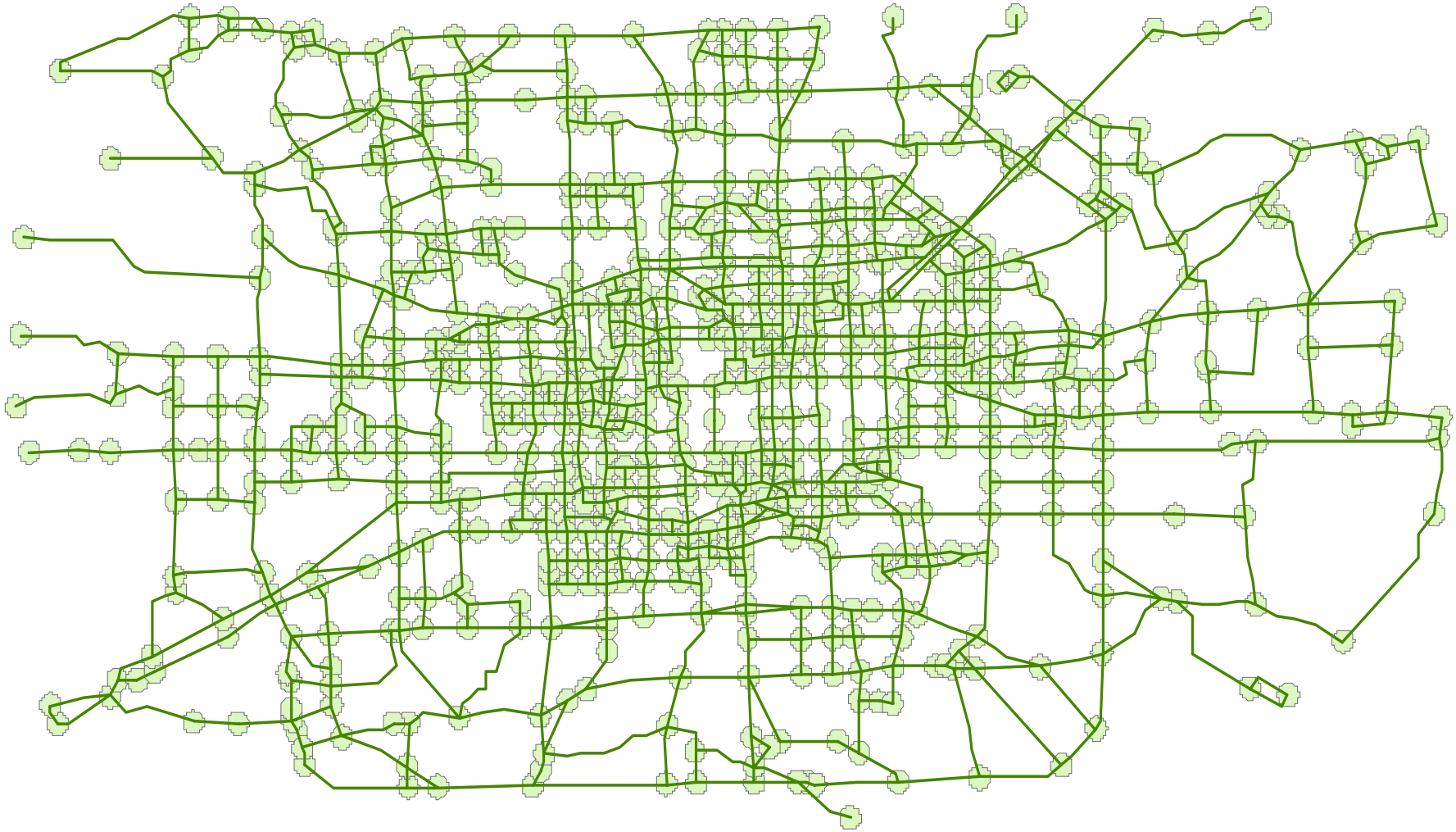
- We adopted a method to approximate unknown traffic volume with the small number of traffic volume data.

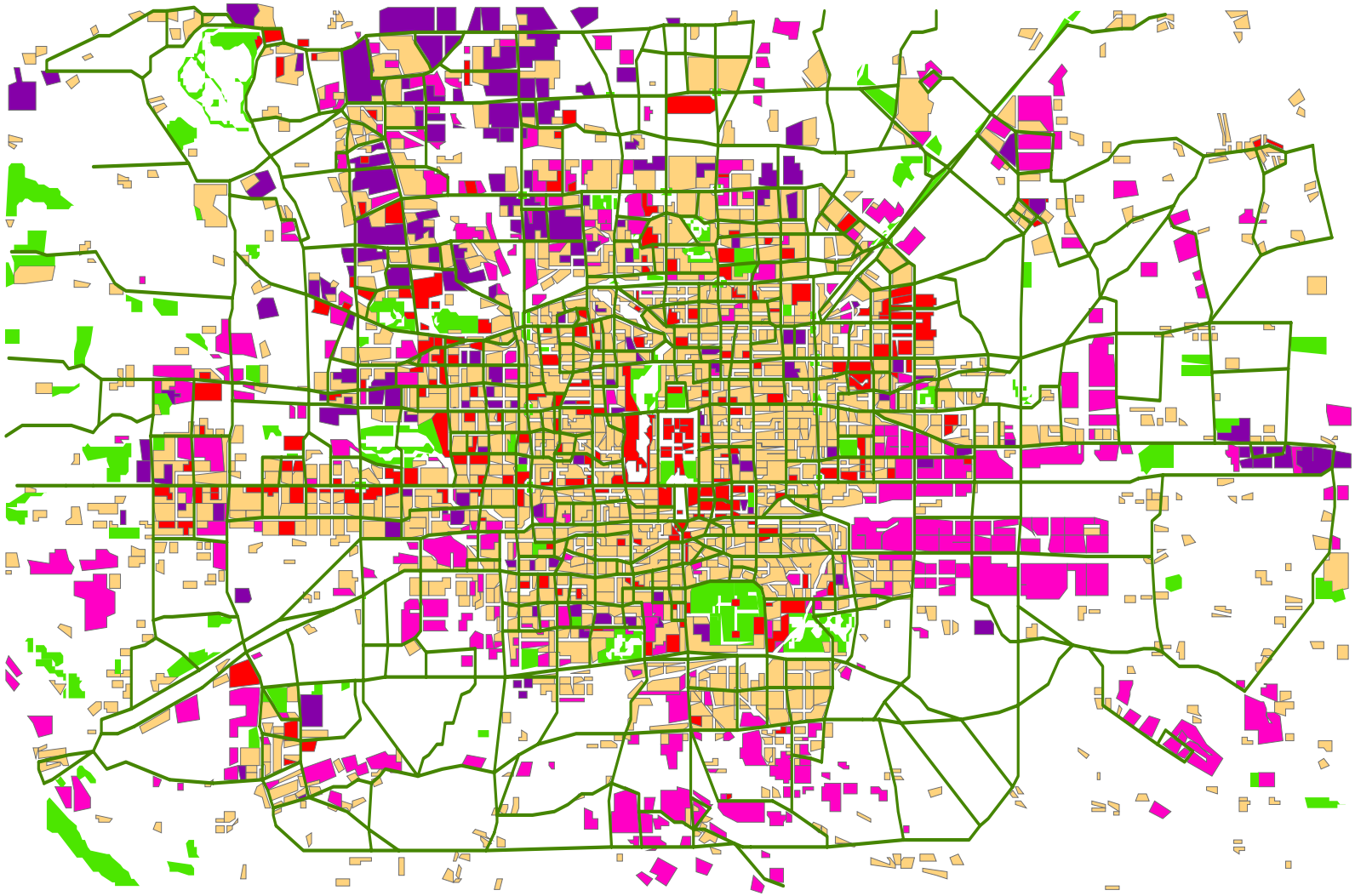
- Traffic volume is estimated based on the following equation, it is so called gravity model.

OD traffic volume $\mathbf{X_{ij} = \alpha A_i B_j t_{ij}^{\gamma}}$

- This model requires information of trip generation (A_i) at one node and trip attraction (B_j) at the other node.

- Land use information is used to identify the characteristics of the node.





Utilization of Land Use Data

- A circle, which radius is 300m, shows a node of road networks.
- A sector which has the largest area in the circle is identified.
- Initial value of trip generation (A_i) and trip attraction (B_j) between two sectors is set.
- Traffic volume data measured are used to predict unmeasured traffic volume.

Procedure of traffic volume estimation - 1-

1) Traveling time at the initial condition that each link traffic volume is zero is estimated.

2)A path with minimum traveling time between OD pairs is searched.

3)Using DIJKSTRA algorithm, each OD traffic volume is distributed to the path with minimum traveling time.

Procedure of traffic volume estimation - 2-

4)Update the minimum traveling time of each link path.

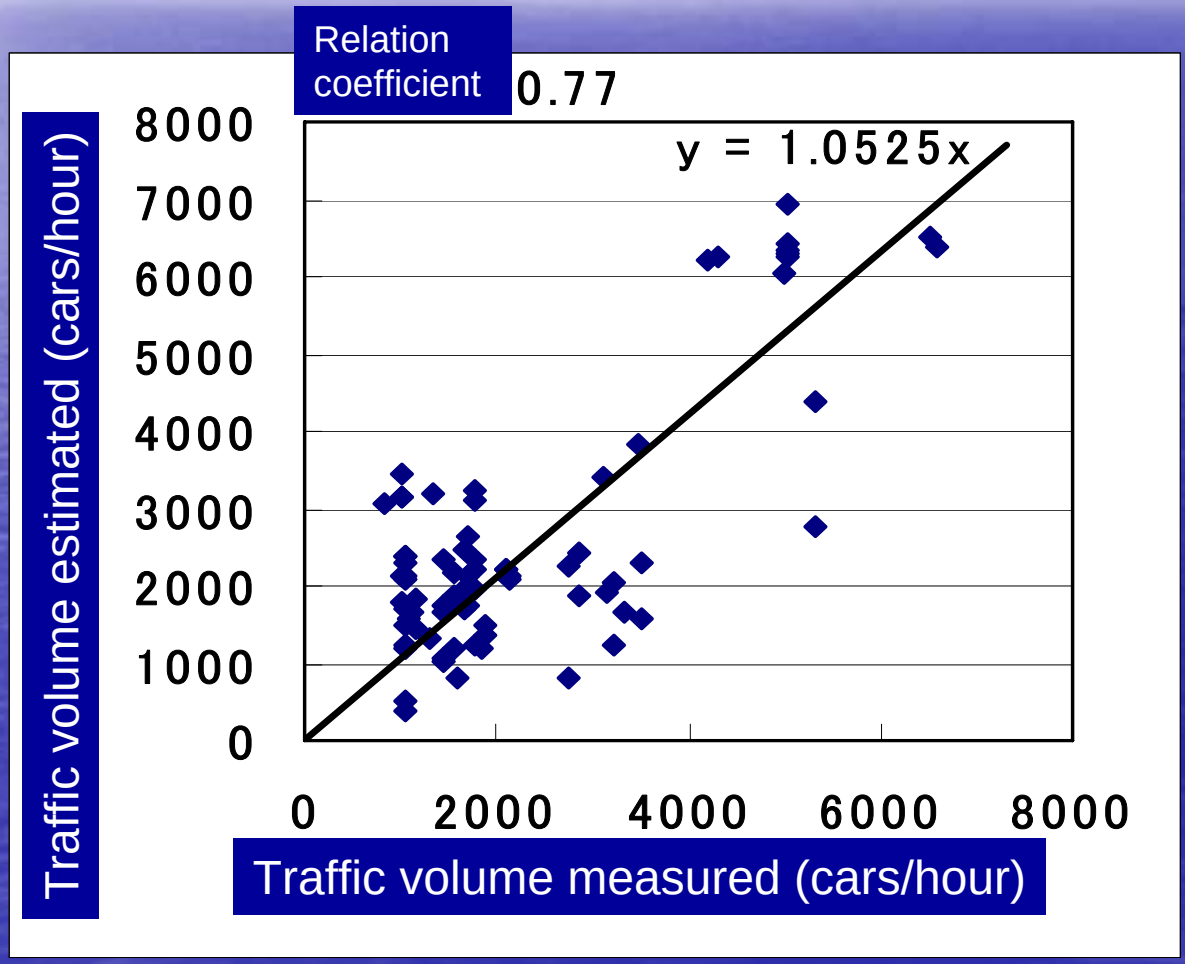
$$T = T_0 \cdot \left(1.0 + 2.62 \times \left(v/C\right)^5\right)$$

5)Update the link traffic volume.

$$v_a^{(m)} = \left(1 - \frac{1}{m}\right) \cdot v_a^{(m-1)} + \frac{1}{m} v_a$$

6)Go back to step 2), until each link traffic volume is converged.

Validation of Traffic Volume Estimation



Diffusion Calculation

- By using ArcGIS, road is divided into fractions by 100m x 100m mesh in order to regard emission source on the road as a series of point sources.
- Diffusion is computed by AIM-AIR with cluster computers.

Diffusion equation

Plume diffusion equation

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

z : Height of receptor (m)

Q_p : Emission at point source (Particles : kg/s, Gas : $m^3{}_N/s$)

u : Wind velocity (m/s)

He : Effective stack height (m)

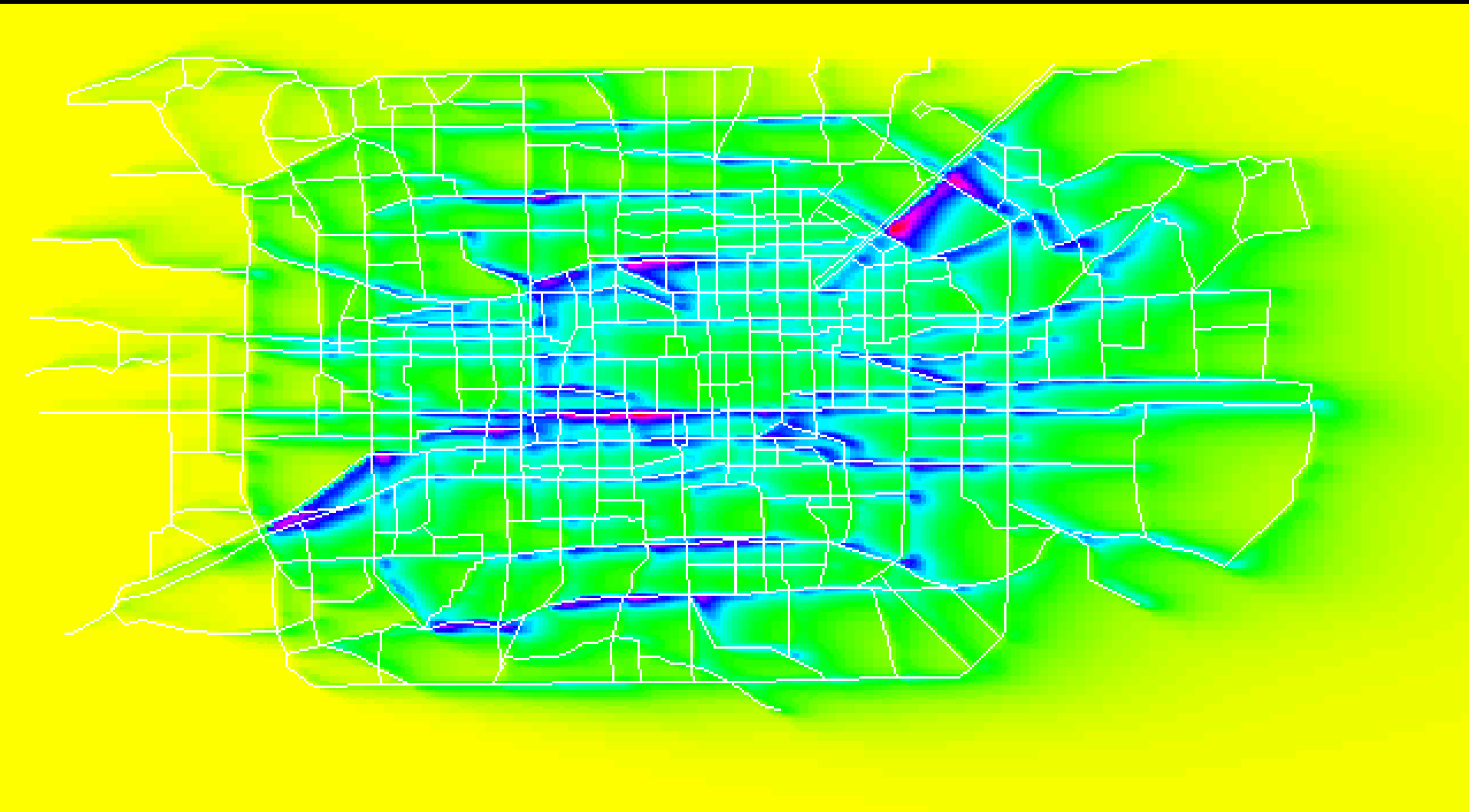
$\sigma_y(x)$: Diffusion parameter of *y* axis at distance x (-)

$\sigma_z(x)$: Diffusion parameter of *y* axis at distance x (-)

$C(x,y,z)$: Concentration at receptor (x,y,z)

Demonstration

- Area: the center of Beijing city
- Period: Jan 1st, 2000 ~ Jan 14th, 2000
- Time step: 1 hour
- Emission source: automobiles
- Traffic pattern: hourly change in a day
- Meteorology data: ECMWF
- Model: Plume or Puff model for a line of point sources (each point source covers emission from automobiles on road within 100m x 100m area)

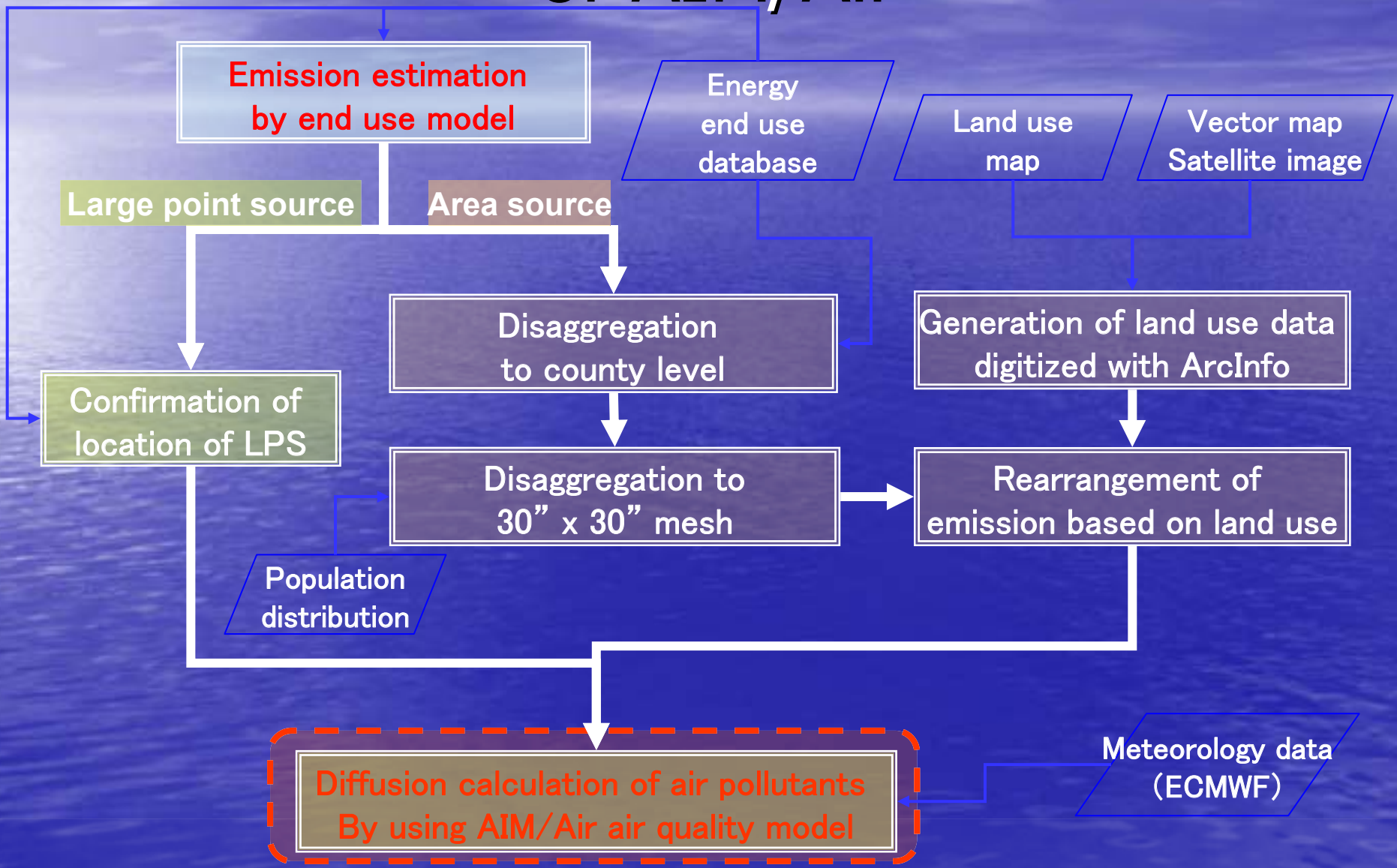


[The 2nd topic]
Improvement of AIM/Air: inclusion of land use information

Purpose of this study

- Improvement of accuracy in emission database
- Spatial distribution of emission by using land information
- Evaluating affection of each sector on air quality
- System integration of emission estimation and diffusion calculation in AIM/Air

Diffusion calculation procedure of AIM/Air



Estimation of emission

- Large point source：Power, cement, iron & steel, nonferrous material sectors and other sectors with large emission.
- Area source：Transport, commercial and public sectors and other sectors with small emission.

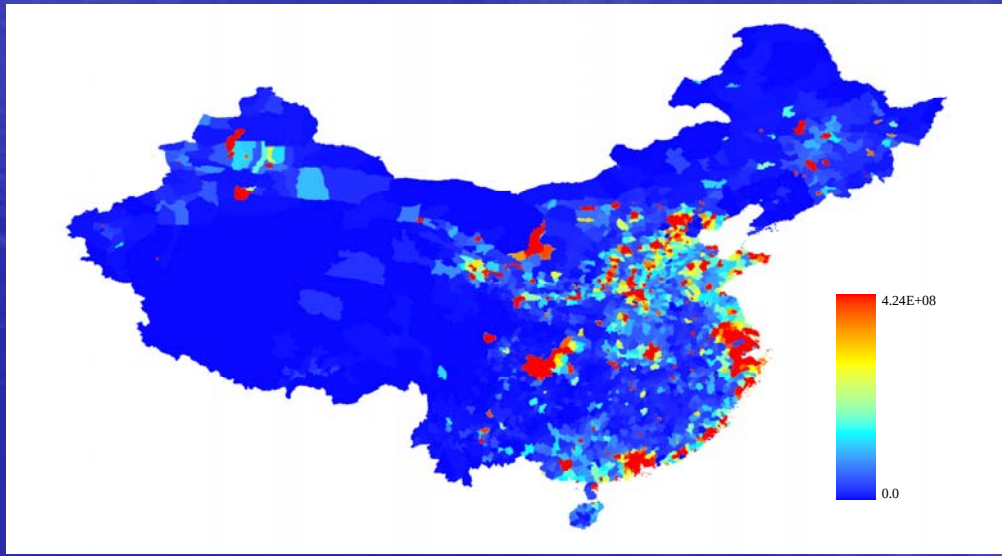
部門				
発電	セメント	鉄鋼	非鉄金属	その他
運輸	商業	家庭（都市部）	家庭（農村部）	

エンドユースモデル地域区分（31地域）				
北京市	河北省	福建省	四川省	内蒙古自治区
上海市	山西省	江西省	貴州省	広西チワン族自治区
天津市	遼寧省	山東省	雲南省	寧夏回族自治区
重慶市	吉林省	河南省	陝西省	チベット自治区
	黒竜江省	湖北省	甘粛省	新疆ウイグル自治区
	江蘇省	湖南省	青海省	
	浙江省	広東省		
	安徽省	海南省		

Disaggregation of Area Source Emission to County Level

- Emission of 31 provinces was disaggregated to more detailed level, 2347 counties.

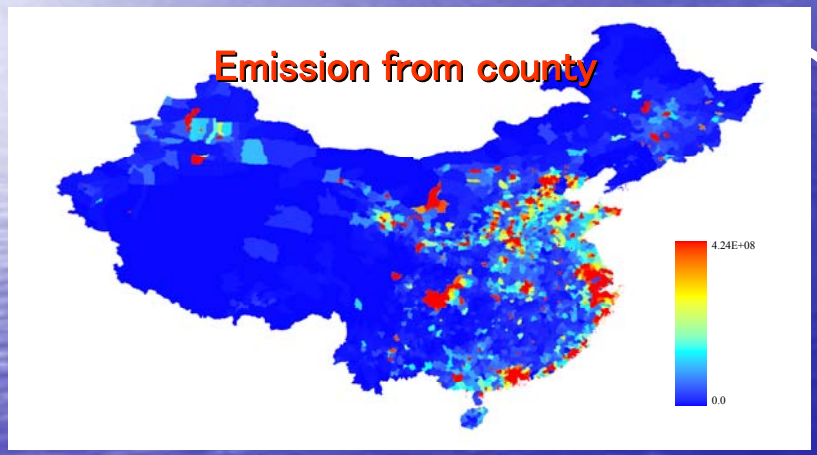
Sector	Index to disaggregate from province level to county level
Power Cement Iron & Steel Nonferros	GDP of secondary industries
Transport Commerce	GDP of tertiary industries
Public Other	Population

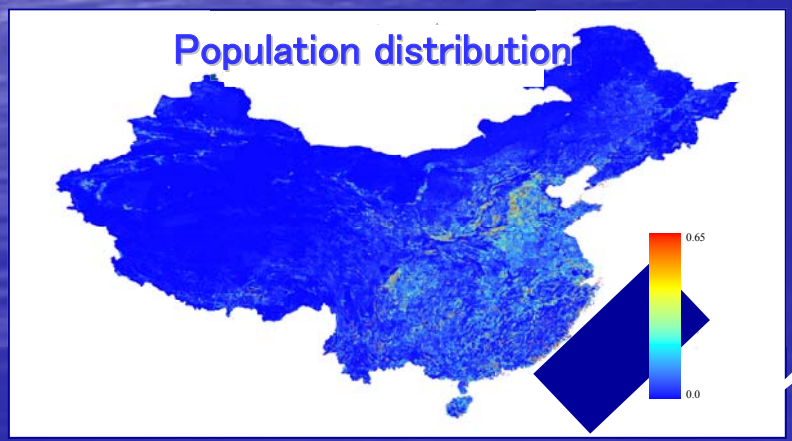


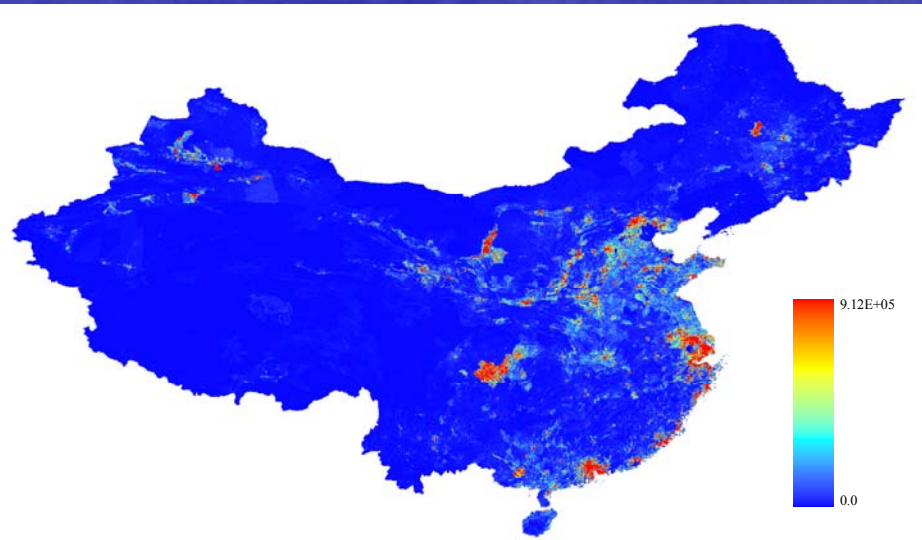
Distribution map of SO2 emission from power sector(kg/yr)

Disaggregation to 30”x30” Mesh

- Emission from county level was disaggregated to 30” x 30” mesh by using population distribution.



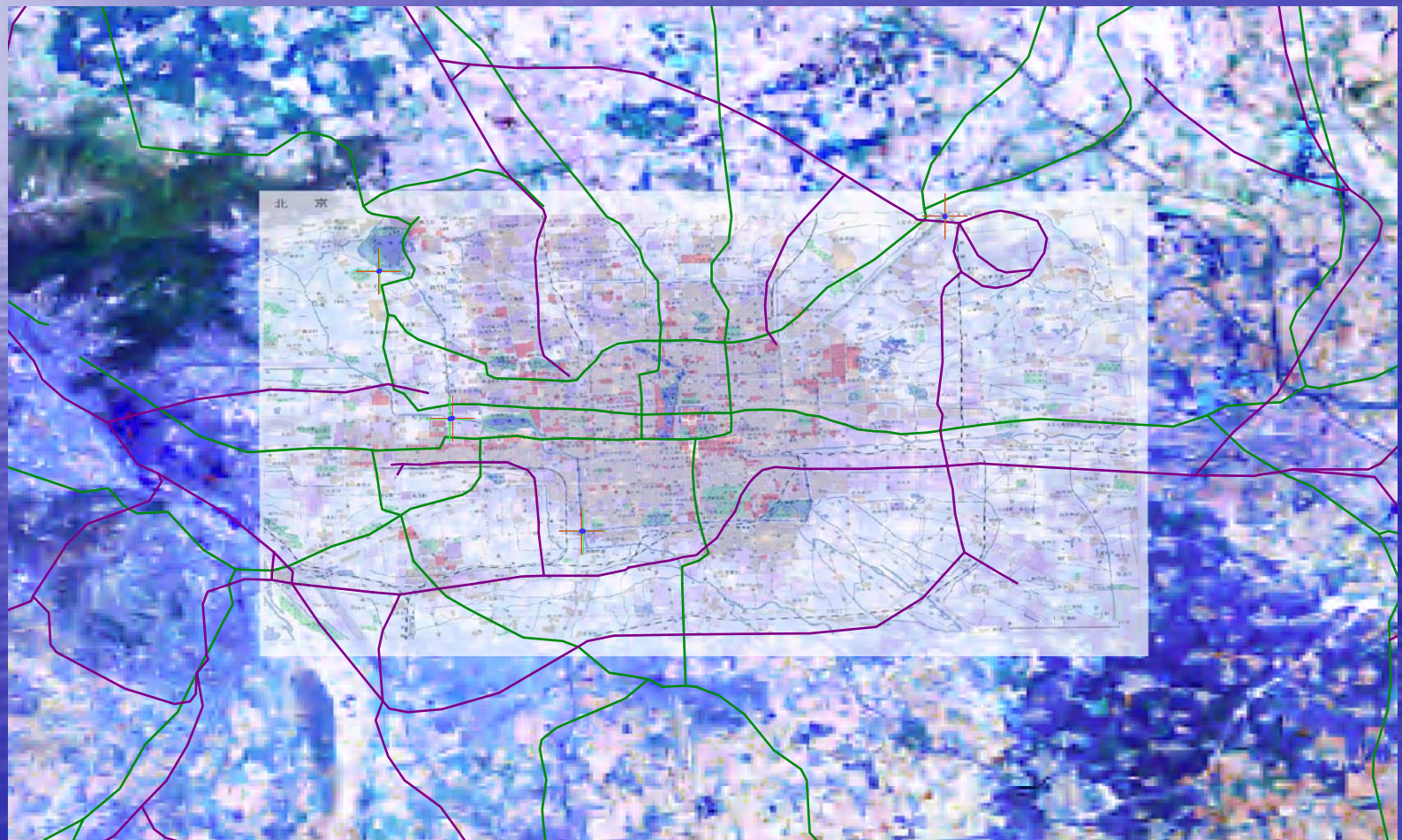




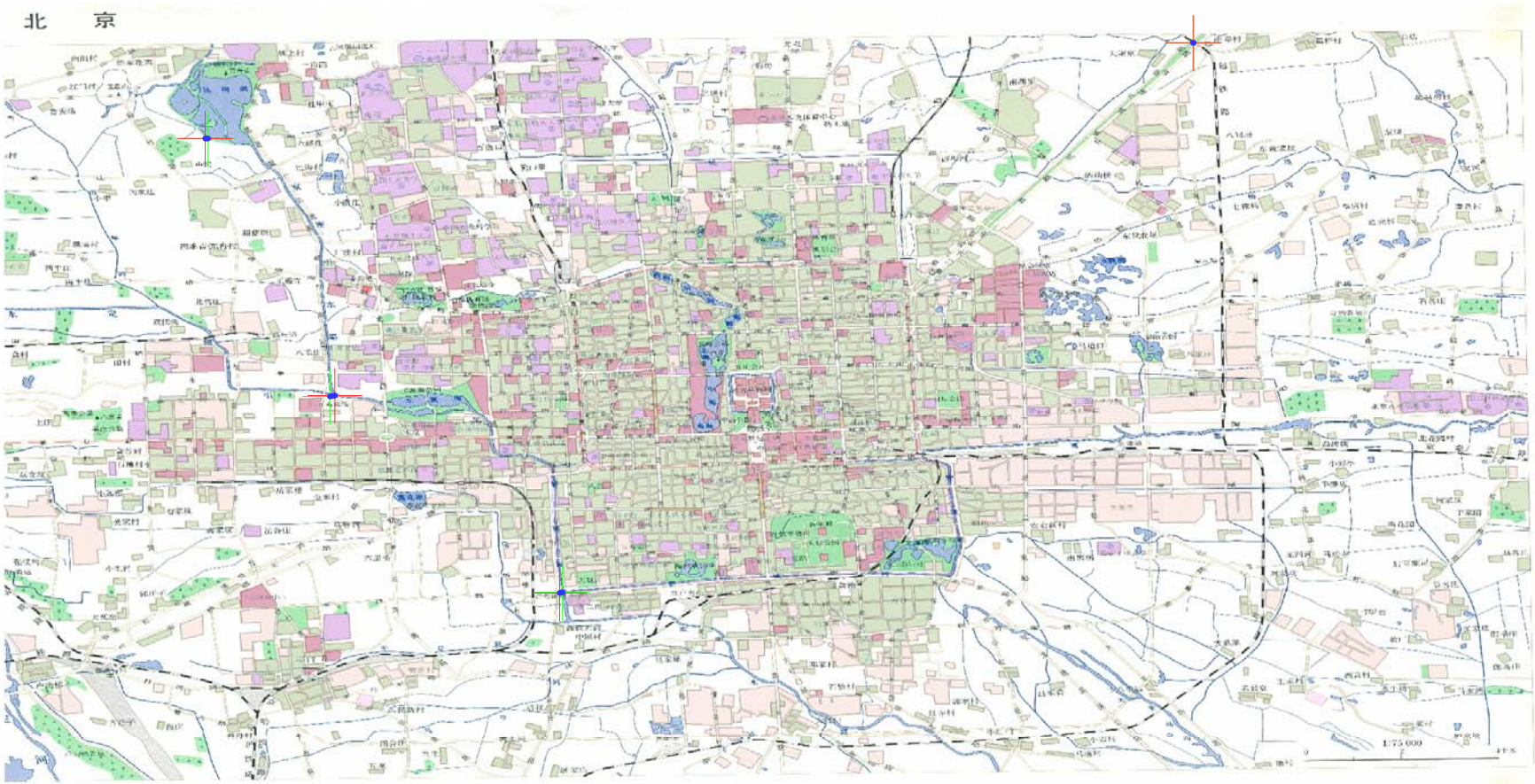
Distribution map of SO2 emission from power sector(kg/yr)

Land Use Map of Urban Area

- A digital map of land use was made by overlaying land use map scanned, location information (VMAP), and satellite image.



Digitized land use information



Public building area

Commercial area

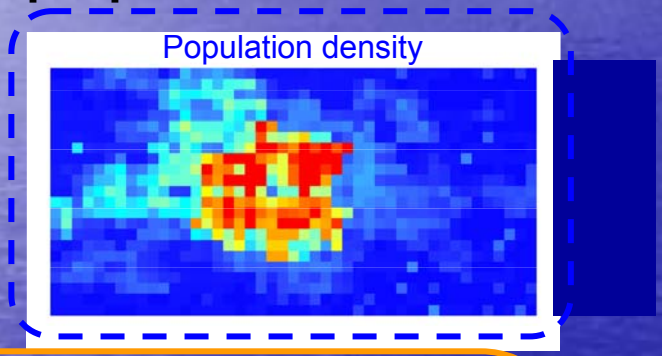
School & Hospital area

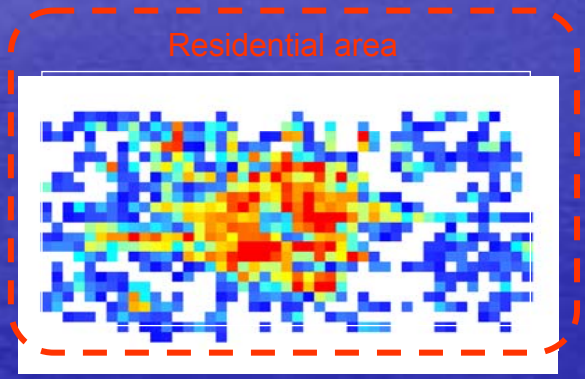
Residential area

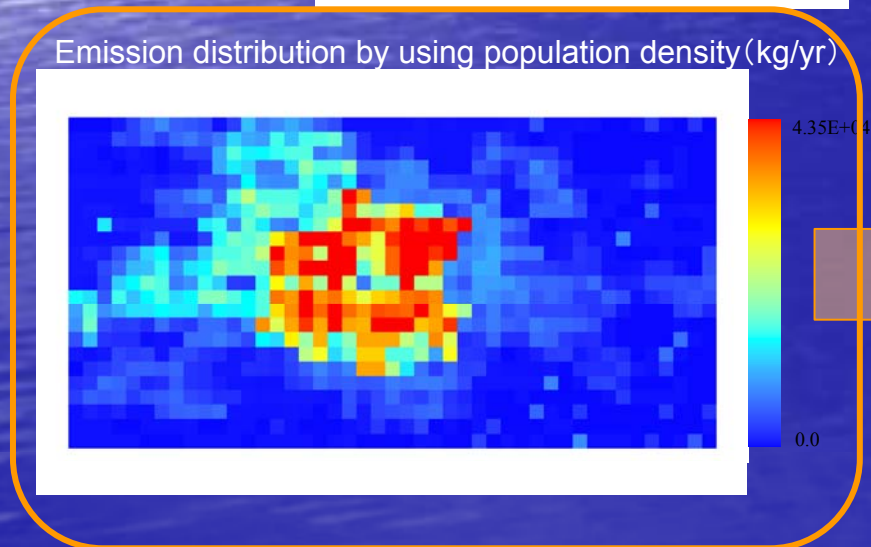
Industrial area & Warehouse

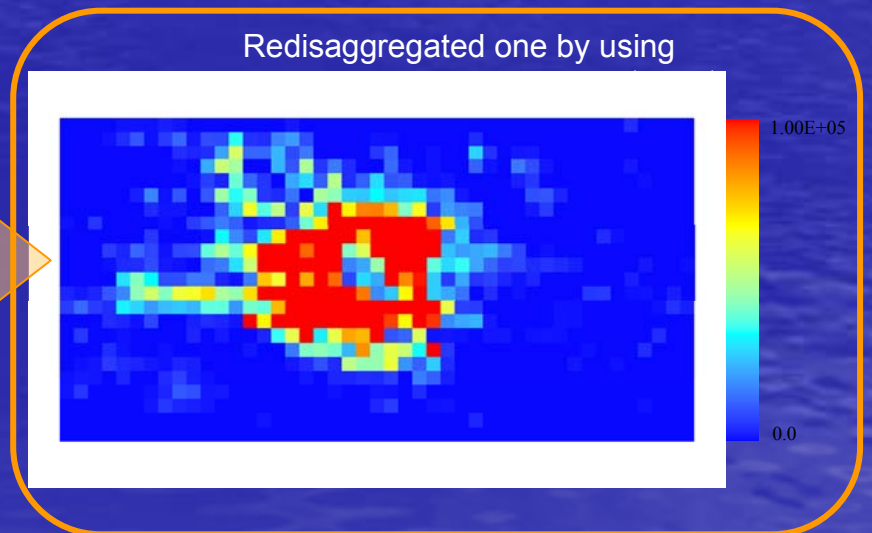
Rearrangement by Using Land Use Information

- Emission data of each 30" x 30" cells is rearranged to actual one by using sector's area and population







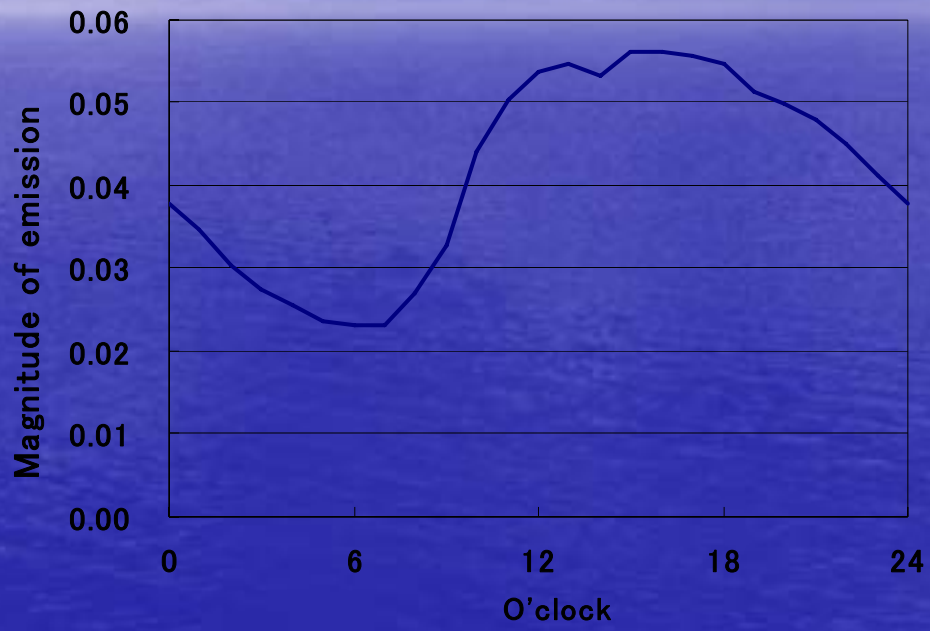


Characteristics of AIM/AIR Air quality model

- Diffusion equations: Puff model is applied at the time the wind speed is small (< 1m/s), otherwise plume model is applied.
- Accelerated algorithm in diffusion calculation is adopted.
- Concentration every hour is calculated.
- Emission pattern (time change of emitting pollutants) is definable for each sector.
- Meteorology data are interpolated at the receptors where concentration is calculated.

Emission Patterns -1-

- **Hourly change**
  - Cement, Iron & Steel, Non-ferrous, Commercial sectors: Constant emission from 9 to 19 o'clock
  - Power and Public sectors: Emission pattern was set based on actual consumption of electricity in a day
- **Daily change**
  - Cement, Iron &steel, Non-ferrous sectors: No emission on Sat. & Sun. Constant emission on the other days



Emission Patterns -2-

- **Monthly change**
  - Commercial and Public sectors: Emission fraction corresponding to each month was decided so that heating devices may be much used in the month which averaged temperature of the month is more than 10 degree.

Month	Emission fractions	
	Commercial	Public
1	0.447	0.243
2	0.169	0.121
3	0.066	0.076
4	0.011	0.052
5	0.009	0.051
6	0.009	0.051
7	0.009	0.051
8	0.009	0.051
9	0.009	0.051
10	0.013	0.052
11	0.071	0.078
12	0.178	0.125
	1.000	1.000

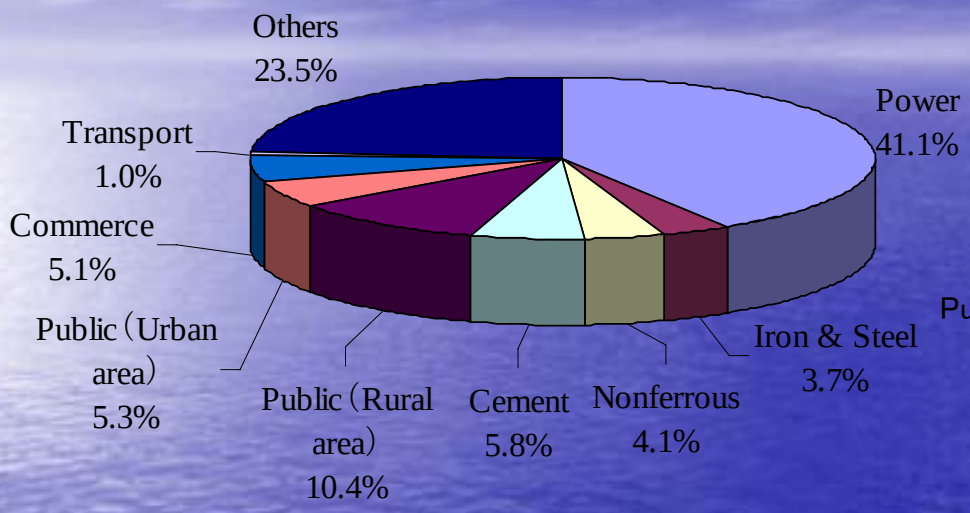
- Special term or day
  - Cement, Iron & Steel, Non-ferrous sections: No emission on the special term or day

Special term or day	
新年	1-Jan
春節	5-Feb ～7-Feb
労働祭	29-Apr ～5-May
国慶祭	29-Sep ～3-Oct

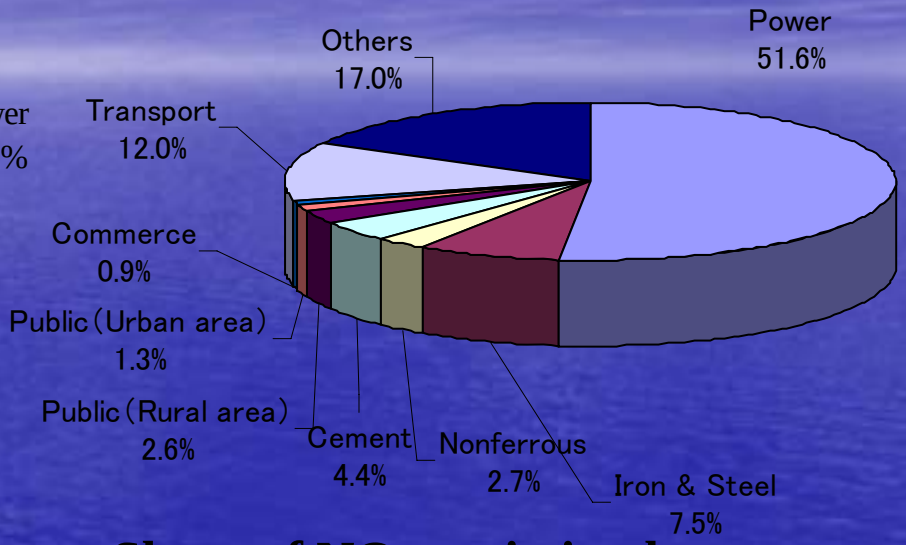
System Integration of Emission Projection and Air Quality Model

- To integrate AIM/Enduse and AIM/Air, reconfirmation of LPS data base, rearrangement of AIM/Air data format, documentation were conducted.
- Spatial disaggregation of emission to sector's area by using land use information was performed with ArcInfo and Access.
- 32 clustered computers aided diffusion calculation.

Result of estimated emission by using end use model, AIM/Local China



Share of SO_2 emission by sector



Share of NOx emission by sector

- Total emission of SO_2 was 18,206Kt、total emission of NOx was 11,033Kt.
- Contribution from power sector was the largest in both SO_2 and NOx emission
- Emission from public sector occupied 15.7% of total emission.
- Emission from traffic sector occupied 12.0% of total emission.

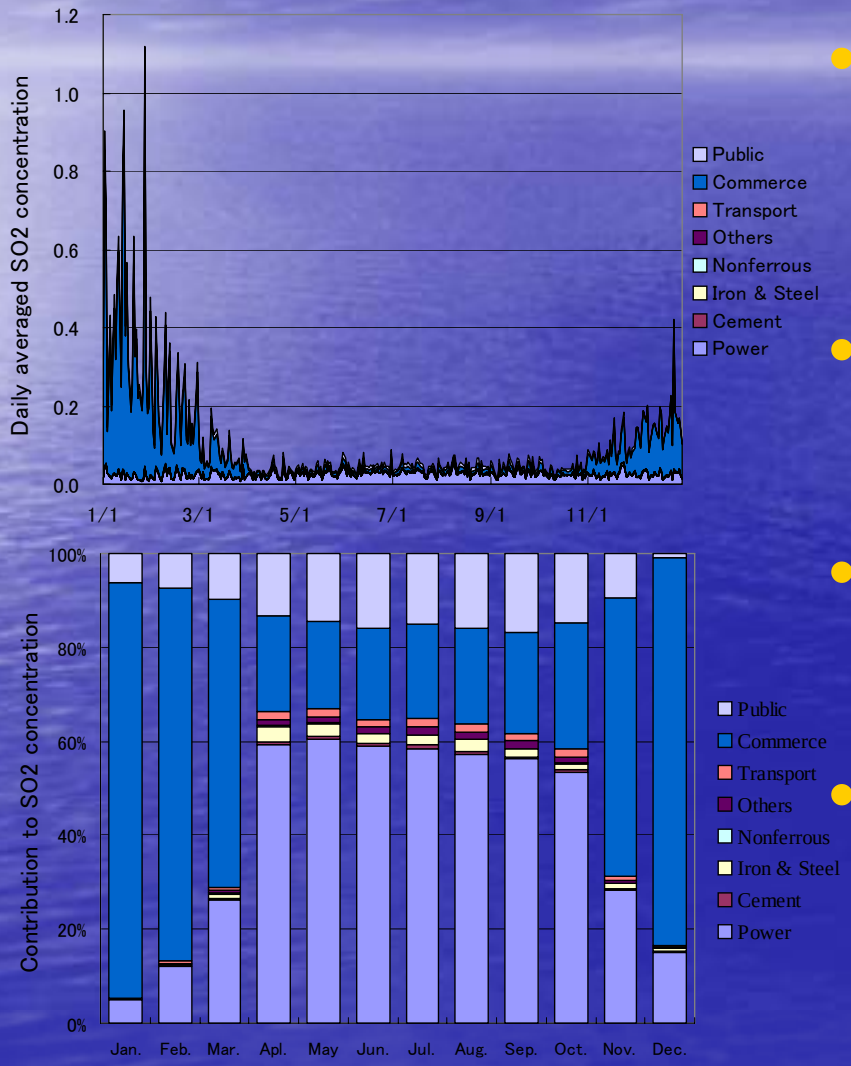
General Result of Air Quality Estimation

- AIM/Air Air quality model was applied to estimation of SO_2、NOx concentration of Beijing, Shanghai, and Chongqing.
- The estimated and the observed values of year averaged concentration were compared.

	$SO_2(mg/m^3)$		$NOx(mg/m^3)$	
	Estimated	Observed	Estimated	Observed
Beijing	0.11	0.08	0.08	0.14
Shanghai	0.03	0.04	0.03	0.10
Chongqing	0.11	0.17	0.07	0.06

*) The observed values are reported in China Energy Databook

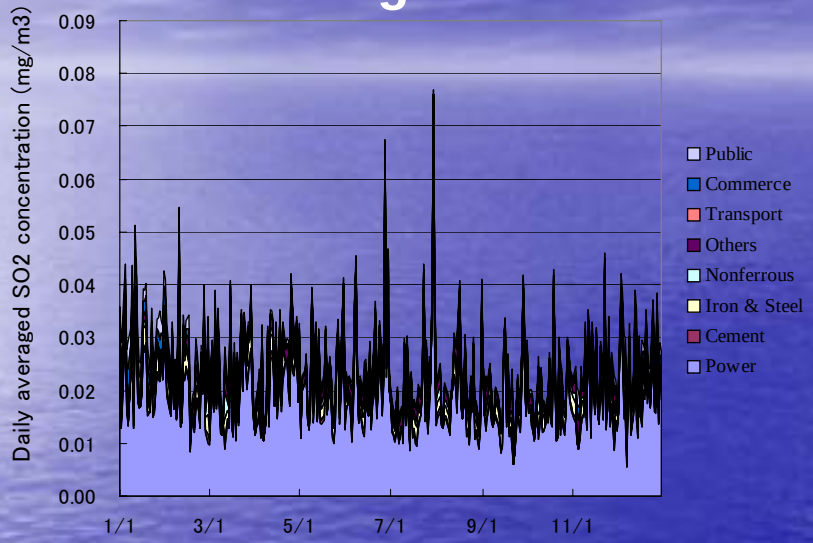
Result of SO_2 Concentration in Beijing

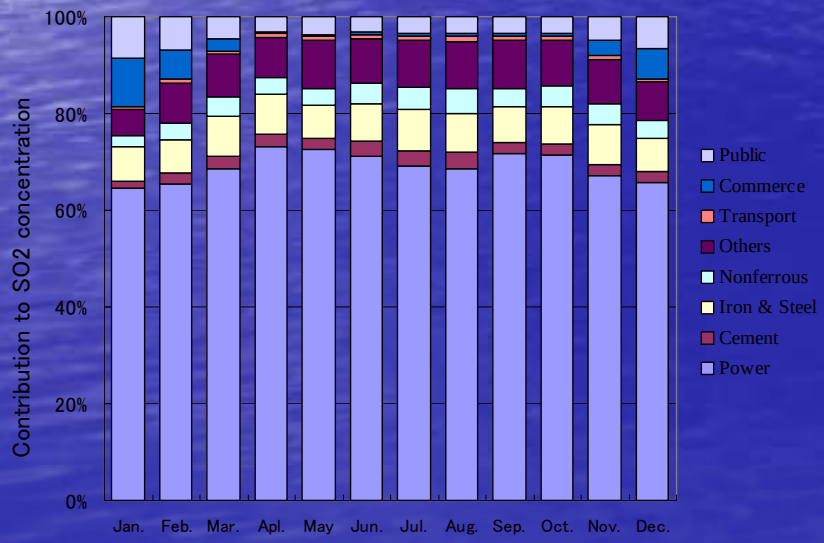


- Remarkable seasonal change, specially high concentration in winter season.
- Concentration on 63 days was over the 2nd level standard ($0.15mg/m^3$)
- Concentration on 35 days was over the 3rd level standard ($0.25mg/m^3$)
- Commercial and power sectors were main contributors to SO_2 concentration

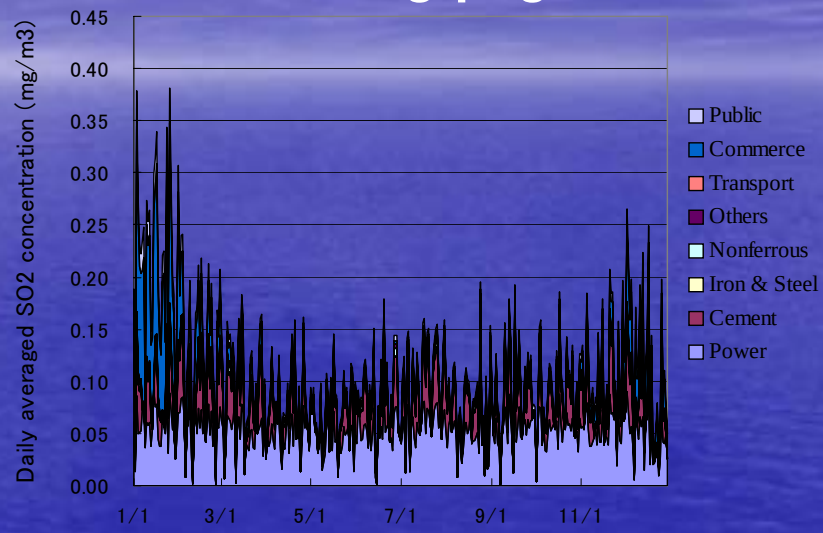
Comparison of SO_2 Concentrations of Shanghai and Chongqing with Beijing's

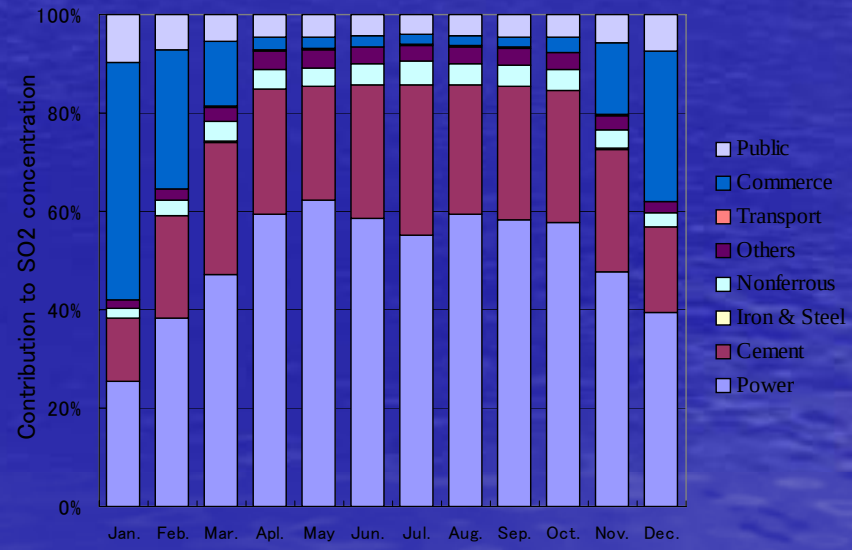
Shanghai



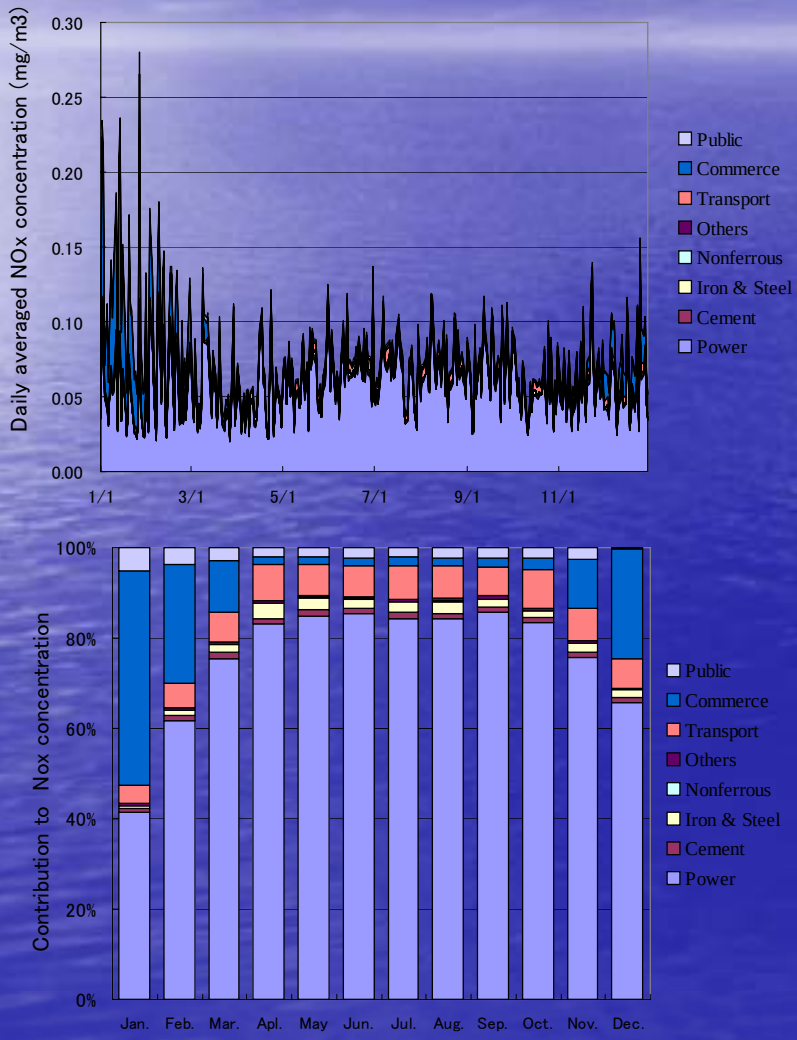


Chongqing





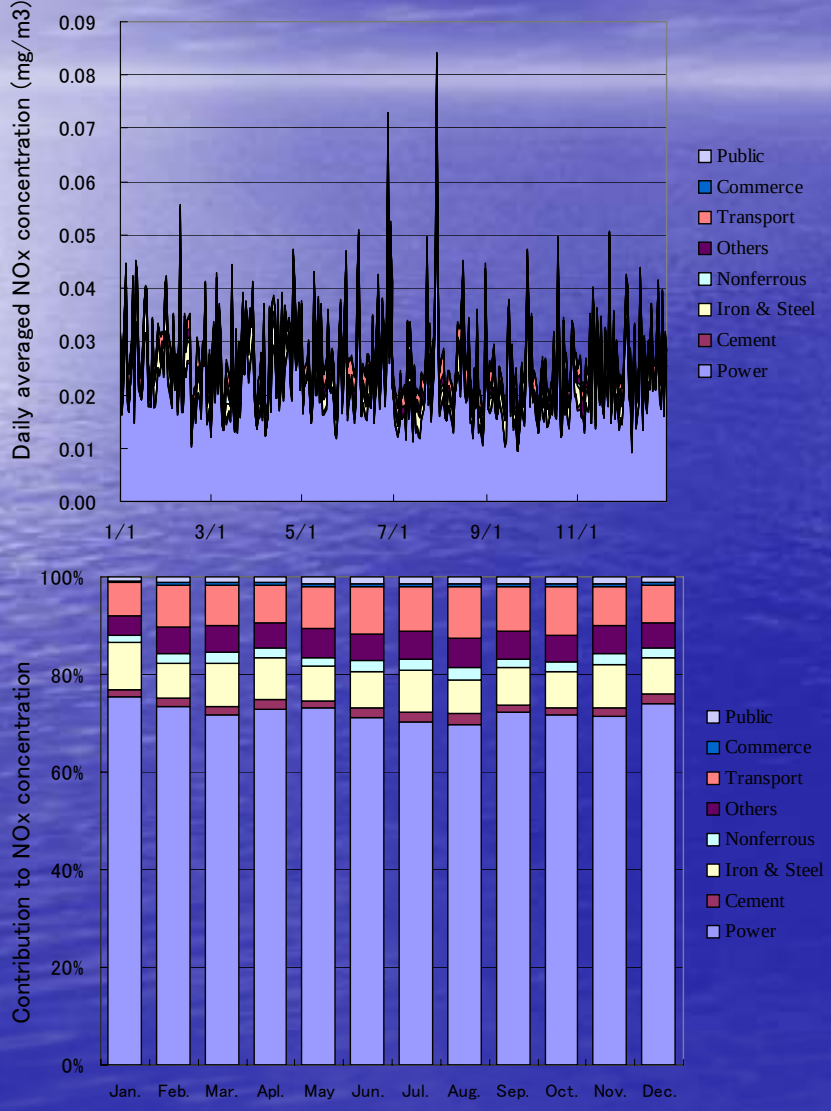
Result of NOx Concentration in Beijing



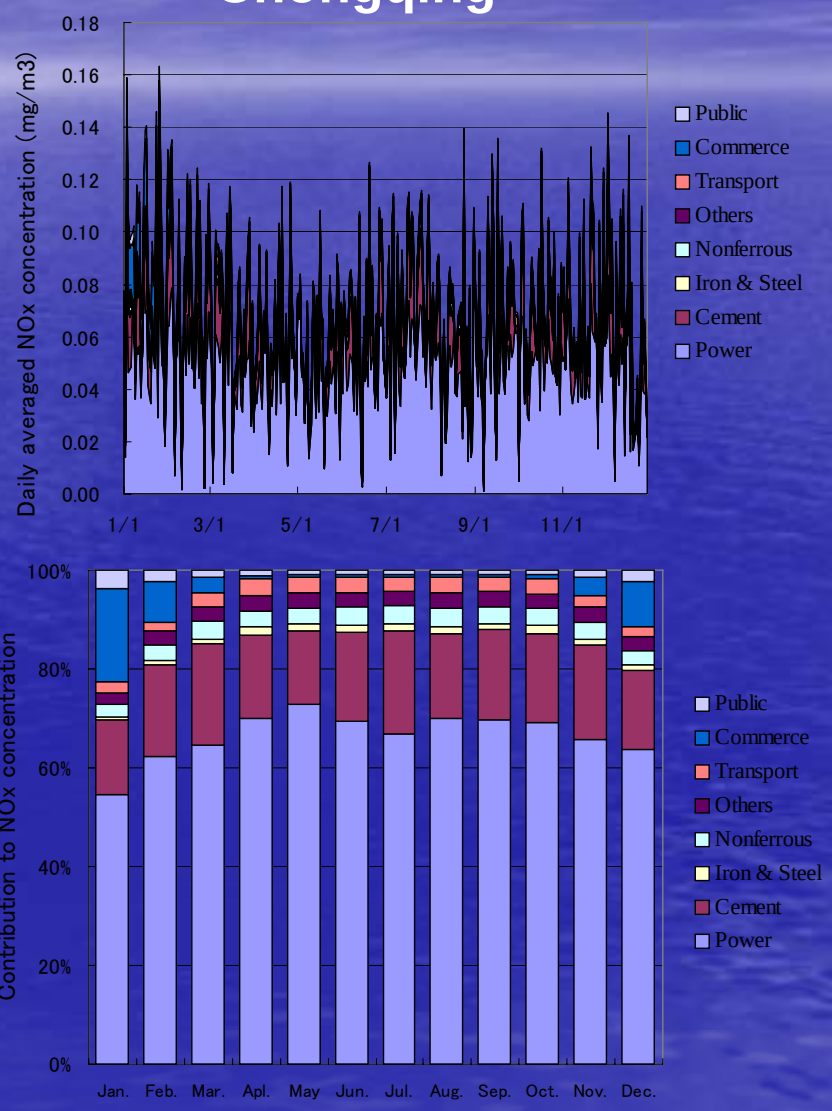
- Seasonal change and high concentration in winter season.
- Concentration on 64 days was over the 2nd level standard (0.15mg/m^3)
- Concentration on 11 days was over the 3rd level standard (0.25mg/m^3)
- Power sectors was a main contributor to NOx concentration.

Comparison of NOx Concentrations of Shanghai and Chongqing with Beijing's

Shanghai



Chongqing



Conclusion

- By estimating emission from road networks, diffusion of air pollutant from transport sector was calculated.
- Land use information added more reality to location of area emission source.
- Concentration of SO_2、NOx in Beijing, Shanghai, and Chongqing were estimated and evaluated .
- This system becomes a powerful tool to assess impact on air pollution briefly.