ESA - MOST Dragon 2 Programme

2011 DRAGON 2 SYMPOSIUM

中国科技部-欧洲空间局合作 "龙计划"二期

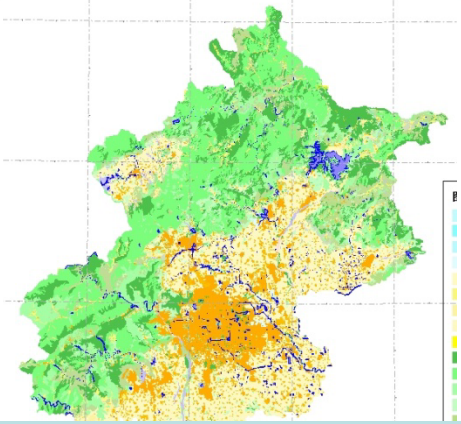
"龙计划"二期2011年学术研讨会

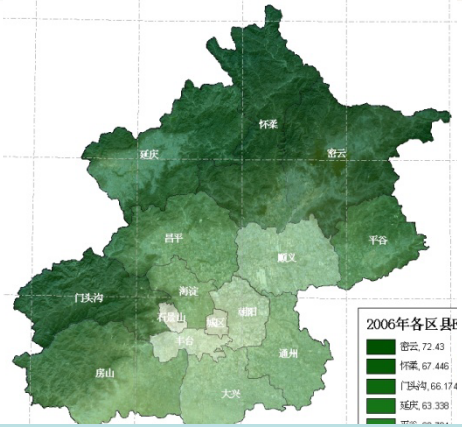
Use of Earth Observation in Support of Major Sport Events

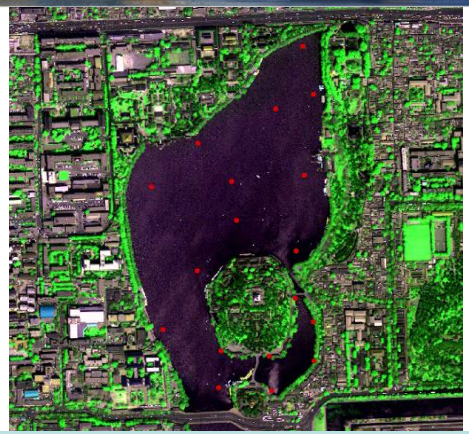
(Proposal ID: 5295)

Capital Normal University

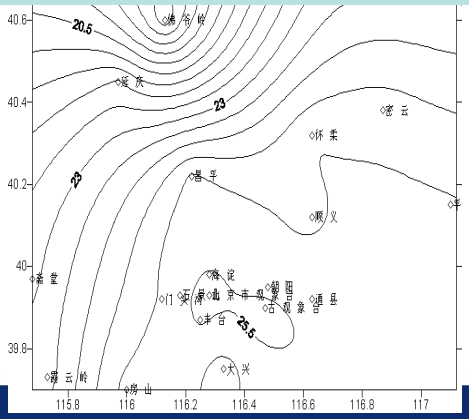
Gong Huili, Zhao Wenji, Li Xiaojuan, Zhao Wenhui

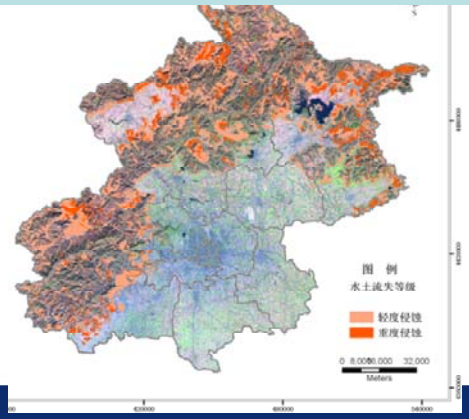


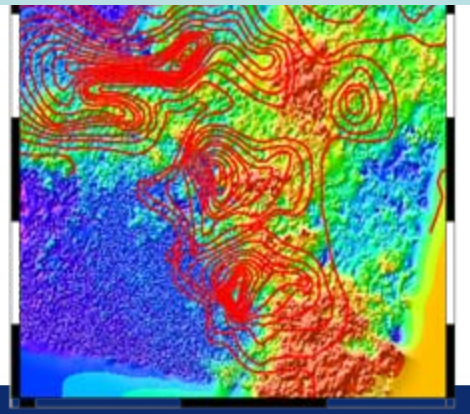




Progress and Its Future Application in Sport Events Supporting







Outline

1、Study on Background of Particles pollution based on **Routine data**

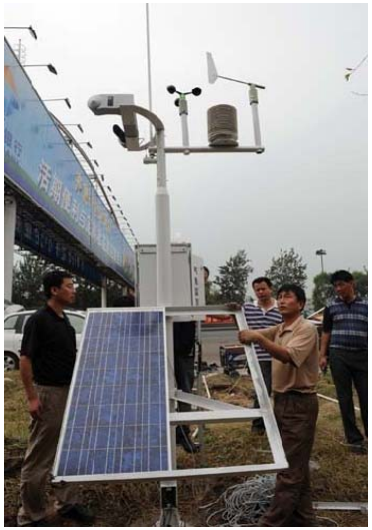
2、The distribution of inhalable particles retrieved by **Multi-source RS** data over Beijing，China

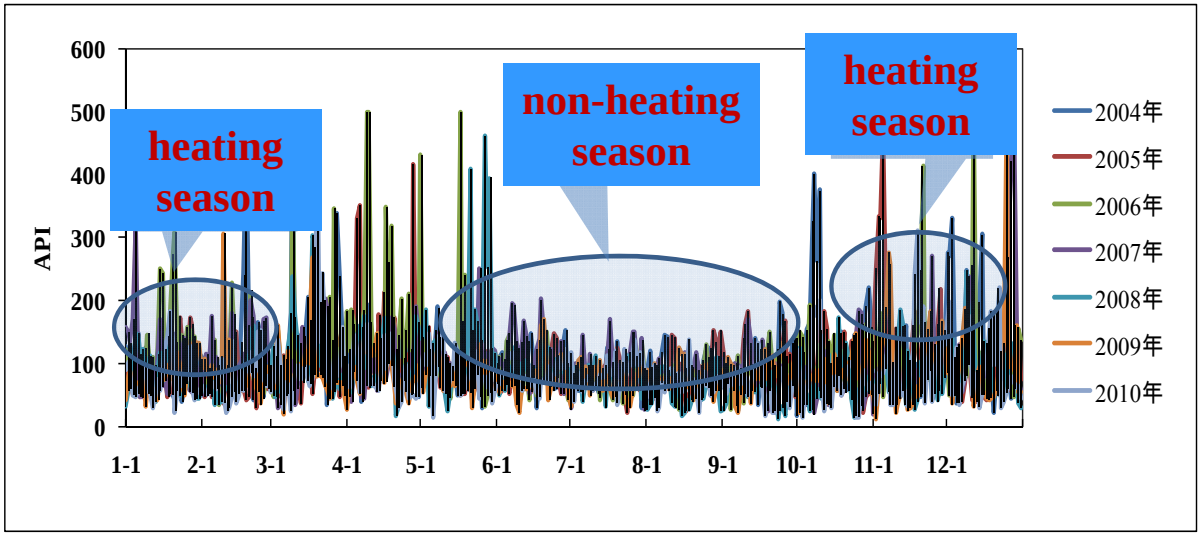
3、**Spatial-temporal features** of the inhalable particles

4、Its main **Effect and mechanism**

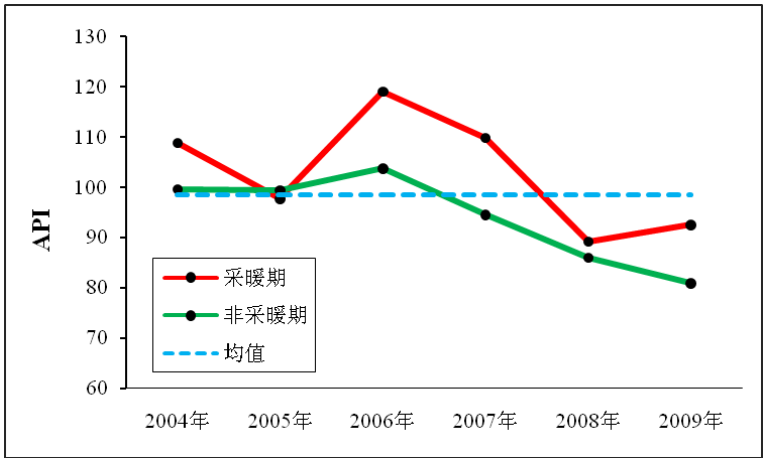
1、Study on Background of Particles Pollution

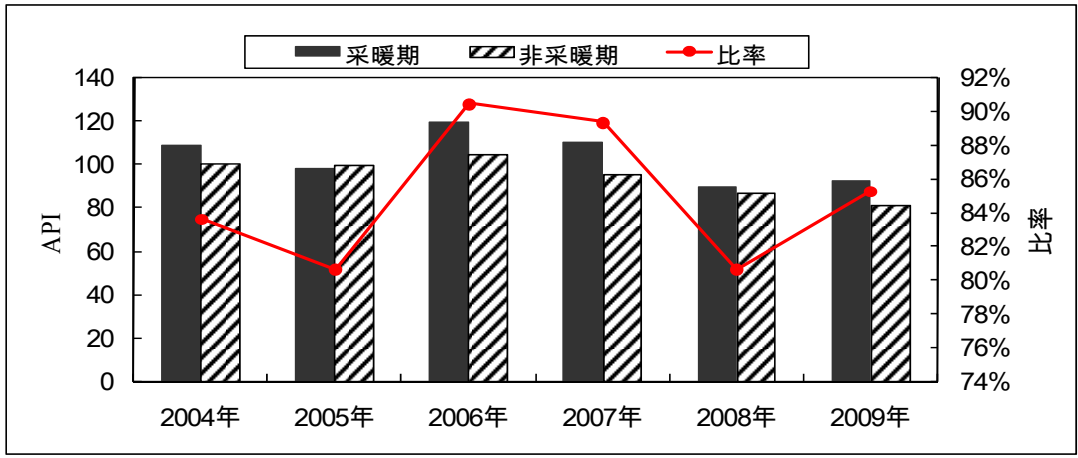
Based on Routine Data

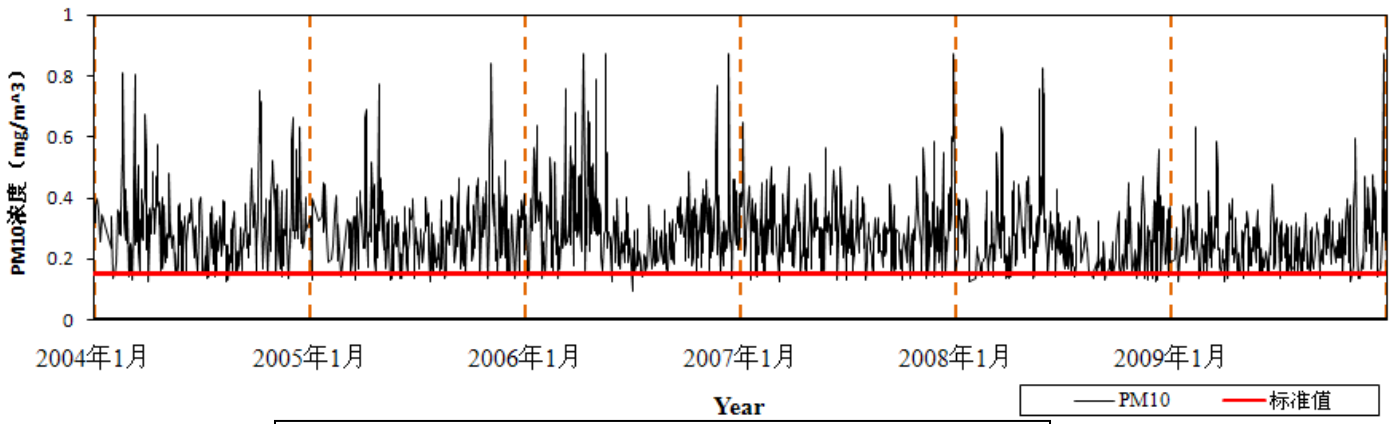




Sample Time：
non-heating season
（ Jun ）
heating season
（ Dec ）

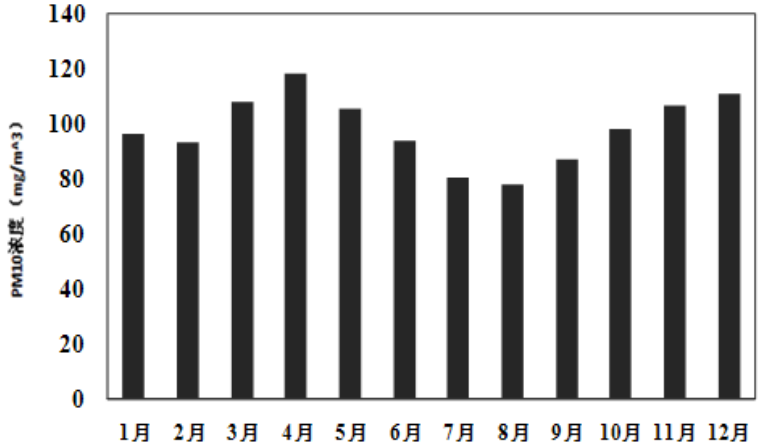




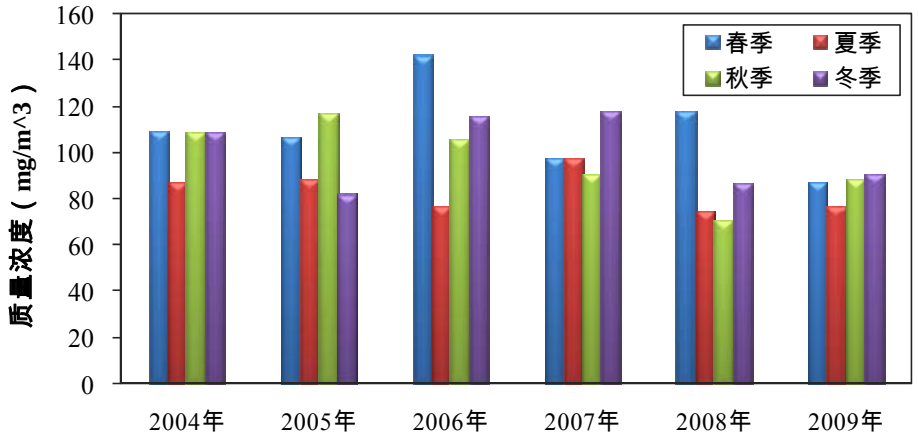


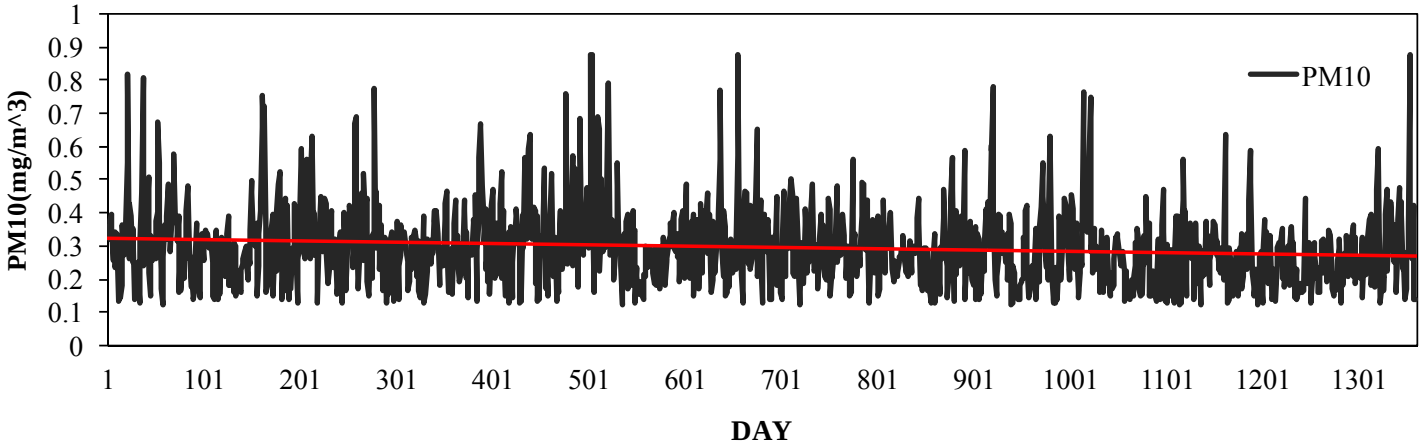
2004-2009 PM_{10} daily average value

2004-2009 PM_{10} month average value



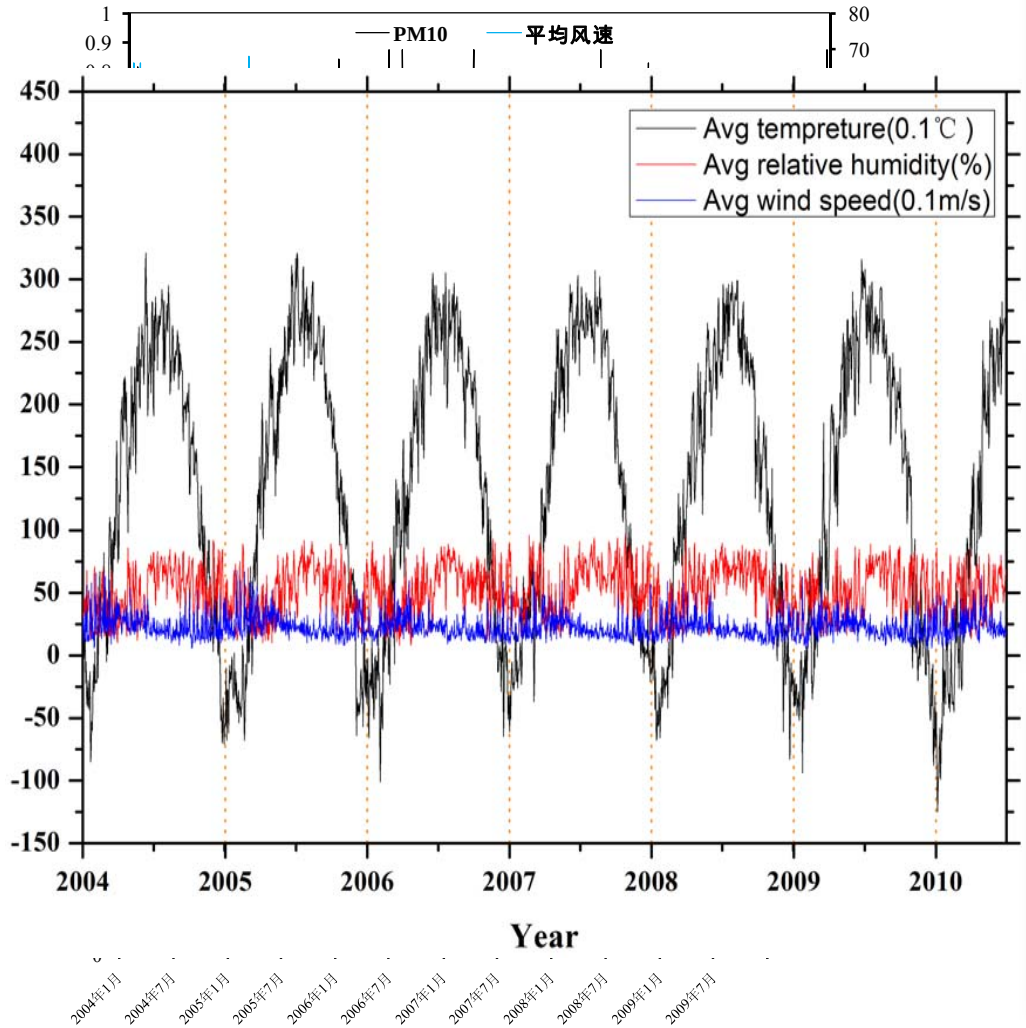
2004-2009 PM10quarter average value

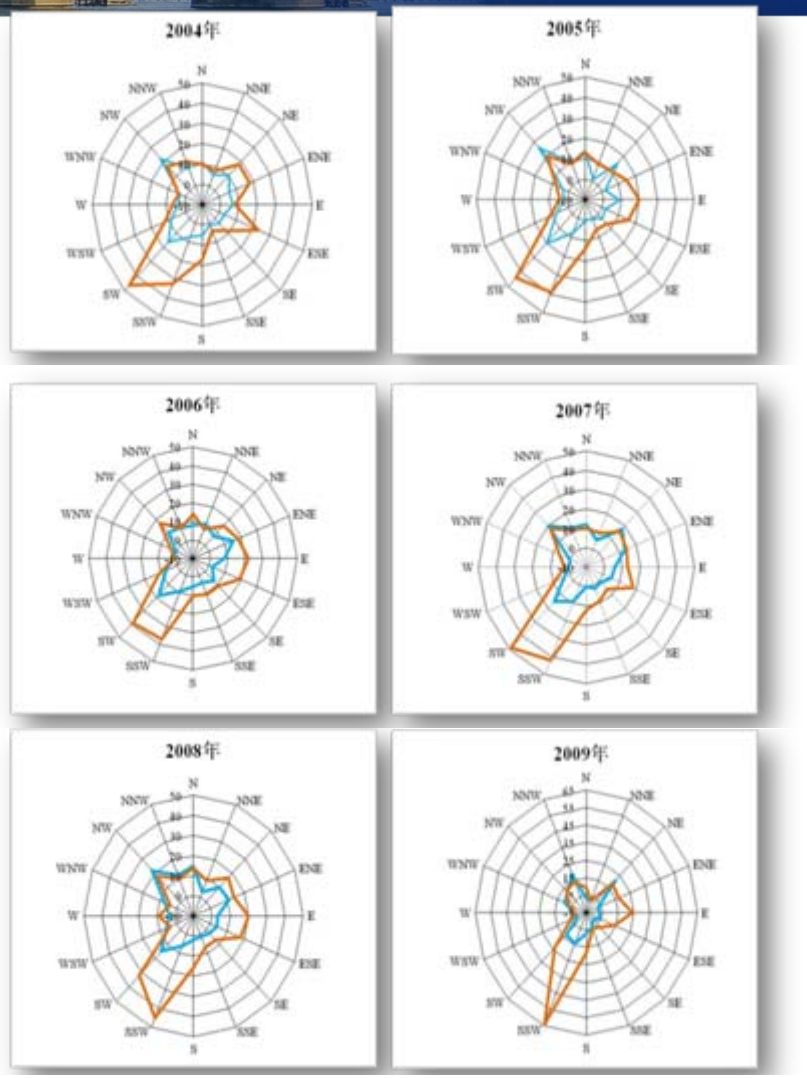




There was no tendency among years in PM_{10} from 2004 to 2009. It was probably because the air quality during these years in Beijing was keeping a better condition.

ADF Test Statistic	**-30.0007**	1% Critical Value	-3.4368
		5% Critical Value	-2.8636
		10% Critical Value	-2.5679





heating season — Un-heating season

2004-2009 wind rose diagram in Beijing

2、The distribution of inhalable particles retrieved by **multi-source RS** data over Beijing，China

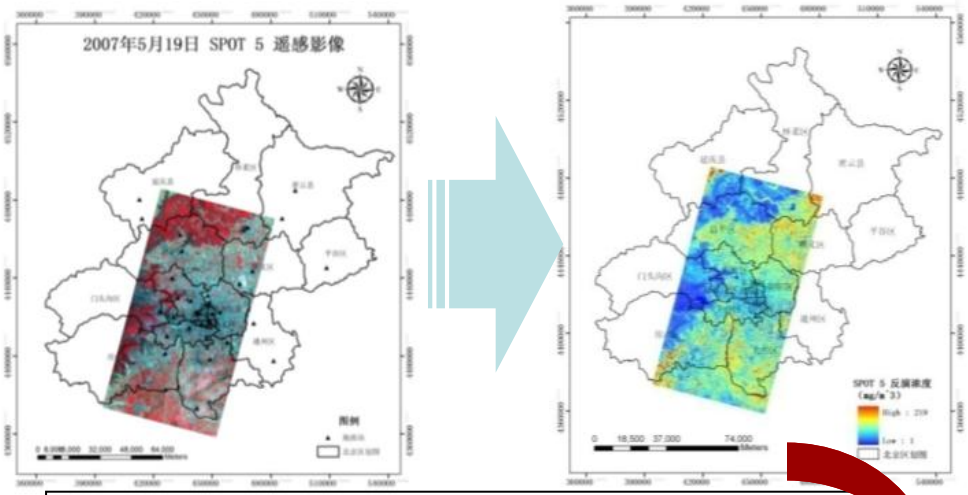
2.1 Results and Precision Validation (the first method)

Retrieval

（1）I_{DVI} index

$$I_{DVI} = Ch_2 - Ch_1$$

Ch1 is reflectance of Visible band
Ch2 is reflectance of near infrared band

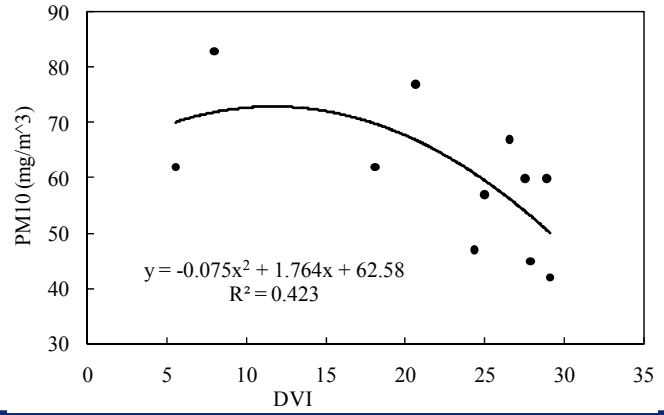


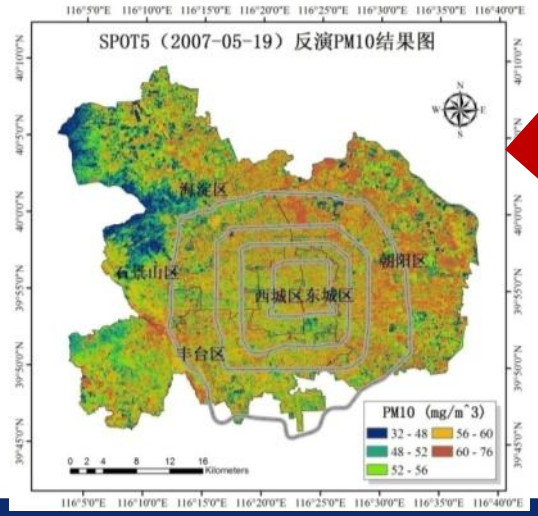
The spatial distribution of PM_{10}

（2）Equation of Linear Regression

$$y = -0.6543x + 79.678$$

（R^2=0.5394）



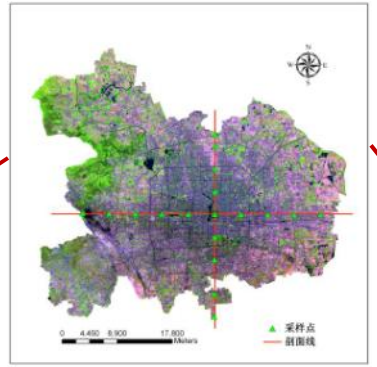


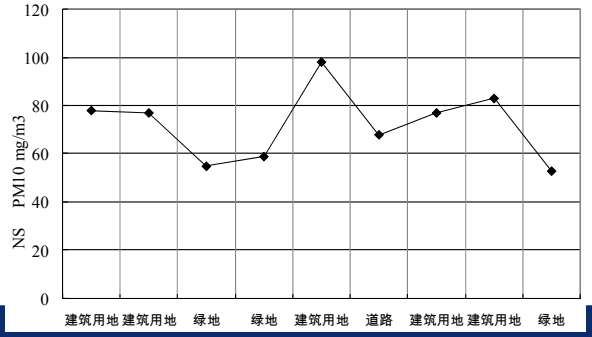
Accuracy Validation

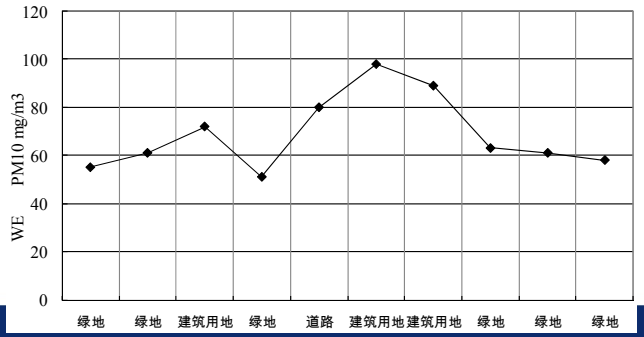
1. PM_{10} (cross-validation)

Number	Error (%)	Number	Error (%)
1	3.033	7	14.401
2	12.476	8	43.984
3	44.813	9	35.845
4	27.765	10	34.144
5	15.772	11	7.691
6	23.546	**Mean error**	**20.952**

2. validate for N-S/W-E profile



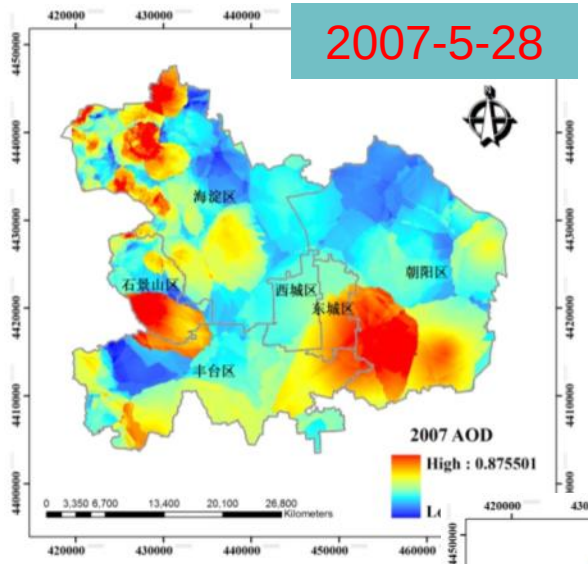




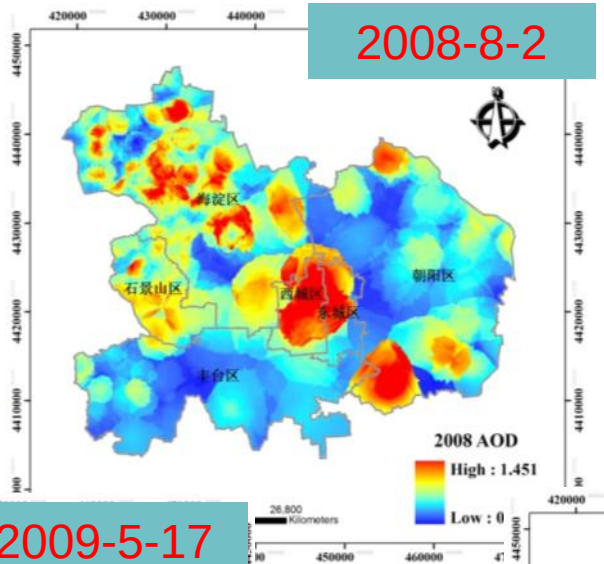
2.2 Results and Precision Validation (the Second method)

Retrieval

2007-5-28

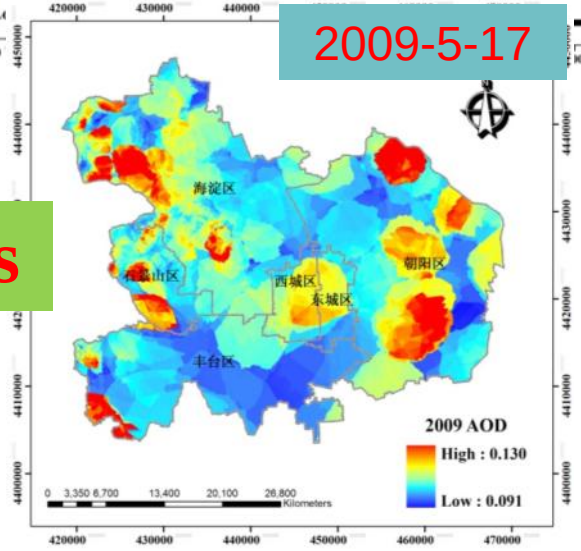


2008-8-2

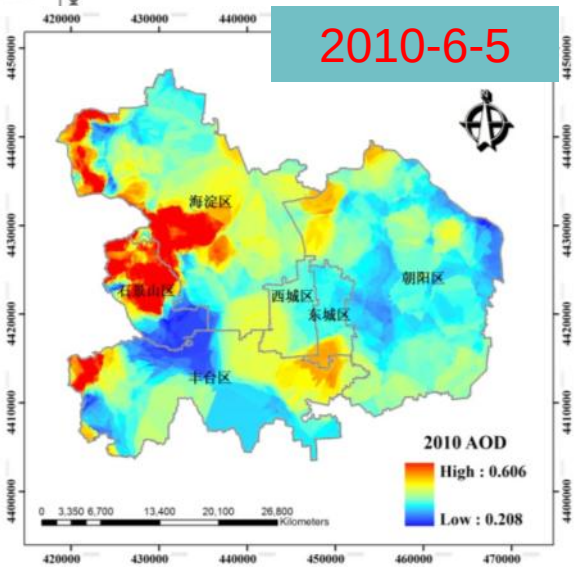


AOD Results

2009-5-17



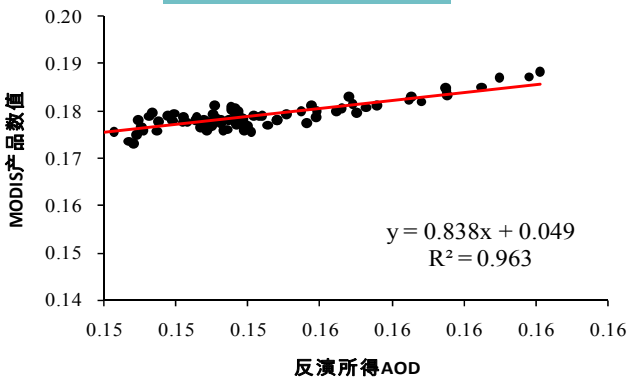
2010-6-5



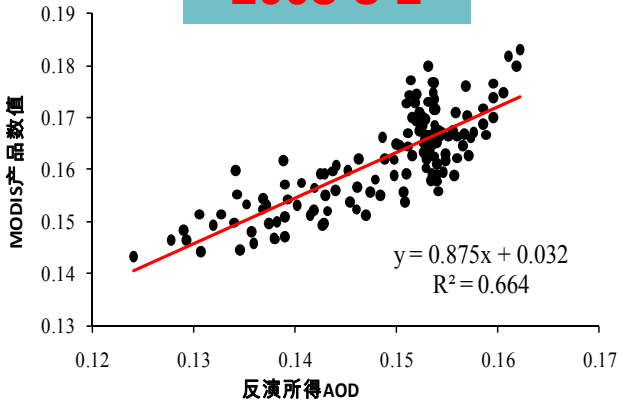
AOD Results

Accuracy Validation

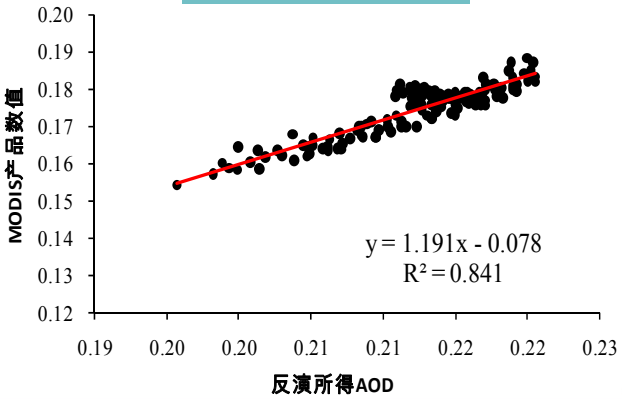
2007-5-28



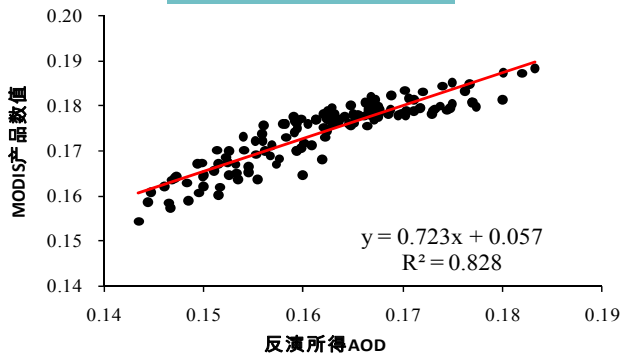
2008-8-2



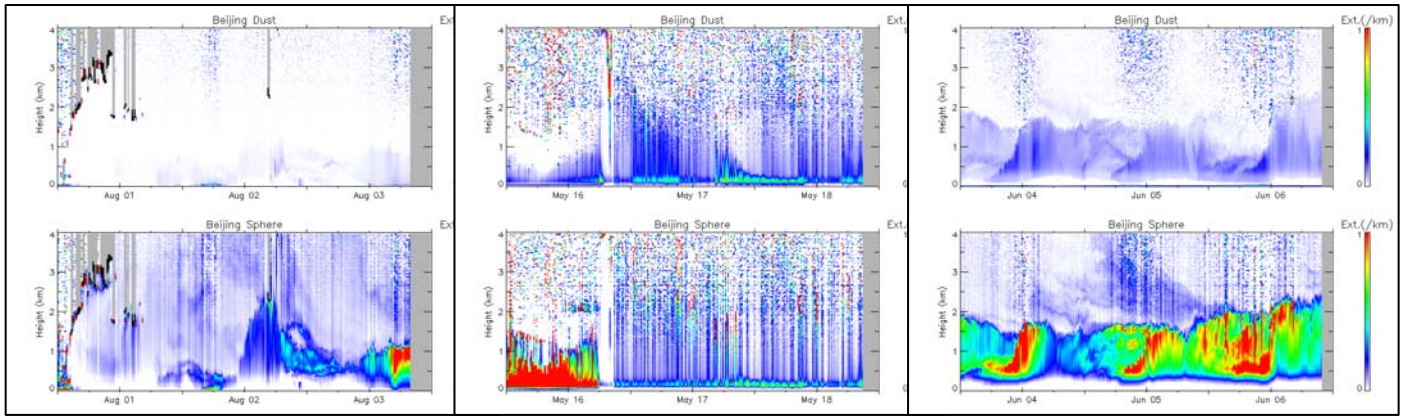
2009-5-17



2010-6-5



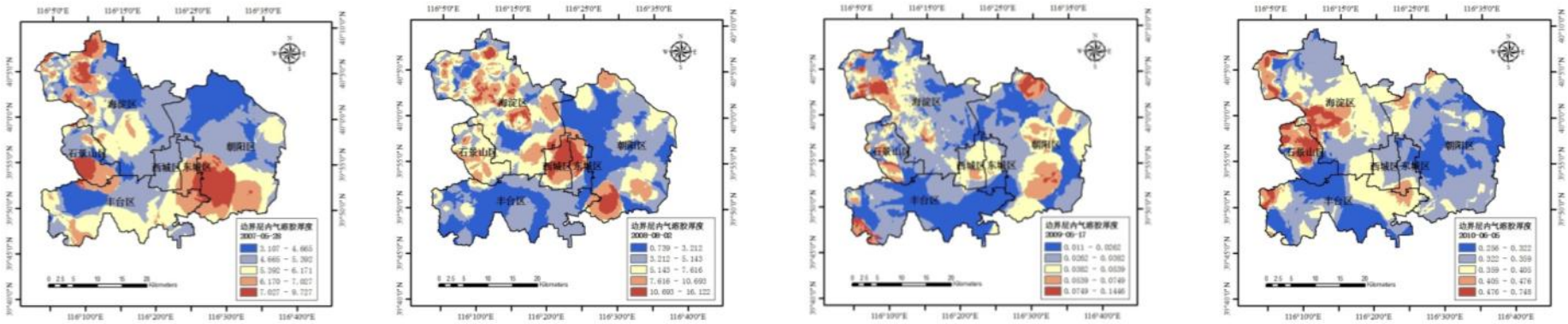
BAOD Based on Extinction Coefficient



BAOD in un-heating season of Beijing urban city was about **1.5km**

Broader Aerosol Optical Depth

BAOD = AOD / HPBL （D.Sarigiannis, 2002）



Construction of PM_{10} Spatial Distribution Model

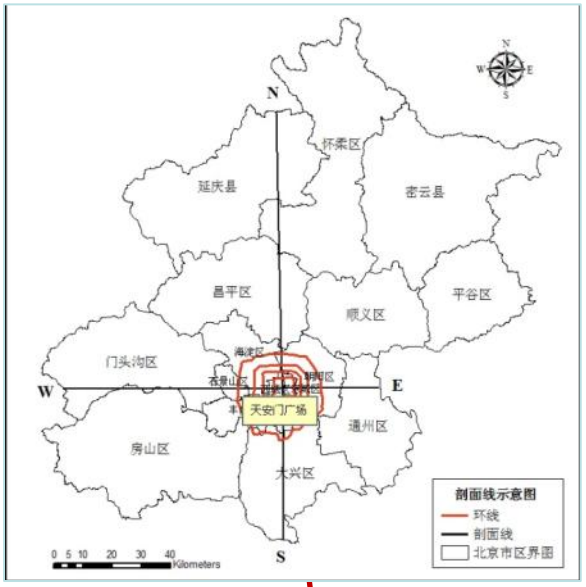
2007-05-28	function expression	R^2
1-2	$y = 1537.x^2 - 1094.x + 343.4$ polynomial	0.645
1-3	$y = 488.6x^2$ pol	
2-3	$y = 1567.x^2$ pol	

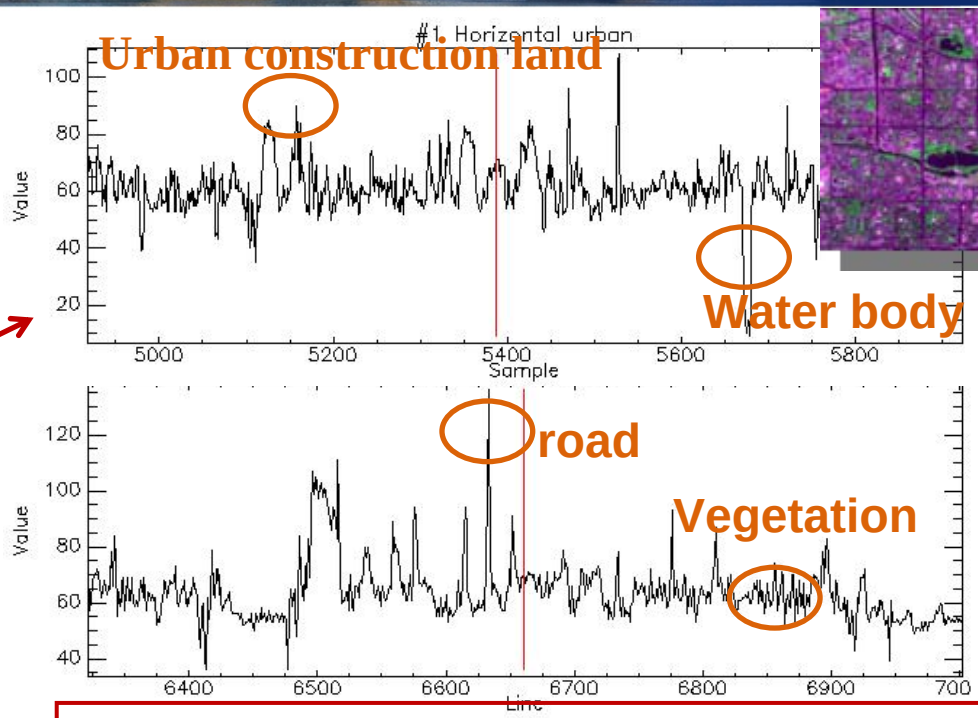
Number	Sample station	Retrieval result	Error
1	Fragrance Hill	169.0903	0.18245
2	Fengtai Garden	165.8830	0.04328
4	YunGang	153.2825	0.05712
5	Wan shao xi gong	168.4121	0.02067
7	Che gong zhuang	158.0278	-0.1812
8	Qian Men	180.8688	-0.17412
9	Dong si	163.5058	0.04144
12	Nong Zhan guan	159.2393	0.02076
15	Dang Xiao	165.8315	-0.03023
16	New Northern area	226.2039	0.13670
17	Wan Liu	201.1490	0.22652
		Mean error	**0.1013**

3、**Spatial-temporal features** of the inhalable particles

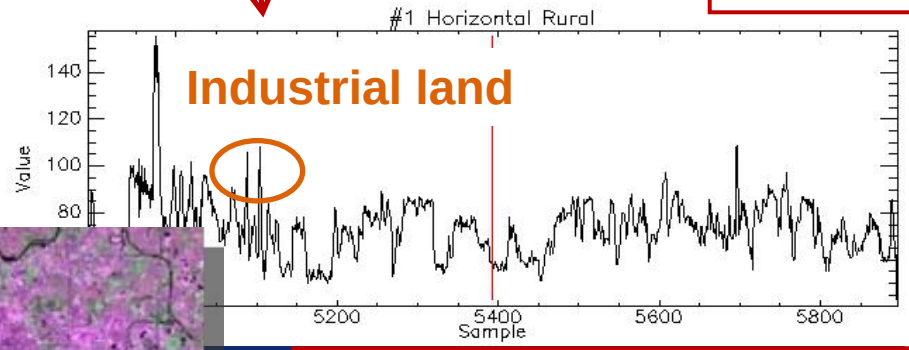
PM_{10} profile analysis based on RS inversion results

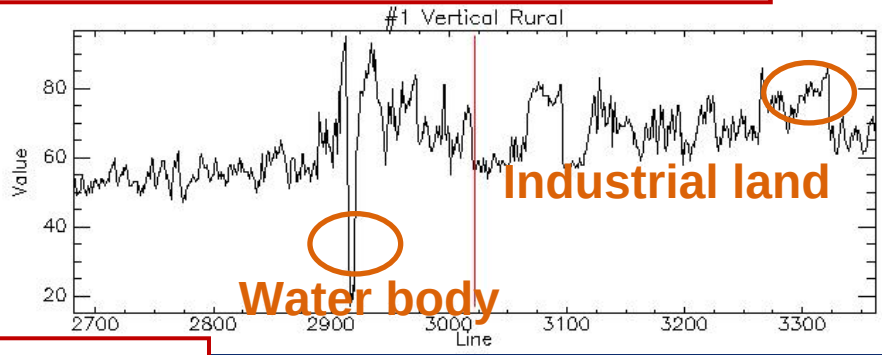
profile analysis

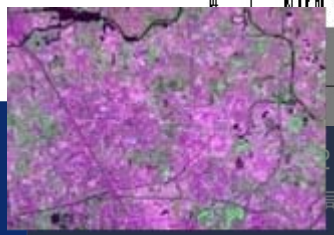




Urban area PM_{10} WE/NS profile







Rural Area PM10 WE/NS profile

Spatial Weight Matrix

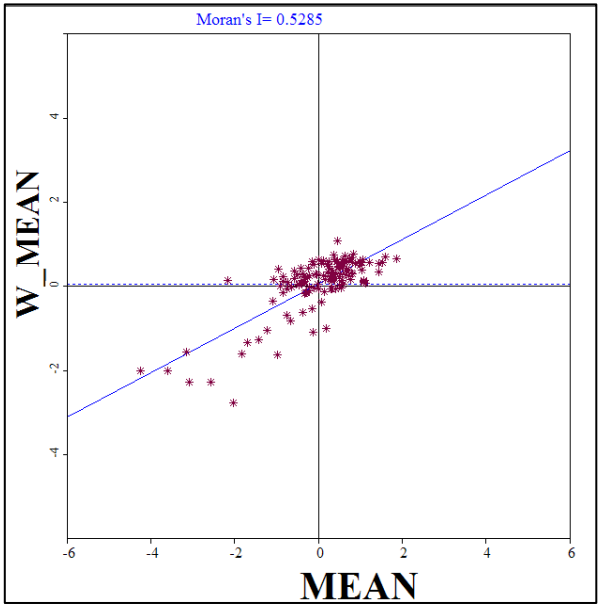
❖ **global spatial autocorrelation**

$$Moran's\ I = \frac{N\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\left(\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}\right)\sum_{i=1}^{N}(x_i-\bar{x})^2}$$

$$W = \begin{bmatrix} w_{11} & w_{12} & \Lambda & w_{1n} \\ w_{21} & w_{22} & \Lambda & w_{2n} \\ \Lambda & \Lambda & \Lambda & \Lambda \\ w_{n1} & w_{n2} & \Lambda & w_{nn} \end{bmatrix}$$

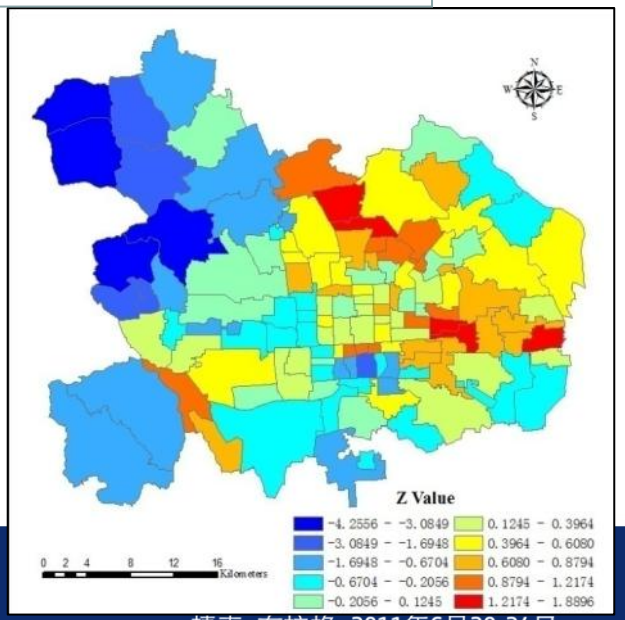
❖ **local spatial autocorrelation**

$$I_i = \frac{(x_i - \bar{x})}{S^2}\sum_j w_{ij}(x_j - \bar{x})$$



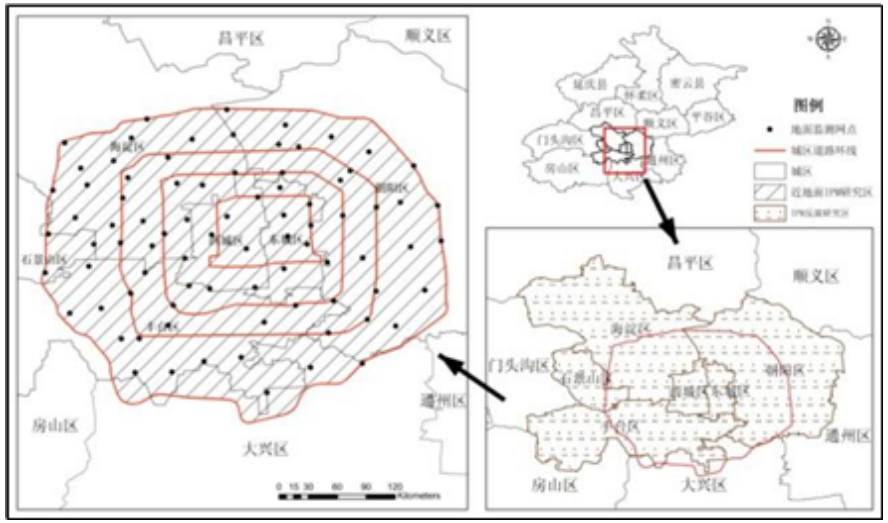
Z value of spatial autocorrelation on Beijing Urban city

The spatial of PM_{10} was not distributed at random, but shows a pattern of spatial agglomeration of similar value.



The spatial distribution of IPM based on Ground Monitoring

In-situ Data Collection

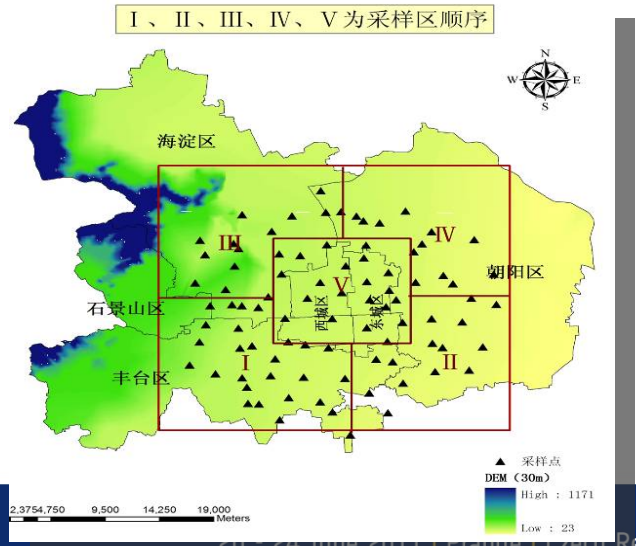


Samples collocation

Principle:

- Universality
- Uniformity
- Orderliness

Sampling belt



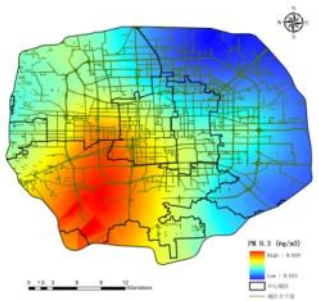
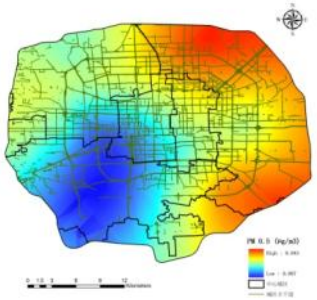
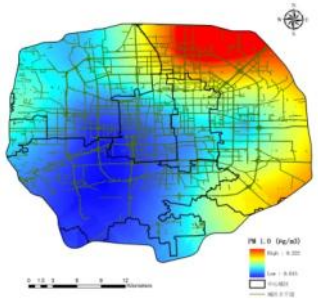
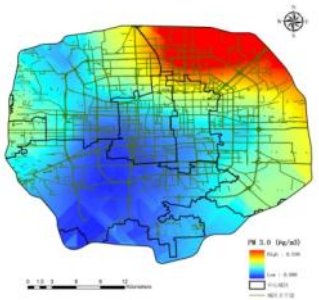
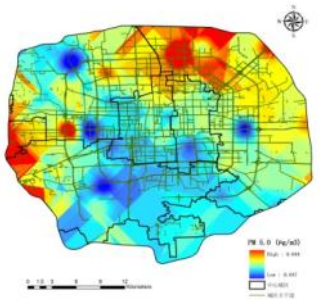
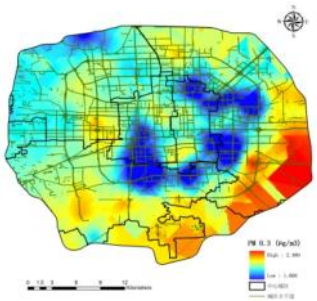
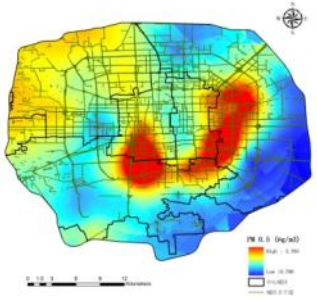
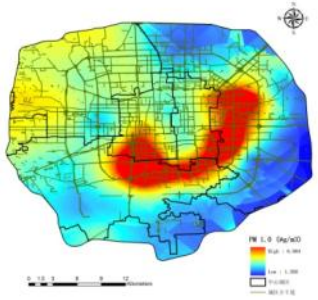
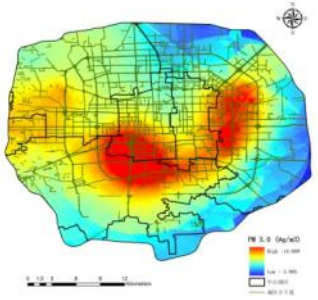
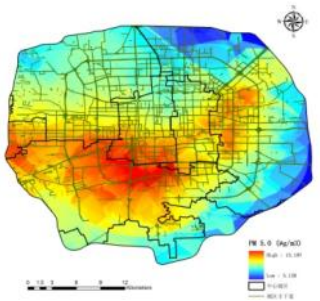
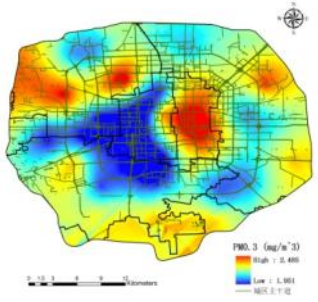
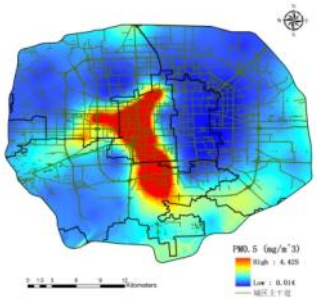
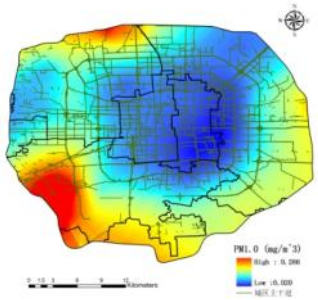
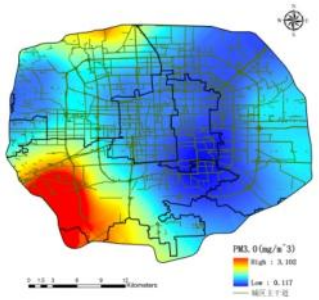
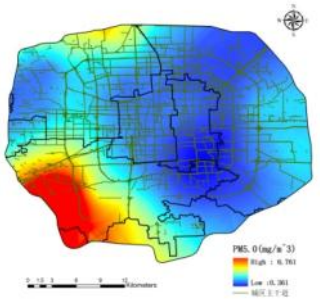
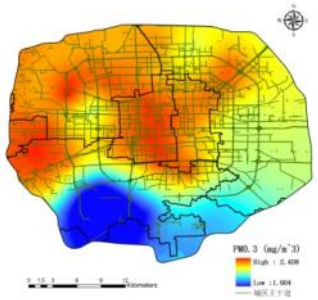
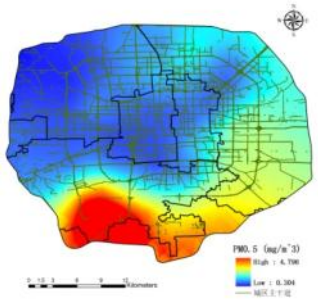
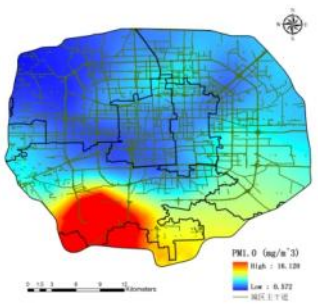
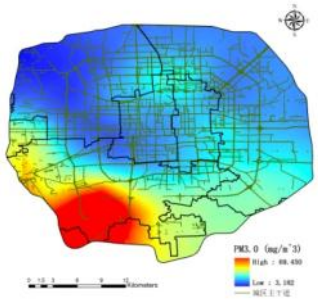
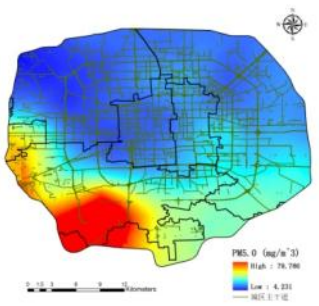
Un-heating season	heating season
2007.6	2007.12
2008.6	2008.12
2009.6	2009.12
2010.6	2010.12

Data type

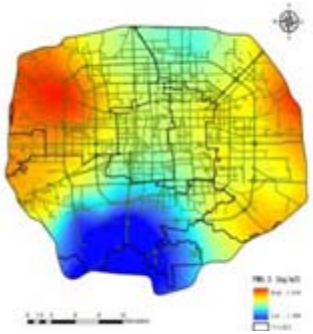
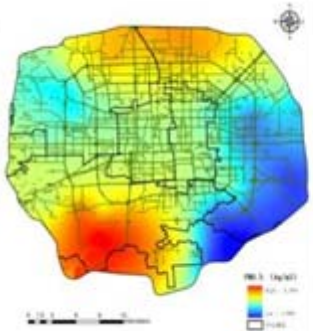
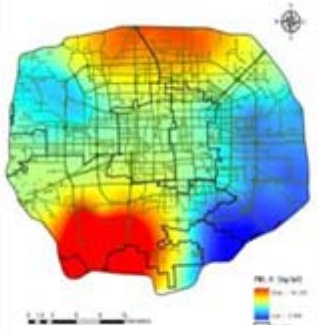
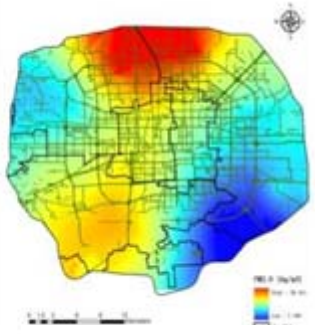
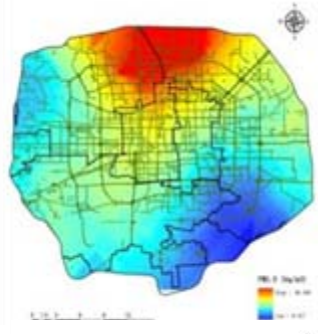
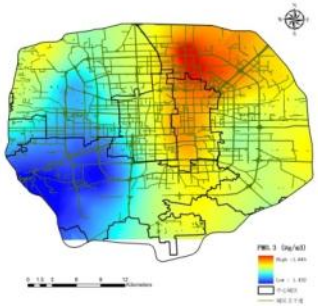
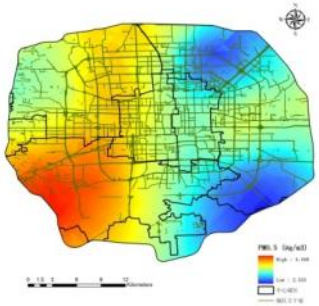
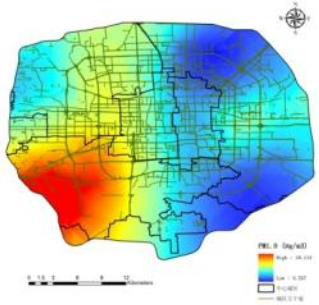
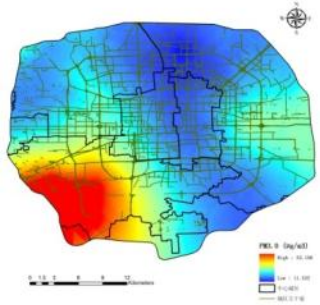
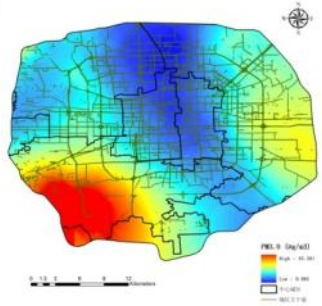
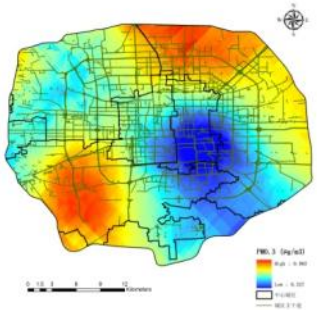
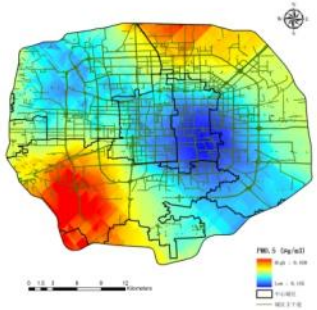
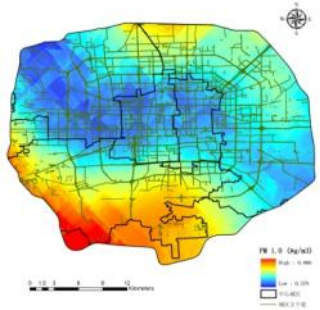
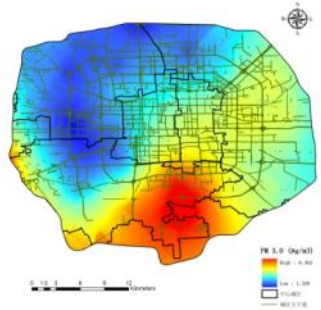
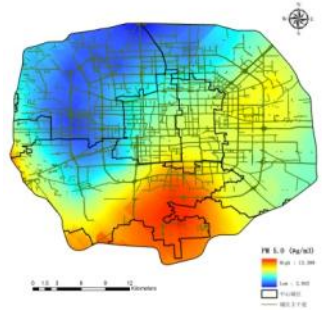
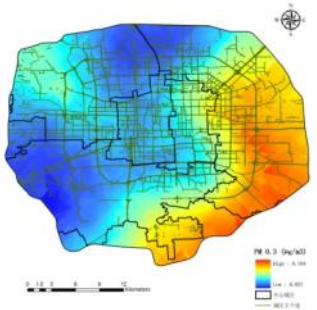
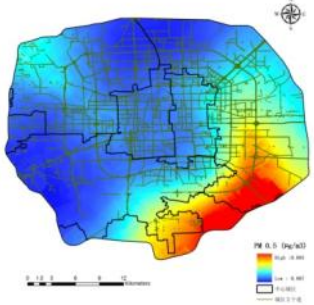
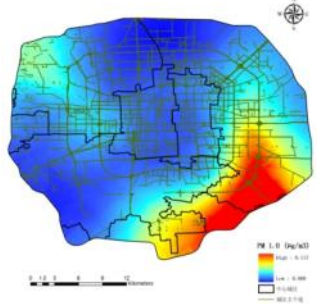
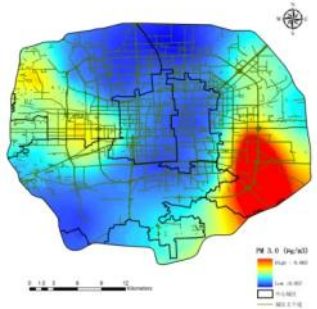
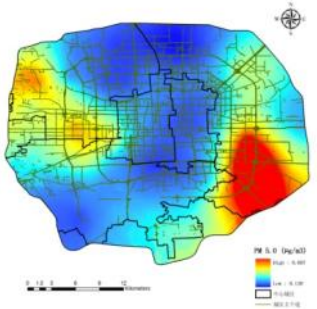
Instrument	The type of data
Handheld Laser Particle Counter	The concentration of PM0.3、PM0.5、PM1.0、PM3.0、PM5.0
	surface temperature (in ℃) humidity of air (in %) wind speed (in m/s)
GPS handset	Geography Coordinate ： Latitude 、Longitude



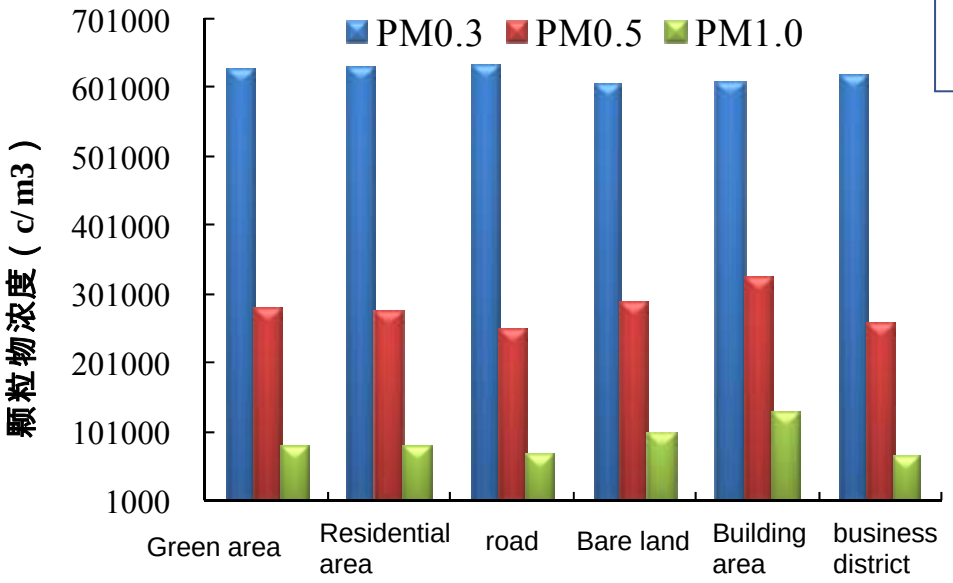
Heating season

	PM0.3	PM0.5	PM1.0	PM3.0	PM5.0
2007					
2008					
2009					
2010					

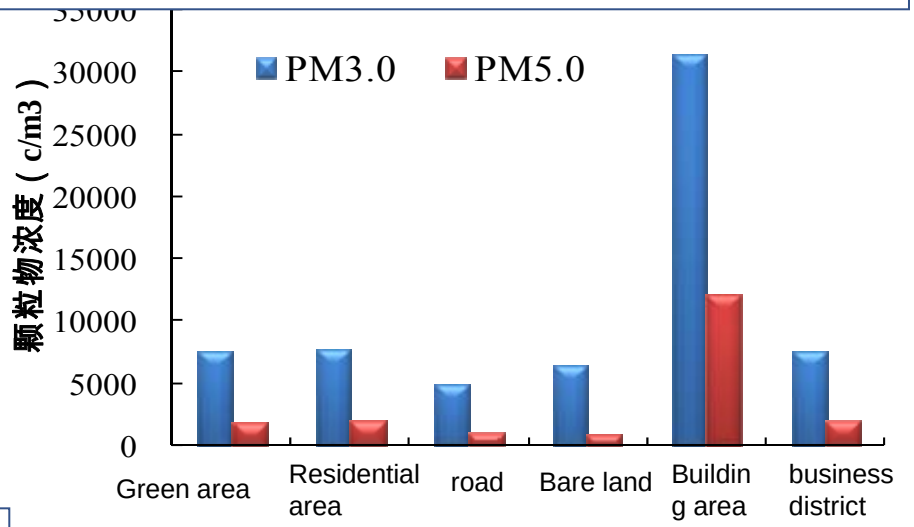
Un-heating season

	PM0.3	PM0.5	PM1.0	PM3.0	PM5.0
2007					
2008					
2009					
2010					

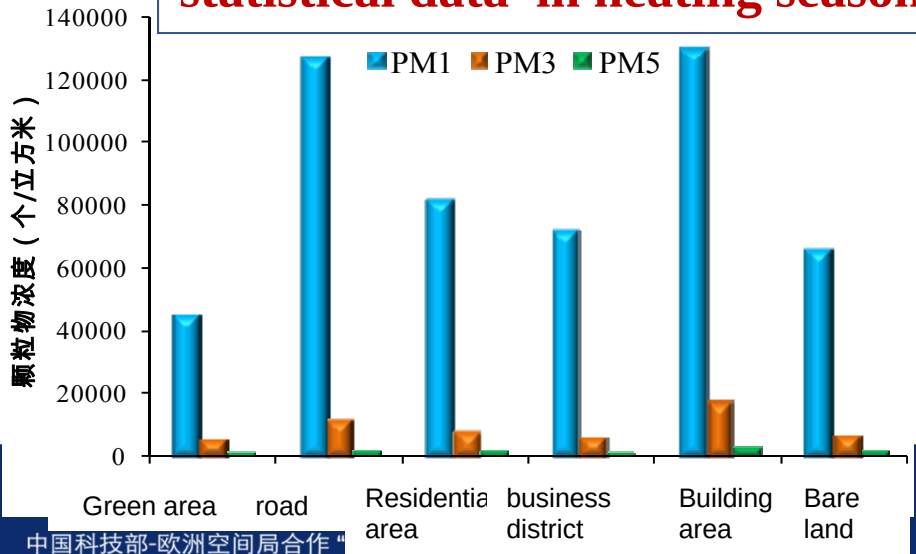
Data Analysis of IPM in different size

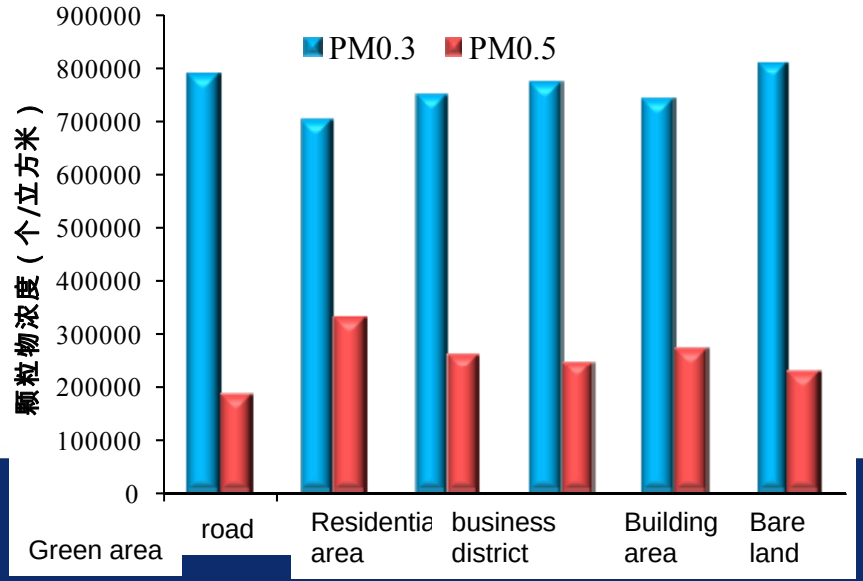


statistical data in un-heating season



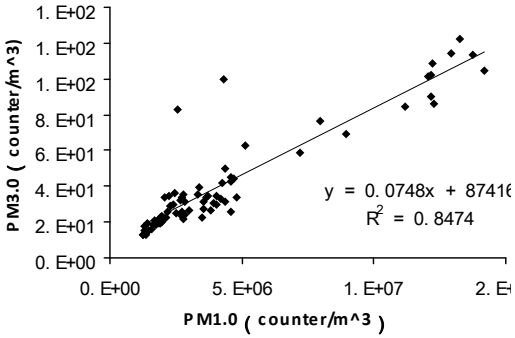
statistical data in heating season

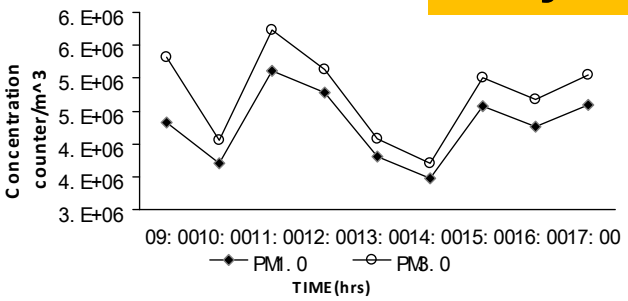




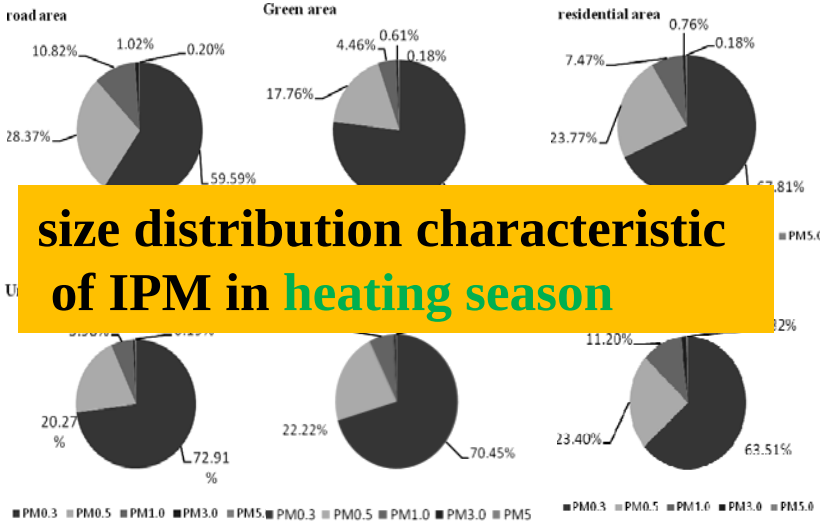
variation characteristic of IPM in urban city

daily variation of particle pollution

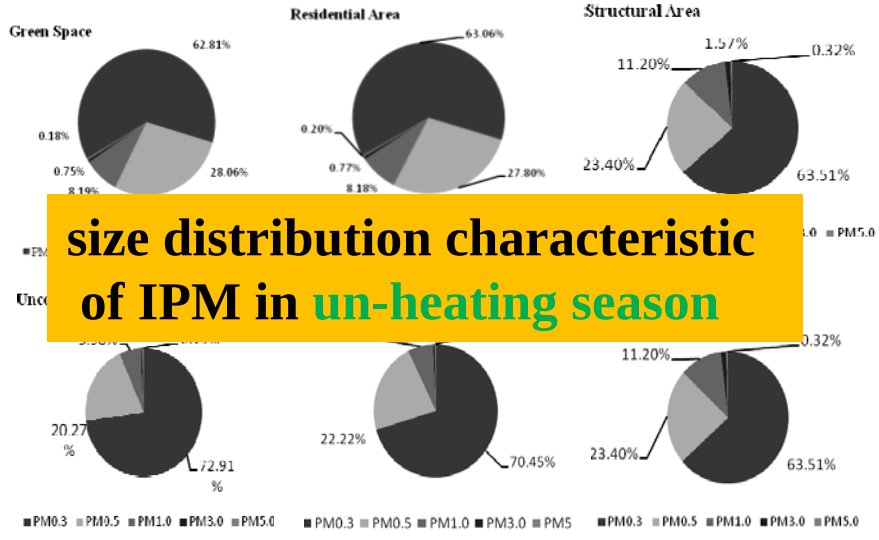




It shows twin peaks & twin valley ， twin peaks appear on 9am and 11am; twin valley appear on 10am and 14pm.



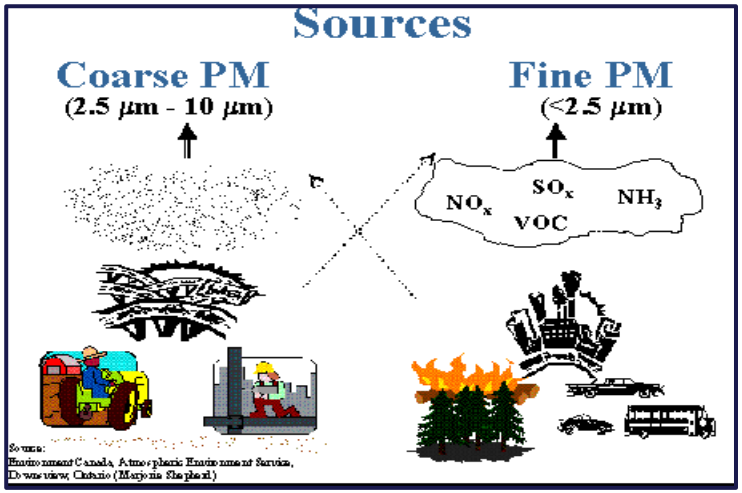
size distribution characteristic of IPM in heating season

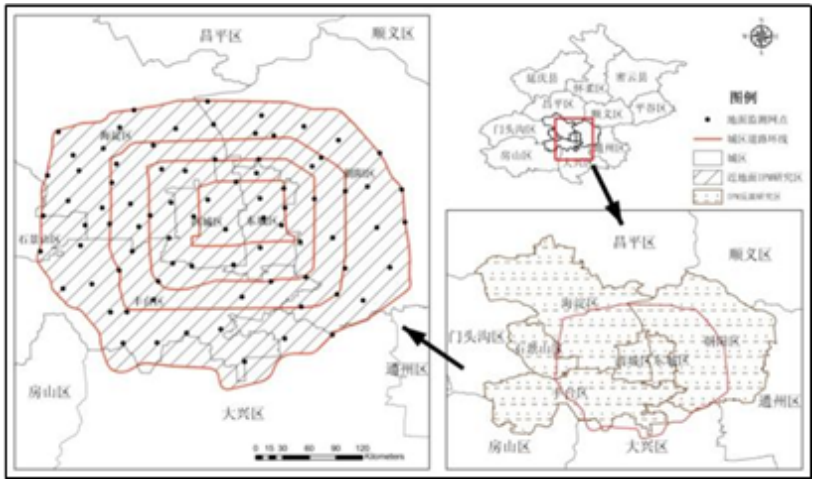


size distribution characteristic of IPM in un-heating season

4、Effect and Mechanism of Particle Pollution in urban city

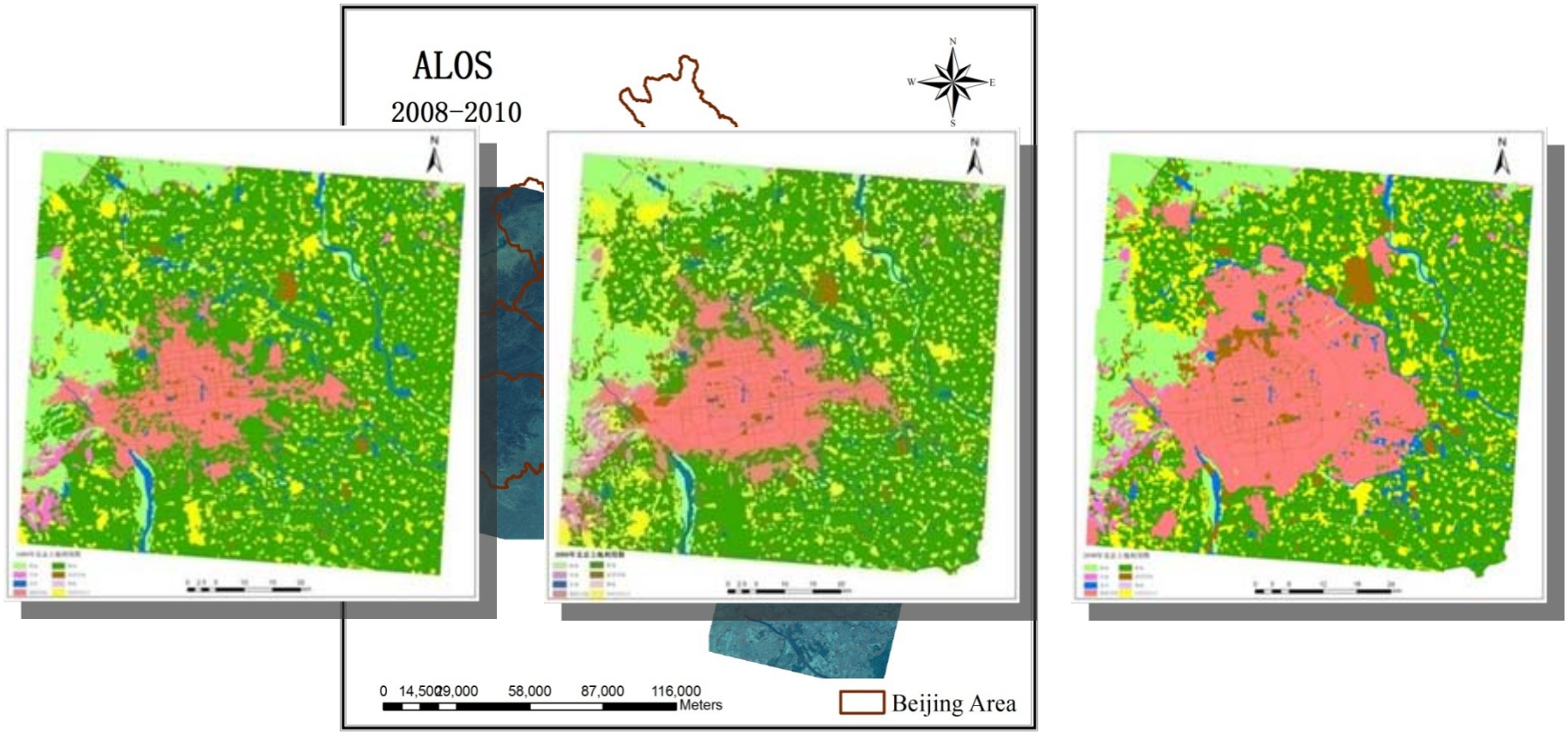
- 4.1 Study on the relationship between LUCC and IPM
- 4.2 How meteorological factors impact on IPM
- 4.3 Analysis on correlation between IPM pollution and other environmental elements
- 4.4 Comprehensive Analysis on influence factors

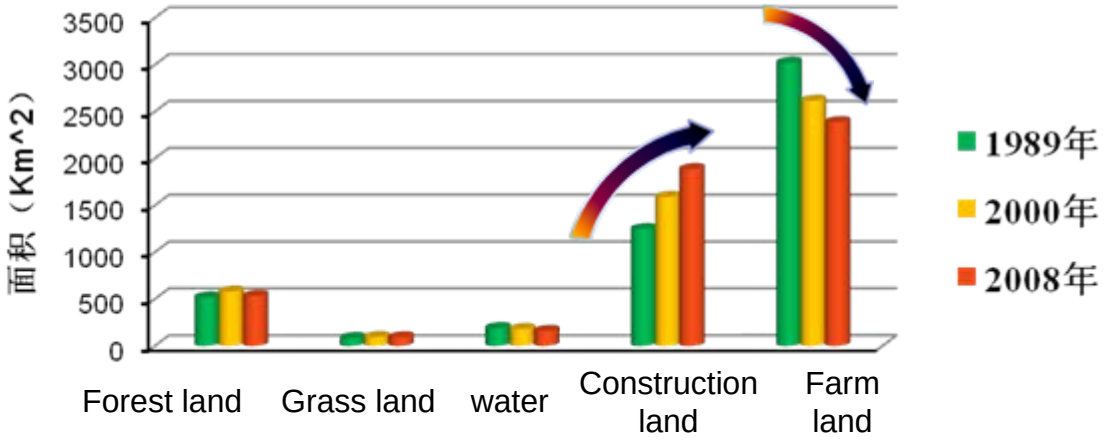




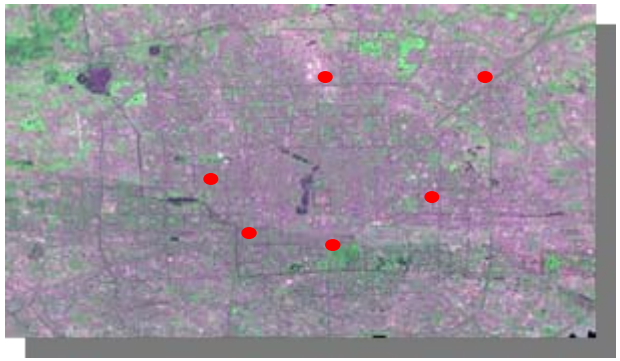
4.1 Land use/ Land cover in Beijing urban city

1989、2000、2008 Beijing Land use Land cover





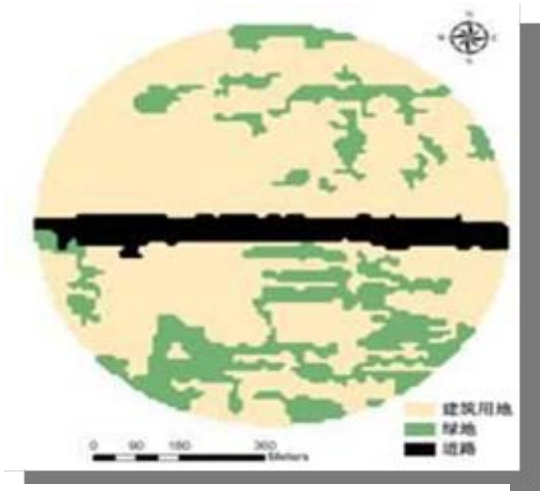
Land use type/Land-use Dynamic Degree	1989-2000(%)	2000-2008(%)
Forest land	1.31	-1.83
Grass land	0.87	1.70
Water body	-0.37	-3.27
Construction land	2.88	3.38
Farm land	-3.23	-6.06



Functional Domain	Sample Numbers	Locations
Business area	2	Gongzhufen、Xinfadi
Residential area	2	Guangqumen、Maliandao
Road	1	Wuyuan Bridge
Construction land	1	Bird nest

Object-based land-cover classification

Extract Information	Methods
Green land	Vegetation index
Road	brightness、length-width ratio、length、topological relationship
water、shadow of building	brightness、DN value in each band
Construction land	brightness、DN value in each ban



1km Buffer area

Accuracy Assessment

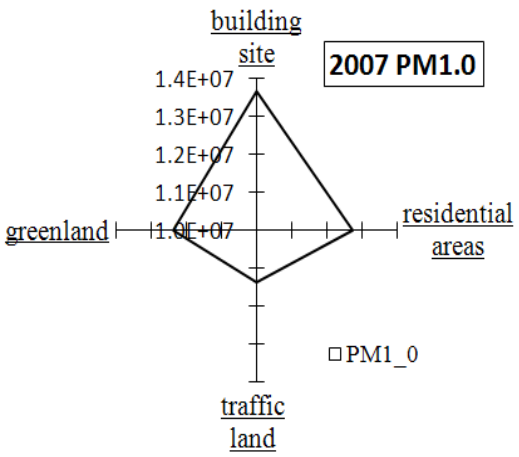
Locations	Green land	Road	Construction land	Total precision
Bird Nest	93.55%	60%	84.85%	**86.96%**
Wuyuan Bridge	92.6%	81.82%	96%	**90.54%**
Xinfadi	97.14%	75%	96.43%	**95.79%**
Maliandao	74.07%	85.71%	95.12%	**86.59%**
Gongzhufen	88.24%	66.67%	93.88%	**94.12%**
Guangqu Gate	88.89%	91.67%	91.43%	**90.54%**

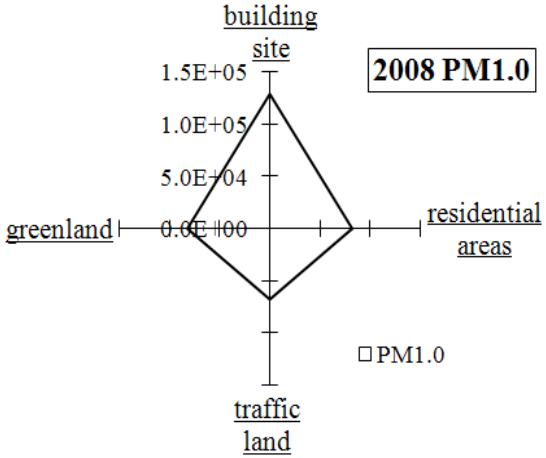
VCR：vegetation cover ratio

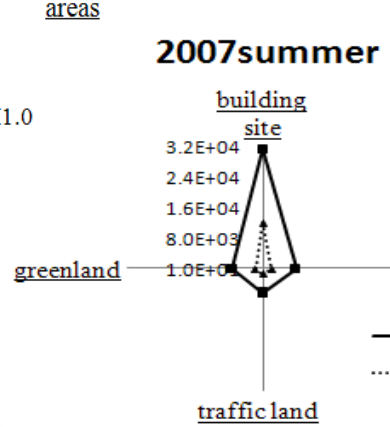
$$VCR = P_g / (P_r + P_b + P_{ba})$$

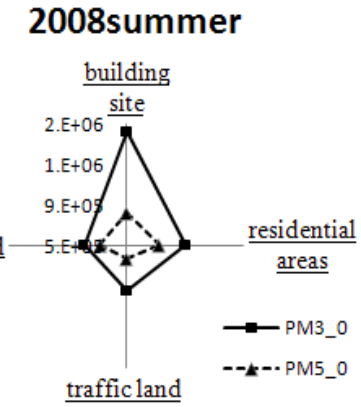
Green land、water、construction land and road

correlation coefficient	Green Land	Construction land	VCR
$PM_{0.5}$	-0.244	0.518	-0.261
PM_1	-0.285	0.553	-0.309
PM_3	-0.685	0.874	-0.677
PM_5	-0.559	0.486	-0.523





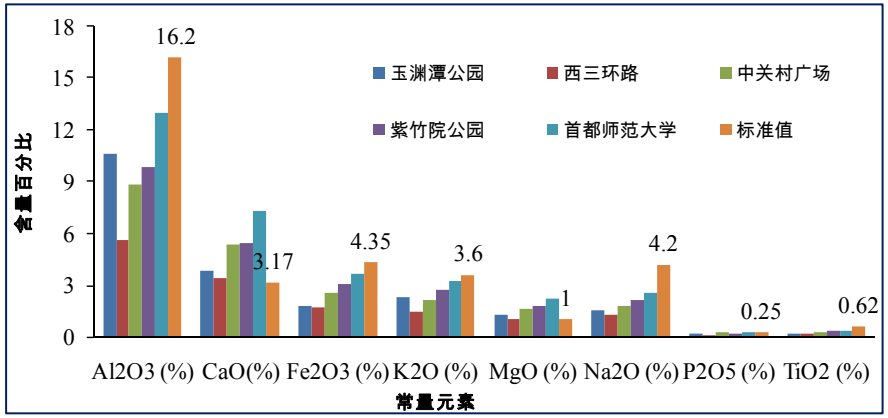




the source of IPM and ultimate analysis

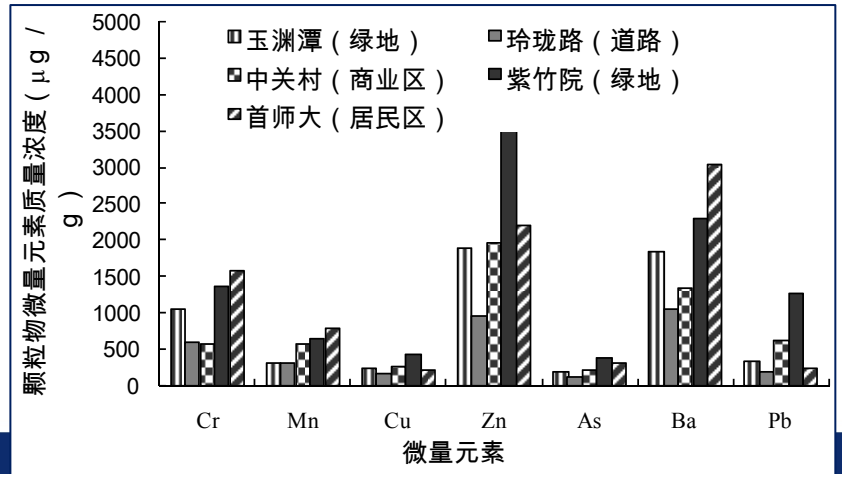
Sampled on different underlying surfaces （business area 、residential area、road、green area ）on Dec,2006, and analyzed by ICP-MS .

the percentage of major element in IPM on different underlying surface



Ca、Al、Fe、K and Na---Urban Fugitive Dust；Ca---construction source。

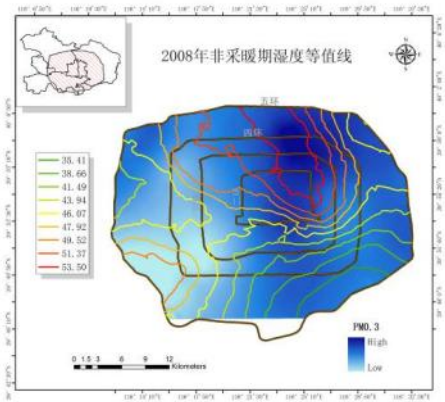
the content of Zn was very high，it was may from Automobile exhaust or other pollution resource.

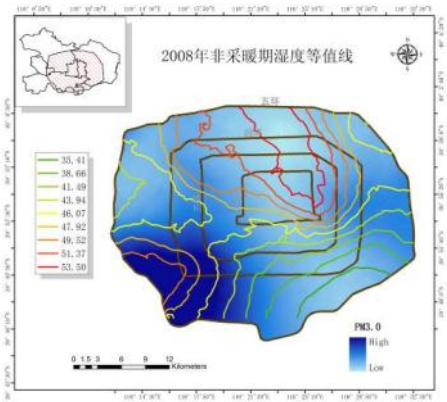


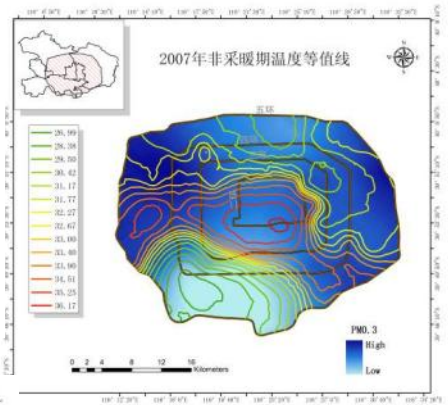
the concentration of partial microelement in IPM on different underlying surface

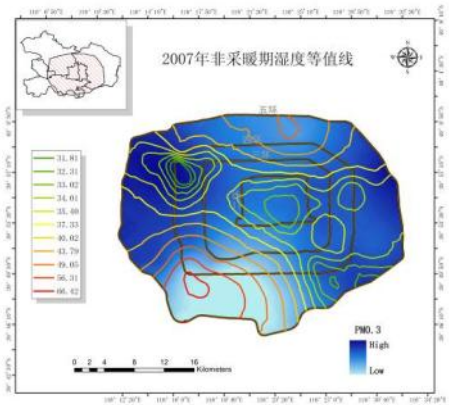
4.2 the influence of meteorological on IPM pollution

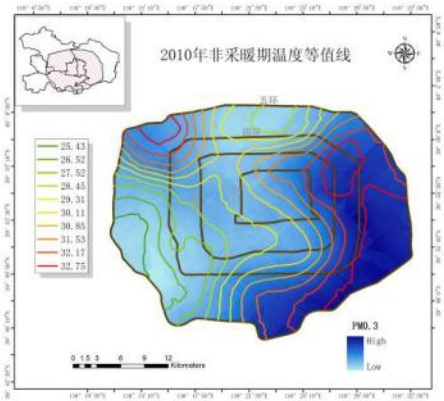
spatial framework of Meteorological factors and IPM

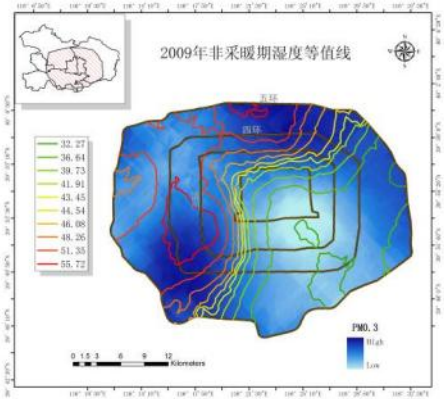


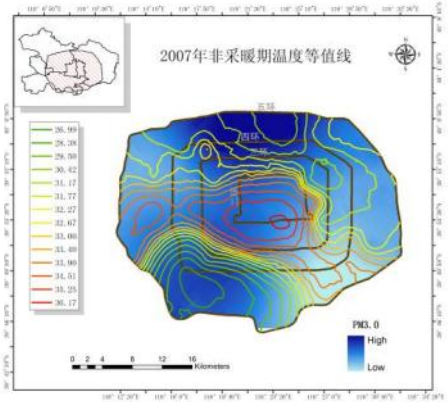


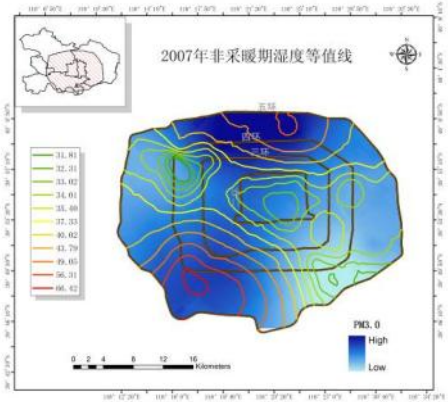




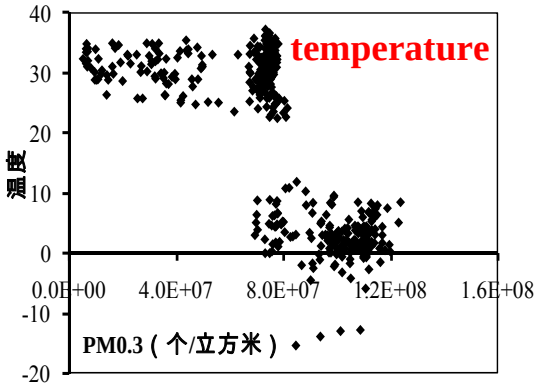


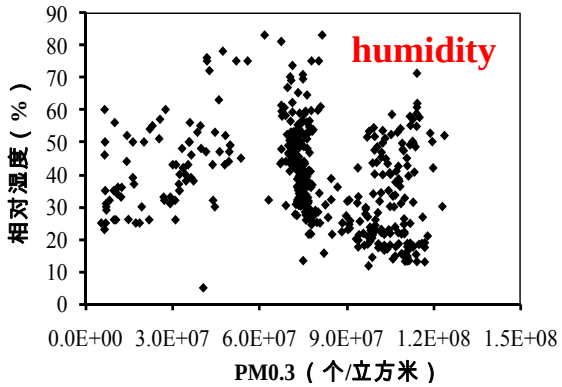


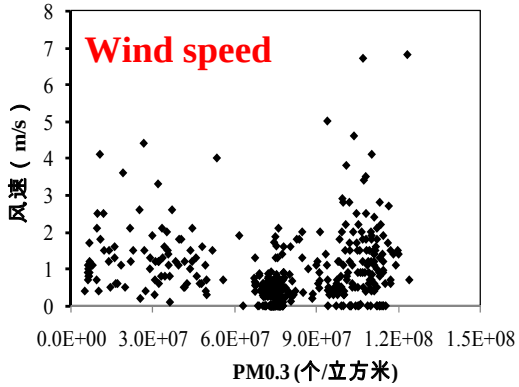




Analysis of Nonparametric





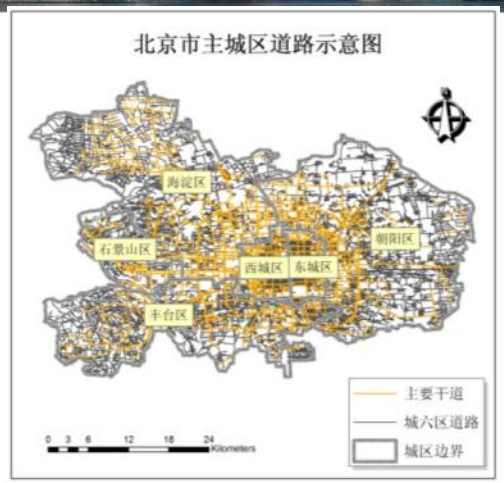


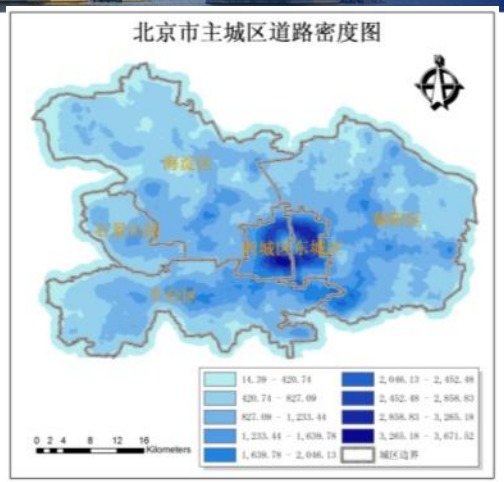
Heating season	$PM_{0.3}$	$PM_{0.5}$	$PM_{1.0}$	$PM_{3.0}$	$PM_{5.0}$
temperature	-0.203	0.456	0.524	0.529	0.640
humidity	-0.332	0.667	0.670	0.719	0.713
Wind speed	0.434	-0.560	-0.667	-0.656	-0.789

Non-heating season	$PM_{0.3}$	$PM_{0.5}$	$PM_{1.0}$	$PM_{3.0}$	$PM_{5.0}$
temperature	0.084	-0.071	-0.090	0.027	0.051
humidity	-0.147	0.173	0.232	0.325	-0.064
Wind speed	0.245	-0.529	-0.413	-0.213	-0.123

Non-heating season：wind speed has much more influence on fine particles than on coarse particles.

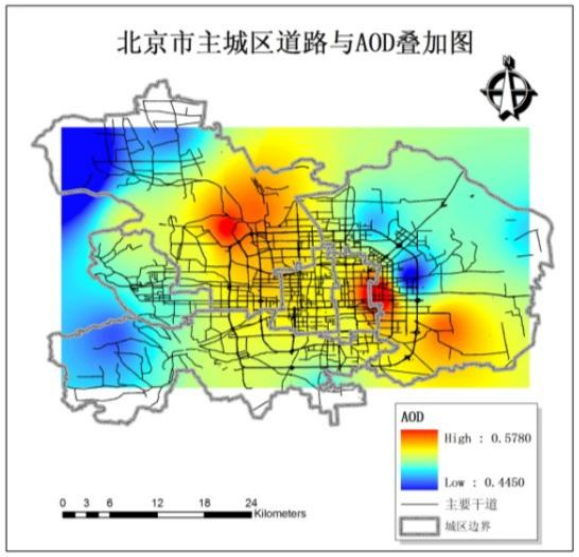
4.3 the influence of urban road on IPM pollution

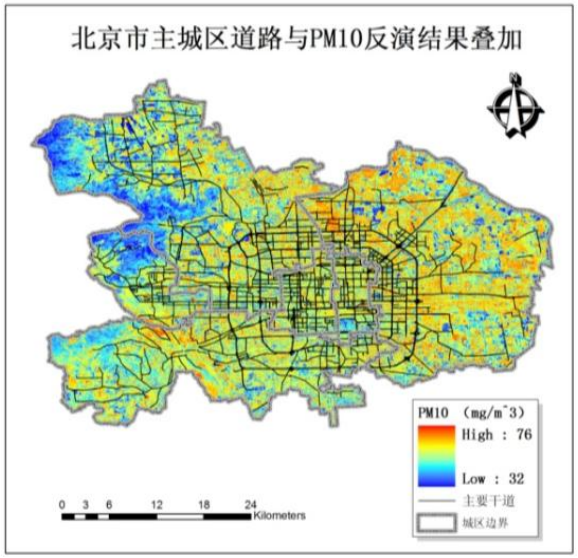


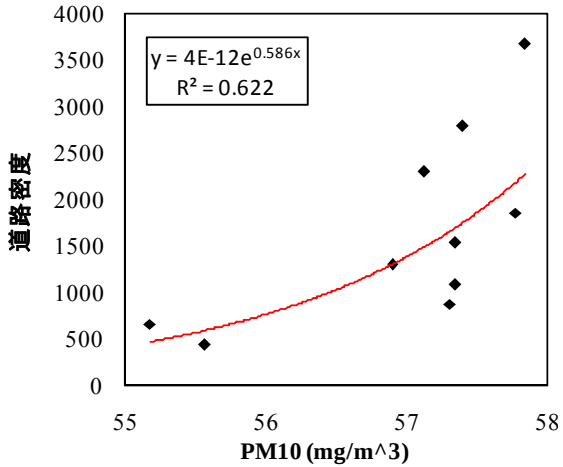


Grade Proportion of Urban Road	Road density	Mean value of PM_{10} on road (mg/m^3)	standard deviation (mg/m^3)
1	131.73 - 431.94	55.5677	2.2801
2	431.94 - 662.31	55.1794	5.1118
3	662.31 - 878.28	56.8998	2.8512
4	878.28 - 1,079.86	57.1260	3.1430
5	1,079.86 - 1,295.83	57.3123	2.5321
6	1,295.83 - 1,540.60	57.3490	1.7505
7	1,540.60 - 1,857.36	57.3513	2.2516
8	1,857.36 - 2,303.70	57.7733	0.5116
9	2,303.70 - 2,793.24	57.4008	0.7862
10	2,793.24 - 3,671.53	57.8445	0.7281

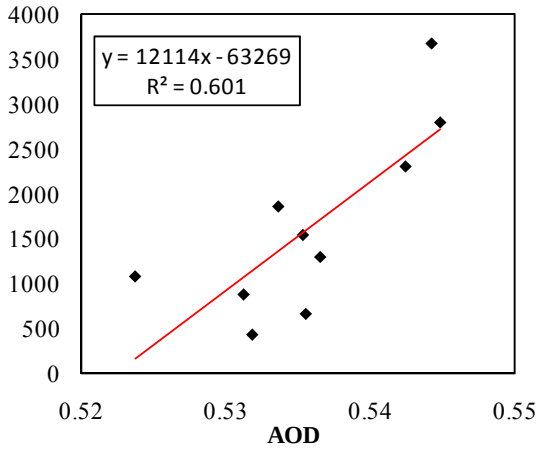
4.3 the influence of urban road on IPM



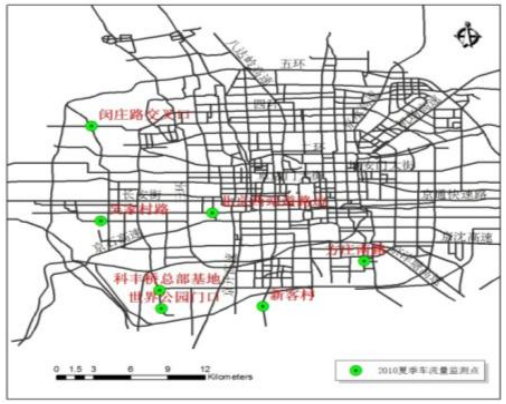




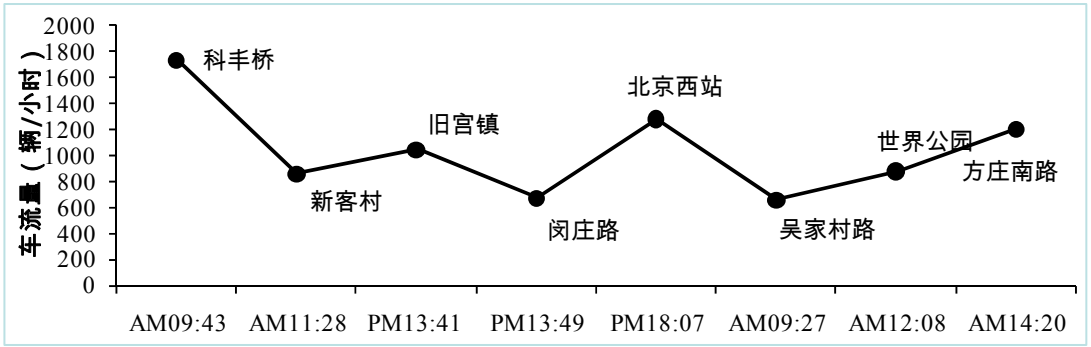
The road density has little more influence on IPM than on AOD.



4.3 correlation between IPM and traffic flow

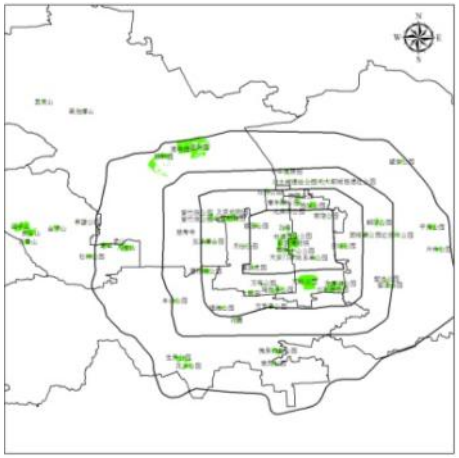


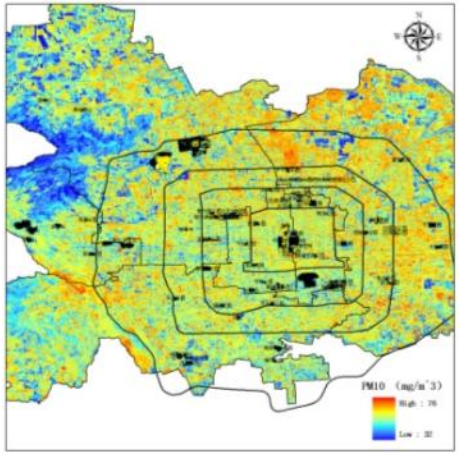
Traffic flow has much more contribution on coarse particle.

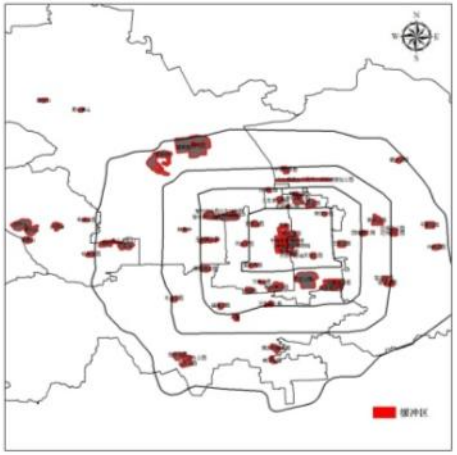


	Traffic flow magnitude	$PM_{0.3}$	$PM_{0.5}$	PM_1	PM_3	PM_5
Traffic flow magnitude	1					
$PM_{0.3}$	0.0553	1				
$PM_{0.5}$	0.1012	0.9378	1			
PM_1	0.3208	0.9179	0.9601	1		
PM_3	0.4915	0.4955	0.3985	0.6323	1	
PM_5	0.56878	0.4760	0.3657	0.6028	0.9984	1

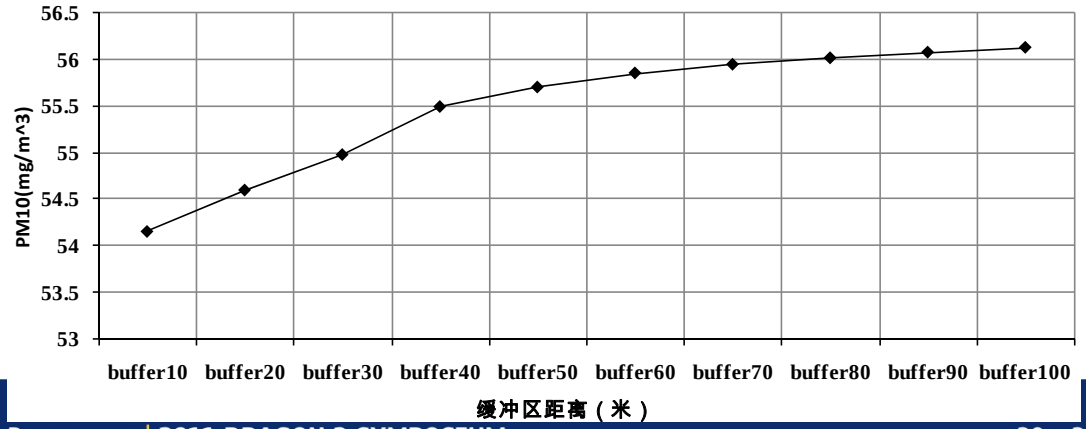
4.3 the Influence of Park Plaque on IPM







PM10 increasing with the distance from Park increased. When the buffer range reaches to 80m, the increasing was become slow.



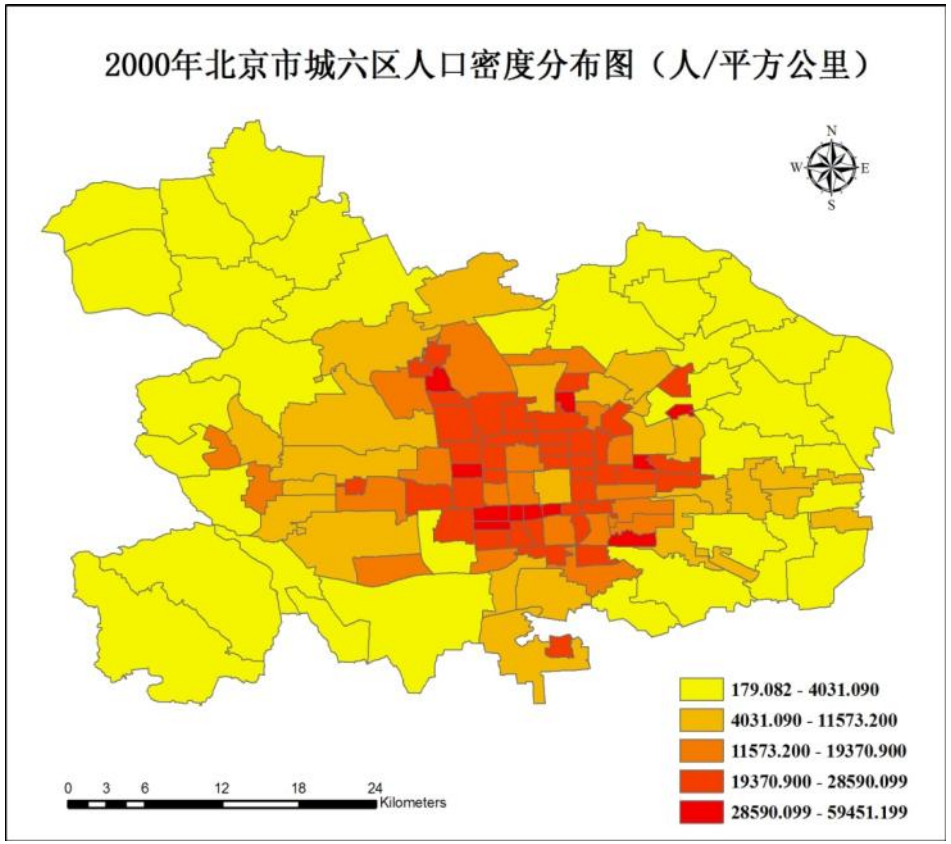
4.4 Comprehensive Analysis on influence factors

The Construction of the Index System in influence factors on urban IPM pollution

First-degree index	Urban underlying surface	Human Activities Intensity	ecological environment index	meteorological factors
Second-degree index	Impervious Surface Area	population density road density	Vegetation Coverage	temperature/ wind speed/relative humidity

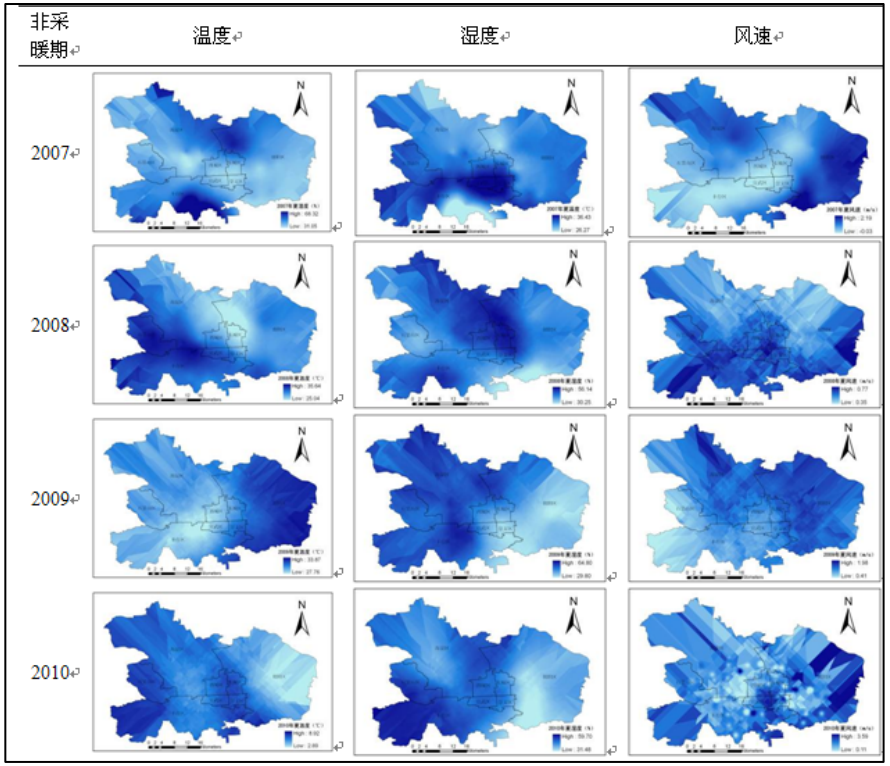
- **Meteorological factors ——Interpolation**
- **Impervious Surface Area、Vegetation Coverage —Linear Spectral Mixture Model**

4.4.1 Index System: Population Density/ Meteorological Factors



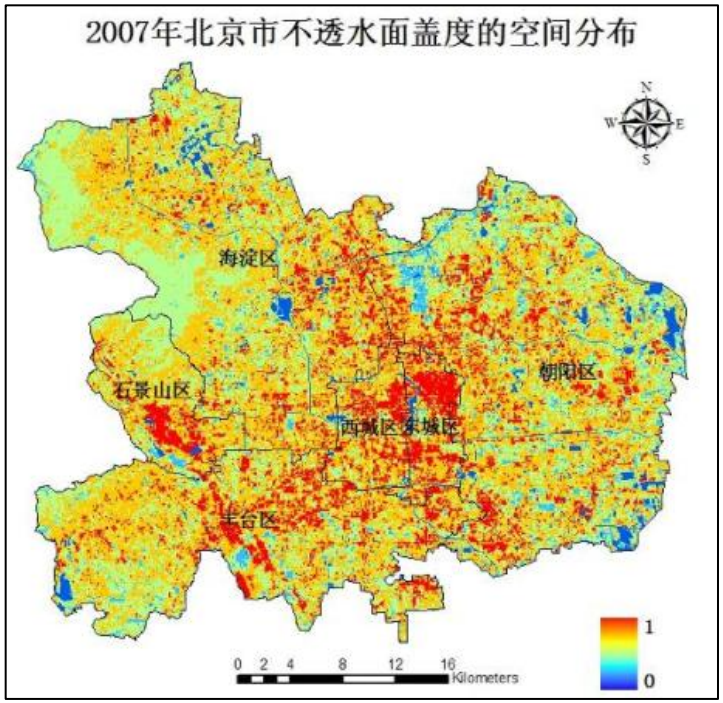
The population density of Beijing urban city in 2000

the spatial distribution of meteorological factors in non-heating season

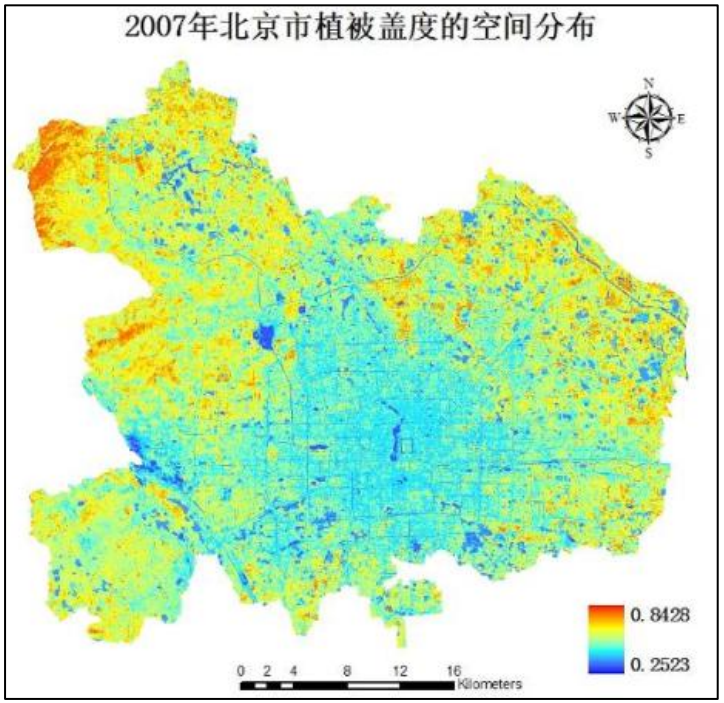


Estimating Formula of Impervious Surface Area：

$$R_{imp,b} = f_{low} R_{low,b} + f_{high} R_{high,b} + e_b$$



The spatial distribution of Beijing Impervious Surface Area in 2007



The spatial distribution of Beijing Vegetation Coverage in 2007

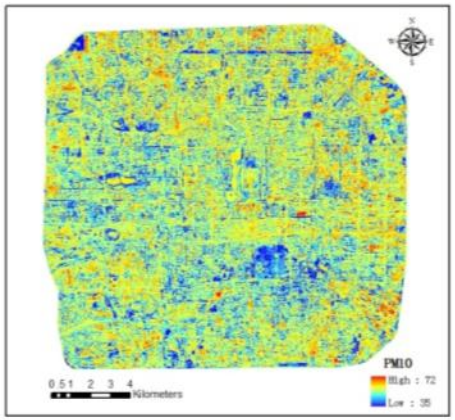
4.4.4 the correlation between PM10 and influence factors

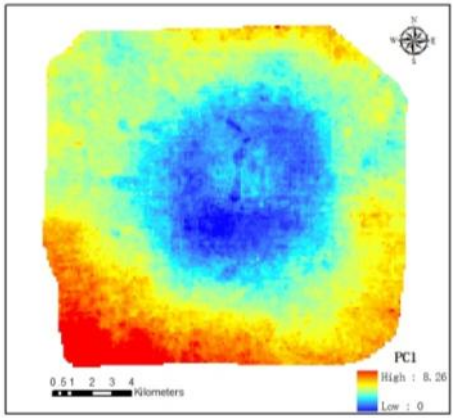
	Wind speed	temperature	Road density	Population density	Impervious Surface Area	relative humidity	PM10
Wind speed	1	-0.01292	-0.01406	-0.04514	-0.01933	0.20941	0.39496
temperature	-0.01292	1	0.00258	-0.54396	-0.30024	0.17982	-0.4967
Road density	-0.01406	0.00258	1	-0.08589	-0.11271	-0.05268	0.3059
Population density	-0.04514	-0.54396	-0.08589	1	0.23582	-0.21729	-0.2287
Impervious Surface Area	-0.01933	-0.30024	-0.11271	0.23582	1	0.12923	-0.10397
relative humidity	0.20941	0.17982	-0.05268	-0.21729	0.12923	1	0.5788

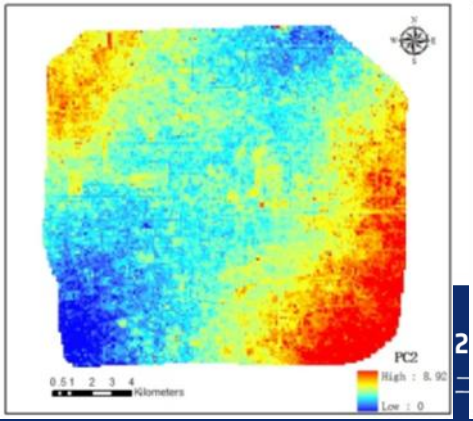
Eigenvalue and Contribution Rate of Principal Component Analysis

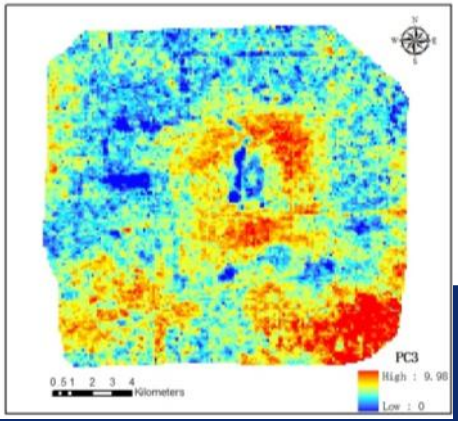
PC	Eigenvalue	contribution rate (%)	Accumulate contribution rate (%)
1	1.72673	84.65%	84.65%
2	1.15445	10.05%	94.70%
3	1.05313	1.35%	96.05%
4	0.83593	1.40%	97.45%
5	0.56134	1.78%	99.23%
6	0.1833	0.77%	100.00%

PC	Wind speed	temperature	Road density	Population density	Impervious Surface Area	relative humidity
1	0.52631	-0.54242	-0.05351	0.1333	-0.24347	0.59065
2	0.14725	0.39787	-0.4522	0.78437	-0.01322	0.01074
3	-0.65165	-0.08153	-0.19436	0.04922	0.66619	0.62802









The first principal component reflects temperature/ wind speed/relative humidity. ;The second principal component reflects Population density ;The third principal component reflects underlying surface types.

conclusions

It is found that API levels during heating period are basically higher than those in the non-heating period except for 2009 with slight increase. The level of air pollution index has shown a fallen tendency. Meanwhile, particular concentration has been proved to have an intensive correlation with meteorological factors.

The result derived from remote sensing images has proved a severe pollution suffered in Beijing. Main polluted area was centralized at southeast plain area; mountain area in northwest was weaker. Pollution level in central city was also relatively high. Obviously, the spatial distribution of aerosol was strongly correlated with various factors.

The contributions of various parameters to urban PM concentration were estimated using principal component analysis (PCA), which is helpful to integrate useful information and reduce redundancy.

Future Steps

- Seeking the understanding of the administration (e.g. EPB Beijing).

- the use of EO for air quality (especially during the Games' period) and for the post Games assessment.

- Further study about IPM retrieval by other RS data, especially EO data.

Field sampling photos

Thanks for your attention!