Urban air quality and regional haze weather forecast in Yangtze River Delta of China

Wang Tijian Jiang Fei Deng Junjun Shen Yi
School of Atmospheric Science，Nanjing University

Fu Qinyan Wang Qian
Shanghai Environmental Monitoring Center

Zhang Danning Fu Yin Xu Jinahua
Nanjing Environmental Monitoring Center

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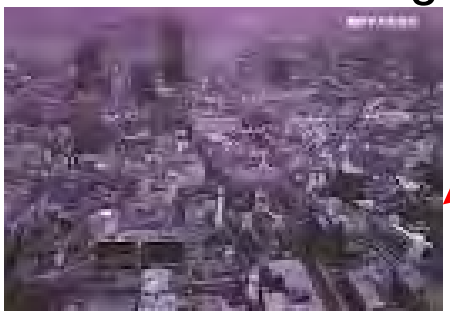
Outline

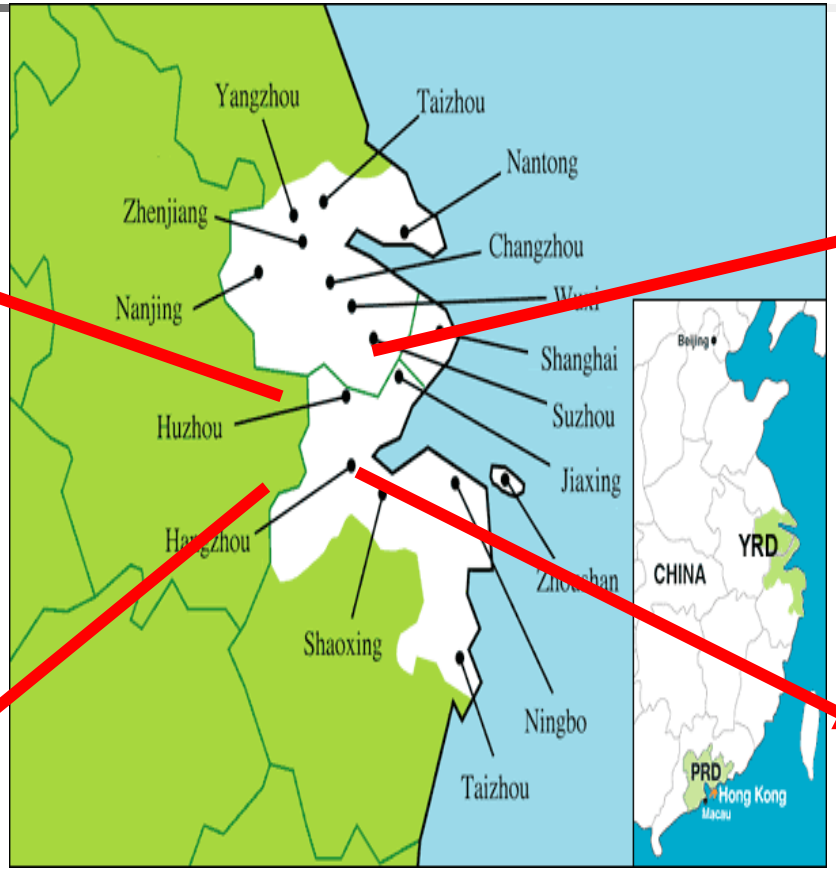
- **Air pollution in Yangtze River Delta**
- **Urban air quality and regional haze weather forecast model**
- **Air quality forecast in urban**
- **Haze weather forecast in YRD**
- **Summary**

Yangtze River Delta(YRD)

Regional haze

Photochemical smog



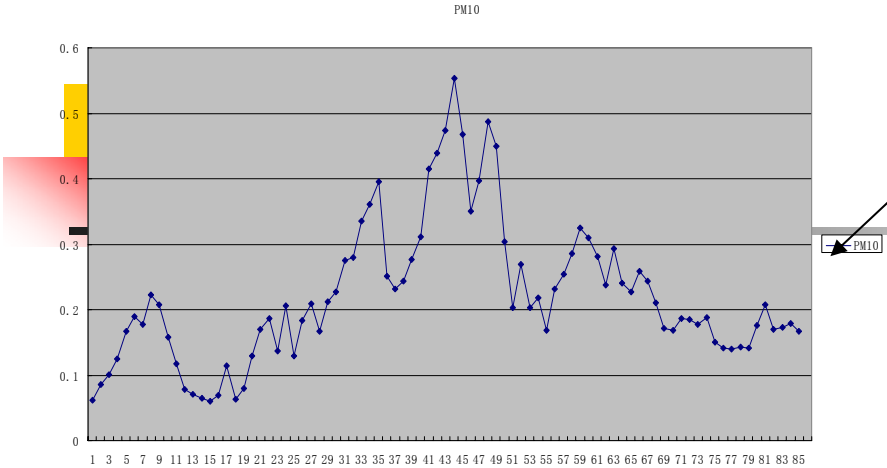


Acid rain

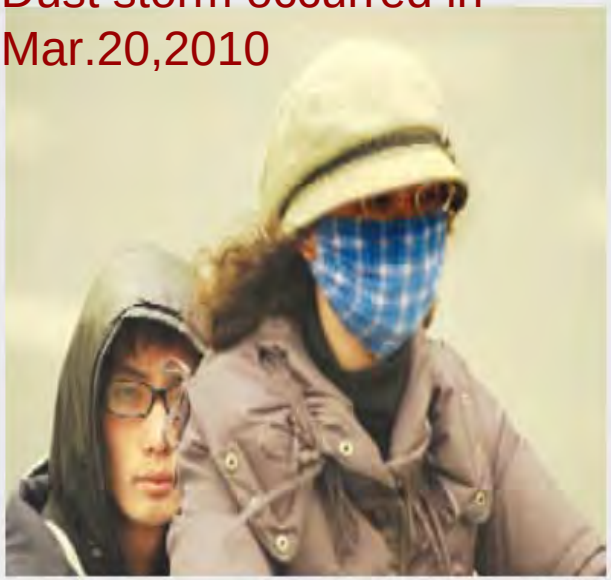
Dust storm

Located on the western coast of the Pacific Ocean and covers an area of about 99,600 km^2, with a population of 75 million.

Heavy haze case 2008.10.27-29



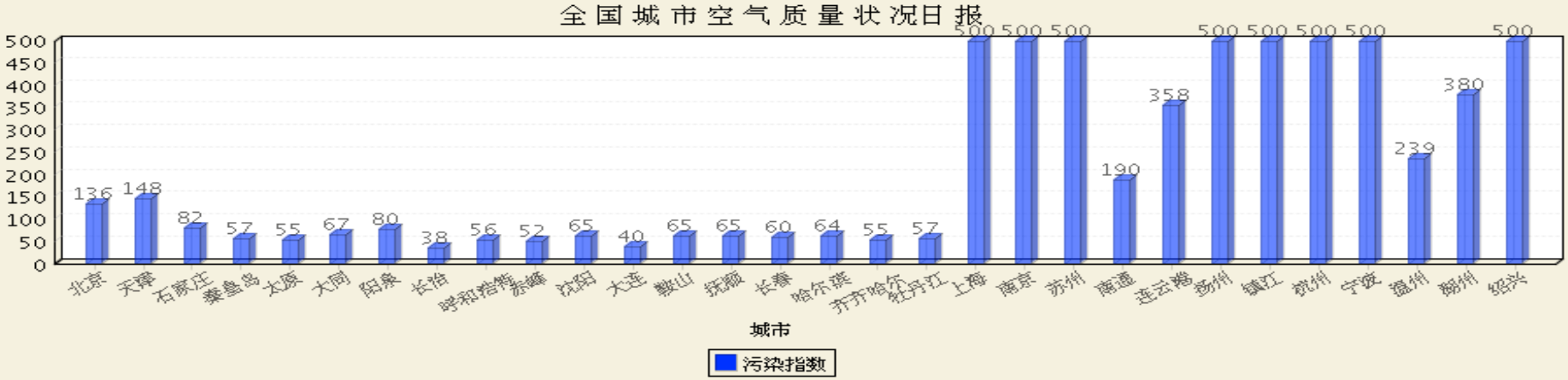
Dust storm occurred in Mar.20,2010



南京 昨天灰蒙蒙的大街上，南京市民多重“装备”出行。 范晓林 摄

天津 20日，在今年首场明显扬沙天气影响下，市民冒着大风和沙尘走在街头。新华社

北京 扬尘天气里，几名游客昨在天安门广场上拍照。 新华社



行照明安全。北京市环保局宣教办主任王小明说，20 日的空气质量肯定是五级重度污染，这是今年以来首次外来沙尘严重影响北京空气质量的事件。此次浮尘天气，是自 2006 年 4 月 17 日一日降 30 多万吨沙尘之后，北京地区出现的最强浮尘。

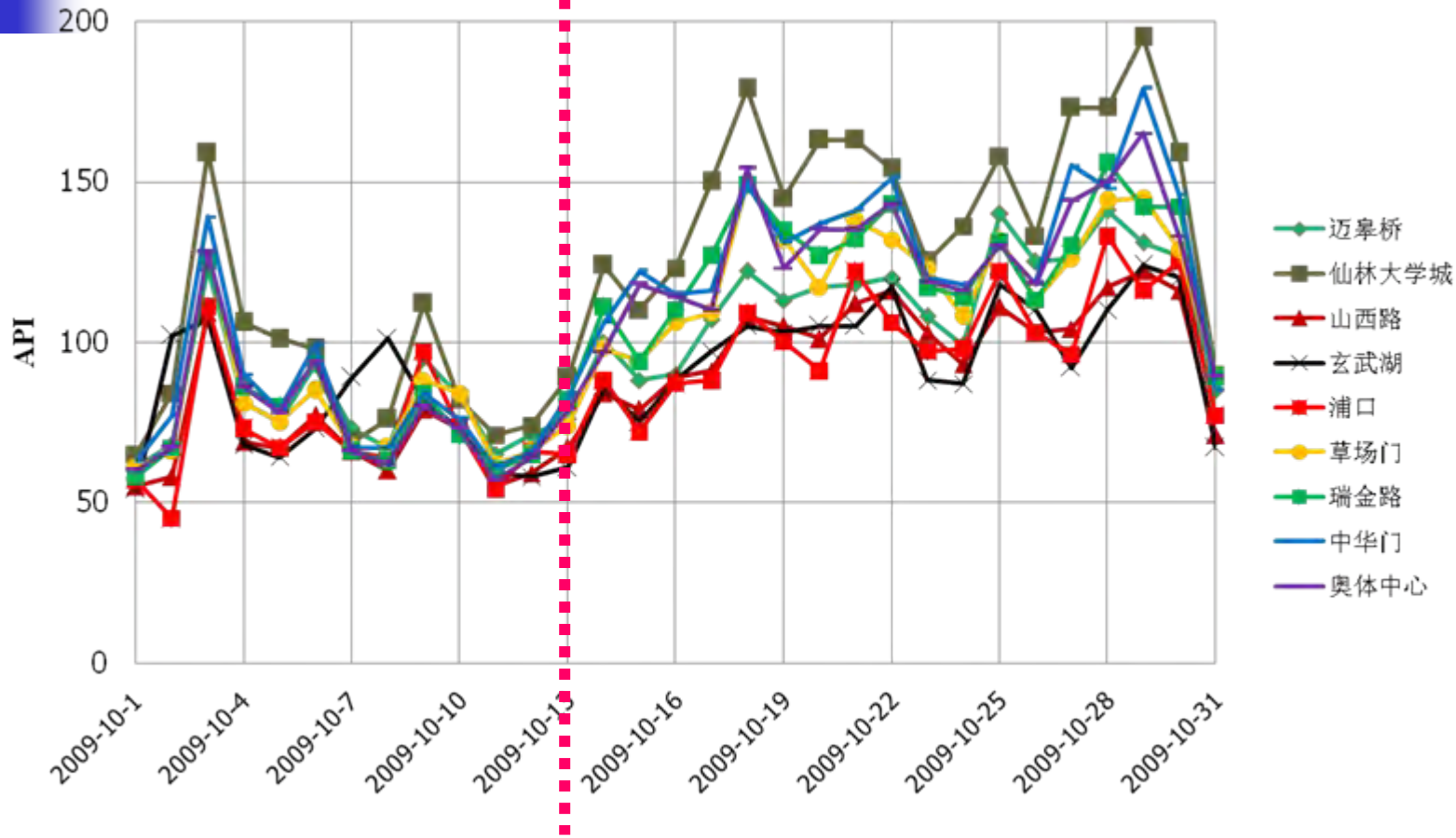
能见度只有 500 米

20 日清晨，沙尘伴随着冷空气东移南下，进入山东西北部地区。11 时许，沙尘天气已蔓延至山东全省。沙尘天气造成山东地区能见度大大降低。8 时许，山东省中西部的大部分地区能见度不足 5 公里，局部地区 500 米左右。除了能见度降

街上几乎没有行人

昨天，位于内蒙古西部的阿拉善盟大部地区出现大风扬沙天气，局部地区出现沙尘暴。阿拉善盟府巴彦浩特全城被笼罩在沙尘当中，能见度不足 500 米，街上几乎没有行人。 综合新华社 中新 中广 《法制晚报》

Continuous air pollution for more than 10 days



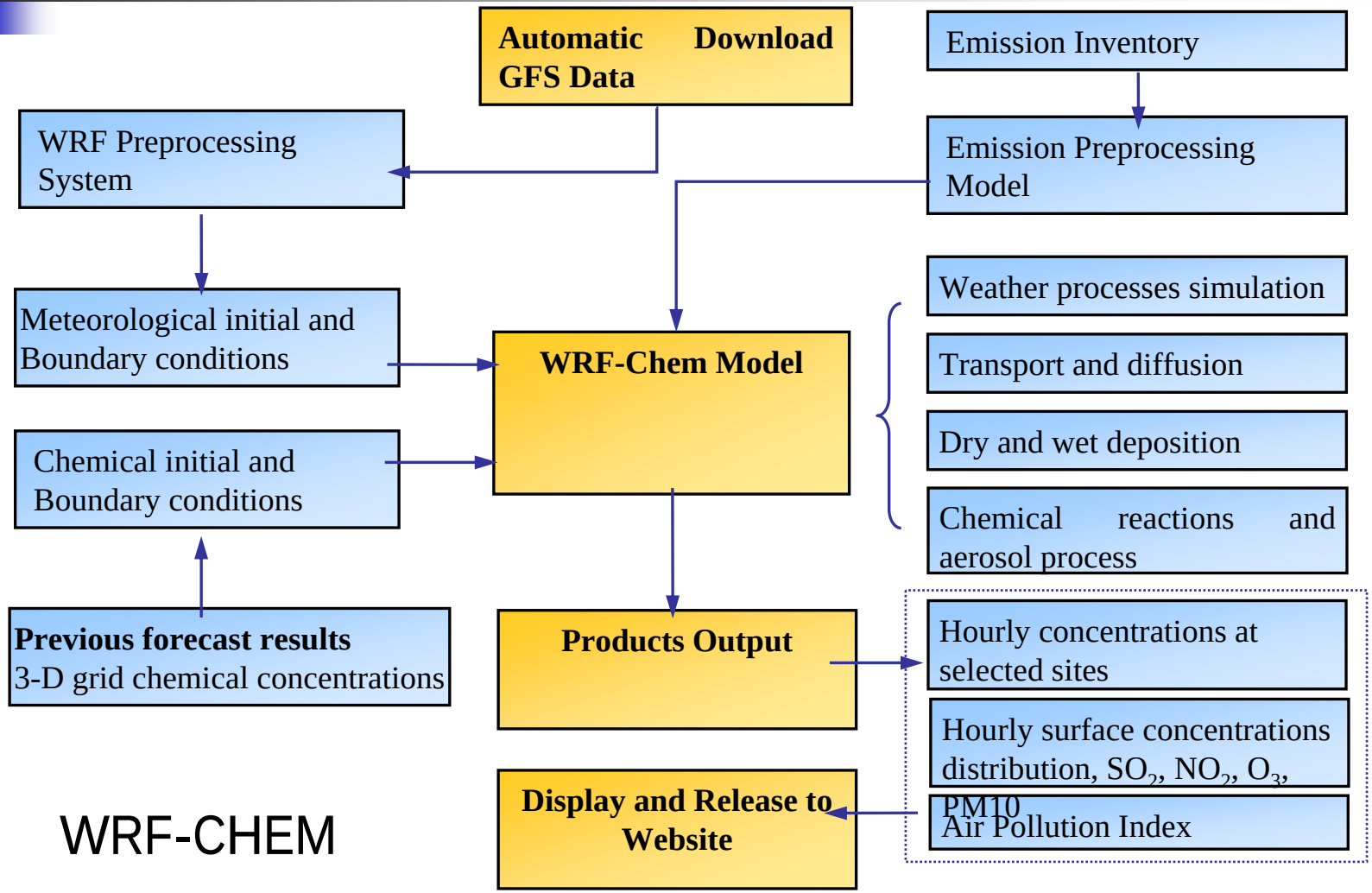
chemical weather forecasting (CWF) models in the word

- On line model: SKIRON/Dust, WRF-Chem, ENVIROHIRLAM, TAPM

- Off line model:ALADINCAMx, CAMx-AMWFG, EURAD-RIU, FARM, LOTOSEUROS, MATCH, MM5-CAMx, MM5-CHIMERE,MM5/WRF-CMAQ, MOCAGE,NAME, OPANA,RCG, SILAM, THOR

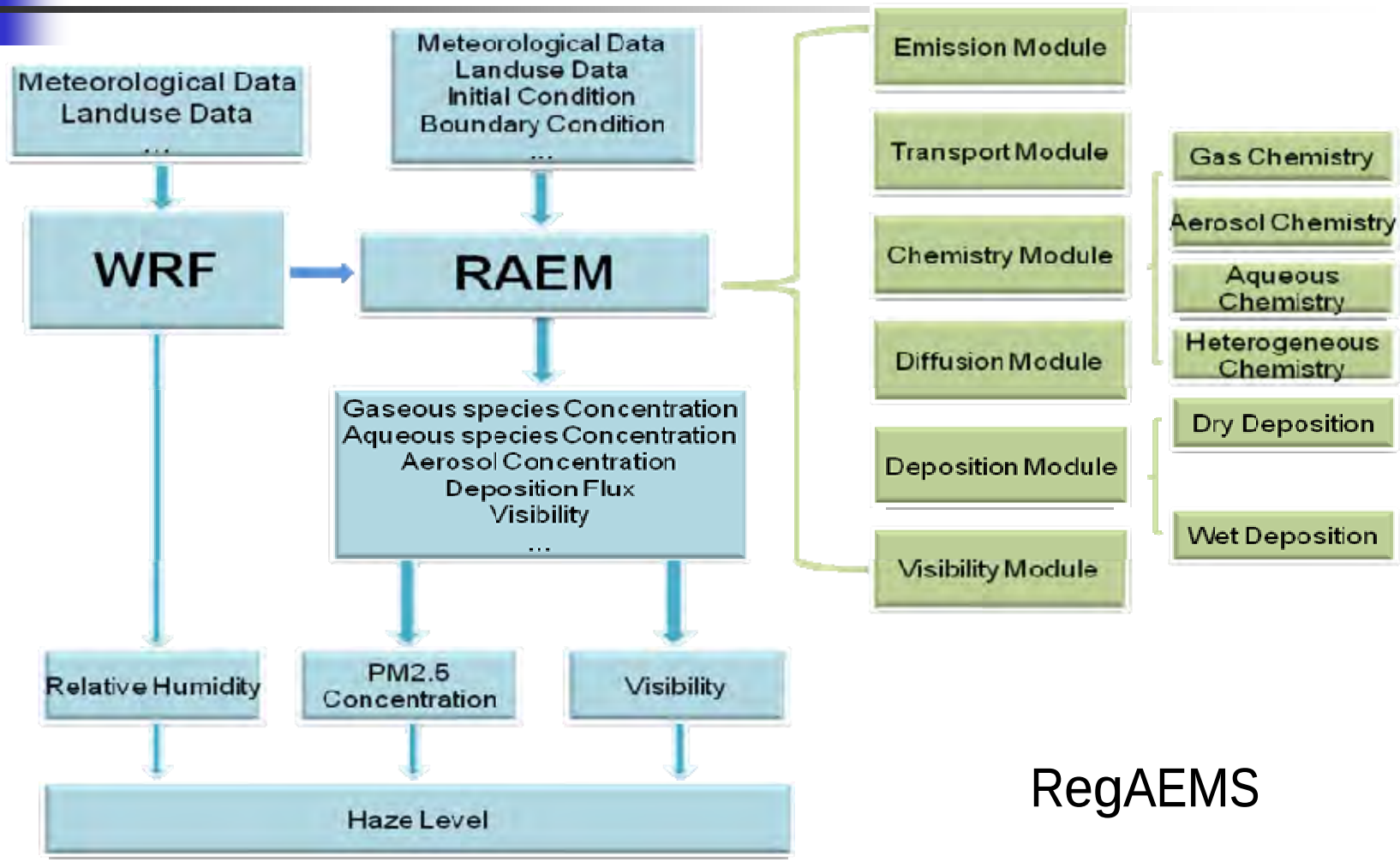
  RegAEMS, NAQPS, PATH,TAQM

Urban air quality forecast system



WRF-CHEM

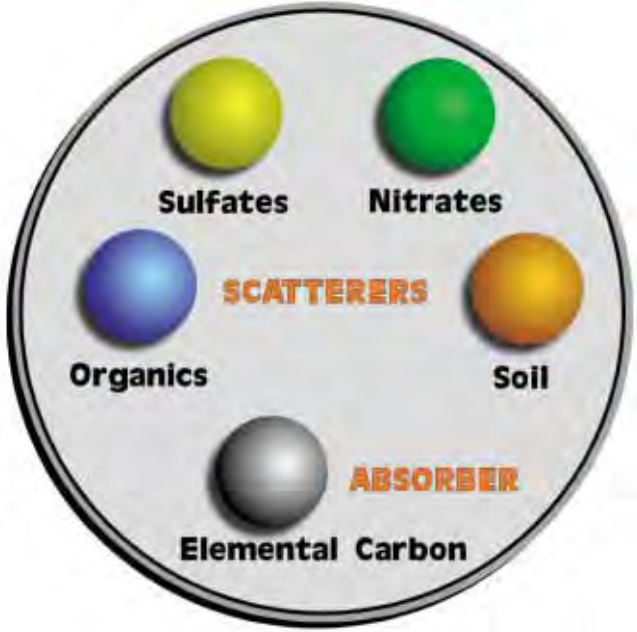
Regional haze weather forecast system



RegAEMS

Different aerosol schemes in RegAEMS

- **SO_4^{2-}, NO_3^-:ISORROPIA(Nenes,1998)**
- **EC,OC**
- **SOA: SORGAM(Schell,2001)**
- **Sea salt: Monahan（1986）**
- **Dust: Gillette(1988)**



Visibility scheme

$$v = K / b_{ext} \quad (\boldsymbol{K} \text{ is } 3.912)$$

$$b_{ext} = b_{scat} + b_{abs} + b_{ag} + b_{sp} + b_{ap}$$

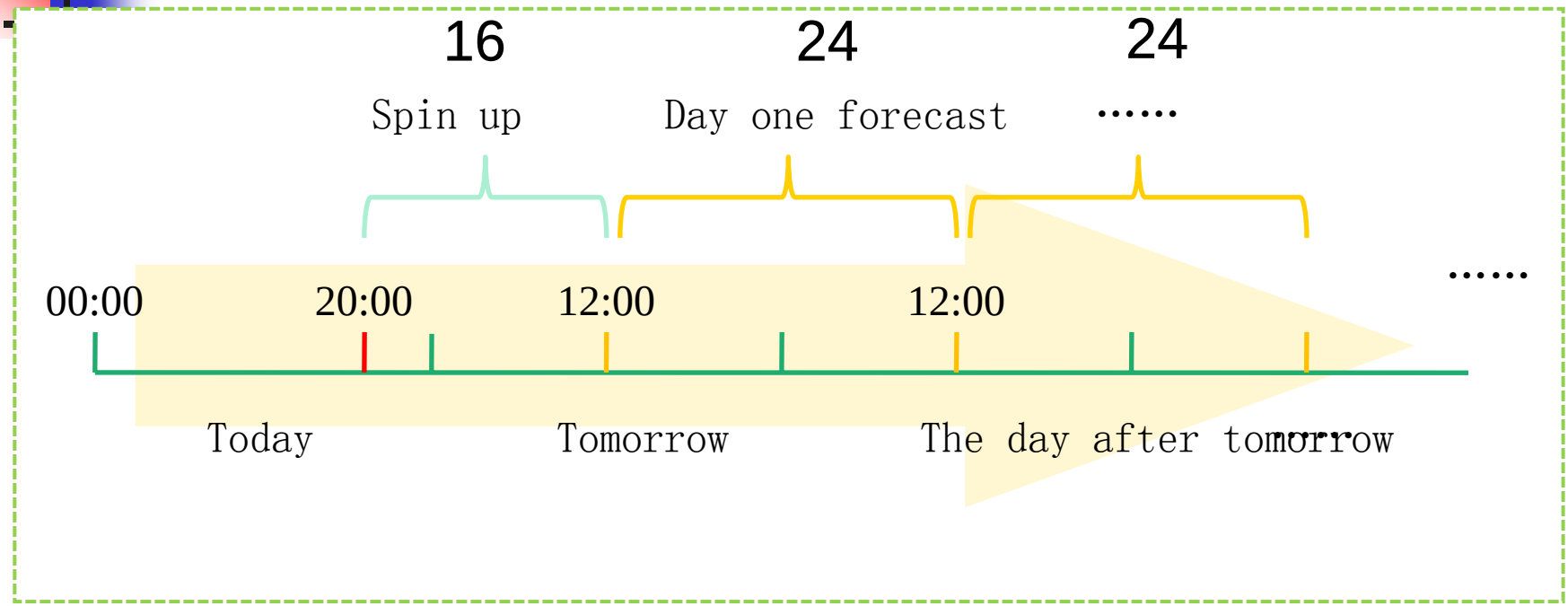
$$b_{ext} = 3 f(RH) \bullet \left((NH_4)_2 SO_4 + NH_4 NO_3 \right) +$$
$$4 Organics + 10 Soot + Soil +$$
$$0.6 Coarsemass + 0.175 NO_2 + 10$$

Haze level classfication

- PM2.5>75 μg/m^3
- RH<0.8
- Visibility<10km

- Super heavy haze: Visibility<2km
- Heavy haze: 2km≤Visibility<4km
- Medium haze: 4km≤Visibility<7km
- Light haze: 7km≤Visibility<10km

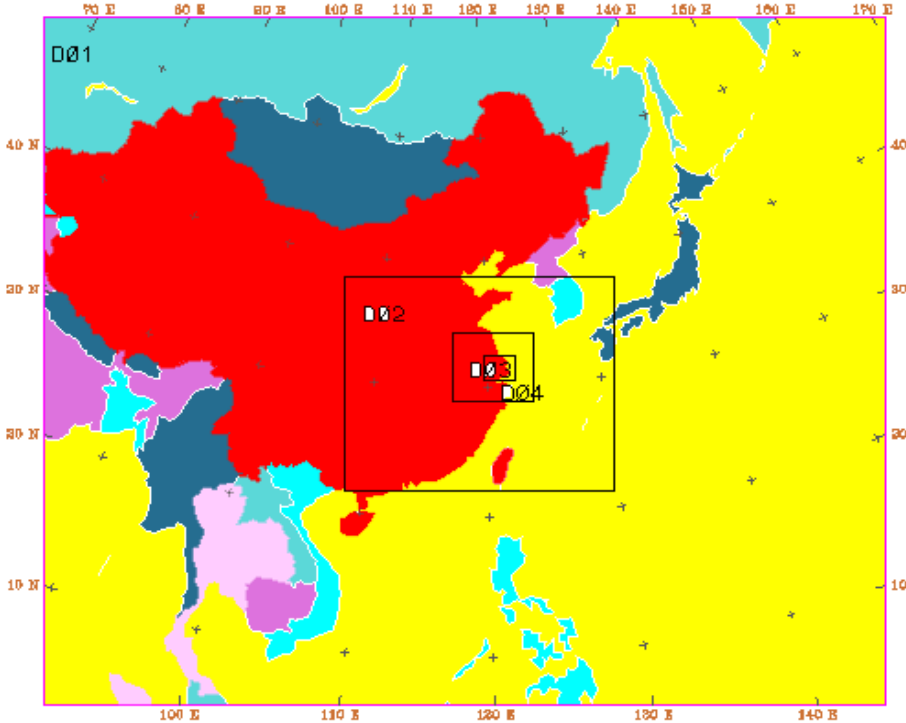
Air quality and haze weather forecast step



48 hours forecast with 16 hours spin up

Model settings for Shanghai forecast

- Horizontal grid: 4 nested domains
  - Domain 1: 88*75, 81km
  - Domain 2: 85*70, 27km
  - Domain 3: 76*67, 9 km
  - Domain 4: 88*73, 3 km

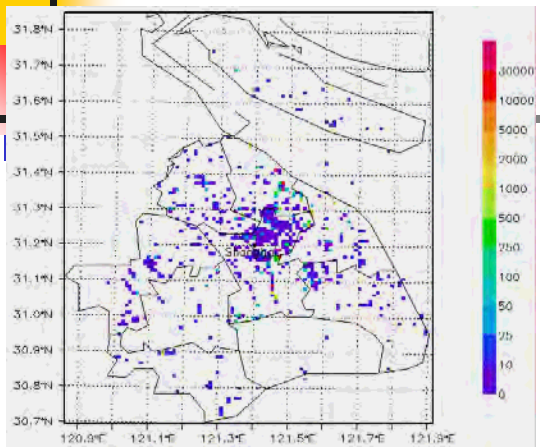


- Vertical level: 24 sigma level

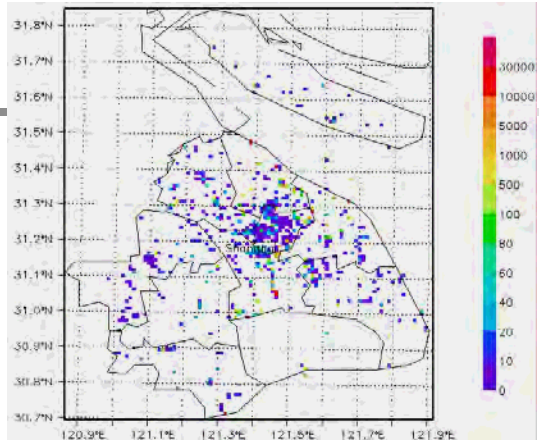
  Model top: 100hpa

- Gas phase mechanism: RACM
- Aerosol: MADE/SORGAM
- Anthro. Emi.: INTEX-B + Shanghai emission inventory
- Natrual Emi.: calculated online by Guenther scheme

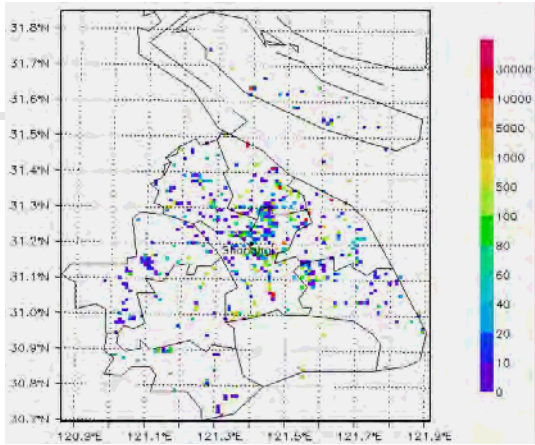
Point source in Shanghai



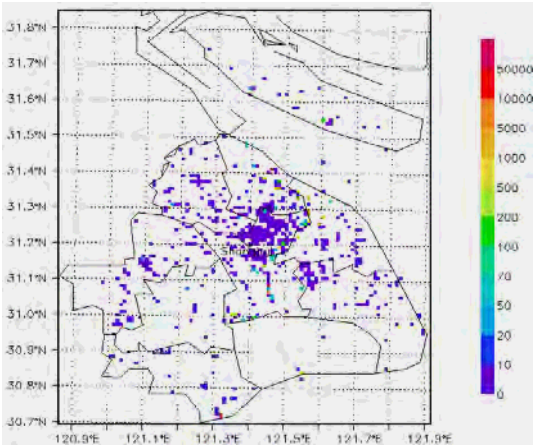
CO



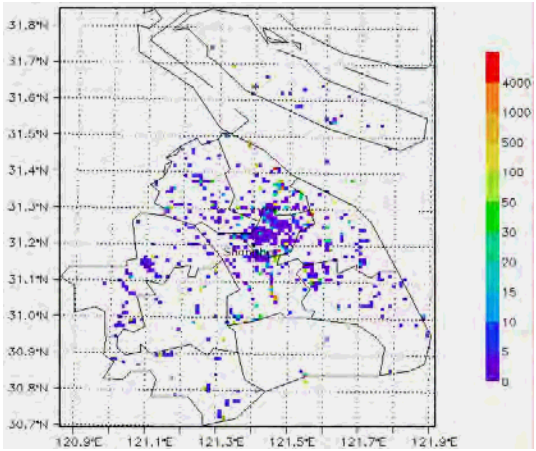
NOx



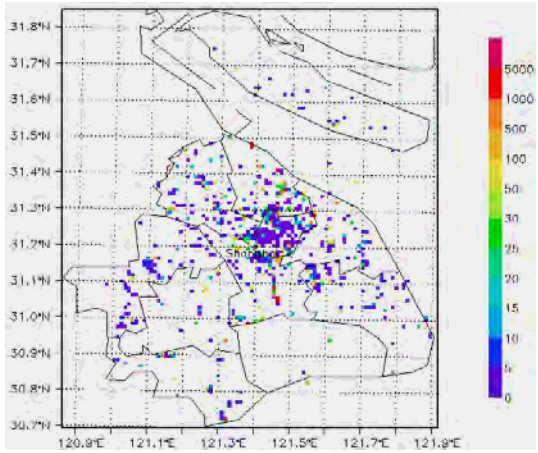
SO2



VOC

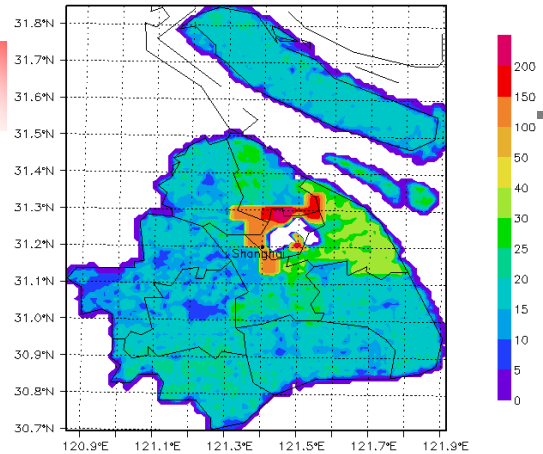


PM2.5



PM10

Area source in Shanghai



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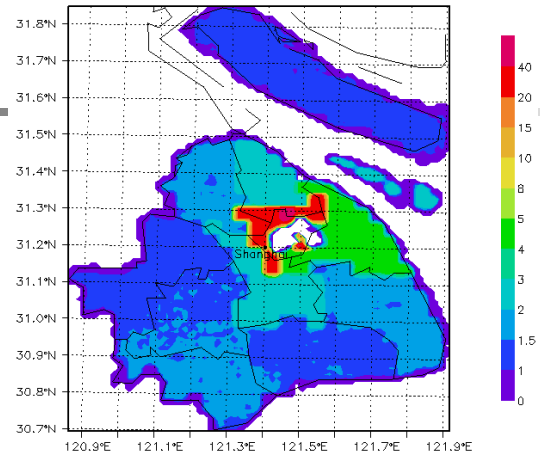
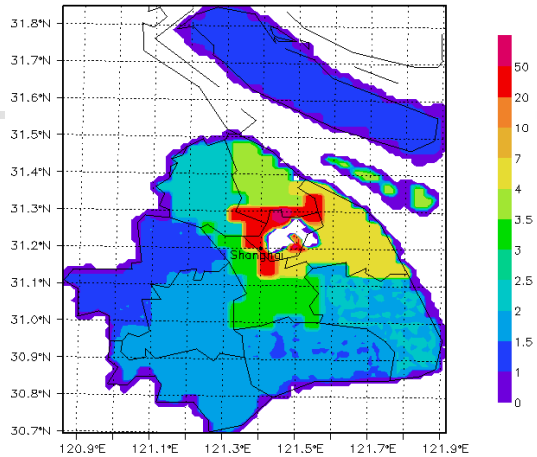
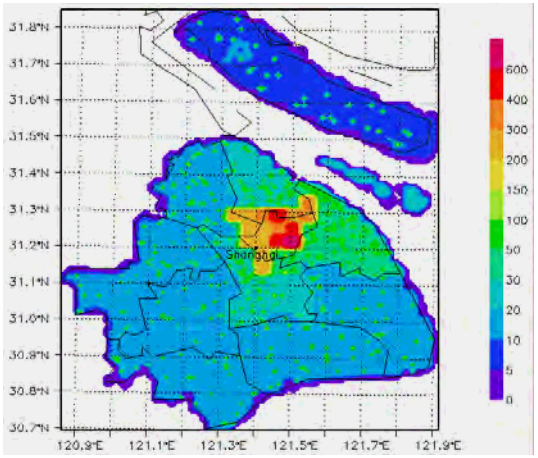


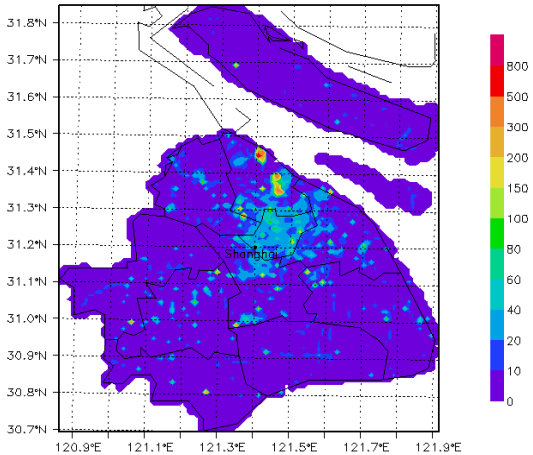
NOx



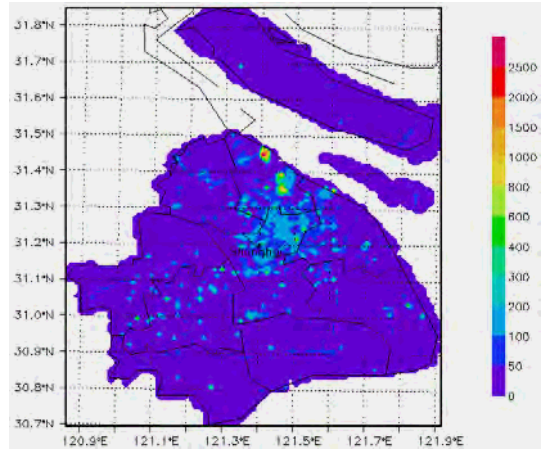
SO2



VOC

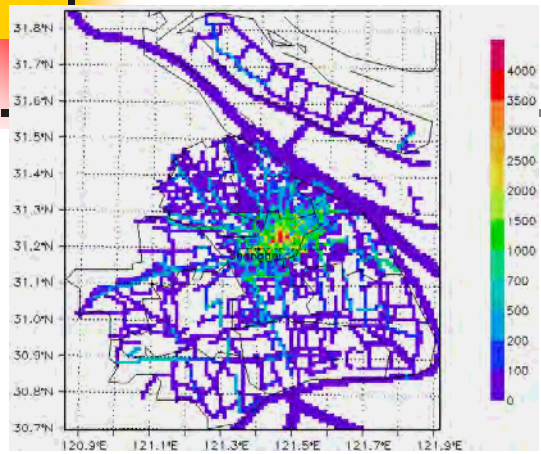


PM2.5



PM10

Line source in Shanghai



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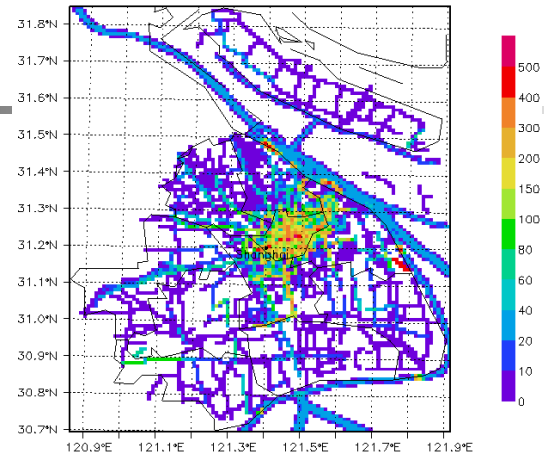
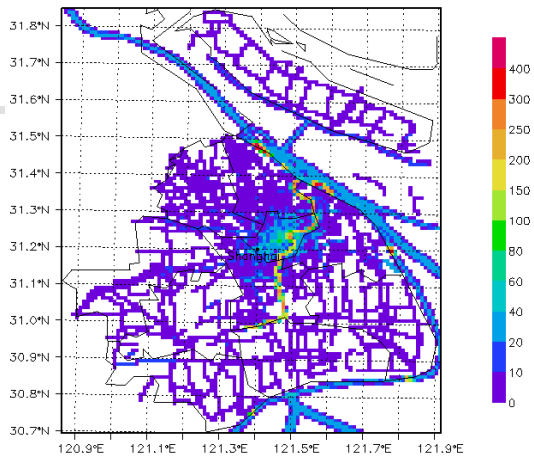
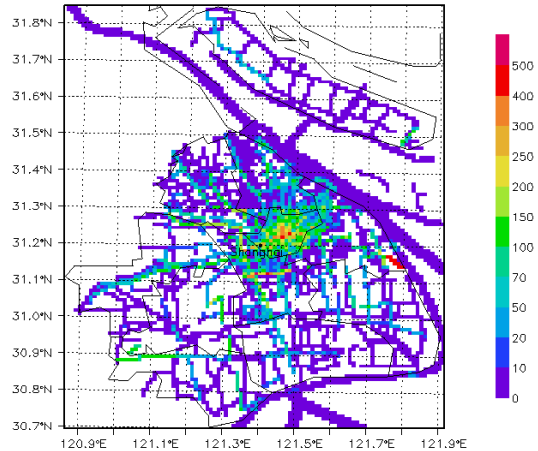


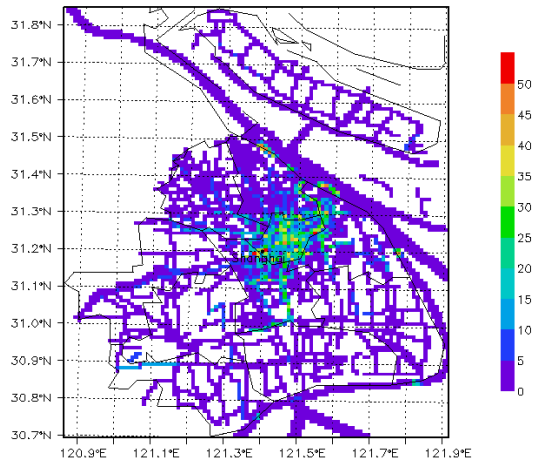
NOx



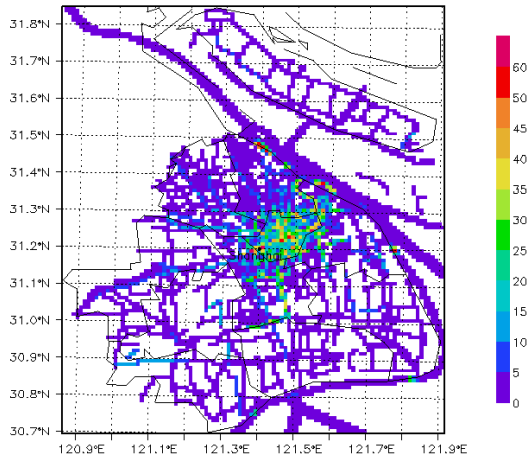
SO2



VOC

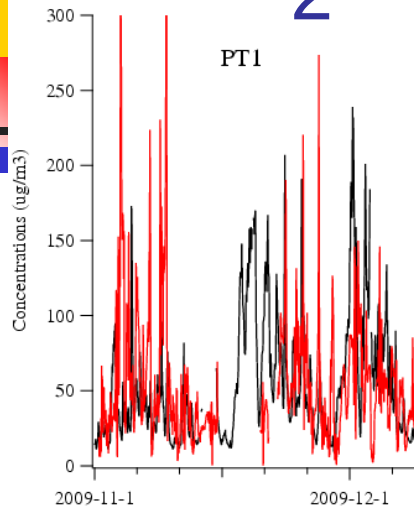


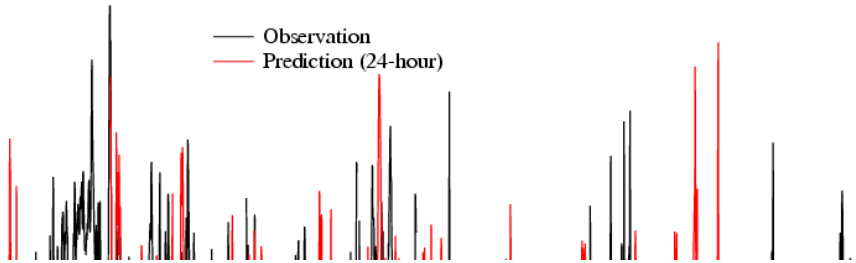
PM2.5

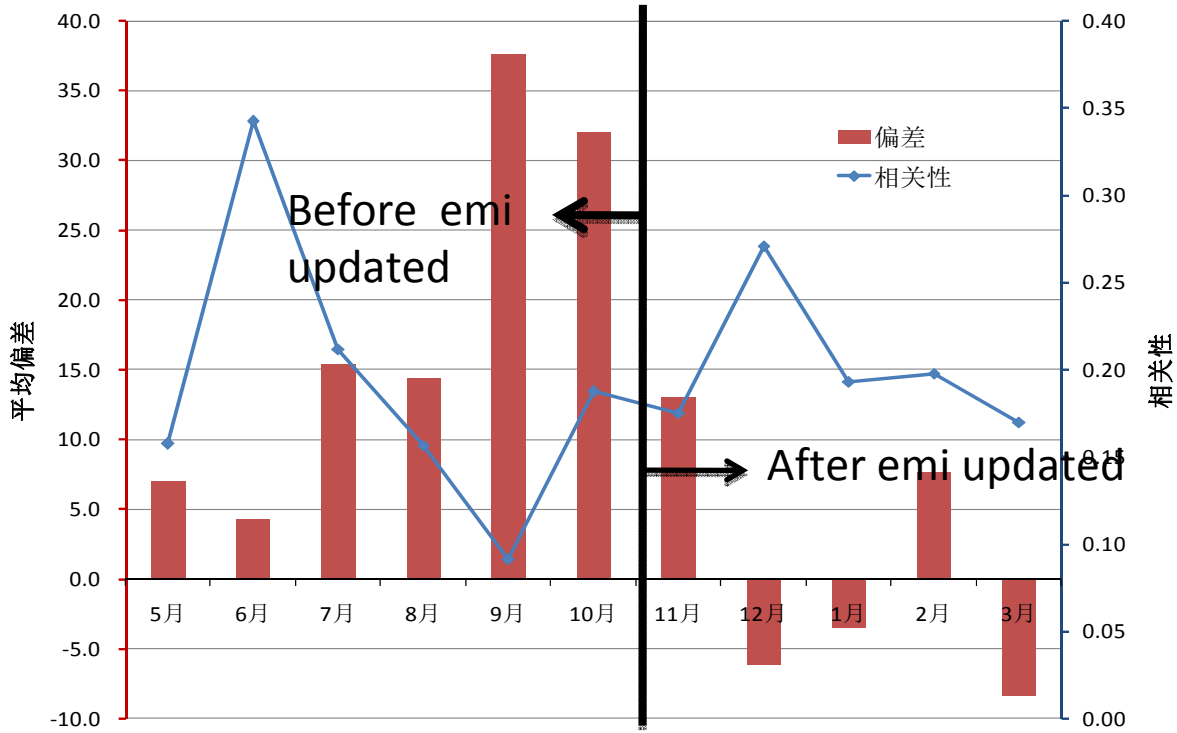


PM10

SO_2 hourly concentration

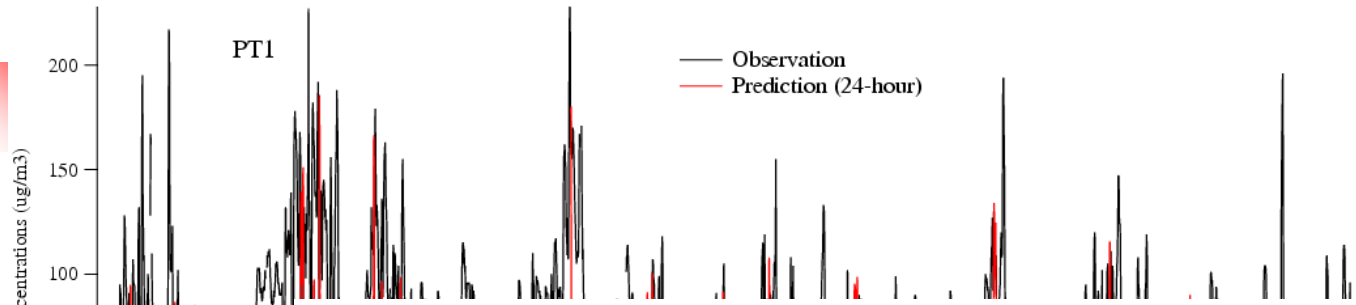


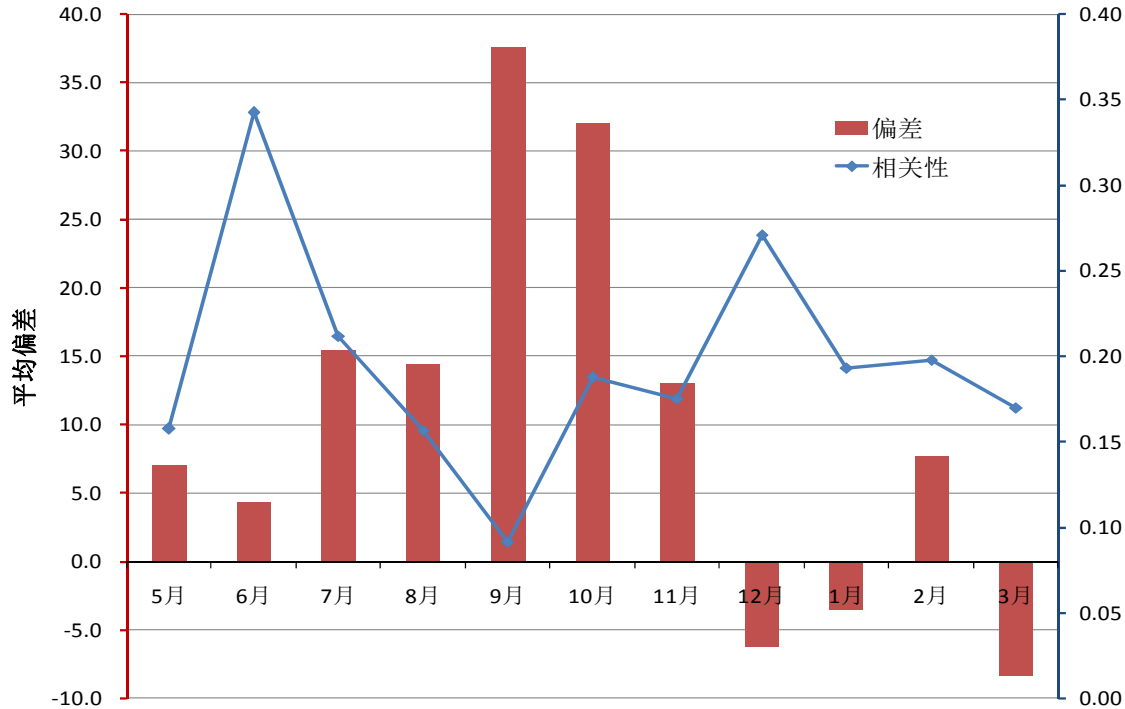




3月	**41.93**	**33.52**	**33.12**	**0.17**	**0.24**	**-8.37**	**-8.71**
平均	34.25	43.83	44.65	0.20	0.19	10.31	11.20

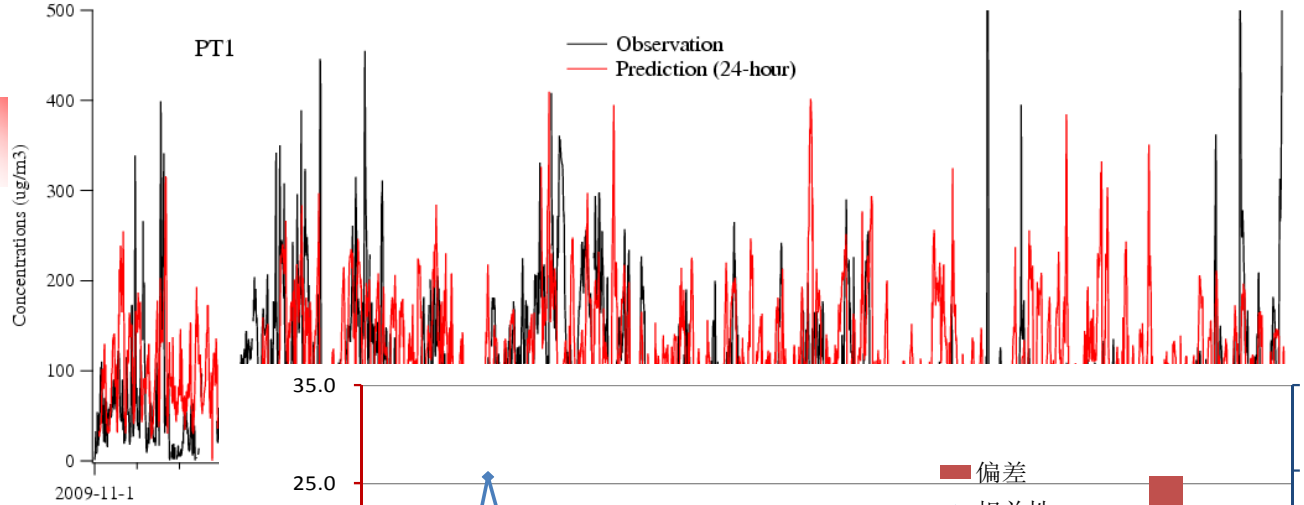
NO_2 hourly concentration

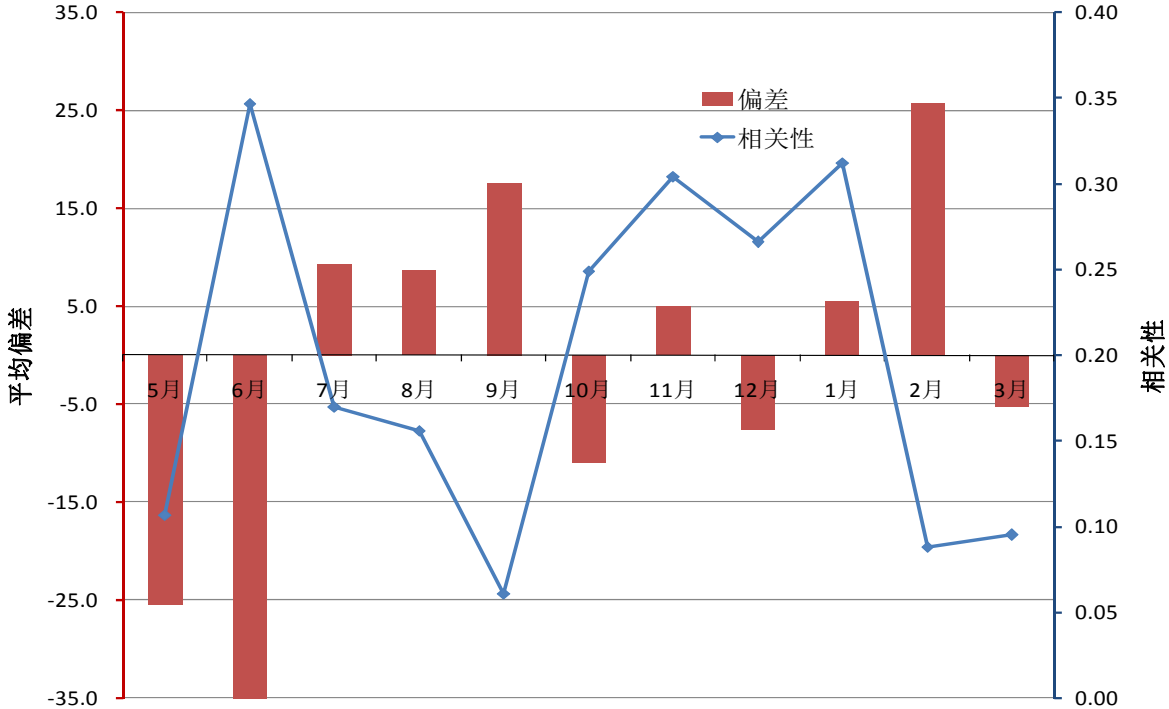




3月	51.78	44.49	46.14	0.29	0.30	-7.15	-5.39
平均	50.25	47.98	50.66	0.29	0.27	-1.91	1.10

PM10 hourly concentration



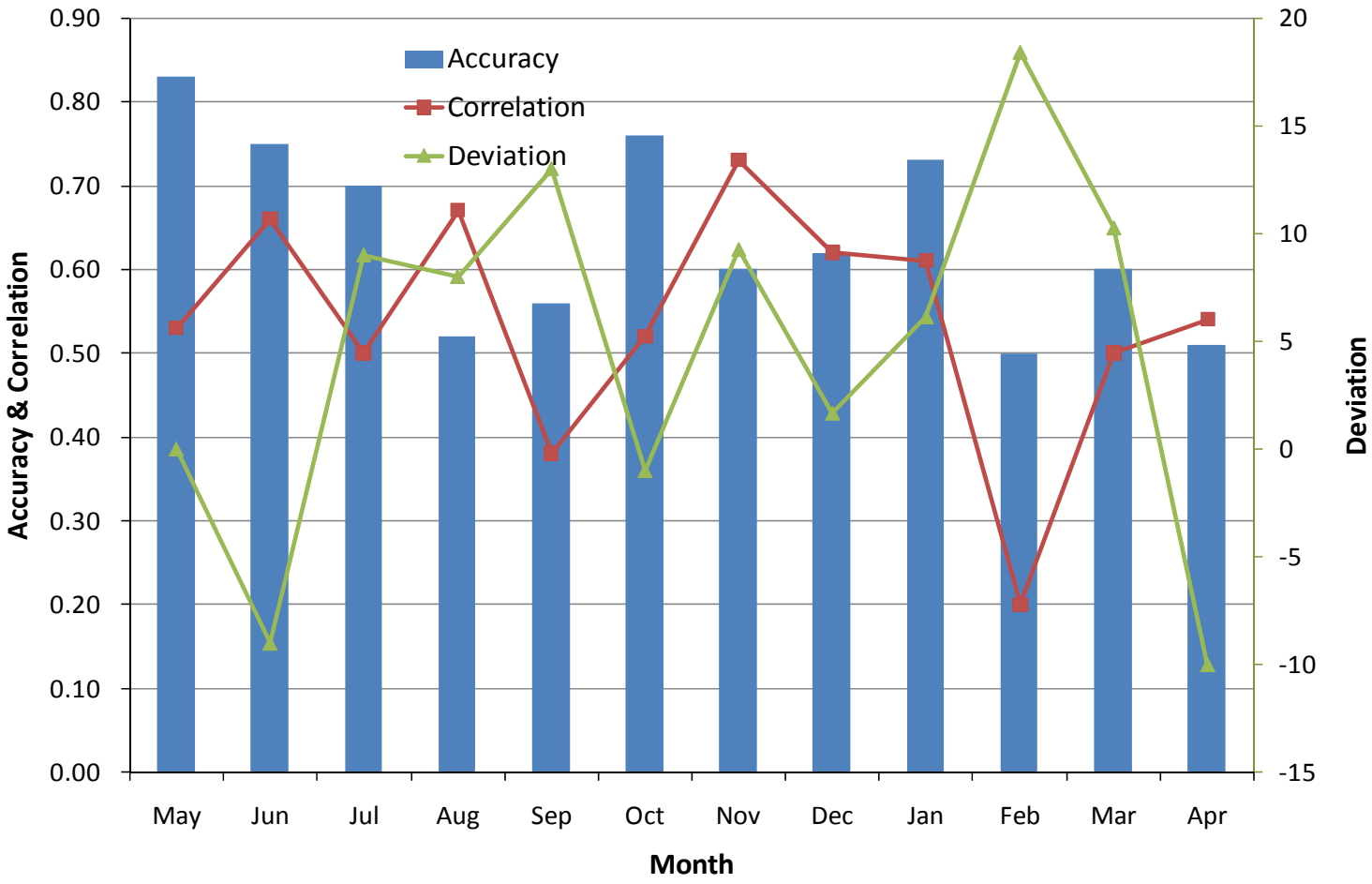


						平均偏差	
						hour	48-hour
						.44	-22.56
						.92	-34.47
						5	18.06
						6	26.96
						53	18.32
						.97	-8.83
						3	9.38
						56	10.53
						6	17.23
						71	35.07
						23	-0.73
平均	78.90	77.63	84.76	0.20	0.20	-1.22	6.27

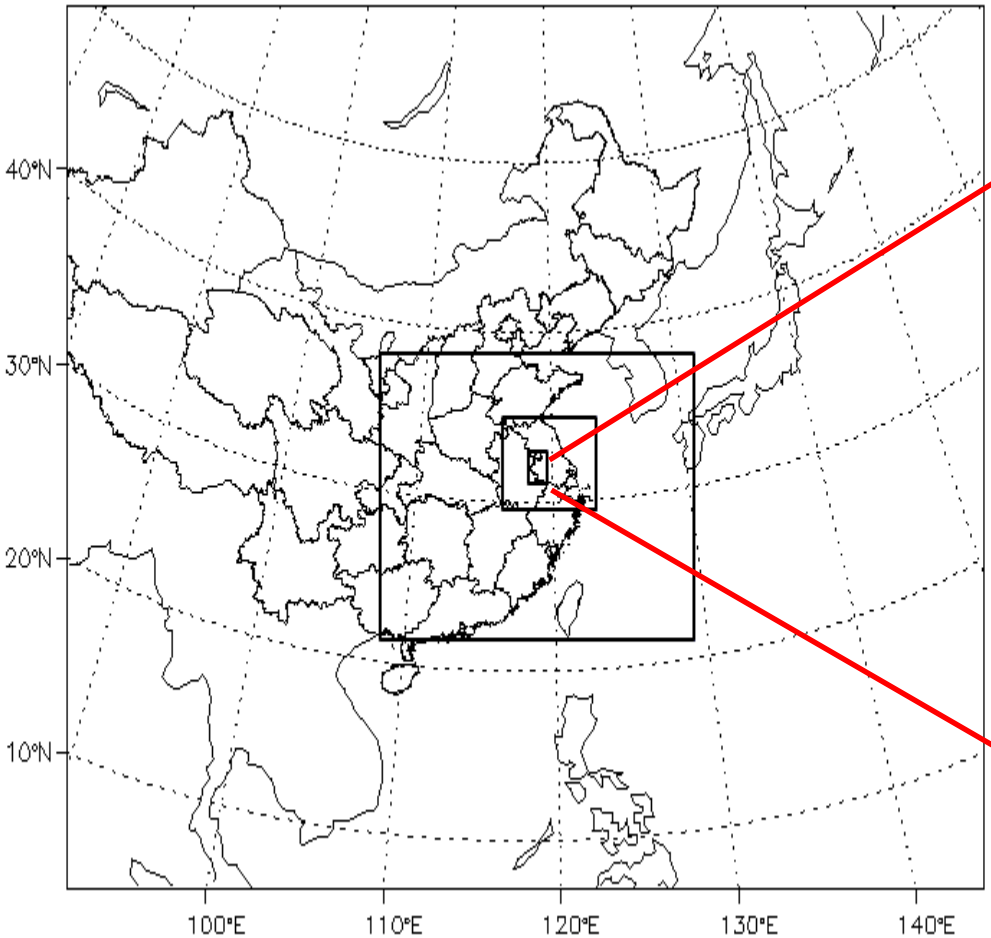
Table 1
Monthly mean observed and predicted concentrations for three air pollutants averaged at 10 monitoring stations in Shanghai.

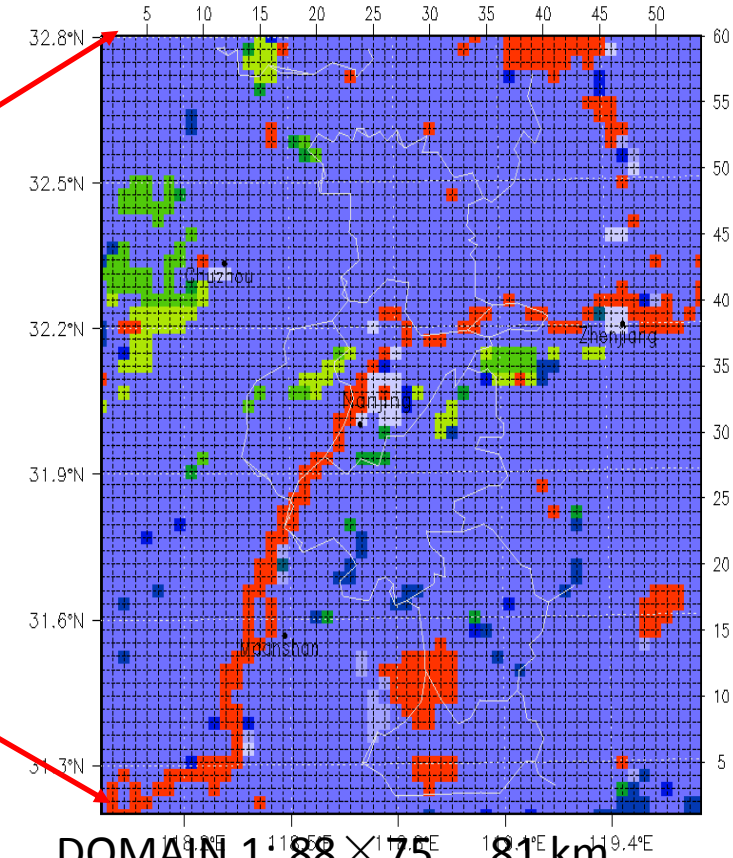
Month	SO_2 ($\mu g\ m^{-3}$)		NO_2 ($\mu g\ m^{-3}$)		PM_{10} ($\mu g\ m^{-3}$)	
	Obs.	Pre.	Obs.	Pre.	Obs.	Pre.
May, 2009	34.2	41.2	54.4	49.1	81.9	60.7
Jun, 2009	31.2	34.9	48.5	44.9	90.4	52.4
Jul, 2009	24.7	40.3	40.5	51.1	56.9	66.7
Aug, 2009	21.0	35.3	32.3	45.3	56.4	63.9
Sep, 2009	18.2	55.7	39.2	47.7	51.4	68.9
Oct, 2009	28.1	60.3	56.9	50.6	93.0	81.7
Nov, 2009	39.8	48.5	61.0	49.5	84.0	91.1
Dec, 2009	60.4	51.3	67.2	52.5	119.6	108.6
Jan, 2010	49.0	45.3	57.9	47.6	90.7	95.9
Feb, 2010	28.2	36.0	43.2	45.0	56.5	82.4
Mar, 2010	41.9	33.5	51.8	44.5	87.2	81.8
Apr, 2010	23.1	36.4	46.1	46.2	72.3	80.2
Mean	33.3	43.2	50.0	47.8	78.4	77.8

Statistics on API prediction



Air quality forecast for 2nd Youngth Olympic game in Nanjing in 2014



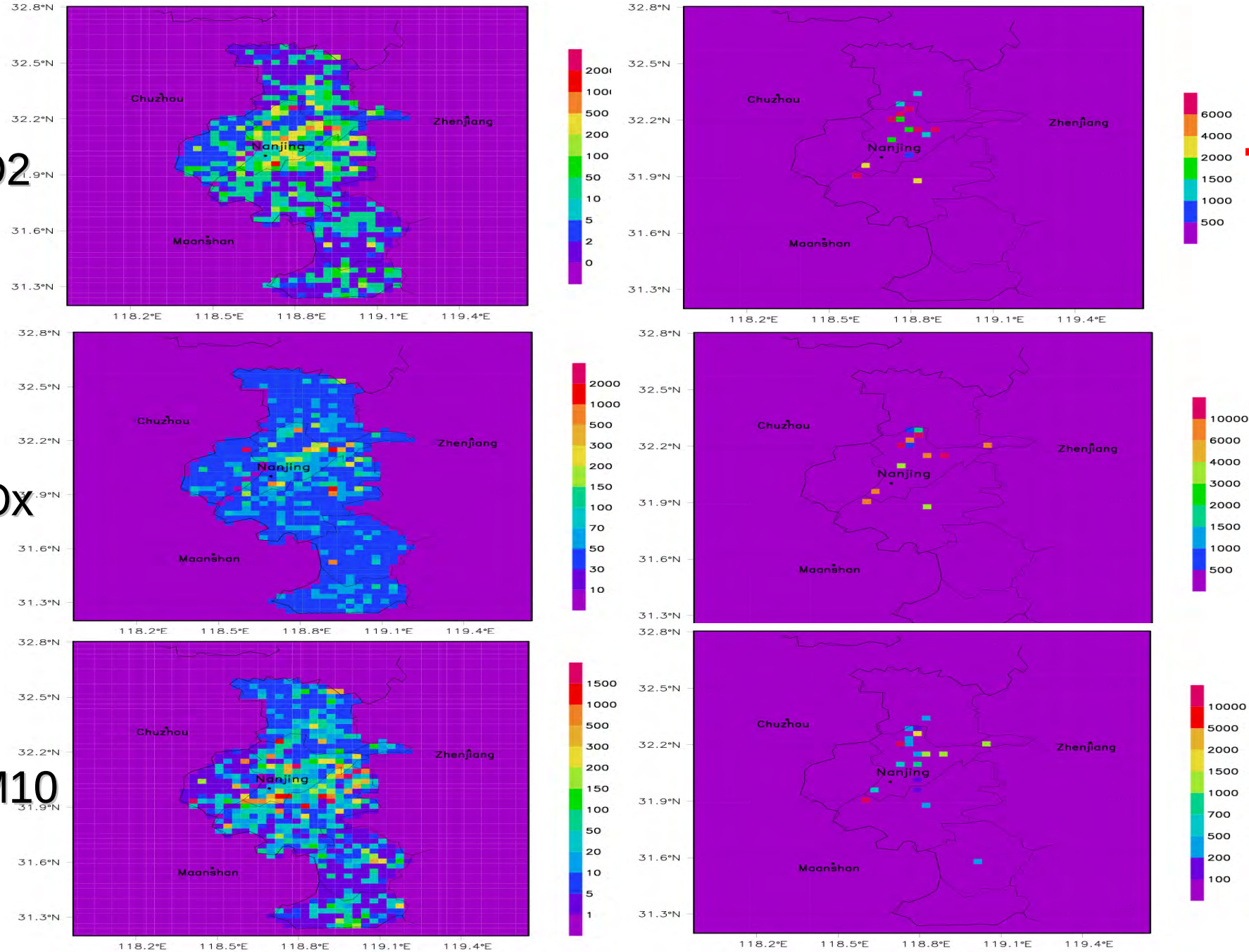


DOMAIN 1: 88×75, 81 km
DOMAIN 2: 85×70, 27 km
DOMAIN 3: 70×64, 9 km
DOMAIN 4: 55×61, 3 km

SO2

NOx

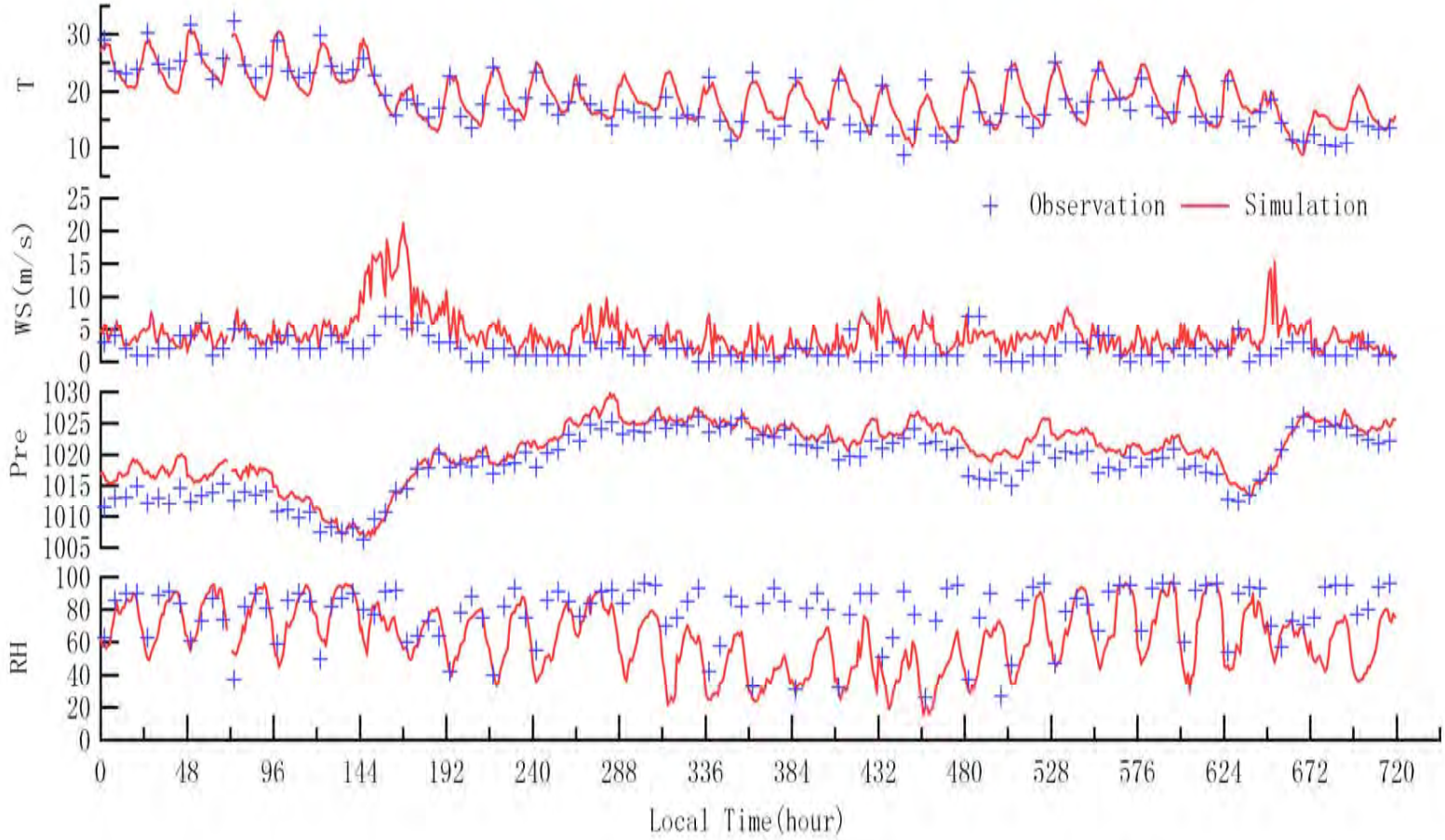
PM10



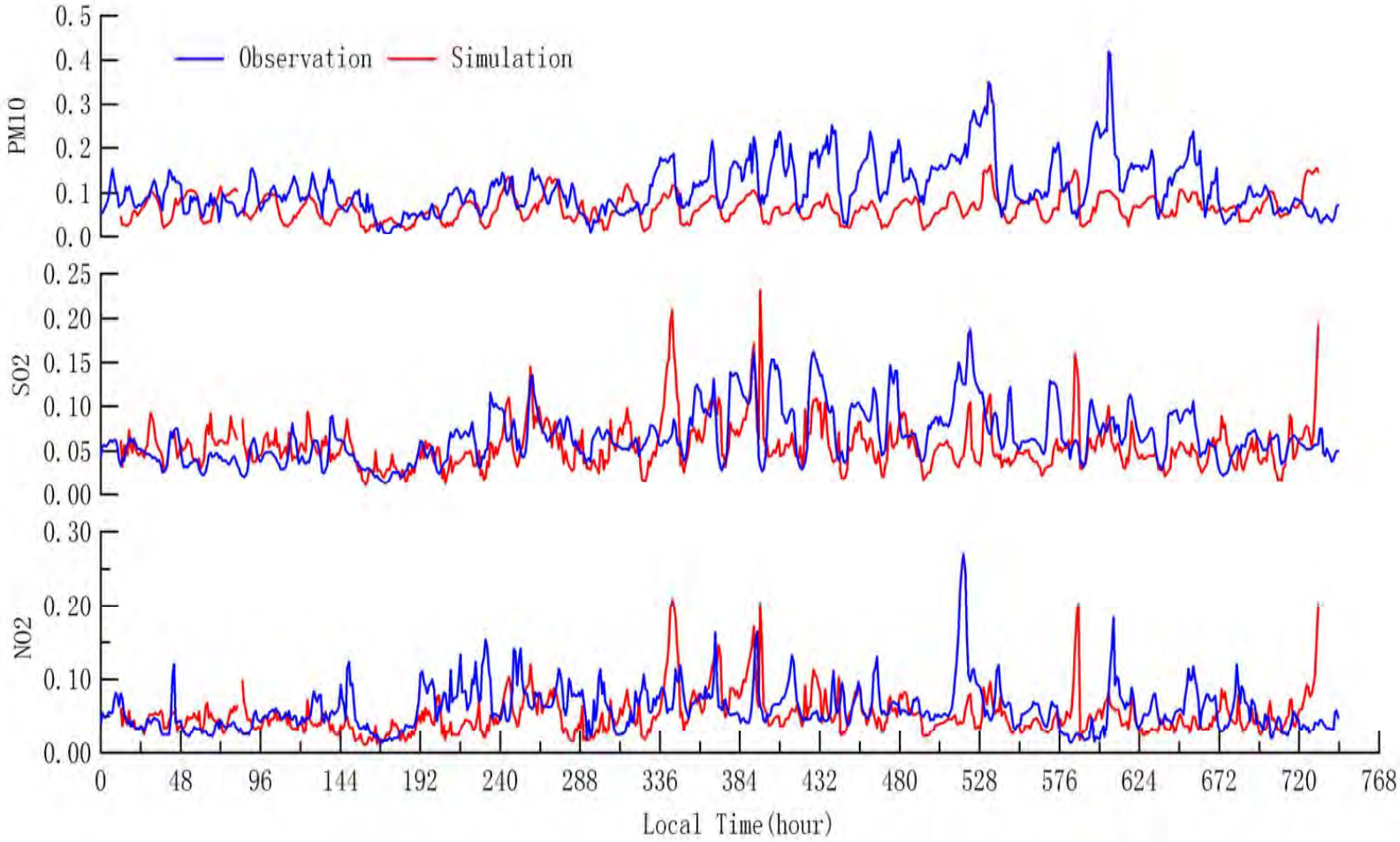
Area source

Point source

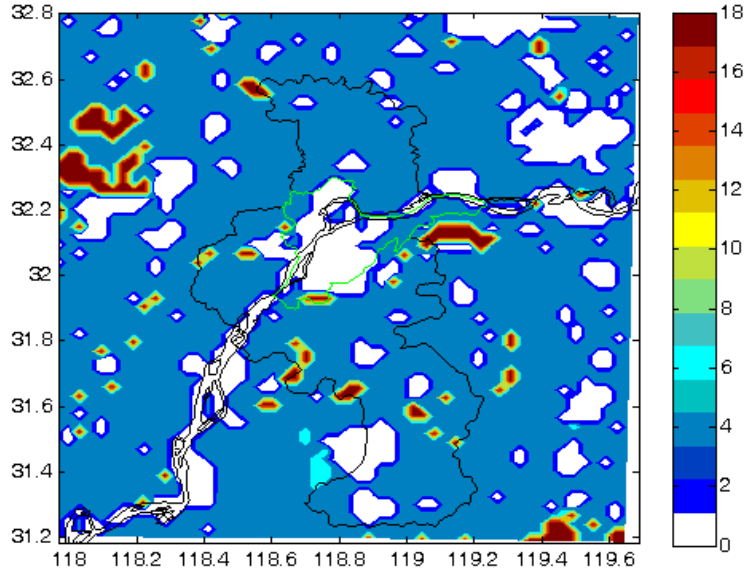
Meteorological variables in Nanjing during Oct., 2007



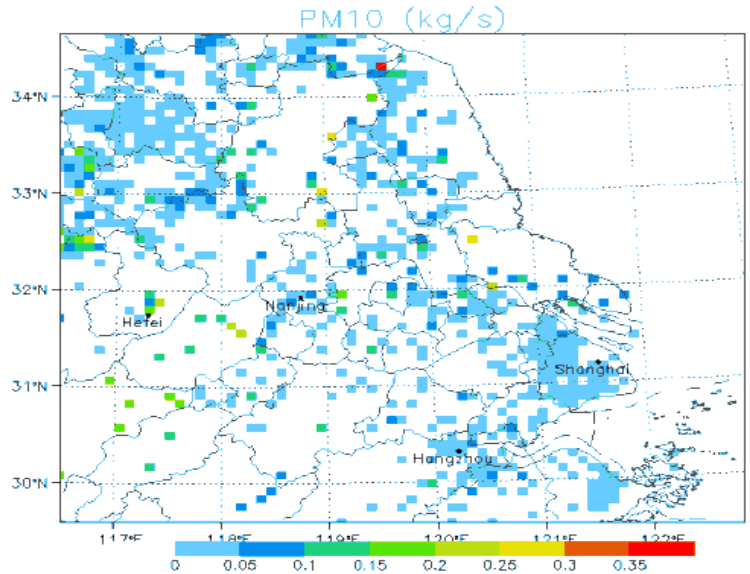
Observed and predicted concentrations of PM10, SO2 and NO2 in Nanjing during Oct., 2007



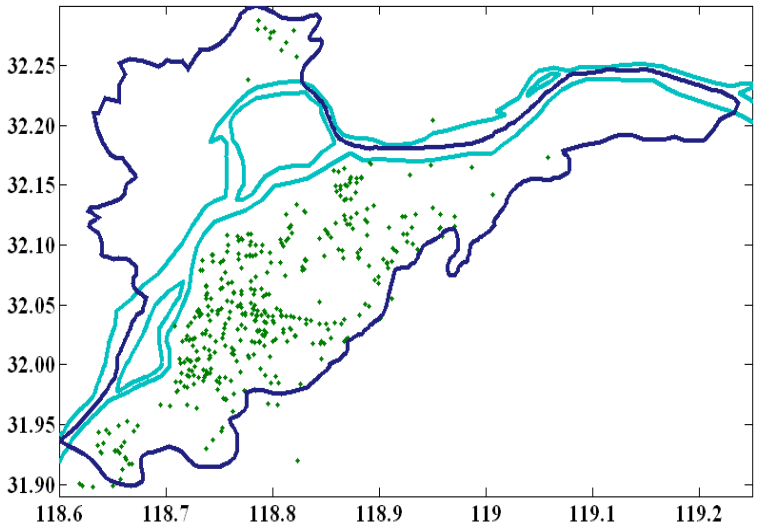
Soil dust



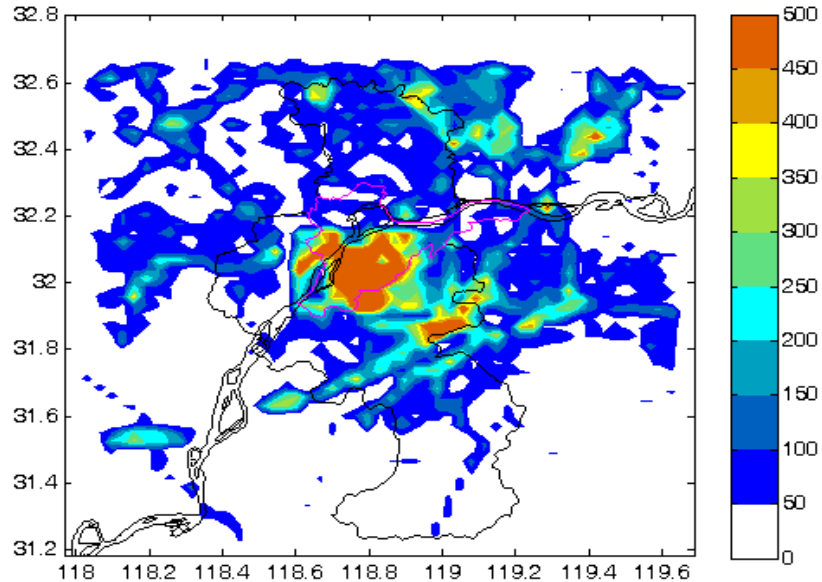
Biomass burning dust



Construction dust



Paved road dust



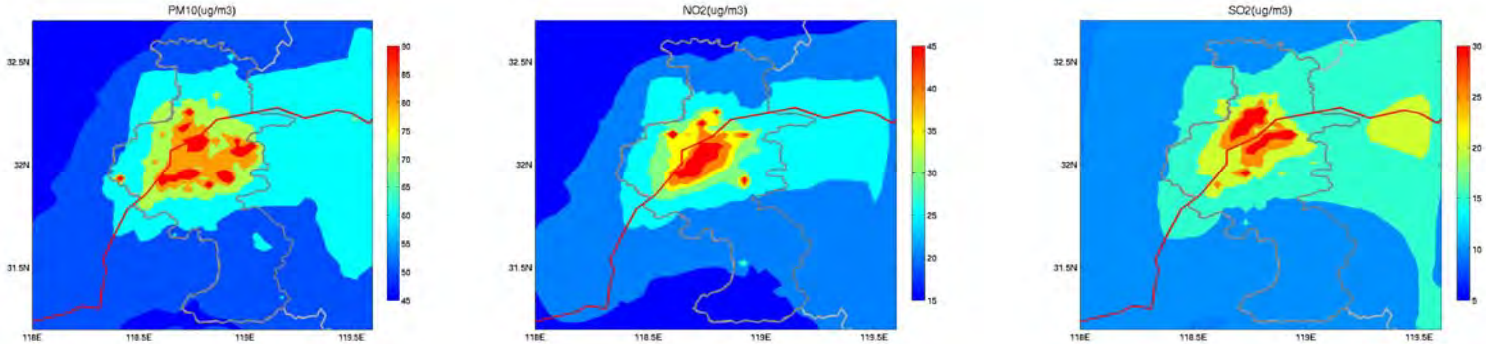
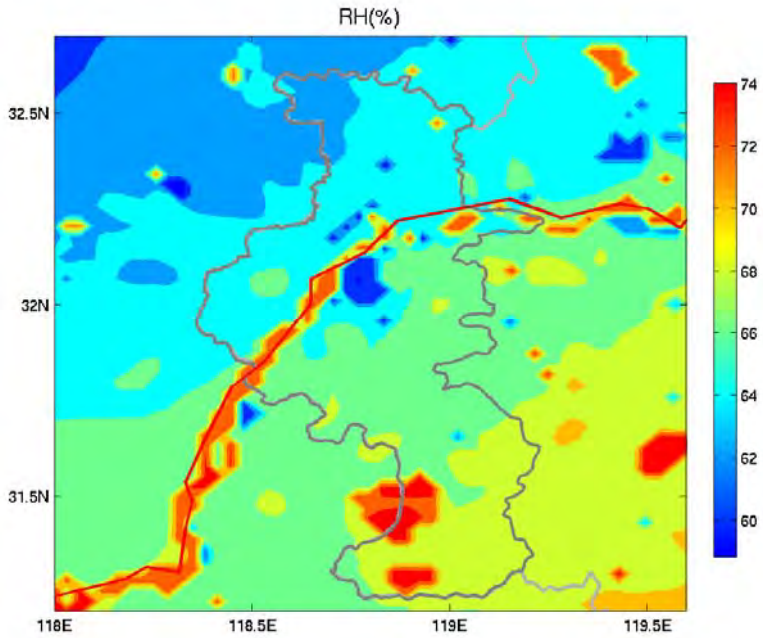


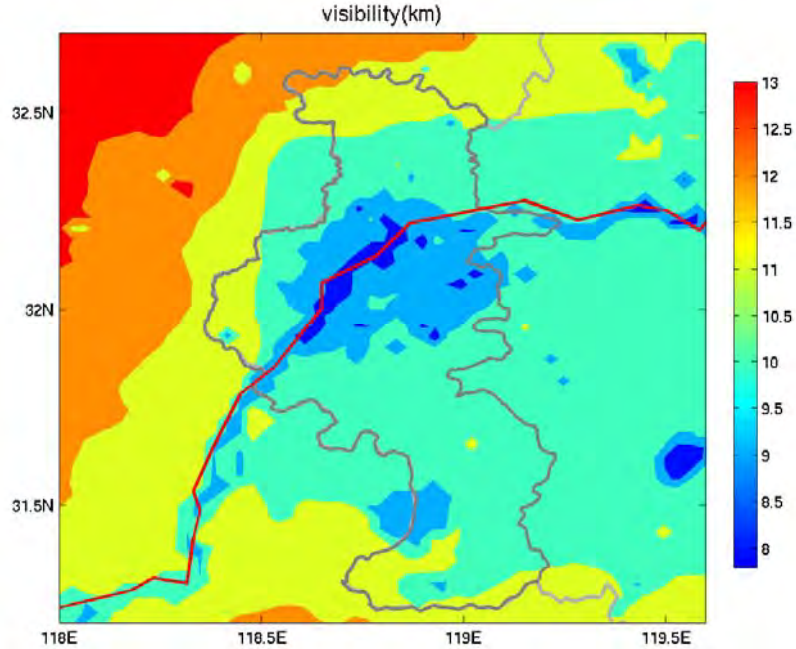
Table 2

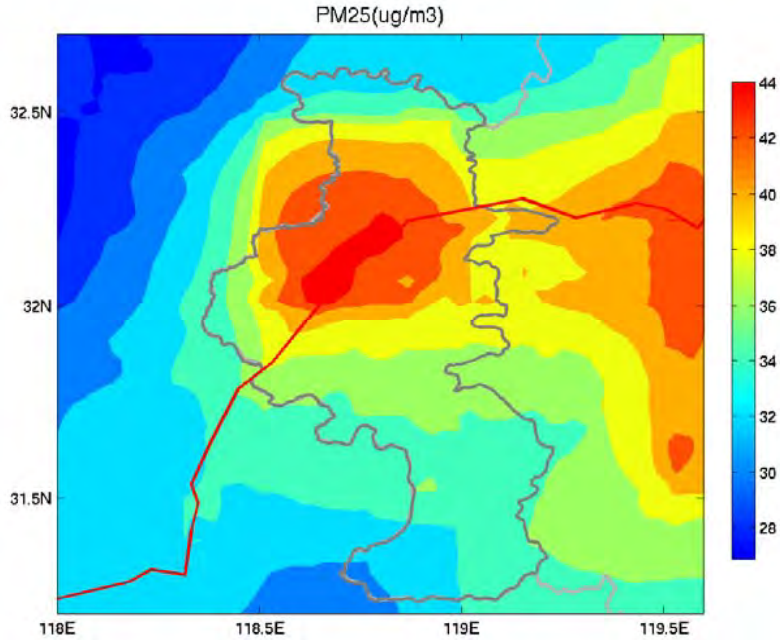
Summary of partial API for three air pollutants and API averaged at 6 monitoring stations in Nanjing during Oct., 2007[a].

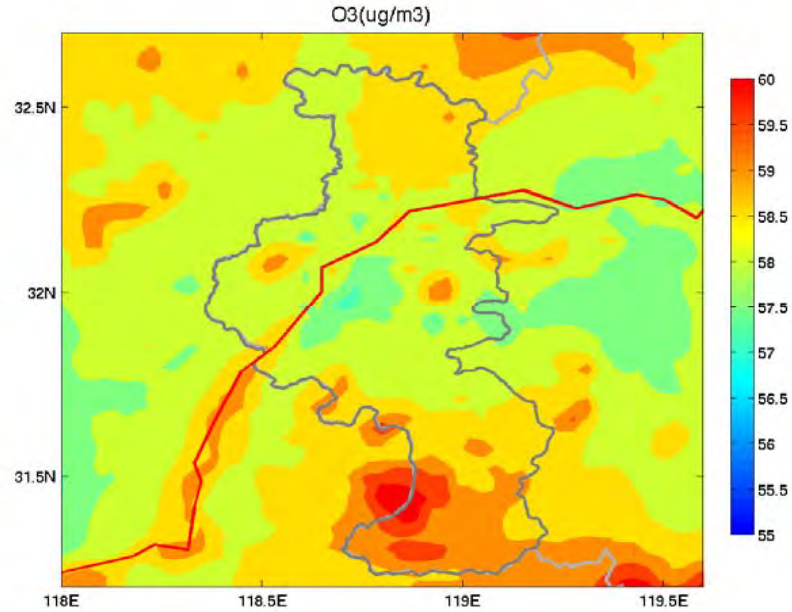
	PM_{10}	SO_2	NO_2	API
OMV	80.80	52.73	44.10	81.10
SMV	57.43	47.73	35.87	58.57
D	23.37	4.90	8.23	22.53
R	0.34	0.13	0.38	0.40
SD	30.86	16.55	18.91	29.71
ARAQG	80%	60%	77%	80%

[a] OMV: Observed Mean Value, SMV: Simulated Mean Value, D: Deviation, R: Correlation Coefficient, SD: Standard Deviation, ARAQG: Accurate Rate of Air Quality Grade.

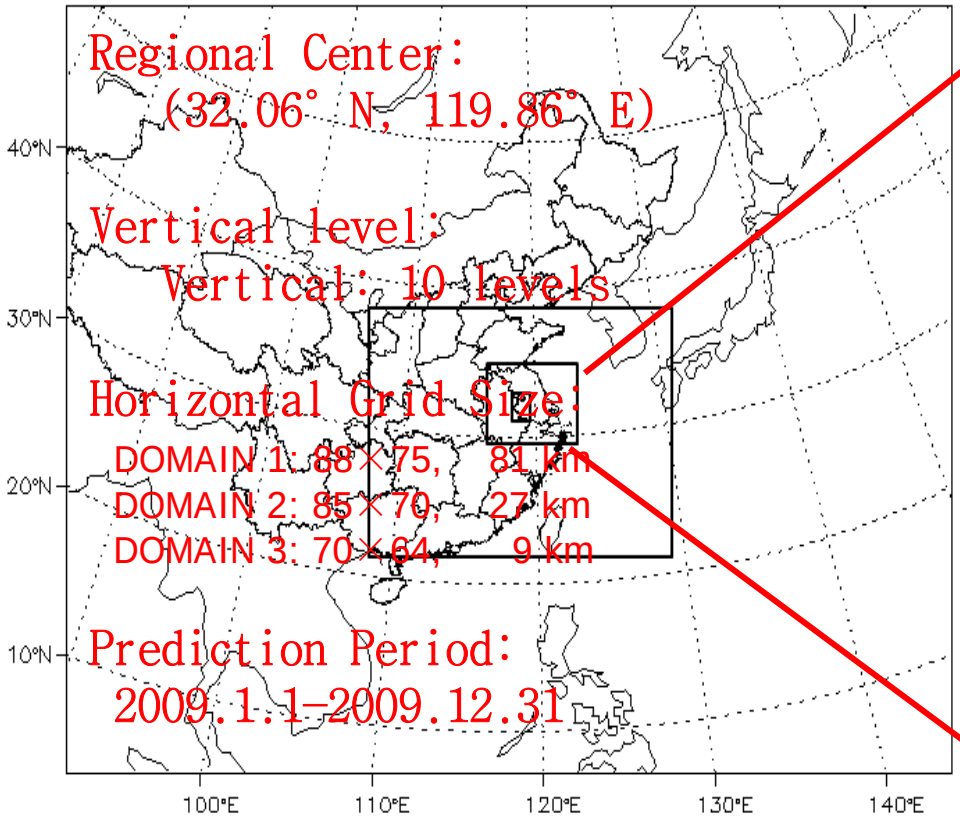

RH(%)
32.5N
32N
31.5N
118E
118.5E
119E
119.5E
74
72
70
68
66
64
62
60

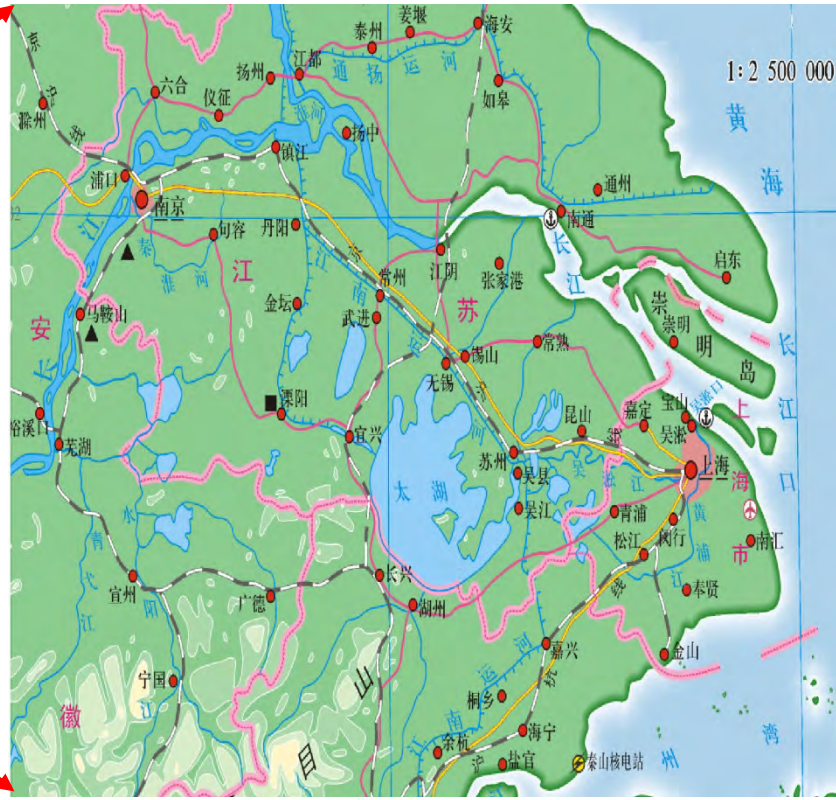

visibility(km)
32.5N
32N
31.5N
118E
118.5E
119E
119.5E
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8


PM25(ug/m3)
32.5N
32N
31.5N
118E
118.5E
119E
119.5E
44
42
40
38
36
34
32
30
28

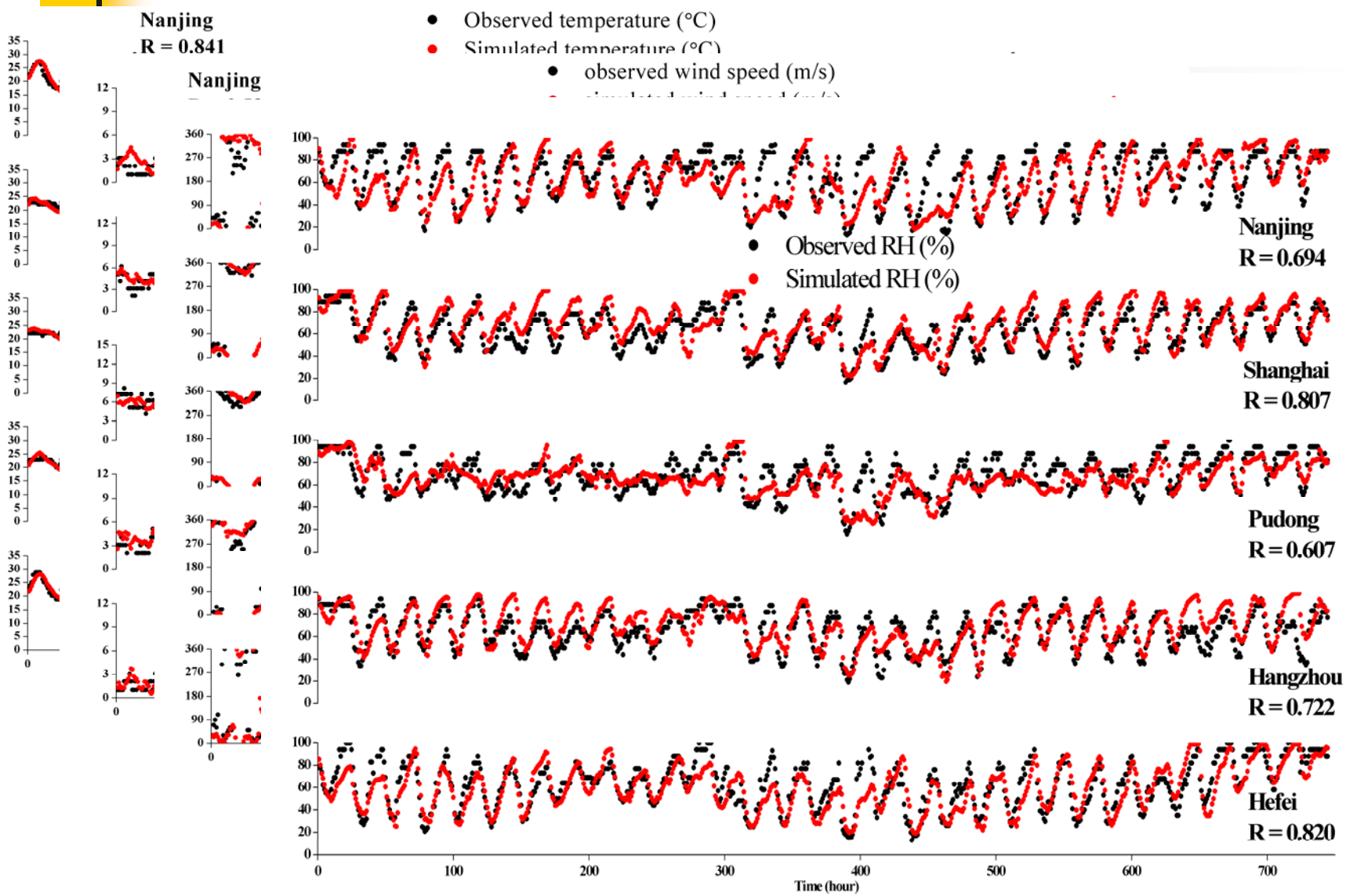

O3(ug/m3)
32.5N
32N
31.5N
118E
118.5E
119E
119.5E
60
59.5
59
58.5
58
57.5
57
56.5
56
55.5
55

Haze weather forecast in YRD using RegAEMS

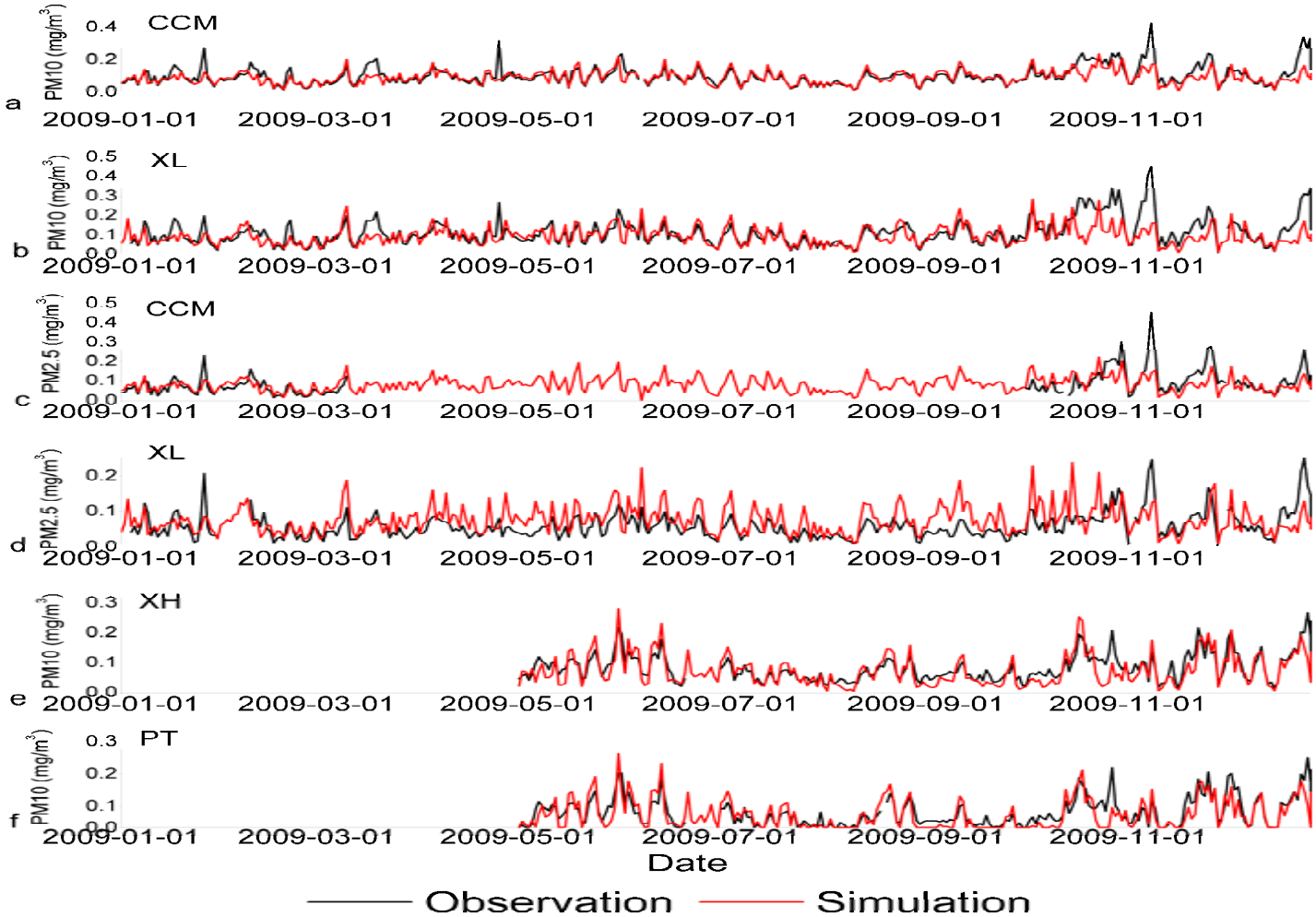




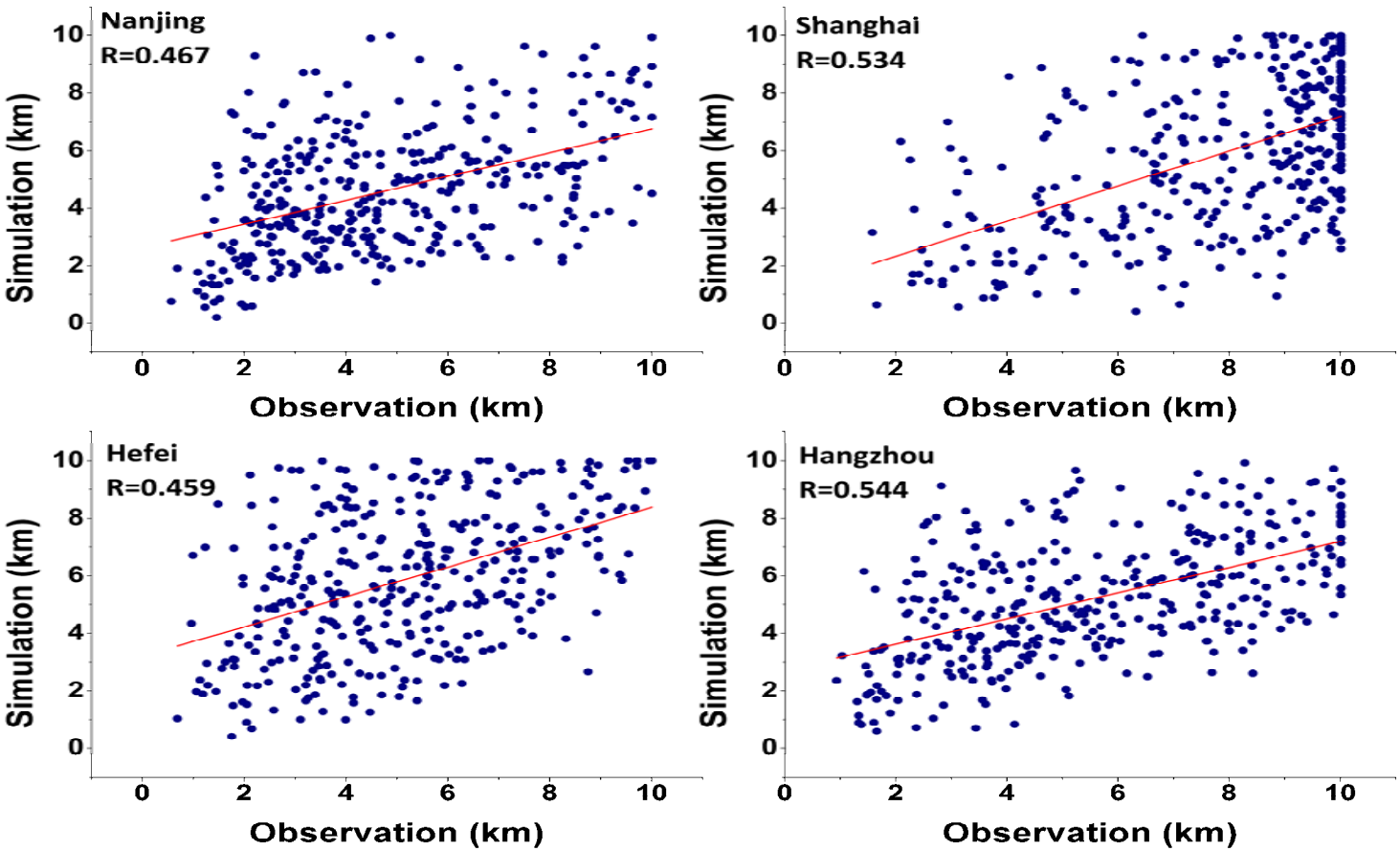
Observed *vs.* predicted meteorological variables



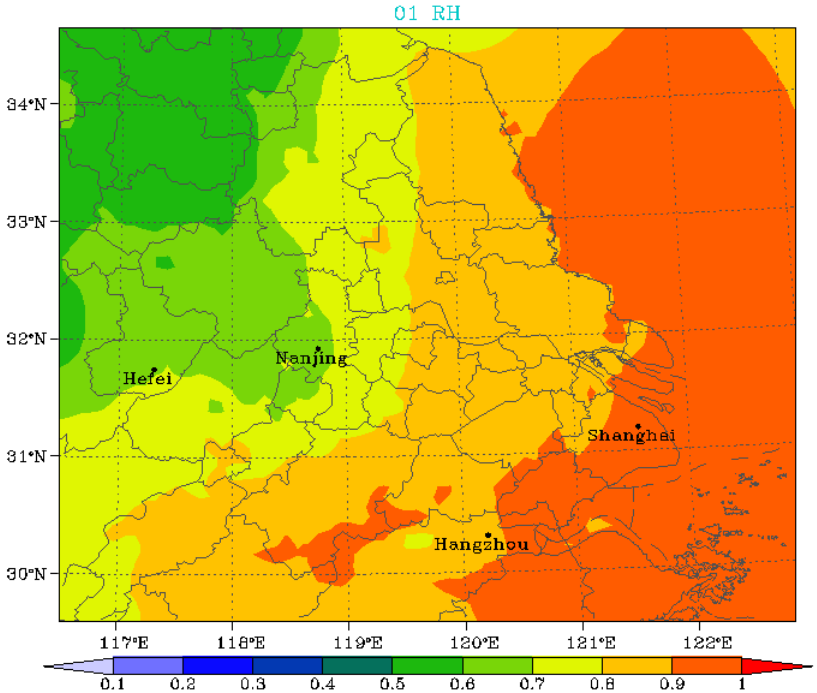
Daily concentrations of PM10 and PM2.5 in YRD during 2009

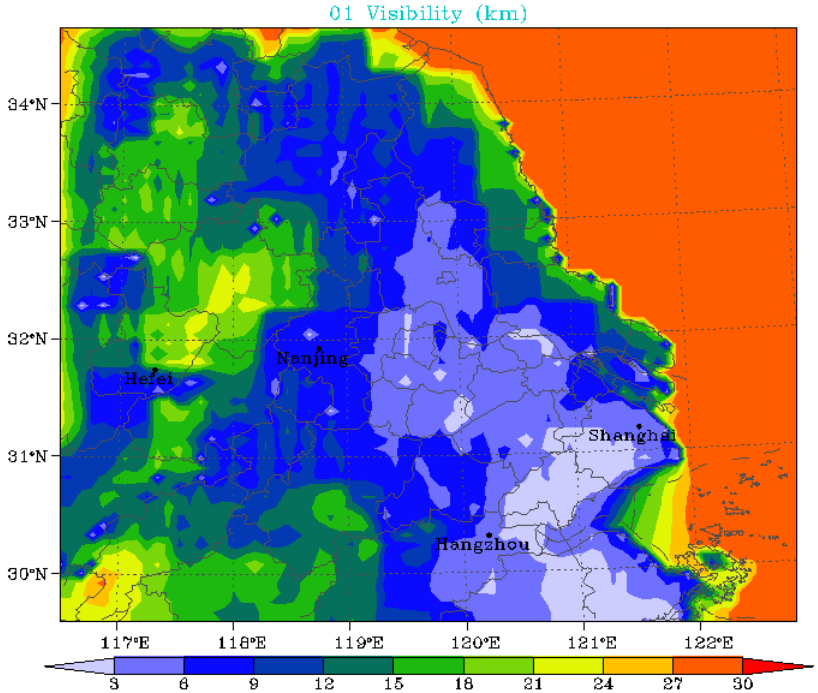


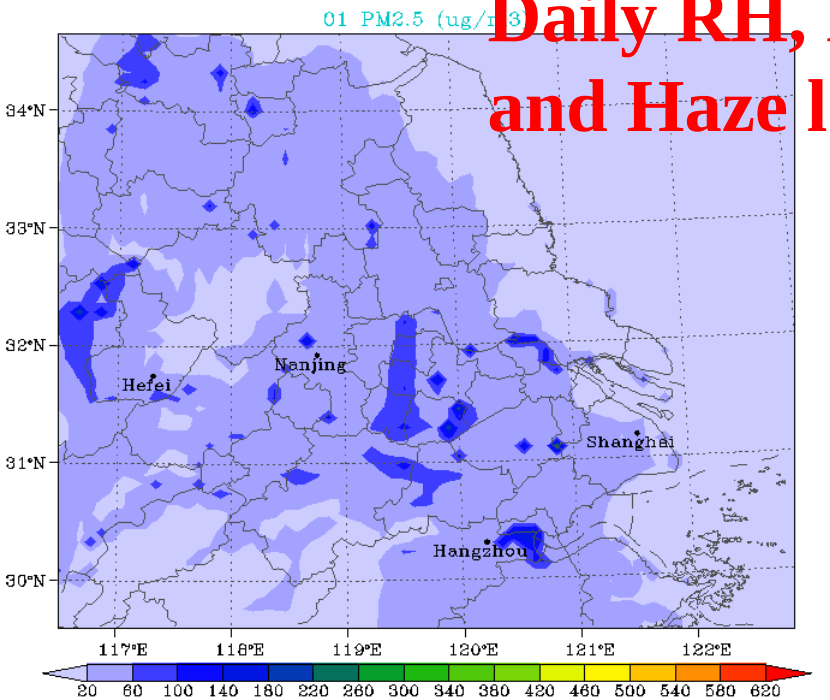
Hourly visibility from observation and prediction in YRD during 2009

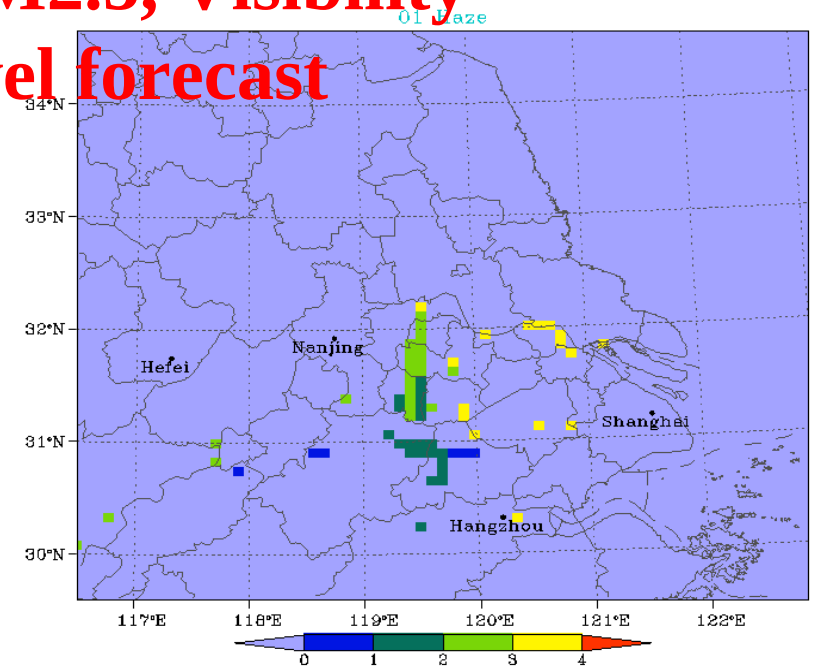


Daily RH, PM2.5, Visibility and Haze level forecast

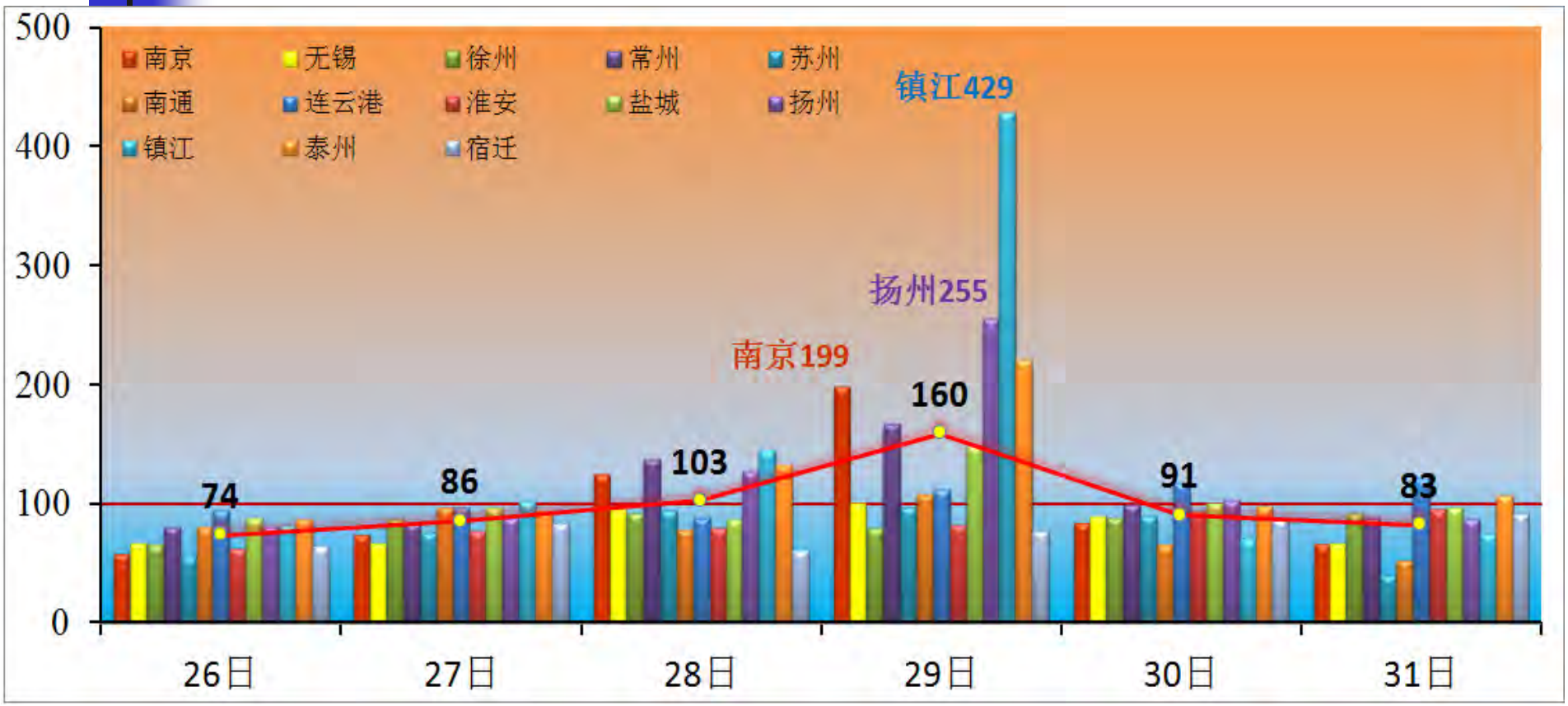




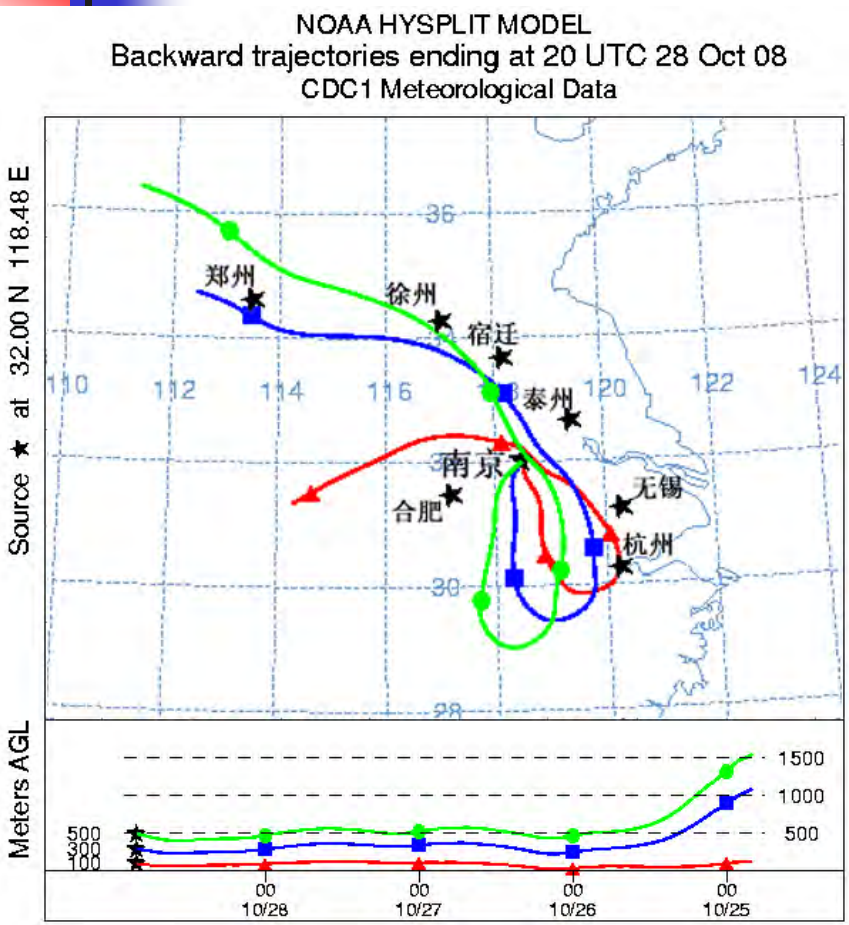


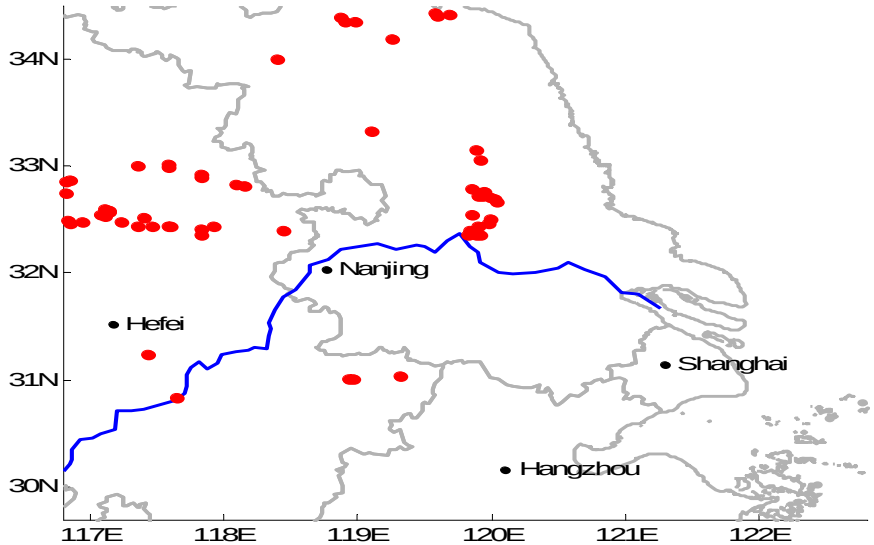


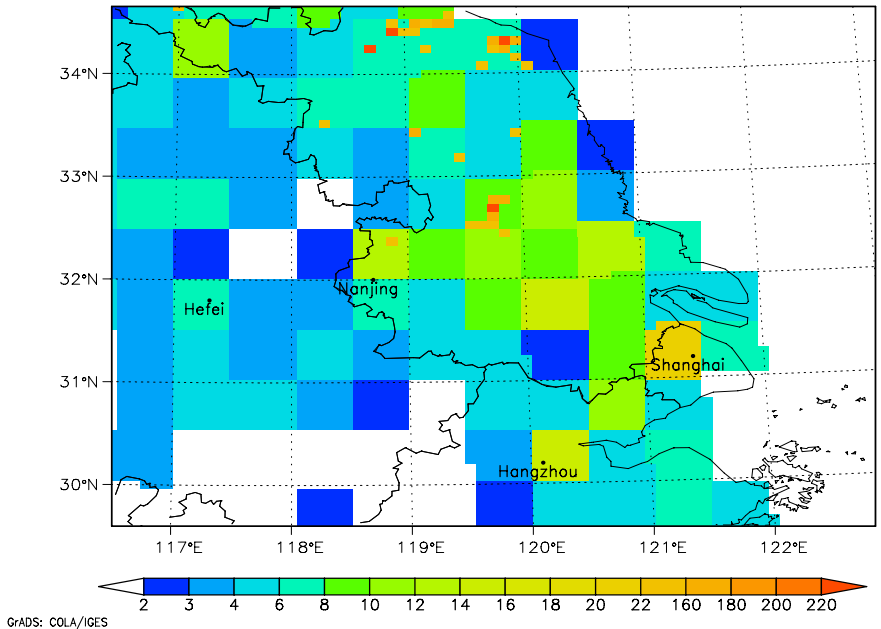
Heavy haze case prediction



Backward trajectory, fire spot and biomass emission





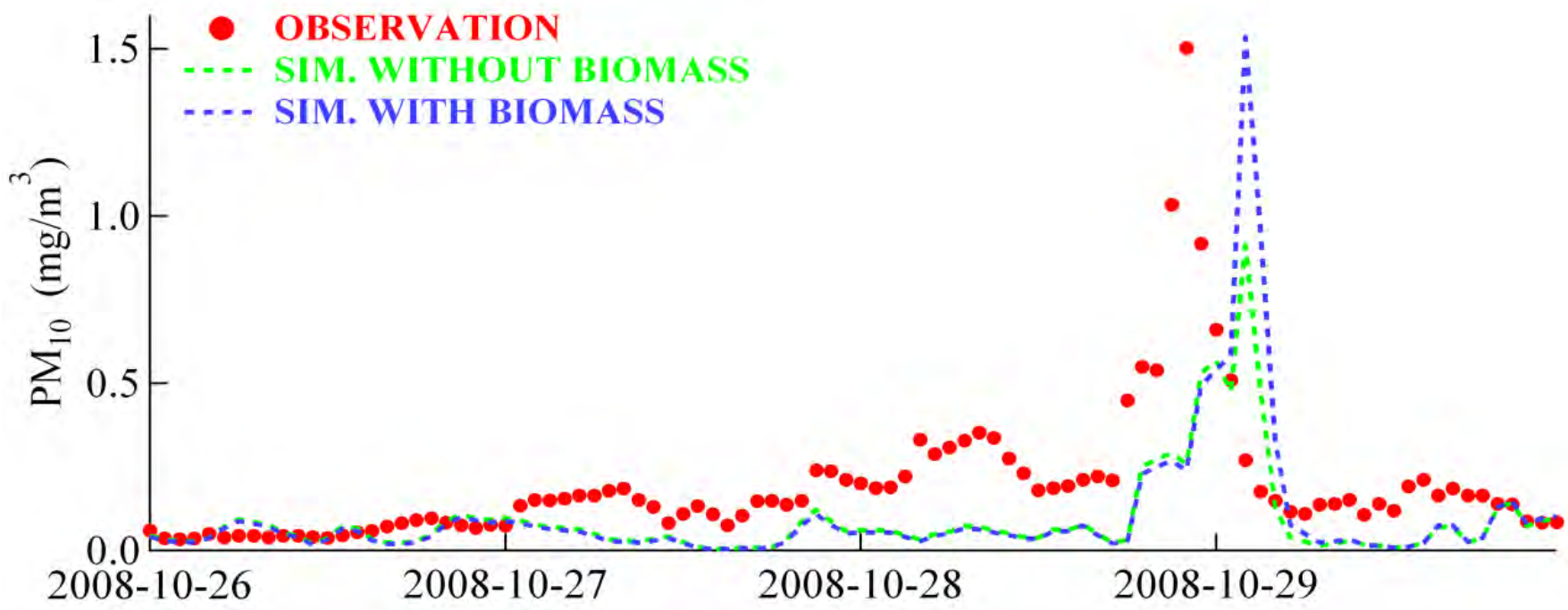


Biomass burning

Fire spot

10月28日18:00~20:00

RegAEMS

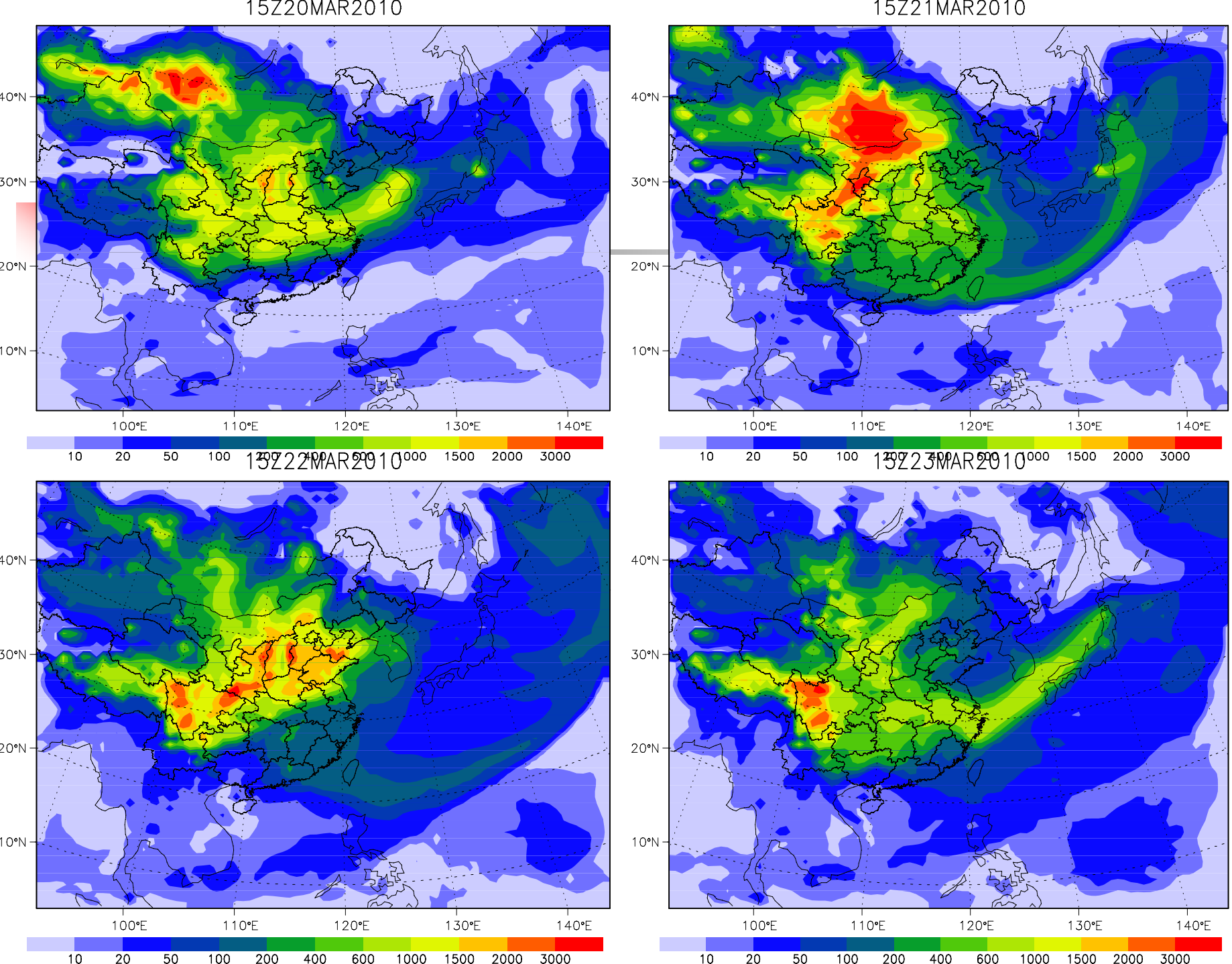


Data Assimilation in dust prediction

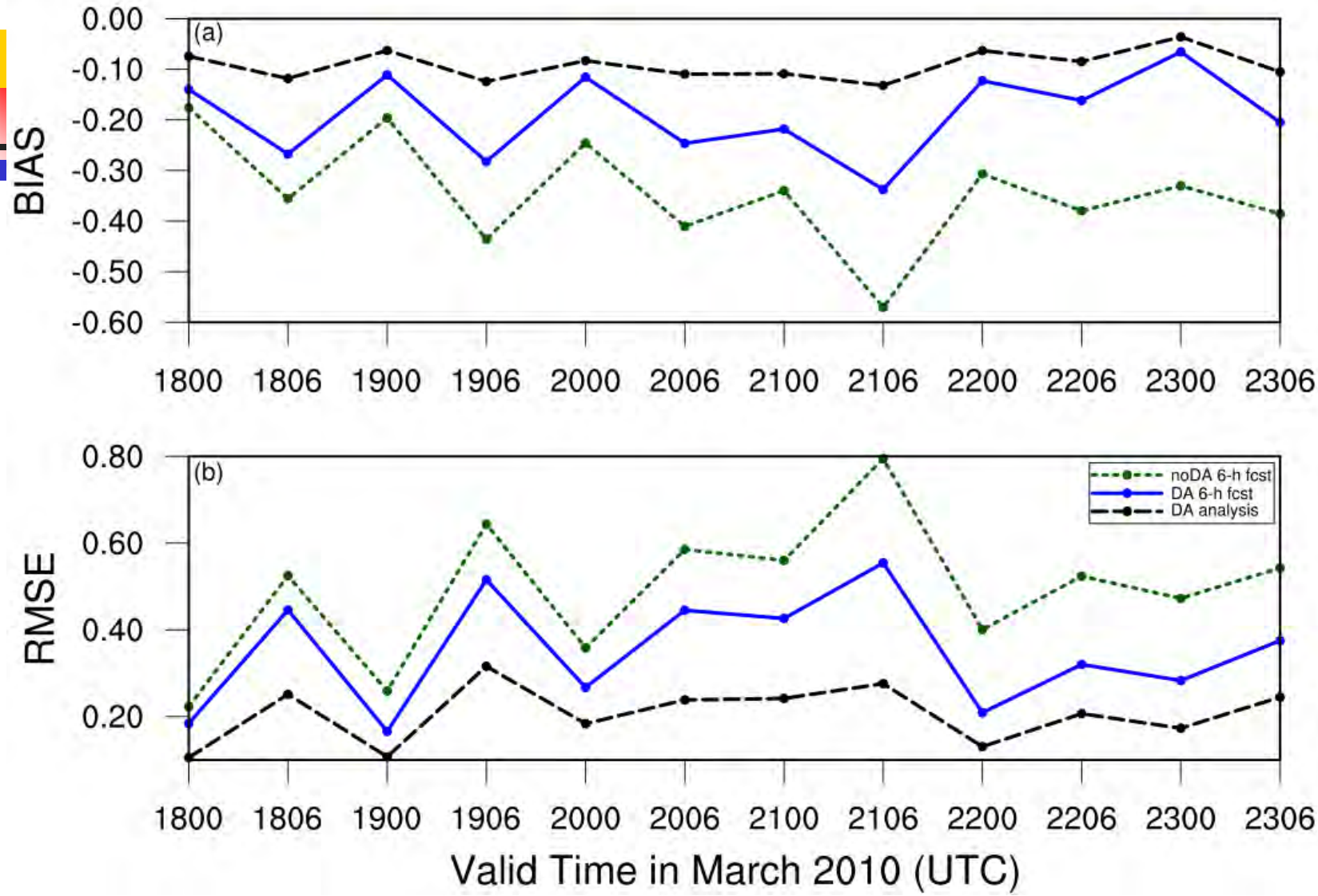
- Directly analyze 3D aerosol mass concentration with a one-step procedure of variational minimization within the GSI
  - Do NOT apply any assumption about vertical shape and relative weight of individual species.

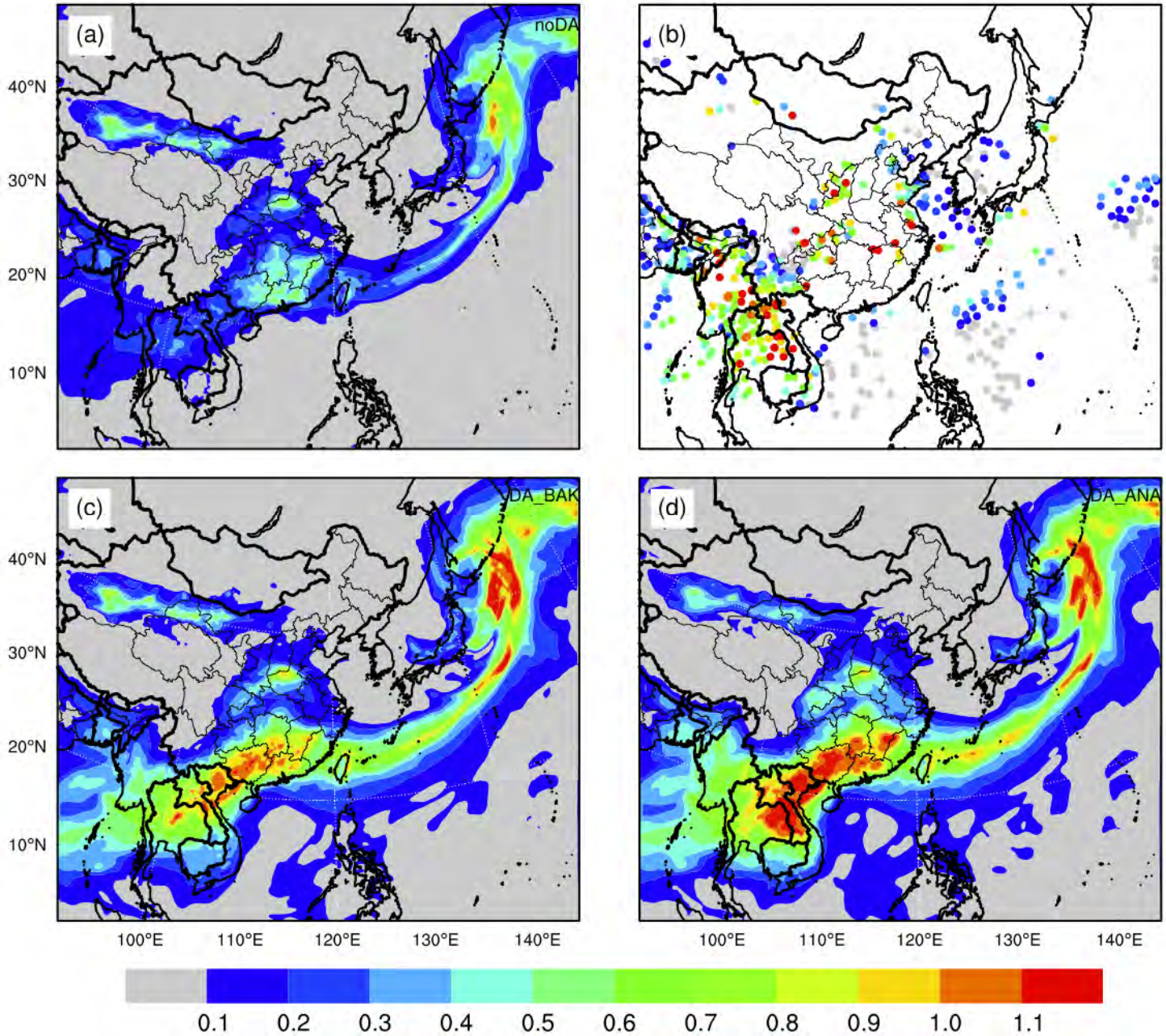
$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}[y - H(x)]^T R^{-1}[y - H(x)]$$

- 14 WRF/Chem-GOCART 3D aerosol mass concentration as analysis variables
  - need background error covariance statistics for each aerosol species
- Use CRTM as the AOD observation operator, including both forward and Jacobian models
- In short, no much difference from 3DVAR DA for meteorological obs.


15Z20MAR2010
15Z21MAR2010
15Z22MAR2010
15Z23MAR2010
40°N
30°N
20°N
10°N
100°E
110°E
120°E
130°E
140°E
10
20
50
100
200
400
600
1000
1500
2000
3000

OMB/OMA of MODIS AOD




(a)
noDA
(b)
(c)
VDA_BAK
(d)
VDA_ANA
40°N
30°N
20°N
10°N
100°E
110°E
120°E
130°E
140°E
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

Summary

- WRF-CHEM and RegAEMS are useful tools for urban quality and regional haze forecast.
- To improve the spatial resolution of emission inventory, especially emissions from fugitive dust, transportation and biomass burning in Yangtze River Delta region, to improve the performance of model prediction.
- To include urban canopy model in the meteorological model to improve the performance of meteorology prediction.
- To improve the model performance of forecast on heavy air pollution case using data assimilation and satellite spot, such as dust storm, and biomass burning.