

Evaluation and Application of Air Quality Model System in Shanghai

Qian Wang¹, Qingyan Fu¹, Yufei Zou¹, Yanmin Huang¹,

Huxiong Cui¹, Junming Zhao¹, Qi Chen²

1. Shanghai environmental monitoring center

2. Shanghai Environmental Protection Bureau

The 3rd International Workshop on Air Quality Forecast Research
Nov 29-Dec 1, 2011



Outline



Introduction



Model performance

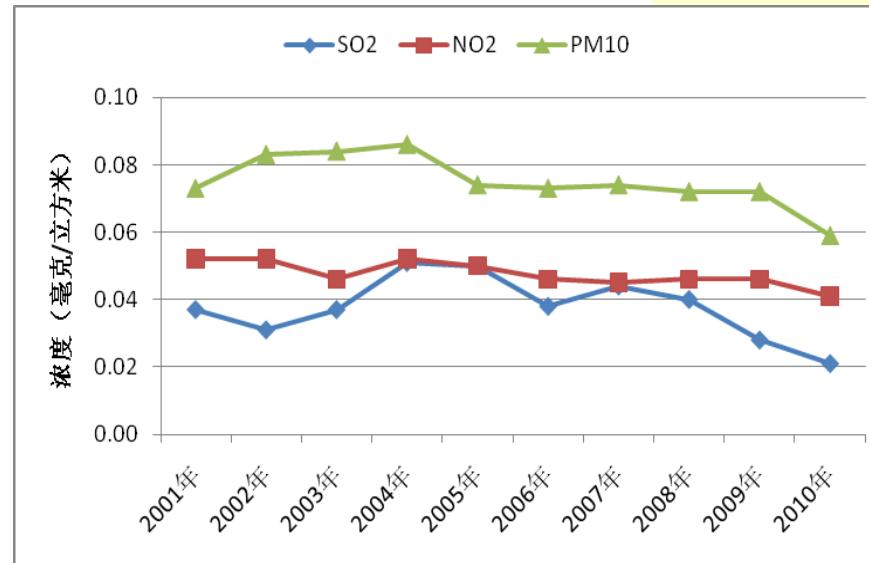
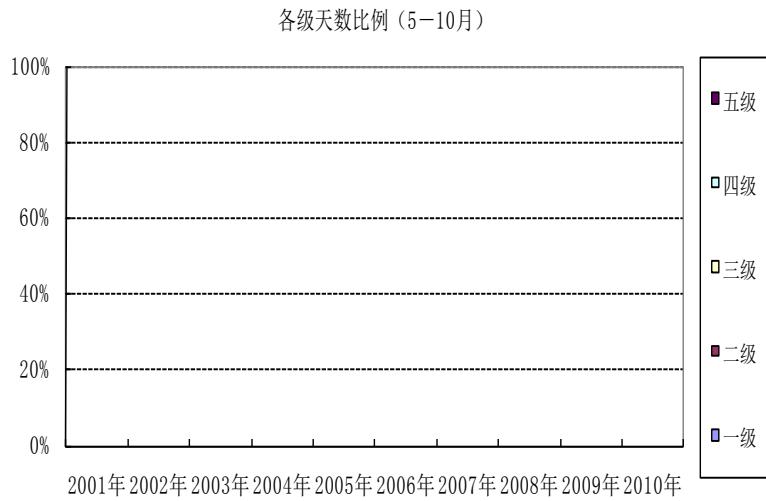


Model application



Future plan

Background-air quality during Shanghai Expo



- Attainment ratio is 98.4%, which is 2.7% higher than in 2009.
- 181 days with excellent and good air quality
- The average concentration of PM₁₀, SO₂ and NO₂ during the expo in 2010 is the lowest.
- Comparing to the other 8 cities in YRD, the attainment ratio of air quality in Shanghai is the second highest.

Continuous “Excellent” air quality for 17 days in July



7月12日(40)



7月13日(48)



7月14日(33)



7月15日(32)



7月16日(50)



7月17日(32)



7月18日(35)



7月19日(39)



7月20日(24)



7月21日(50)



7月22日(32)



7月26日(22)



7月27日(16)

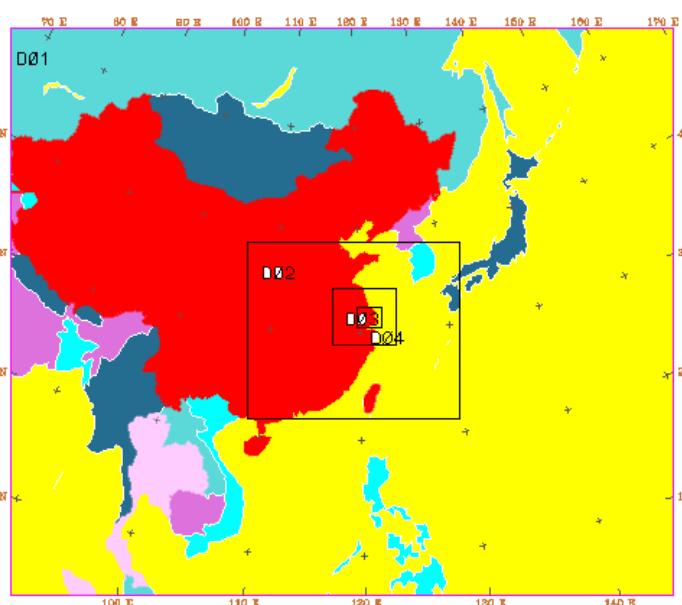
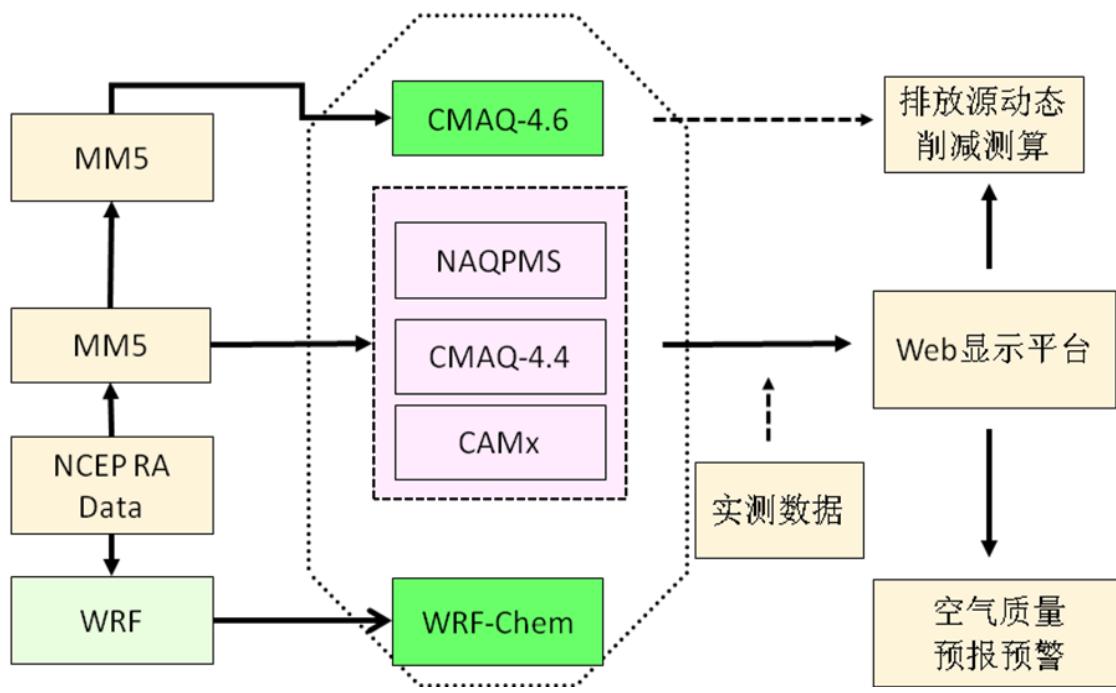


7月28日(36)



(Air Pollution Index)

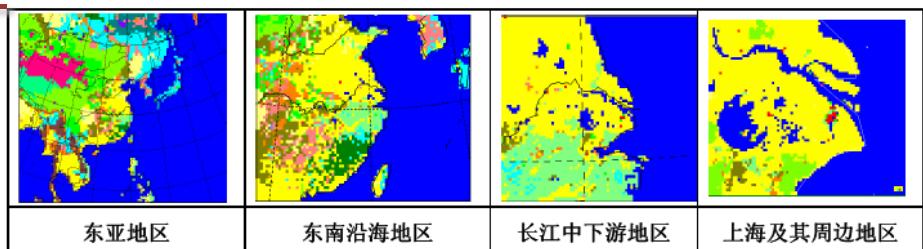
Air quality model system



Same domain setting

Same emission inventory

Operational run



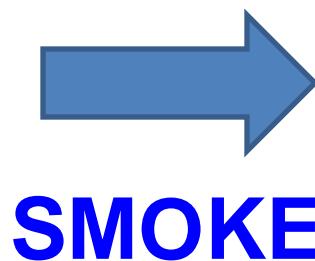
Emission inventory in model



Trace-P Asia emission
inventory in 2006

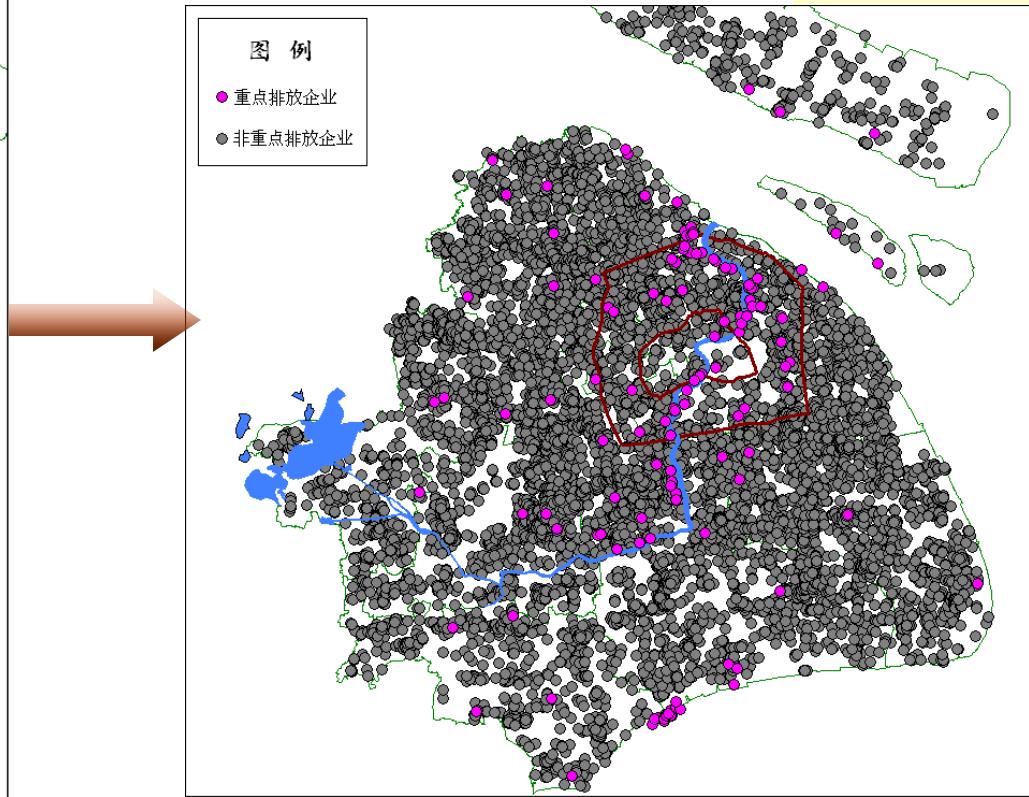
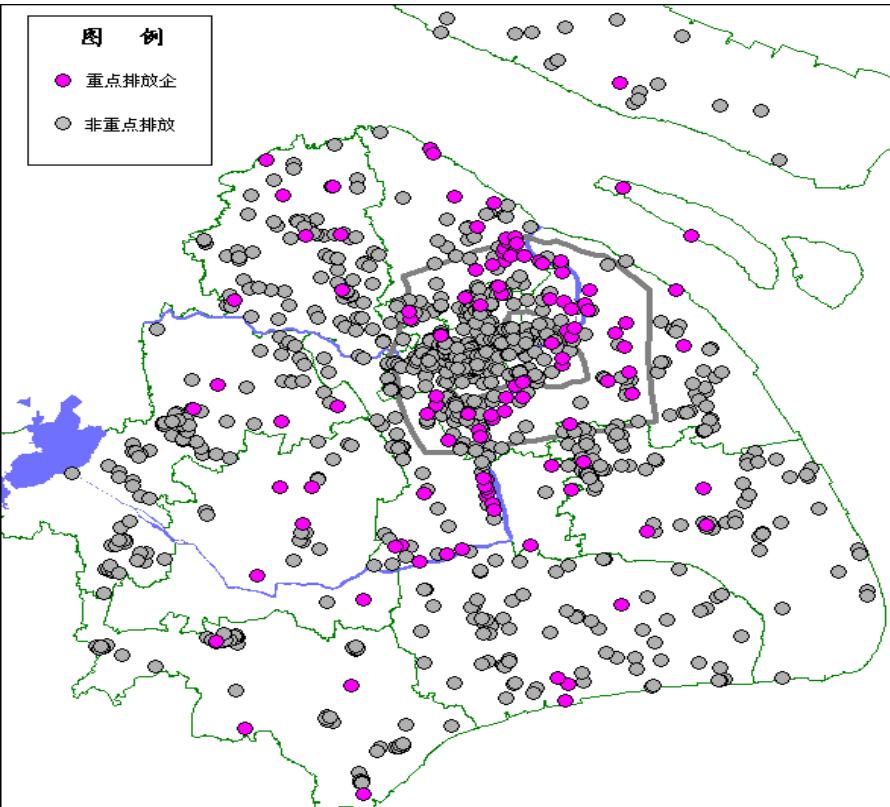
Shanghai emission
inventory in 2007

Power plant emission
inventory in YRD in 2007



Gridded emission
inventory in model
system

Update of point source EI in 2007



SO2 NO2 PM10 PM2.5 CO O3

全市预报		2010年5月18日					2010年5月19日					2010年5月20日					2010年5月21日				
		SO2	NO2	PM10	最大值	偏差率	SO2	NO2	PM10	最大值	偏差率	SO2	NO2	PM10	最大值	偏差率	SO2	NO2	PM10	最大值	偏差率
实测	API	20	34	55	55		30	45	74	74		36	41	113	113		14	20	65	65	
	当前小时 2010-6-1 12:00																				
综合预报		13	20	42	42	-23.600%	30	55	92	92	24.300%	38	42	103	103	-8.800%	25	28	65	65	0%
	NAQPMS2004	47	22	62	62	12.7%	77	31	102	102	37.8%										
	NAOPMS2008	36	30	59	59	7.3%	51	19	68	68	-8.1%										

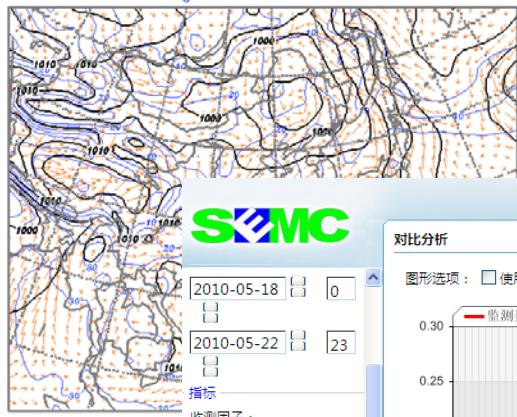
气象图/污染浓度分布图

日期 : 2010-05-19

模式 : MM5 WRF

区域 : 全国 华东 长三角 上海

预报高度 : 地面 850 700 500 (单位 : 百帕) 垂直断面 (宝山)

Surface Weather Chart & Rain(mm/3h) 12Z19MAY2010
Beijing time 20Z19MAY2010

SMC

MM5 00 hours forecast

2010-05-18 [0]

2010-05-22 [23]

指标 :

PM10

 监测因子浓度 监测因子API 最大API

数据源 :

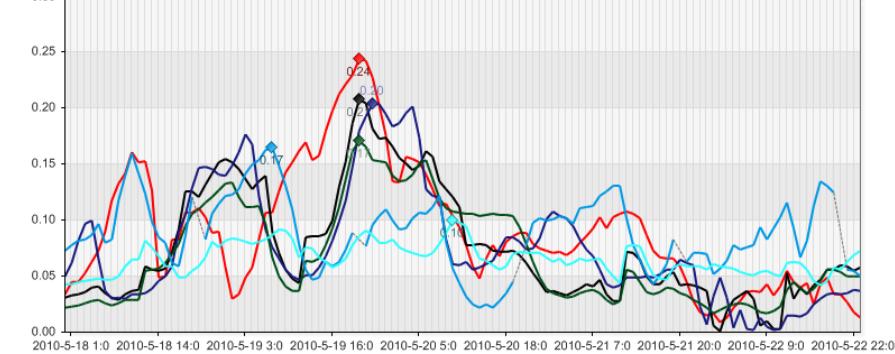
 污染 气象 监测数据 CMAQ4_4 CMAQ4_6 CAMx WRF_Chem NAQPMS2004 NAQPMS2008

显示

对比分析

图形选项 : 使用3D 自动匹配宽度 显示标记 显示数值

— 监测数据 — CMAQ4_4 — CMAQ4_6 — CAMx — WRF_Chem — NAQPMS2008



数值预报-NAQPMS2008 2010-05-18 00:00

区县	二氧化硫	二氧化氮	可吸入颗粒物	PM2.5	臭氧	一氧化碳
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Outline



Introduction



Model performance



Model application



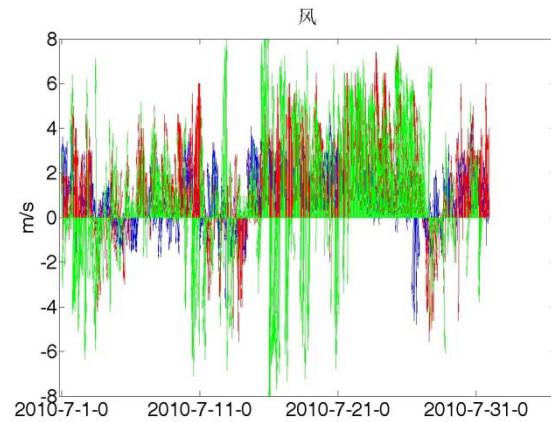
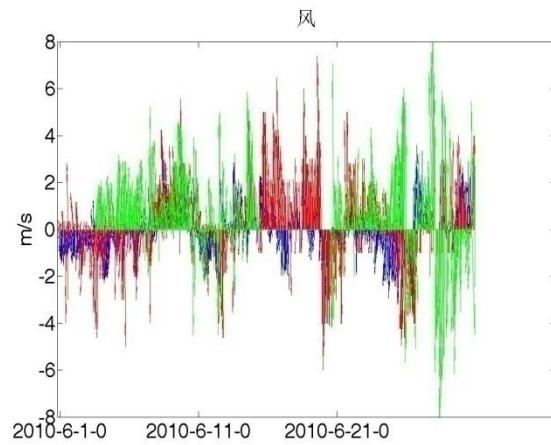
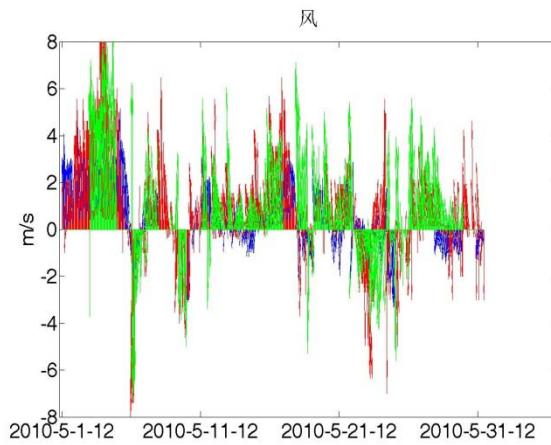
Future plan

Meteorological simulation evaluation

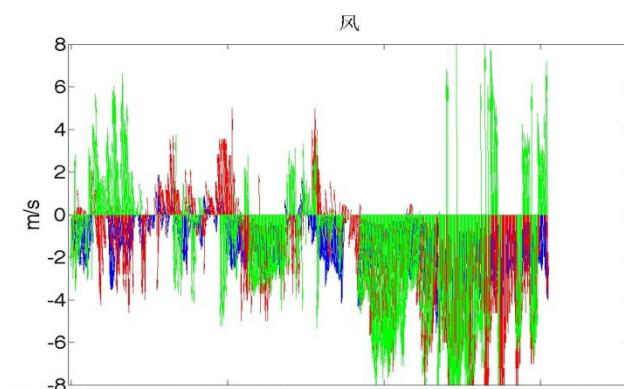
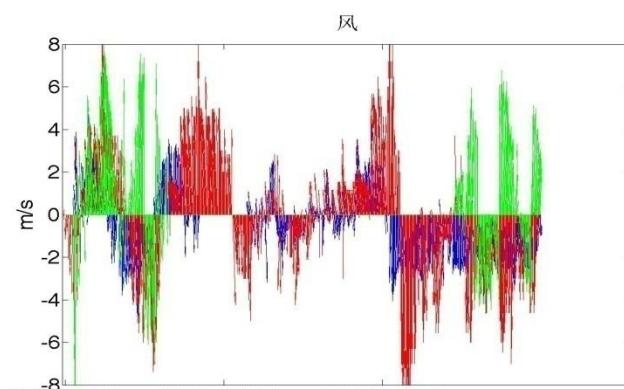
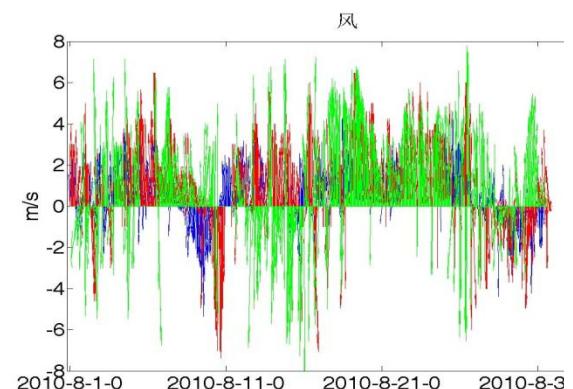
Model	Parameter	Number	MeanSim	MeanObs	corr	MB	NMB (%)	NME (%)	RMSE
MM5	T	3978	24.65	25.05	0.86	-0.40	-1.59	9.63	3.13
	WS	3978	2.51	3.70	0.33	-1.19	-32.07	46.48	2.19
	RH	3978	70.80	72.03	0.55	-1.23	-1.71	16.87	15.73
	PRE	3978	1011.84	1010.43	0.91	1.41	0.14	0.23	2.91
WRF	T	3347	23.58	25.05	0.93	-1.46	-5.84	8.16	2.48
	WS	3347	4.42	3.70	0.54	0.72	19.41	39.02	1.89
	RH	3347	77.17	72.03	0.76	5.14	7.13	12.65	11.51
	PRE	3347	1005.91	1010.43	0.96	-4.51	-0.45	0.44	4.75

- the correlation coefficient of T, Rh ,Pre simulation and observation is above 0.7.
- MM5 and WRF could well predict the hourly variation of major elements.

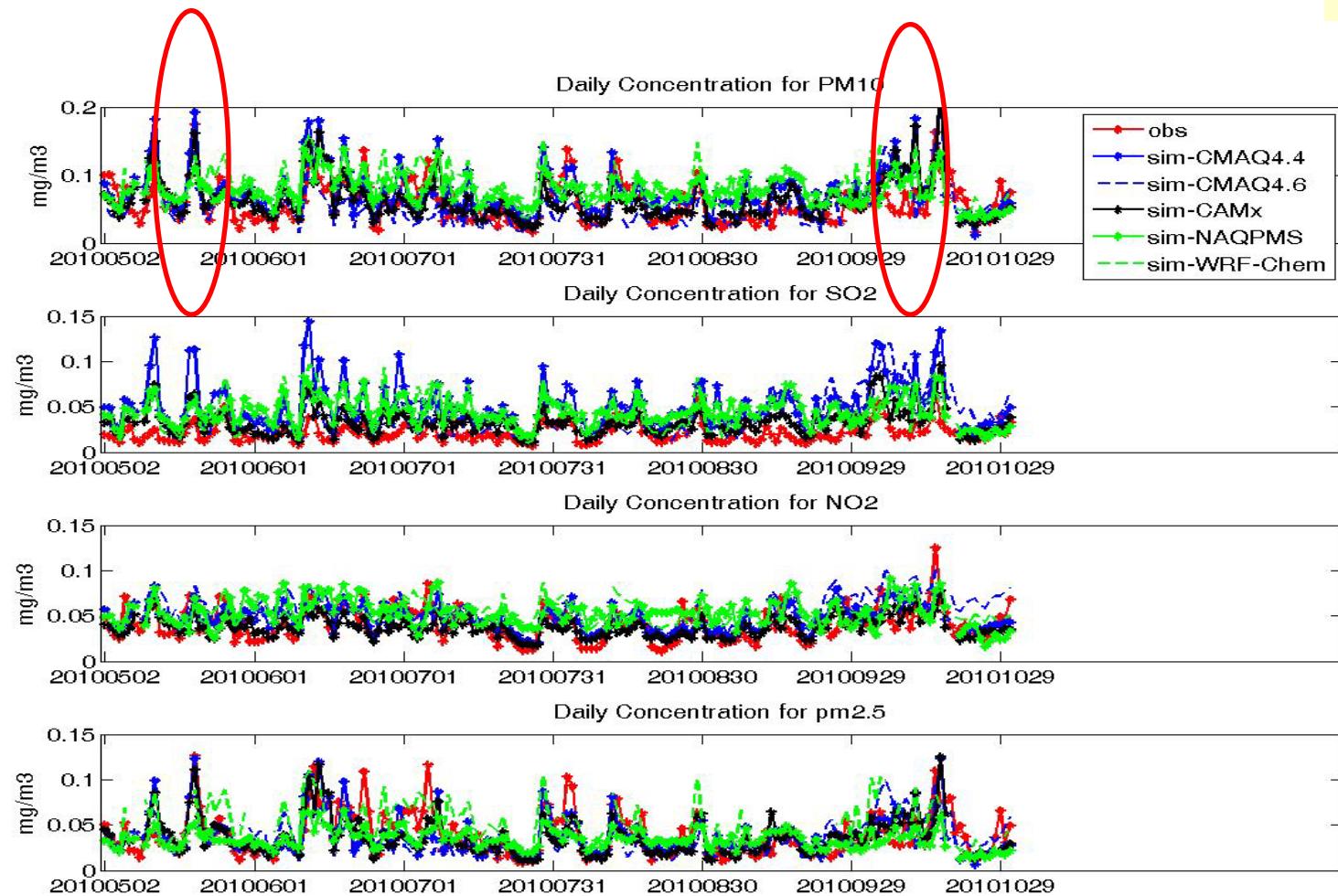
Wind



The predicted wind direction of MM5 is much accurate than that of WRF, especially when the wind speed is low.



Air quality forecast evaluation-1



Model system well predicts the daily variation of PM₁₀, SO₂ and NO₂ in shanghai.

Air quality forecast evaluation-2

Model	Parameter	Number	MeanSim	MeanObs	MB	NMB (%)	NME (%)	RMSE
NAQPMS	PM ₁₀	180	0.077	0.058	0.019	32.15	51.40	0.035
	SO ₂	180	0.044	0.021	0.023	107.25	110.39	0.027
	NO ₂	180	0.053	0.041	0.012	29.93	50.26	0.024
	PM _{2.5}	180	0.034	0.039	-0.005	-12.99	37.78	0.020

PM₁₀、 NO₂、 SO₂-over predicted, PM_{2.5}-under predicted—PM_{2.5}、 NH₃ emission sources is under predicted, SO₂ emission sources is over predicted.

	Parameter	Number	MeanSim	MeanObs	MB	NMB (%)	NME (%)	RMSE
CMAQ4.6	PM _{2.5}	100	0.051	0.059	-0.001	-19.89	35.99	0.019
	PM ₁₀	165	0.051	0.058	-0.007	-12.03	40.40	0.030
	SO ₂	165	0.041	0.021	0.020	91.46	98.75	0.028
	NO ₂	165	0.057	0.041	0.016	39.66	47.68	0.024
WRF-Chem	PM _{2.5}	165	0.035	0.039	-0.004	-10.98	44.42	0.023
	PM ₁₀	143	0.084	0.058	0.026	44.73	54.01	0.038
	SO ₂	143	0.041	0.021	0.019	89.70	87.68	0.024
	NO ₂	143	0.054	0.041	0.013	30.58	38.00	0.018
	PM _{2.5}	143	0.052	0.039	0.013	33.66	50.32	0.024

Outline



Introduction



Model performance

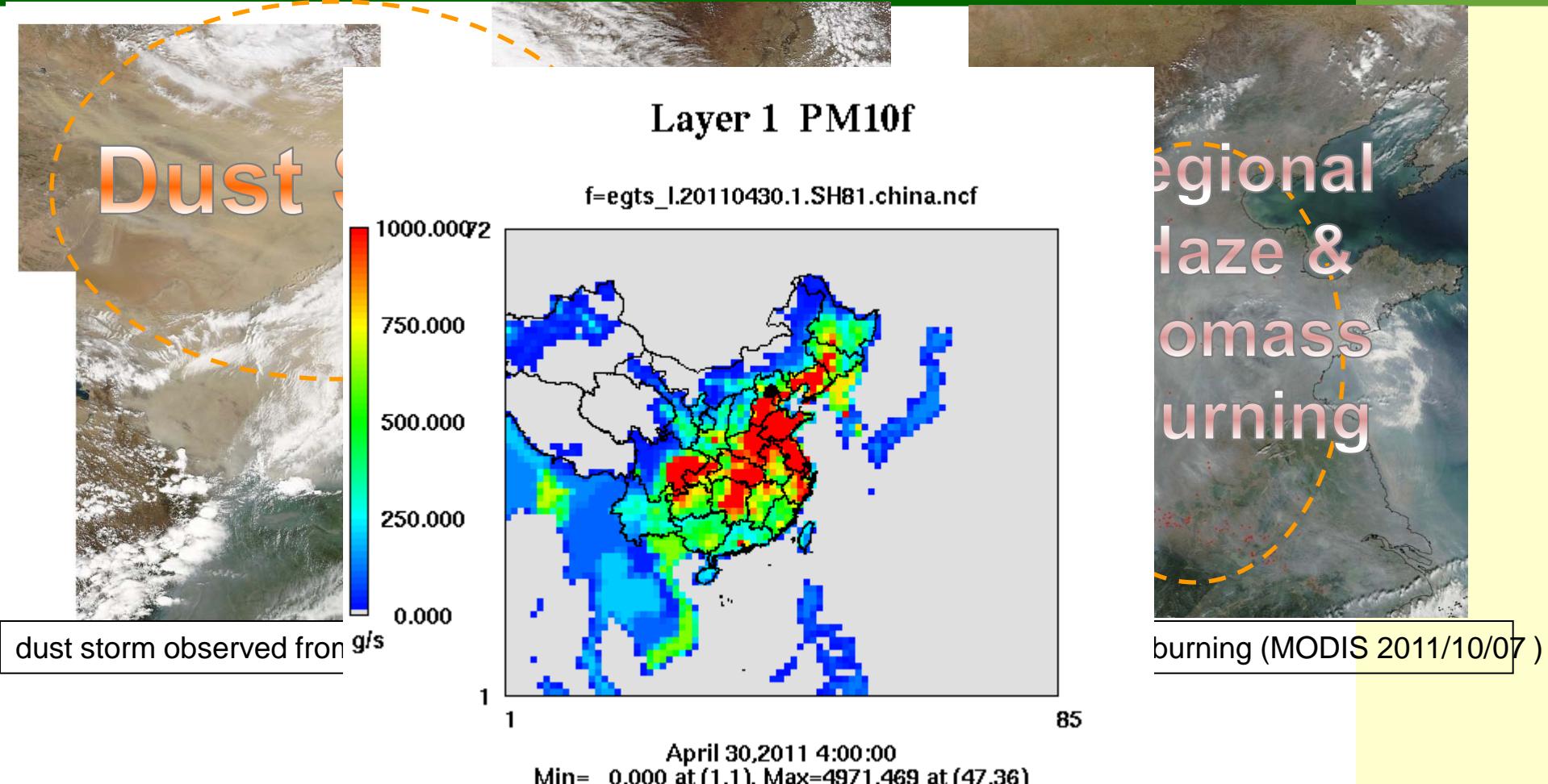


Model improvement



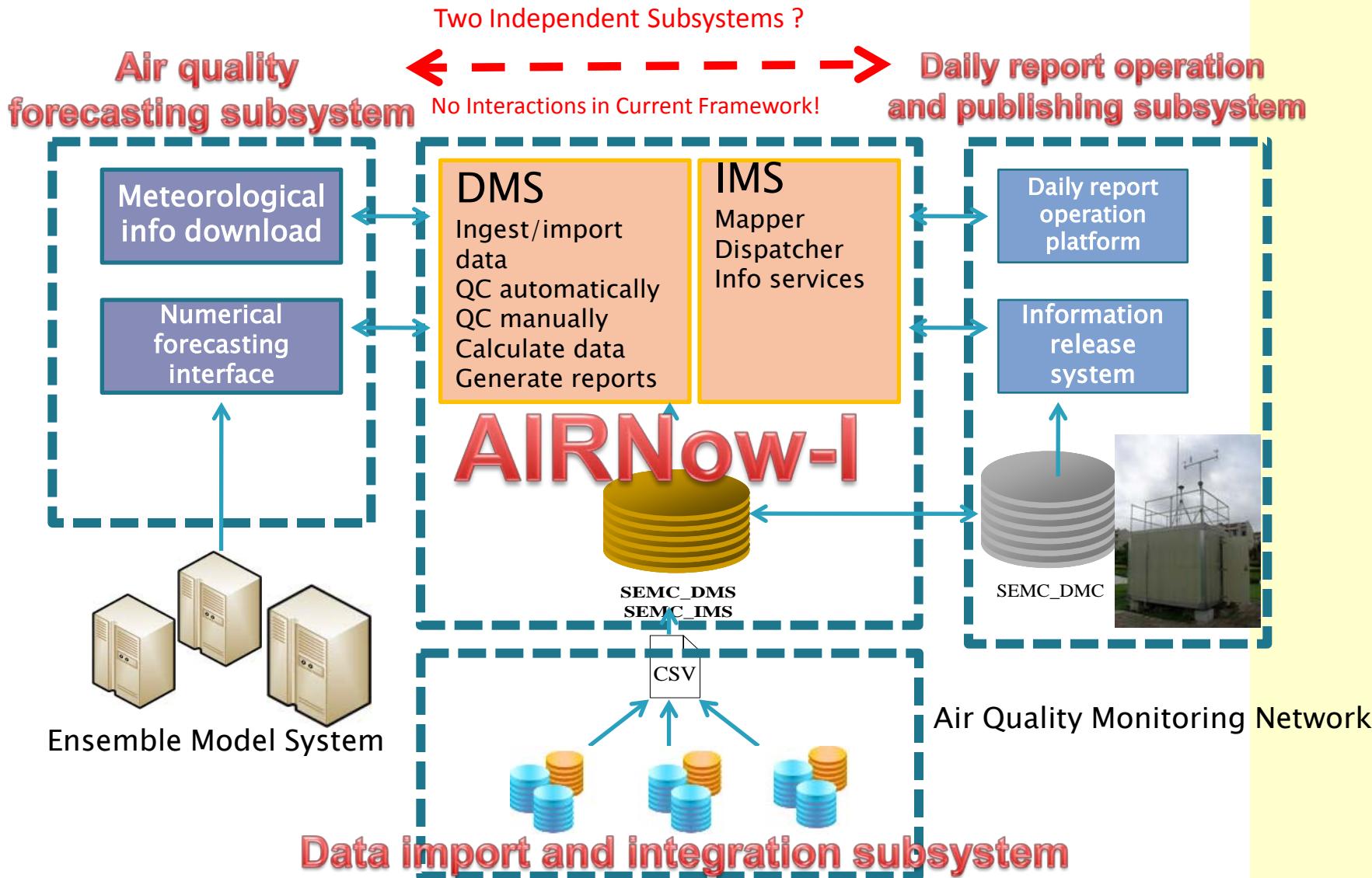
Future plan

Difficulties in air quality model forecast



Only anthropogenic emissions are quantified (with great uncertainty) in our operational EMS
Dust & Biomass Burning emission are missing!

Defect in current system framework



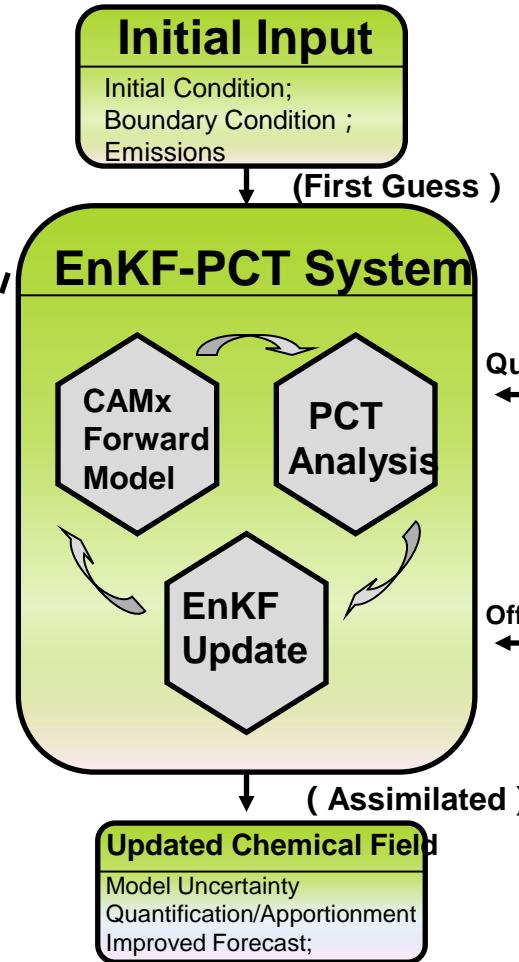
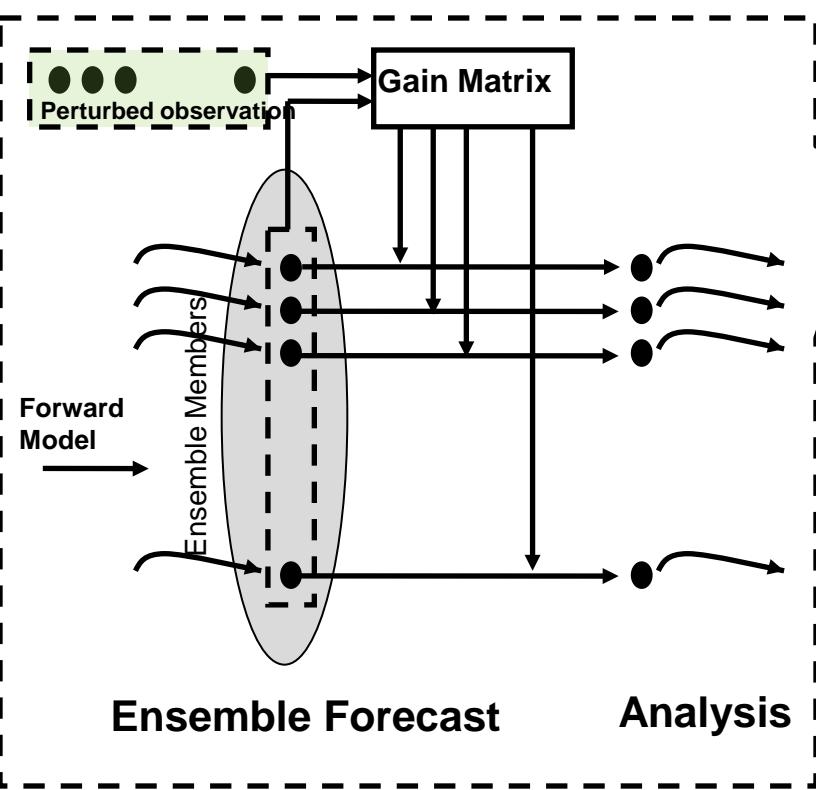
Data assimilation scheme

EnKF formula:

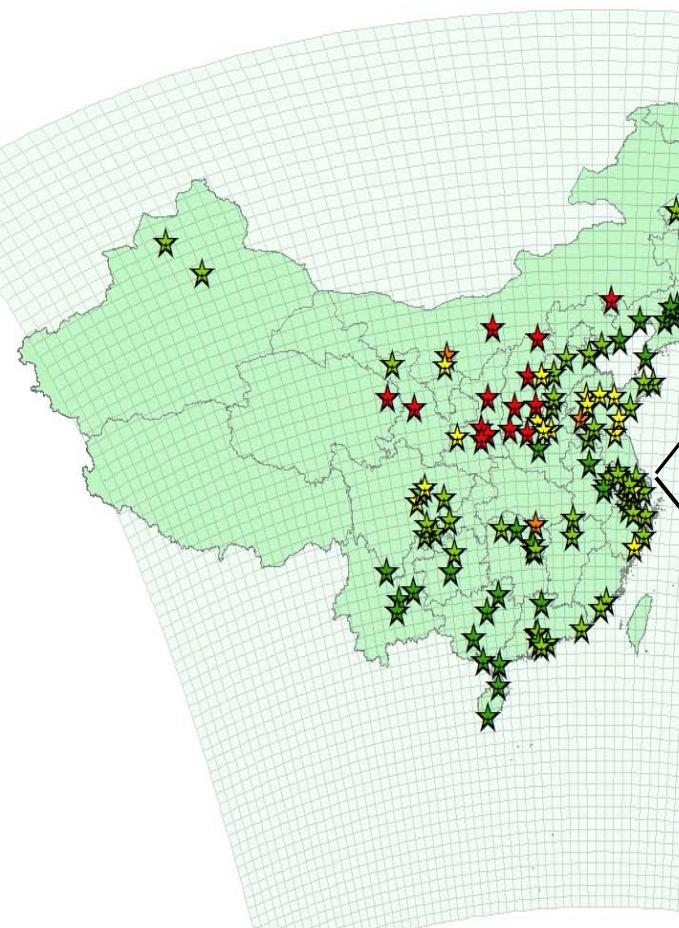
$$(\mathbf{u}^a)_i = (\mathbf{u}^f)_i + \mathbf{K}_e ((\mathbf{d})_i - \mathbf{H}(\mathbf{u}^f)_i), \quad i = 1, \dots, M,$$

where,

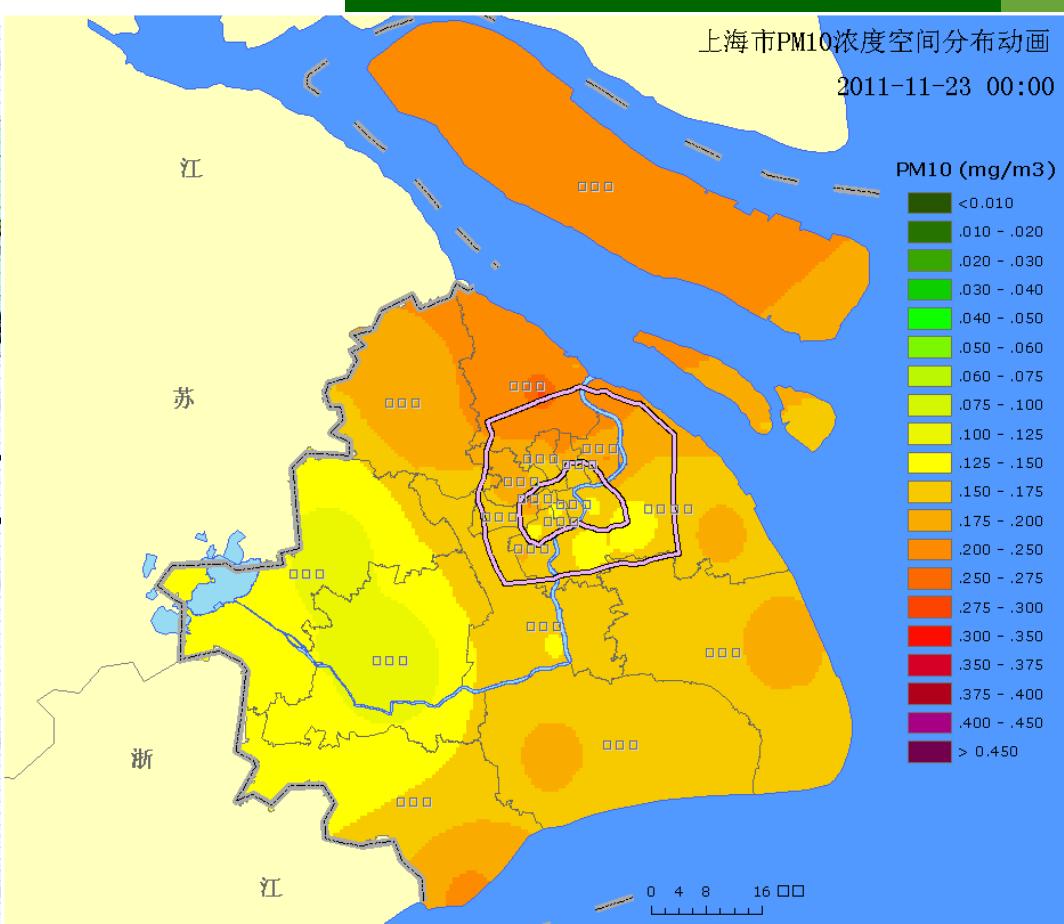
$$\mathbf{K}_e = \mathbf{P}_e^f \mathbf{H}^T (\mathbf{H} \mathbf{P}_e^f \mathbf{H}^T + \mathbf{R}_e)^{-1}$$



Monitoring network



National Monitoring Network



Automatic Monitoring Network in Shanghai

Model uncertainty analysis

Uncertainty sources:

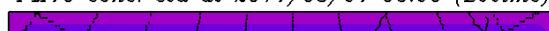
$$\overline{(C_o - C_p)^2} = \underbrace{\overline{(\delta C_p)^2}}_{(a-1)} + \underbrace{\overline{(\delta C_o)^2}}_{(a-2)} + \underbrace{\overline{(\bar{d})^2}}_{(b)} + \underbrace{\sigma_c^2}_{(c)}$$

	Parameters	Species	Perturbation	Distribution	Polynomial
UA1	Emission	PM, NOx, SO2	[-10%,+10%]	Beta	Jacob
UA2	Dry Deposition Velocity	PM	[-10%,+10%]	Beta	Jacob
UA2	Dilution rate/Entrainment rate	NOx, SO2	[-10%,+10%]	Beta	Jacob
UA3	Wind field	PM, NOx, SO2	[-10%,+10%]	Beta	Jacob

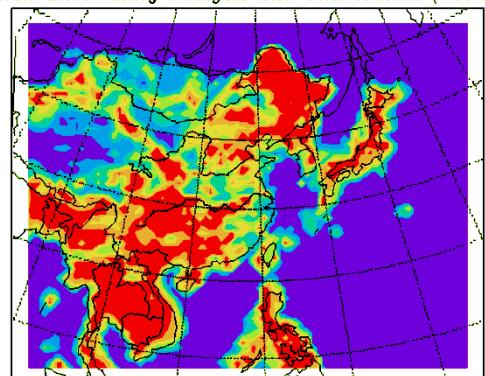
PM10 concentration at 2011/05/01 06:00 (BJtime)



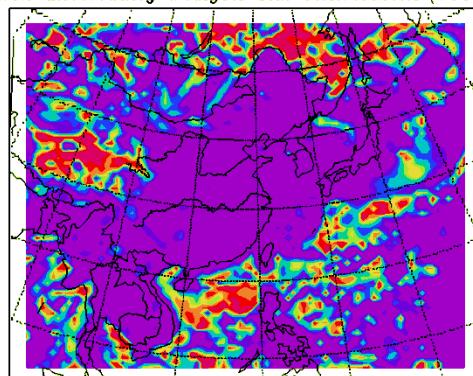
PM10 conc. std at 2011/05/01 06:00 (BJtime)



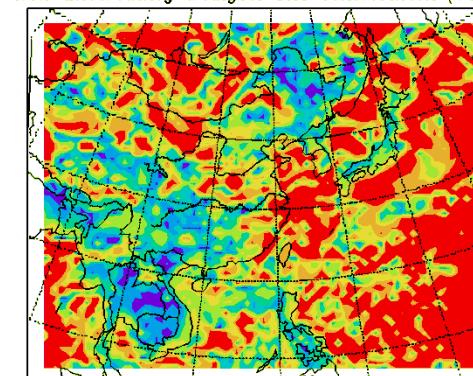
NO2 uncertainty analysis UA1 contribution (100%)



NO2 uncertainty analysis UA2 contribution (100%)



NO2 uncertainty analysis UA3 contribution (100%)



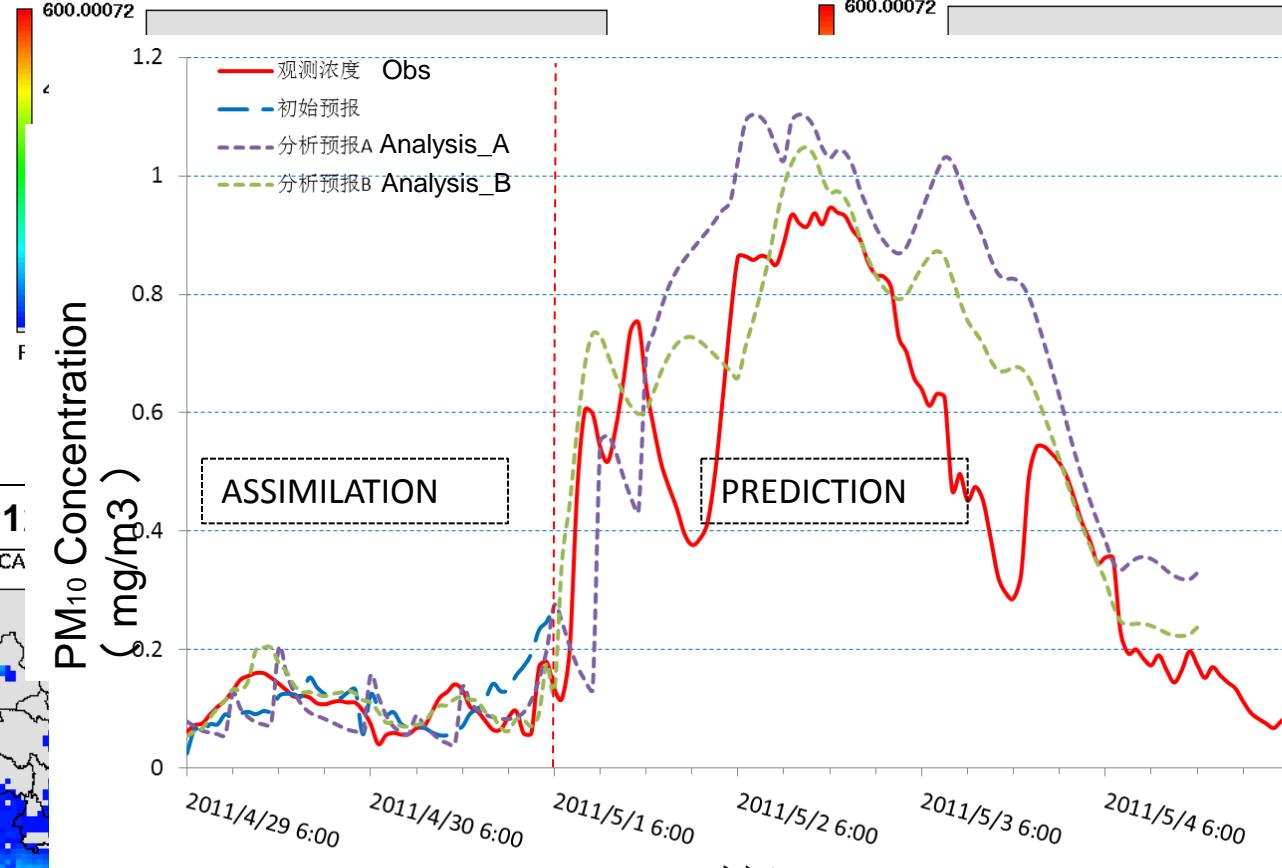
Application-----dust storm forecast

2011-04-29 12 : 00 (24h forecast)

2011-04-30 12 : 00 (24h forecast)

CAMx 4.20 Shanghai case - Mech 4CF - 29, 2009
a=CAMx.v4.40.SH.20110429.avrg.grd01

CAMx 4.20 Shanghai case - Mech 4CF - 30, 2009
b=CAMx.v4.40.SH.20110430.avrg.grd01



2011-05-01 12:00

c=CA

600.00072

450.000

300.000

150.000

0.000

PPM

1

85

PPM

1

85

PPM

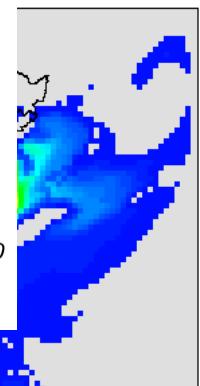
1

November 21,2001 4:00:00
Min= 0.000 at (1,1), Max= 969.762 at (35,42)

November 22,2001 4:00:00
Min= 0.000 at (1,1), Max= 822.071 at (47,36)

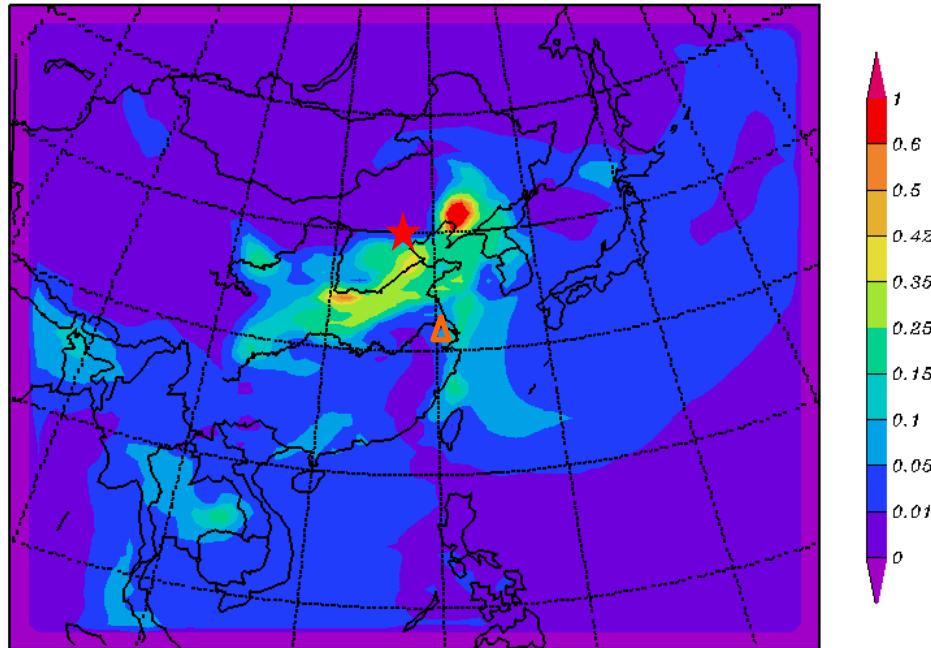
November 23,2001 4:00:00
Min= 0.000 at (1,1), Max= 861.225 at (35,42)

PM₁₀
(24h forecast)
avrg.grd01

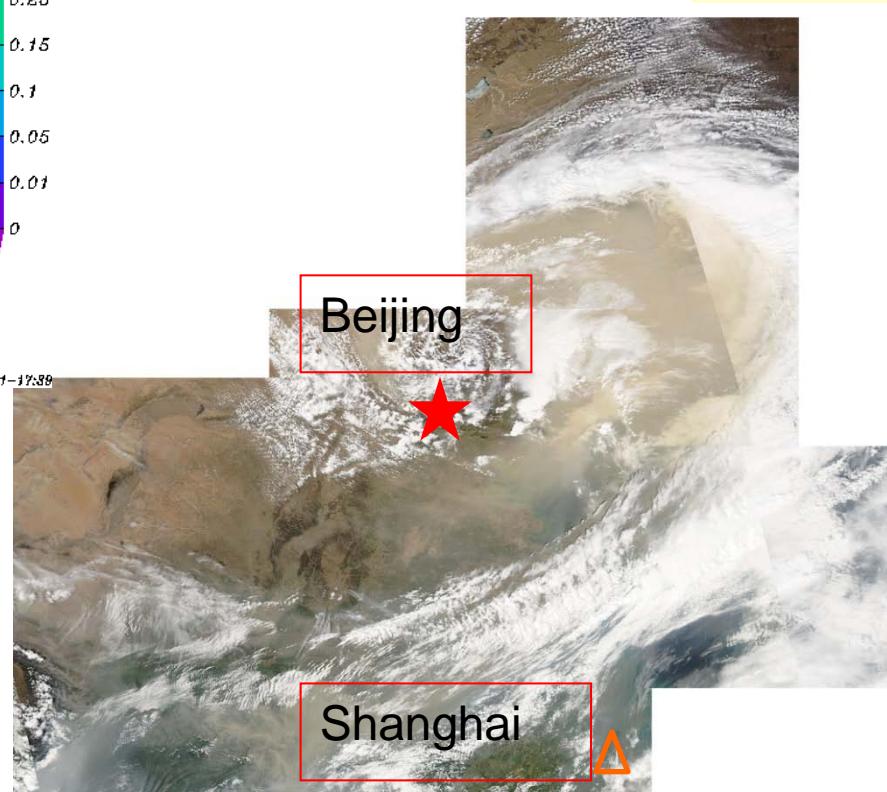


Application----dust storm forecast

PM10 Concentration (mg/m³) at 2011/04/30 12:00(BJtime)



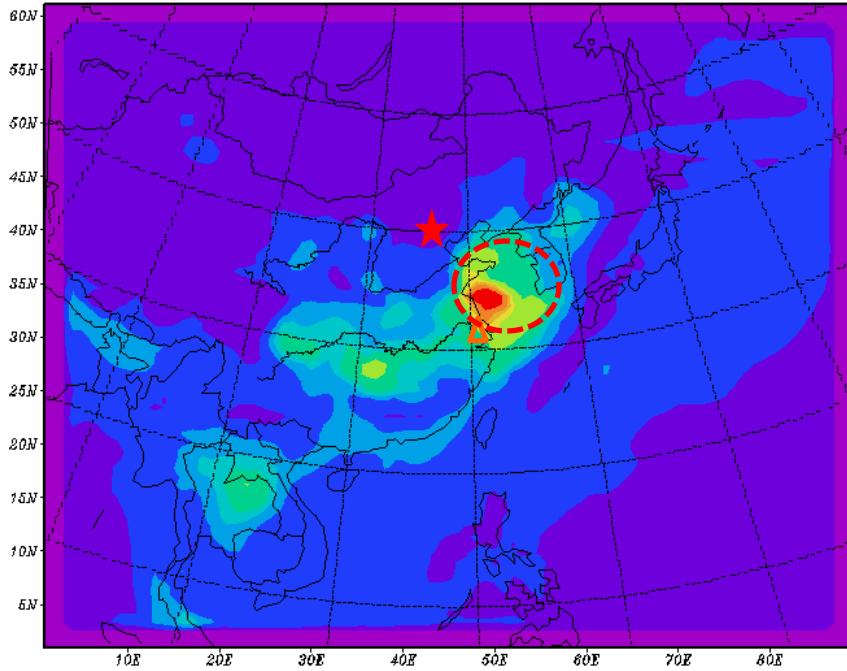
2011/04/30 11:00 -14:00 am
(MODIS aqua & terra: NASA)



2011/04/30 12:00 am
(CAMx simulation with assimilation)

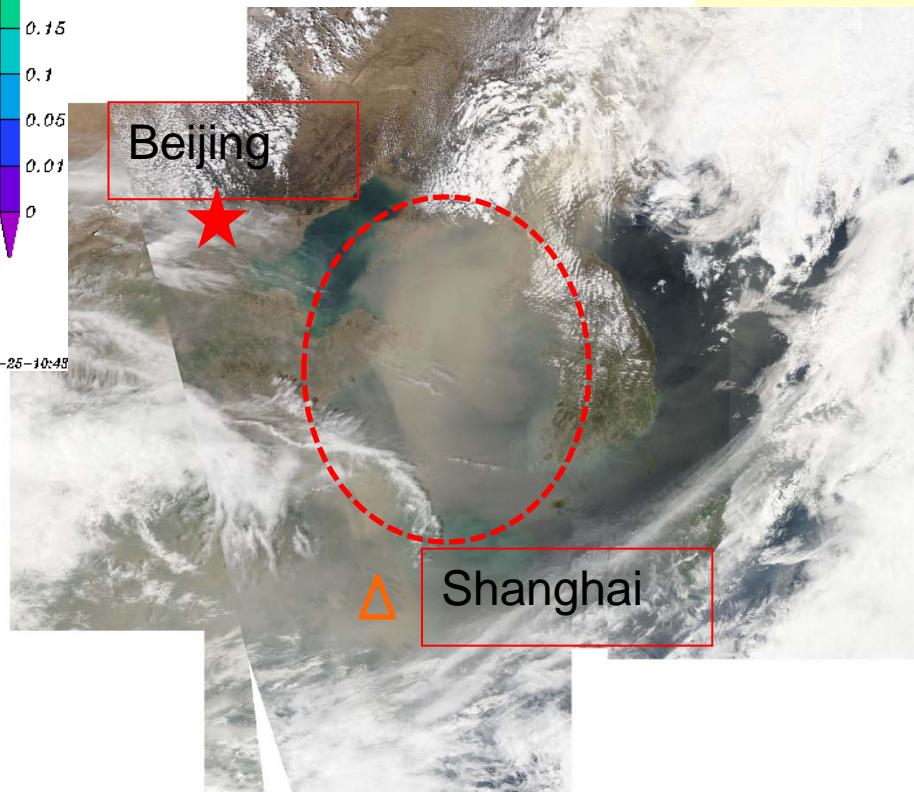
Application----dust storm forecast

PM10 Concentration (mg/m³) at 2011/05/01 12:00(BJtime)

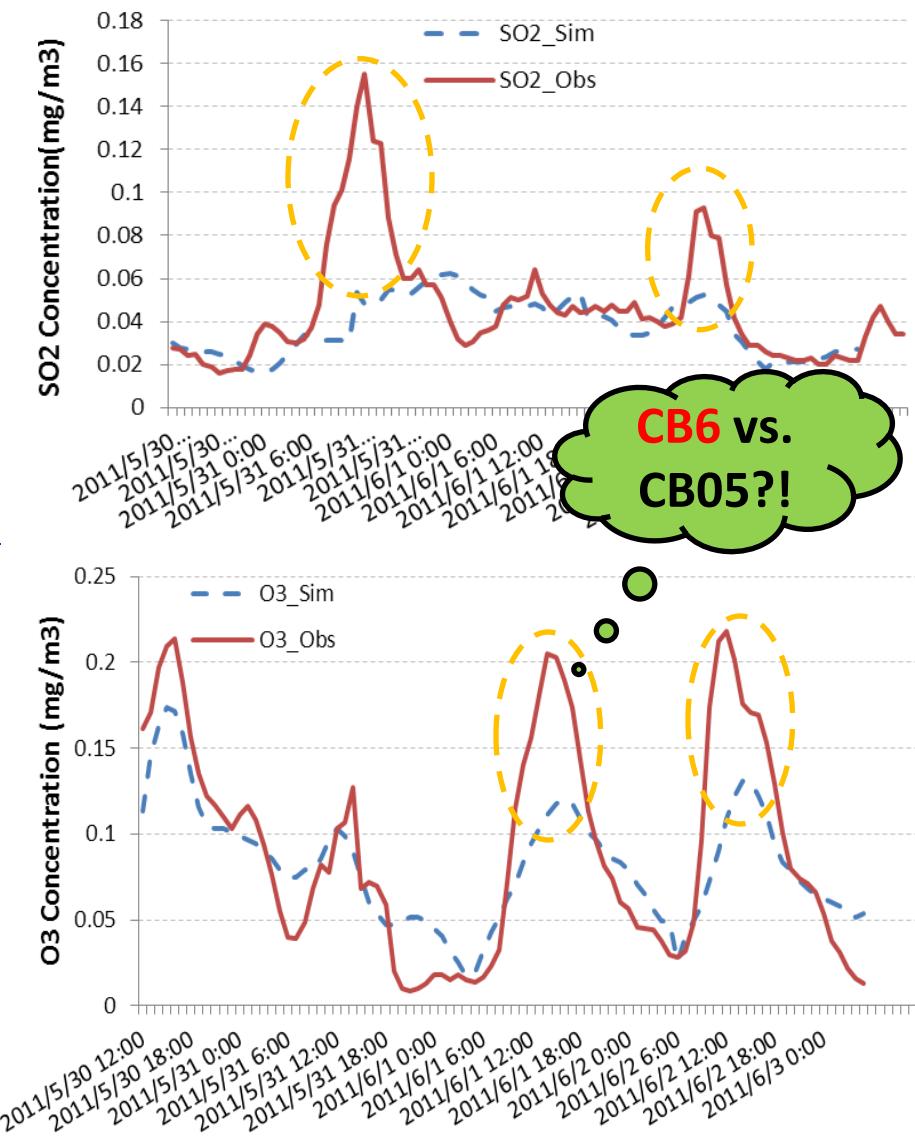
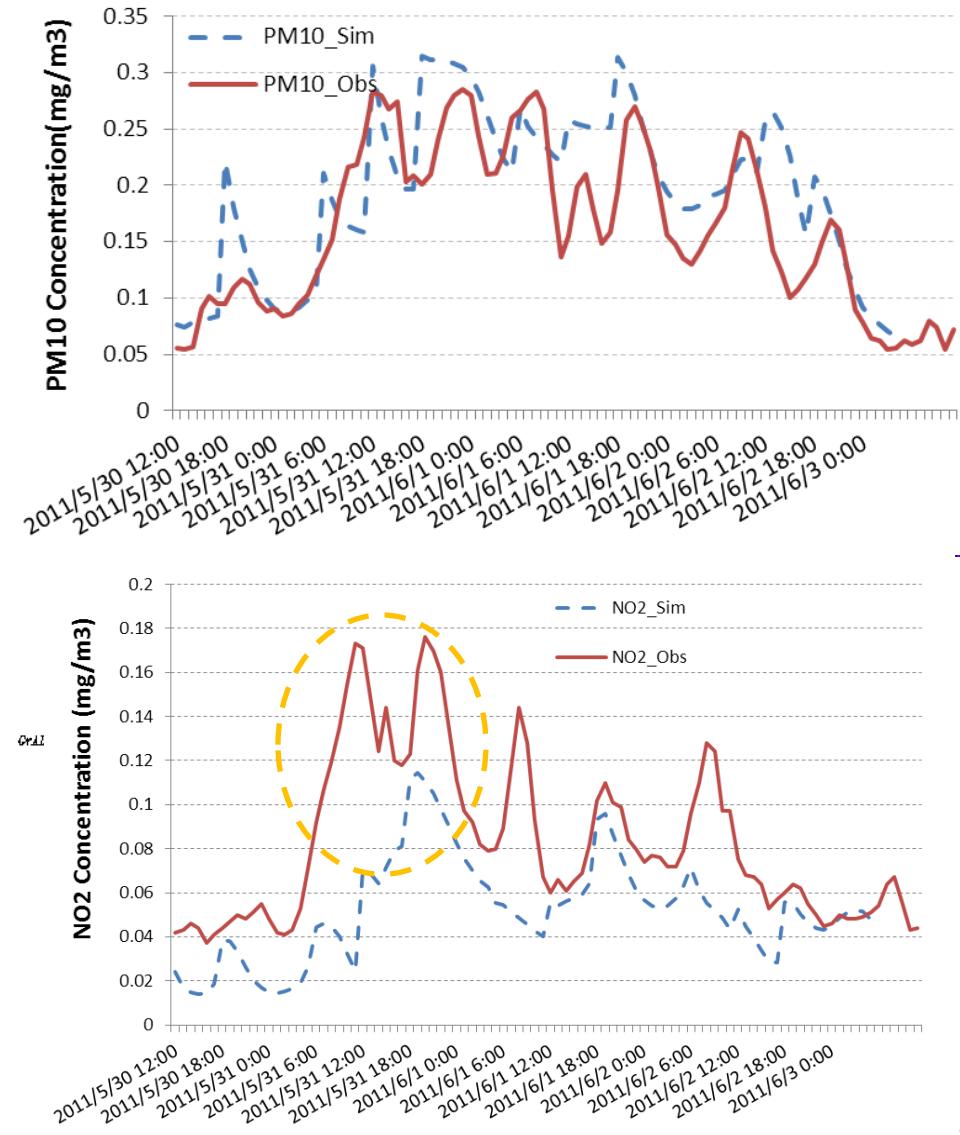


2011/05/01 12:00 am
(CAMx simulation with assimilation)

2011/05/01 11:00 -14:00 am
(MODIS aqua & terra: NASA)



Application----regional haze forecast



(Greg Yarwood et al., 2010)

Outline



Introduction



Model performance



Model application



Future plan

Future plan

More sufficient observations

- Three dimensional monitoring network for air pollution transportation events;
- Increased monitoring species with higher spatial and temporal resolution;

Performance evaluation

- Improvements of emission inventory on regional and local scale based on model performance evaluation
- More ensemble method for improving model performance

Continuously operational running and improving

- Operational running with a large amount of business practices and application;
- Keep improving and providing advanced forecasting services to the public;

Thanks for your attention!