

Development of an **E**nsemble air quality **M**odeling forecast **S**ystem for **Beijing** Olympic Game 2008 (EMS-Beijing)

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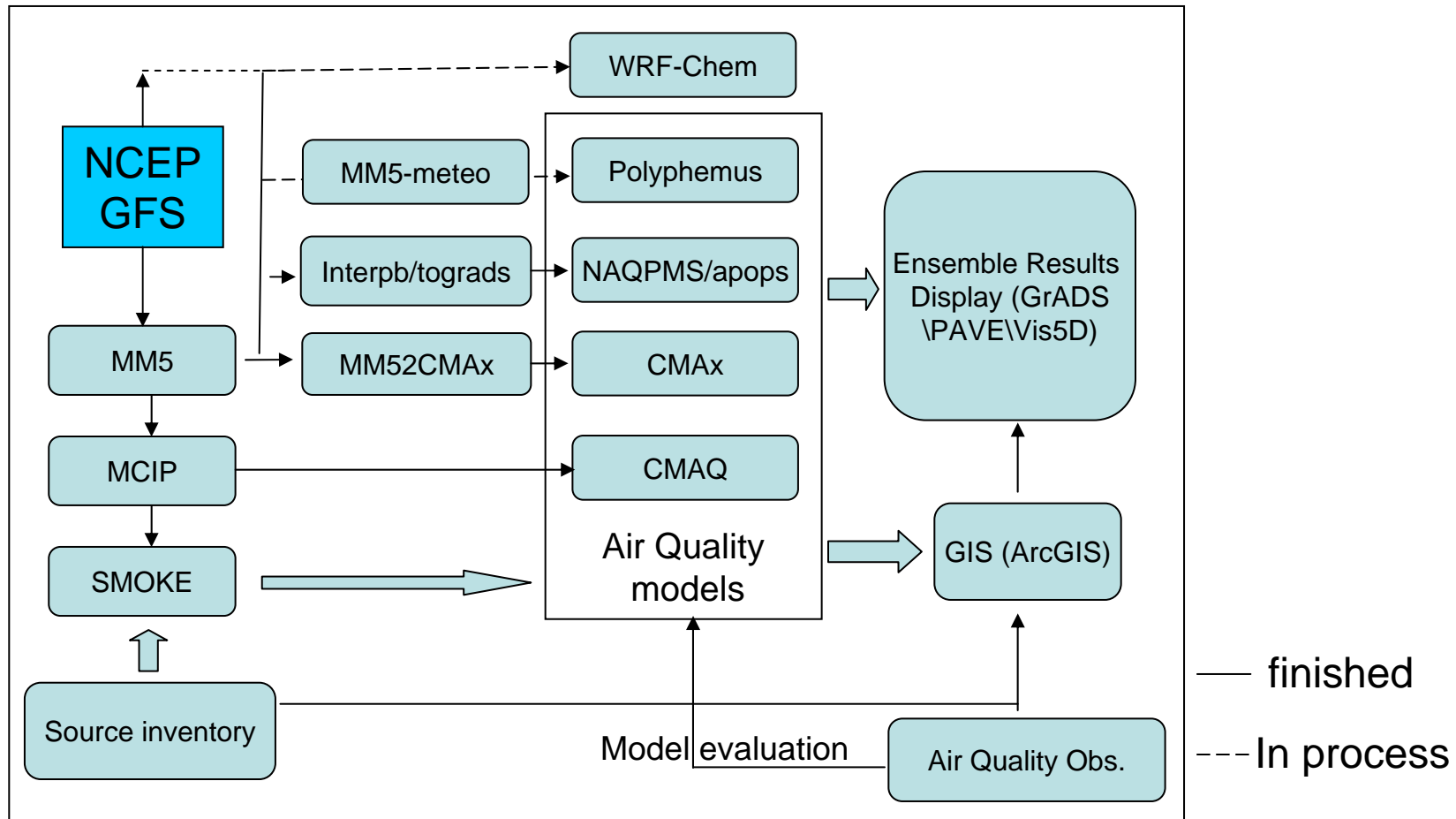
Development of an Ensemble air quality Modeling forecast System for Beijing Olympic Game 2008 (EMS-Beijing)

Outline

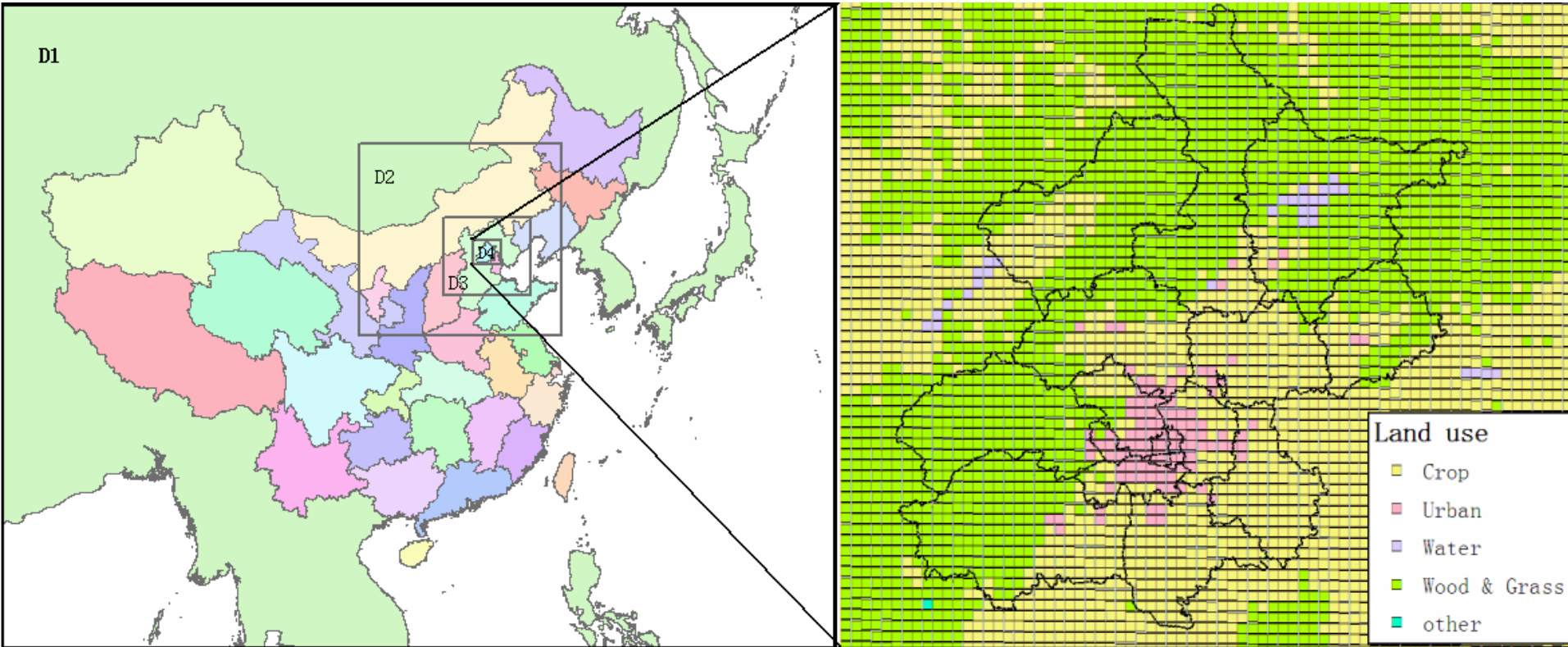
- I. EMS-Beijing System Design
- II. Our efforts on GCTM (GEATM)
- III. Comments on MICS-Asia Phase 3



Ensemble Air Quality system Framework

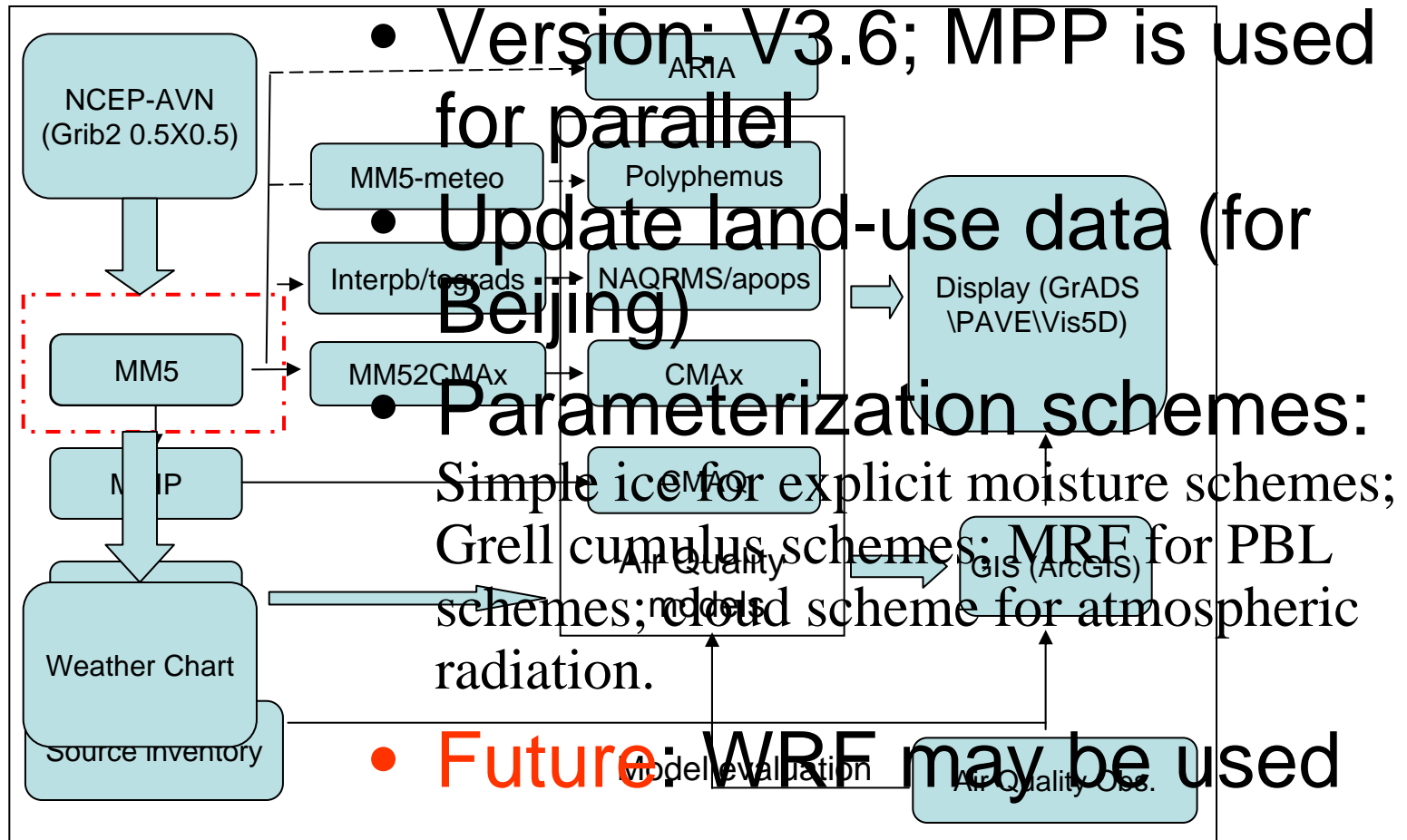


Domain Setup



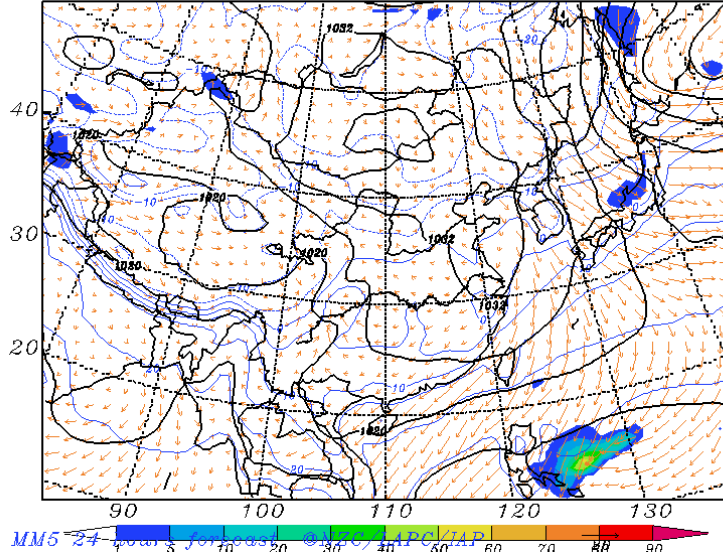
- D1 covers East Asia with 83x65 grids; D2 with 61x58 grids includes North China; D3 with 79x70 grids consists of Beijing and its surrounding cities. D4 with 73x64 grids covers Beijing Municipality.

Meteorological field

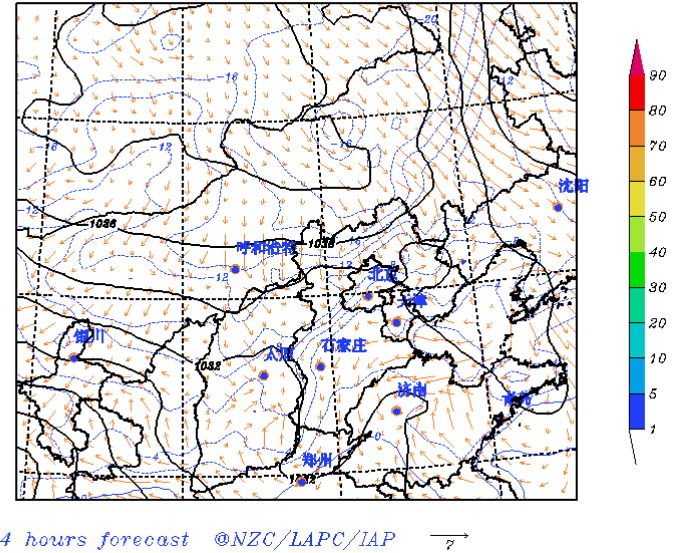


Weather Chart

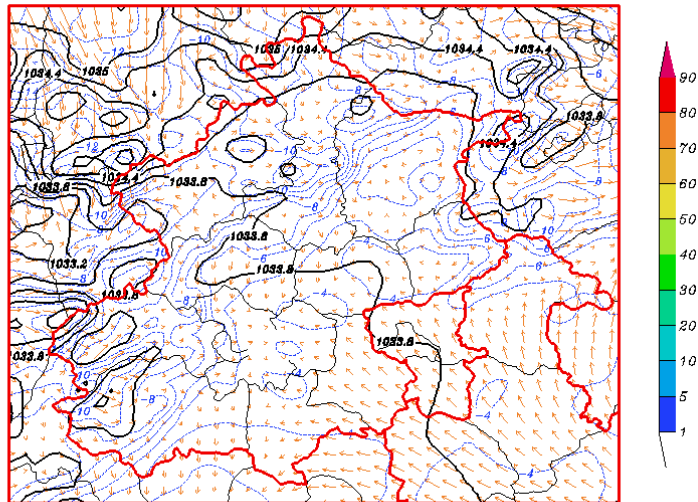
Weather Chart & Rain(mm/3h) 20Z15FEB2008(BJT)



Weather Chart & Rain(mm/3h) 20Z15FEB2008(BJT)

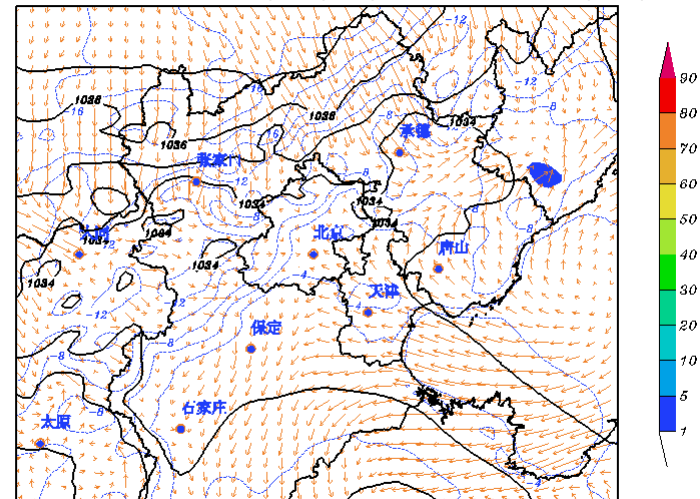


Weather Chart & Rain(mm/3h) 20Z15FEB2008(BJT)



MM5 24 hours forecast @NZC/LAPC/IAP

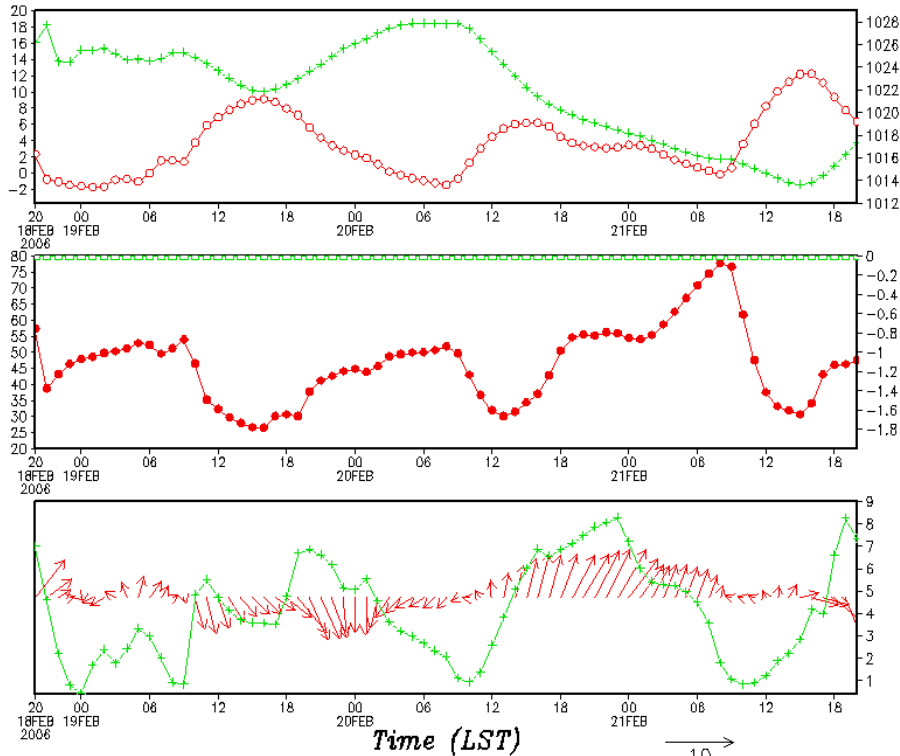
Weather Chart & Rain(mm/3h) 20Z15FEB2008(BJT)



MM5 24 hours forecast @NZC/LAPC/IAP

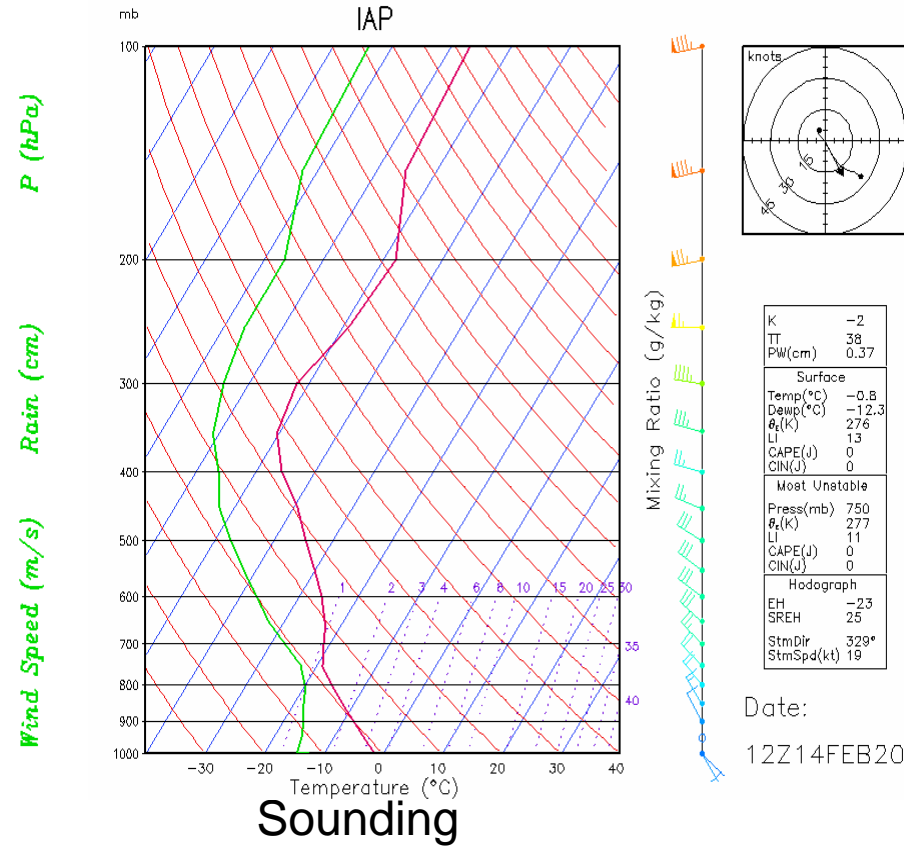
Station forecast

Aoti



Time series (for T/P/Rh/Rain/U-V)

IAP

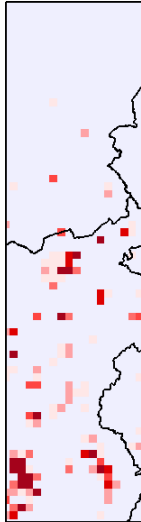


Sounding

Date:
12Z14FEB2008

Trajectory analysis

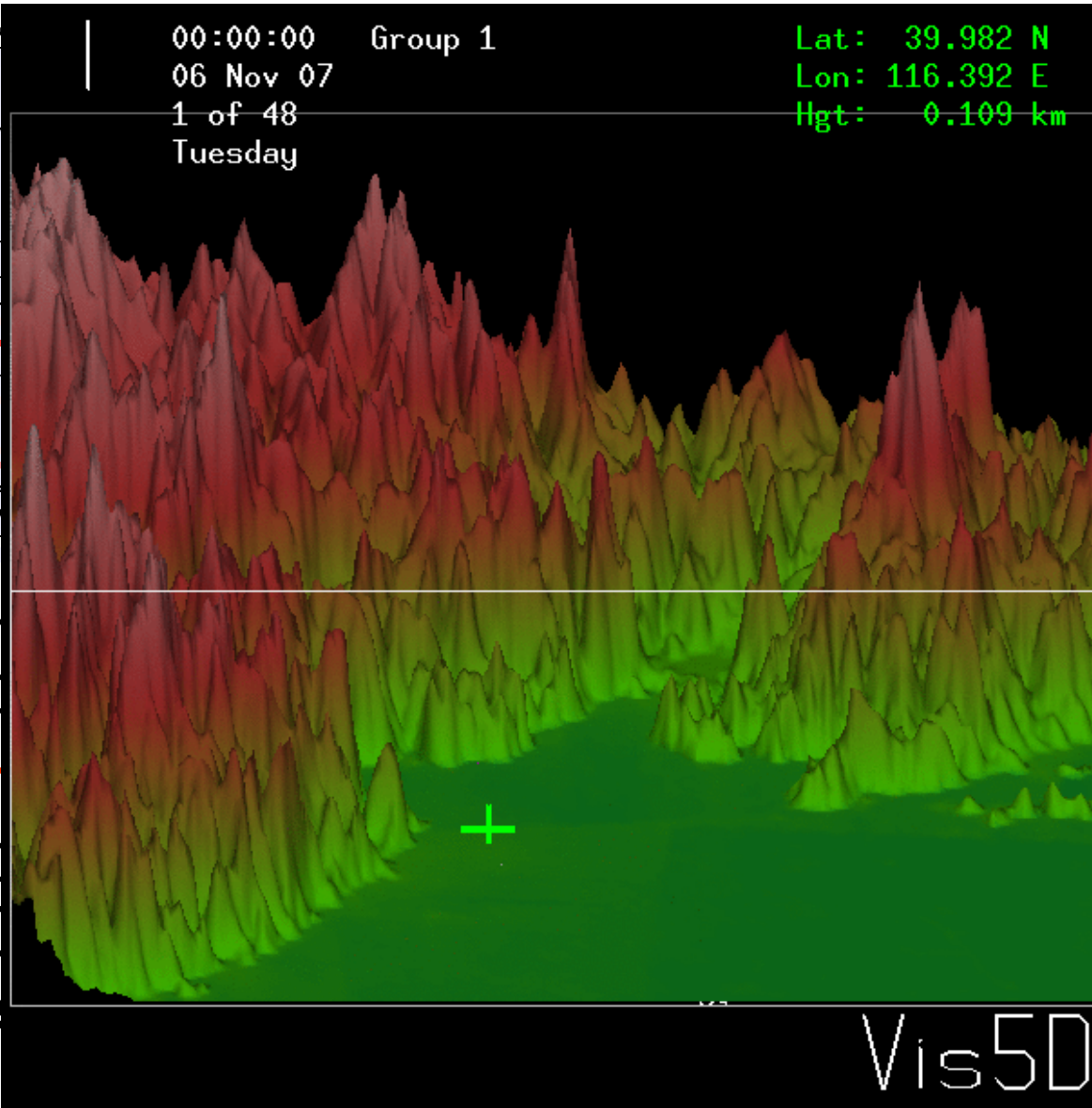
the 24hr bac



00:00:00 Group 1
06 Nov 07
1 of 48
Tuesday

Lat: 39.982 N
Lon: 116.392 E
Hgt: 0.109 km

KU
950hpa
850hpa
700hpa
SO2 emiss

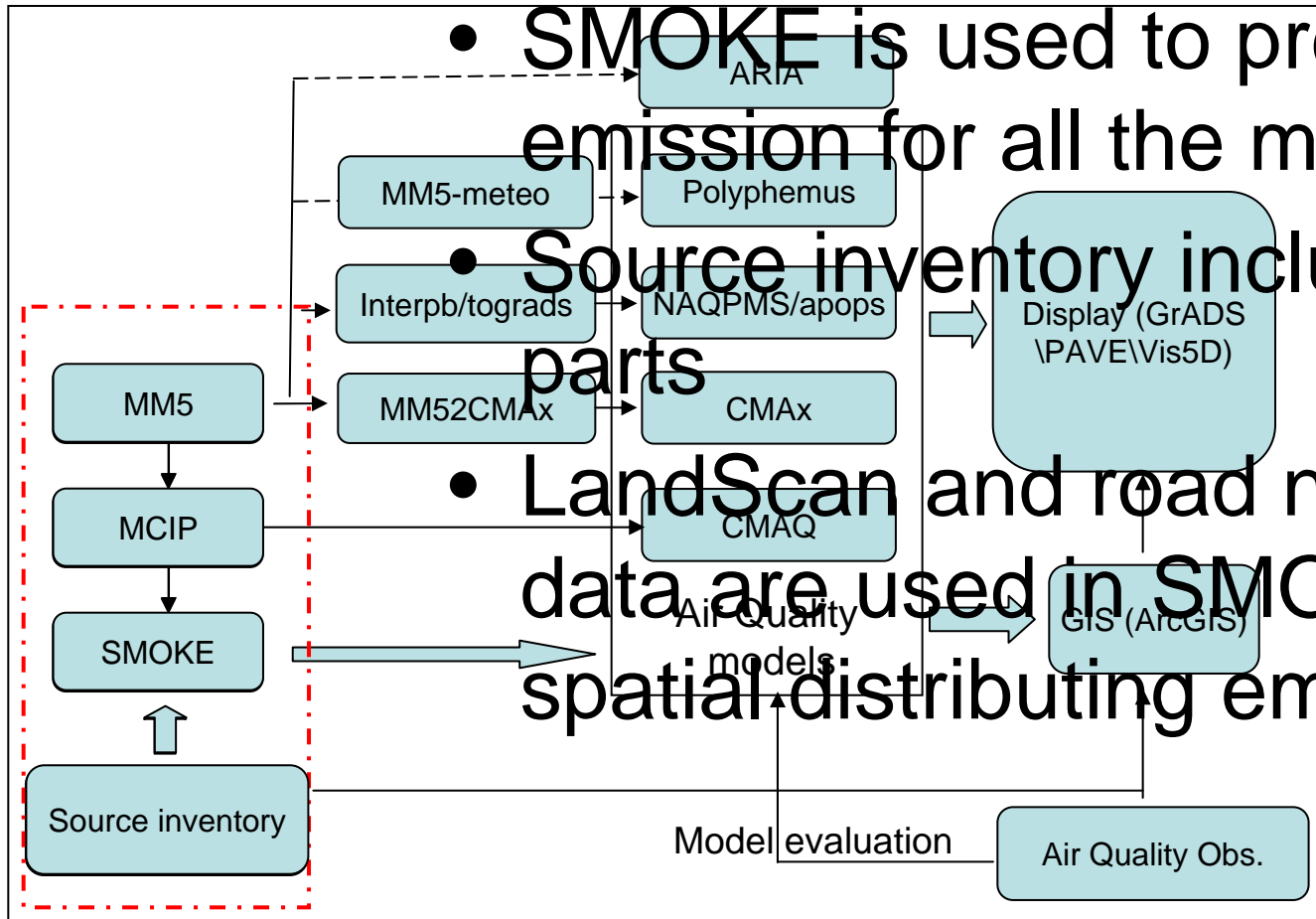


aida
950hpa
850hpa
700hpa
SO2 emiss

©ADS: COLA/IGES

- 24-\4
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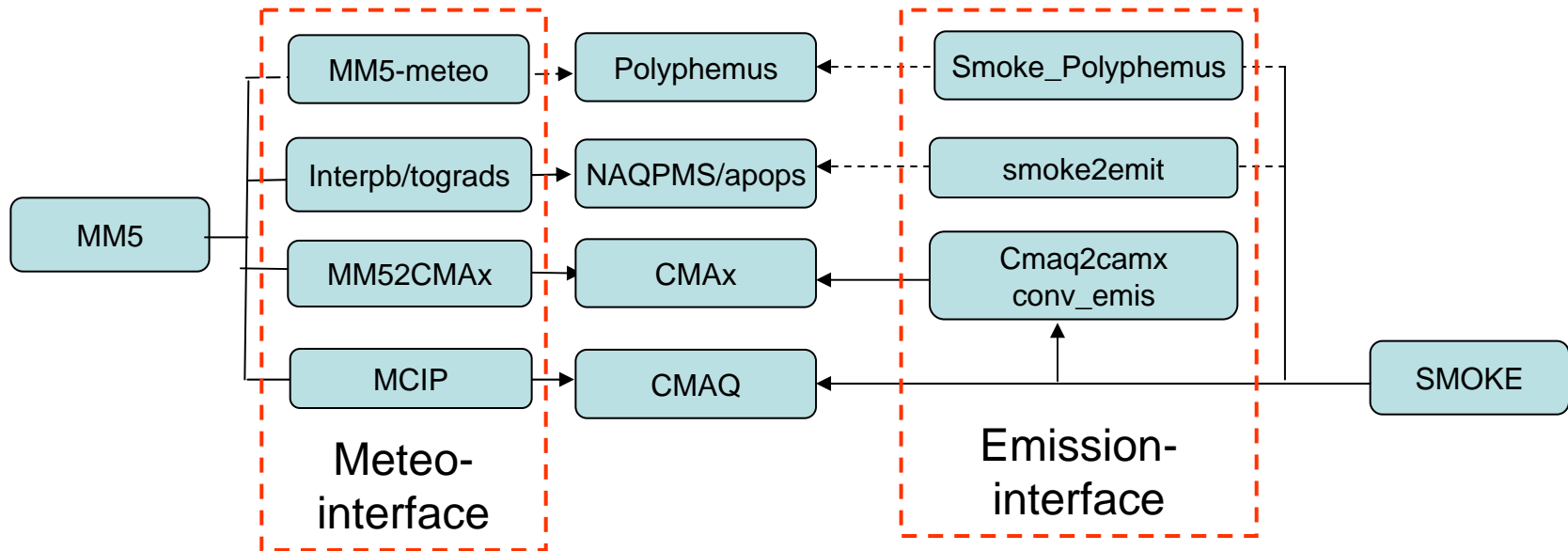
Emission Process



- SMOKE is used to prepare emission for all the model

- Source inventory includes 3 parts

- LandScan and road network data are used in SMOKE for spatial distributing emission



- The same meteorological field and the same emission will be used for the system

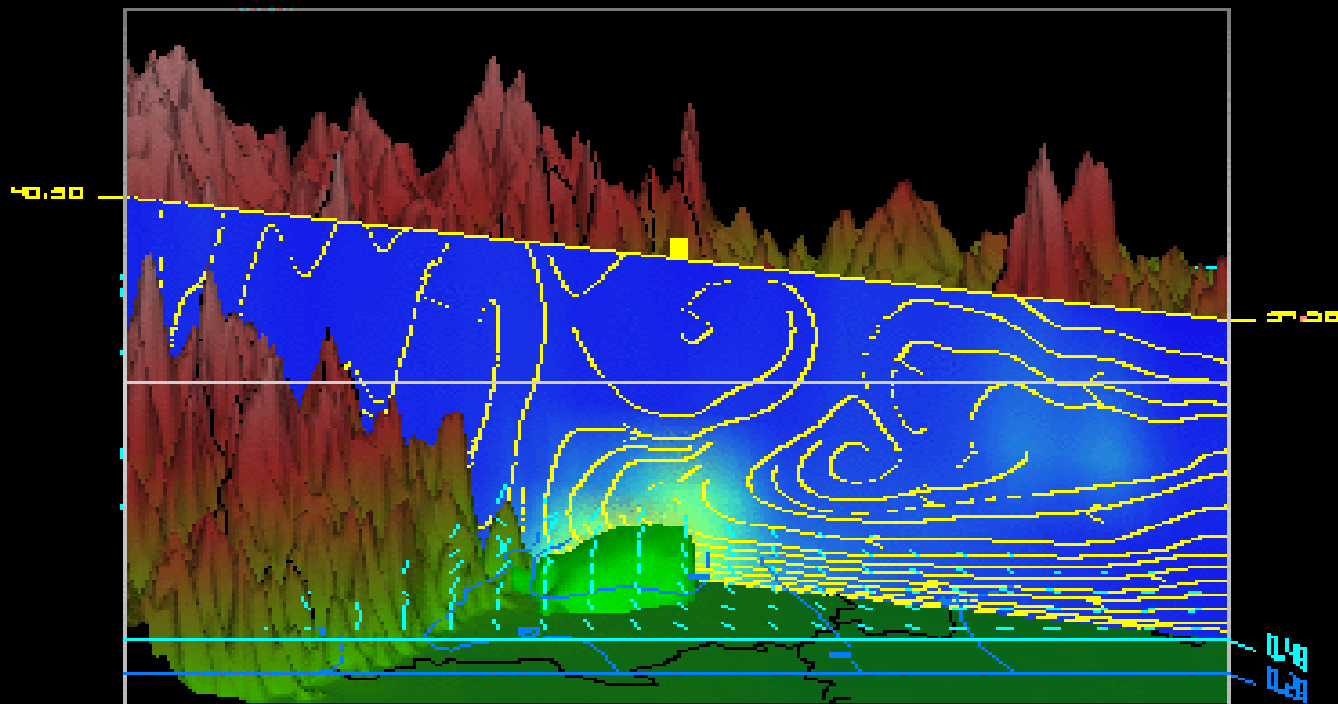
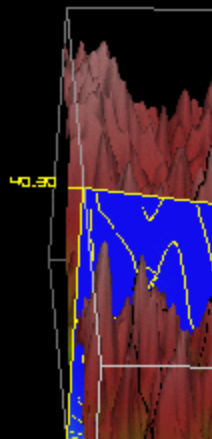
BC and IC

- Boundary Condition:
 - NAQPMS model: two-way nested
 - BJ81's BC is cold start, GEO-chem will be used soon
 - BJ81<->BJ27<->BJ09<->BJ03
 - CMAQ model: one-way nested
 - BJ81's BC is cold start, GEO-chem will be used soon
 - BJ81->BJ27->BJ09->BJ03
 - CAMx model: two-way nested
 - BJ09's BC is from CMAQ-BJ27
 - BJ09<->BJ03
- Initial Condition:
 - Use the previous day's 24-h forecast as initial condition, in near future, observations will be assimilated into the initial condition

19:00:0
07 Nov
44 of 4
Wednesd

01:00:00 Group 1
06 Nov 07
2 of 48
Tuesday

Output analysis



U = -2.89
V = -2.19
W = -0.00
SO2 = 18 ppb
O3 = 52 ppb
CO = 164 ppb
PM10 = 47.2 ug/m³
NO2 = 7.41 ppb

PM10 = 111 ug/m³
NO2 = 44.7 ppb

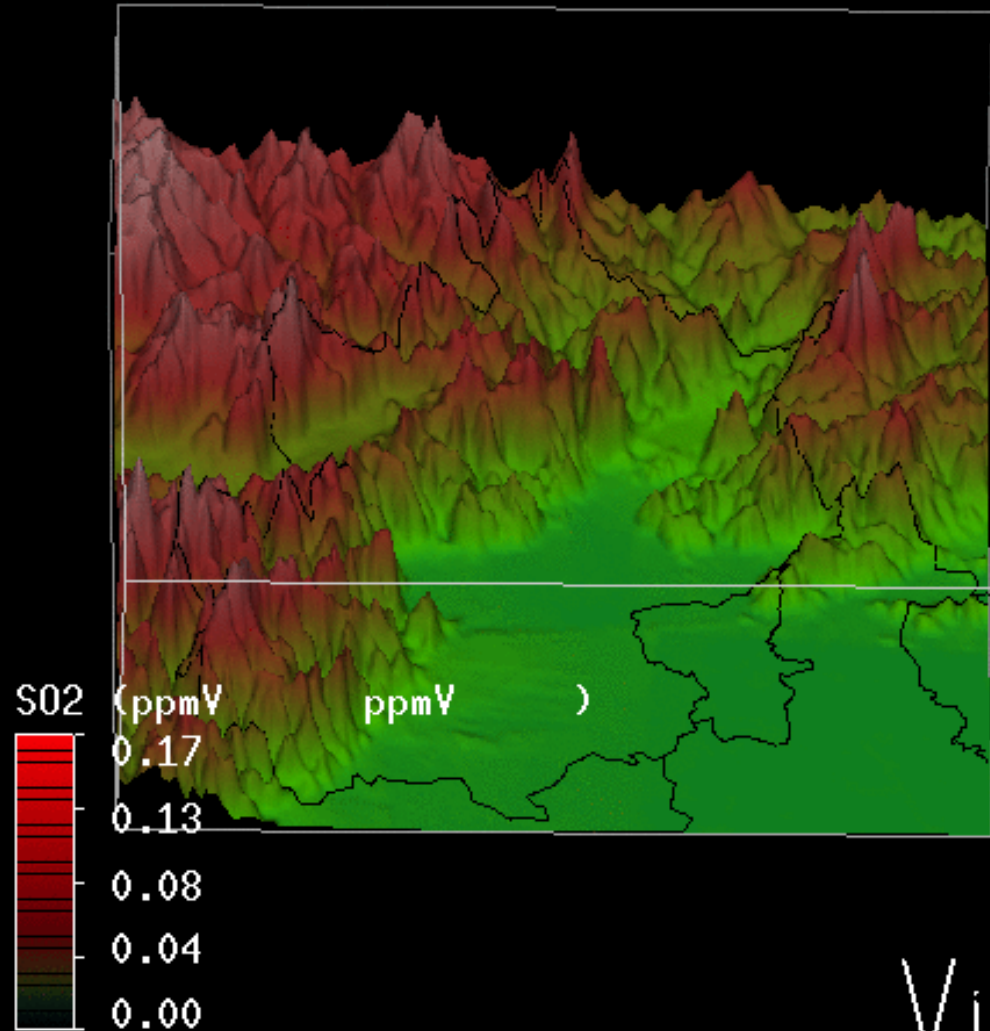
Vis50

Vis5

The output of NAQPMS

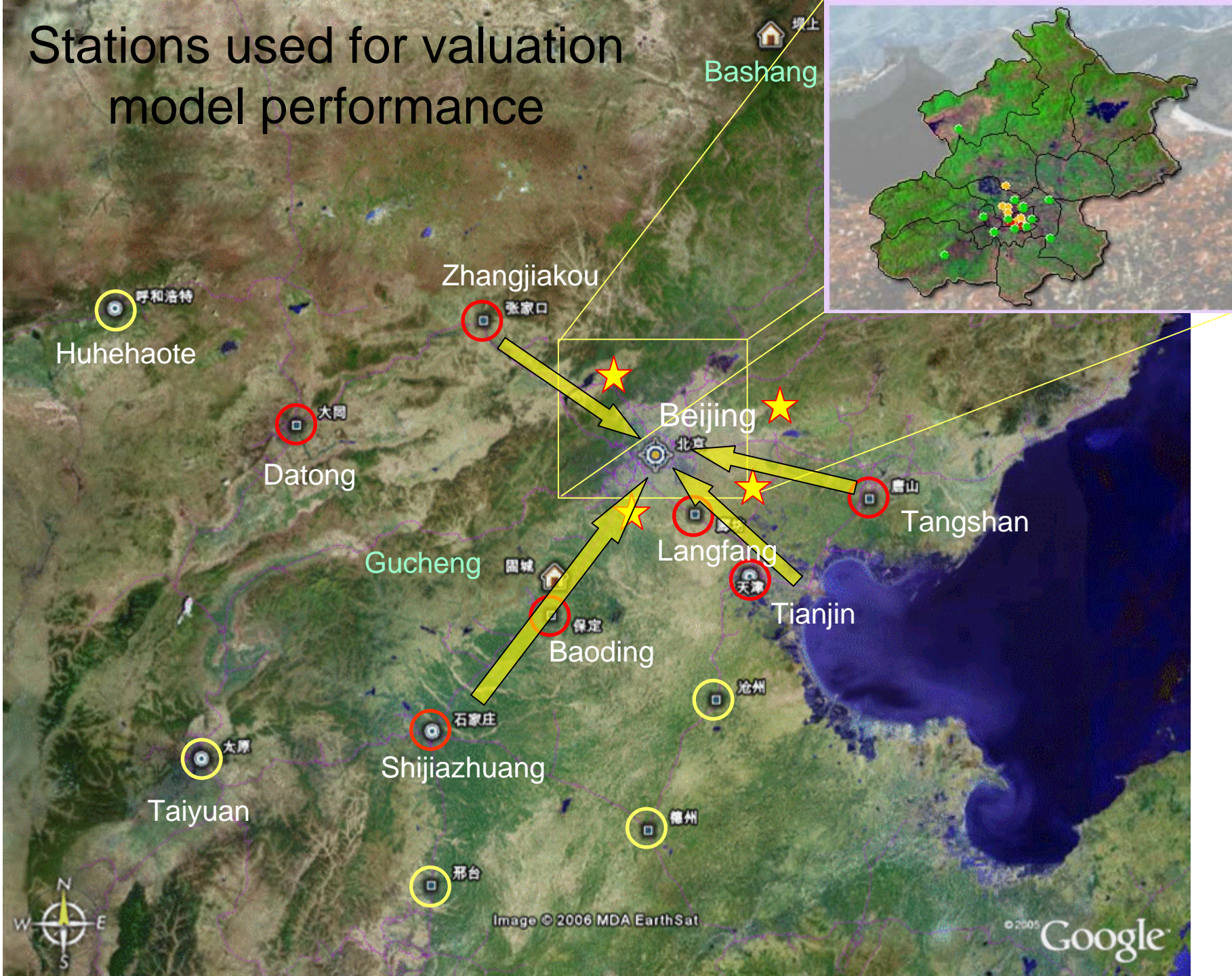
The output of CMAQ

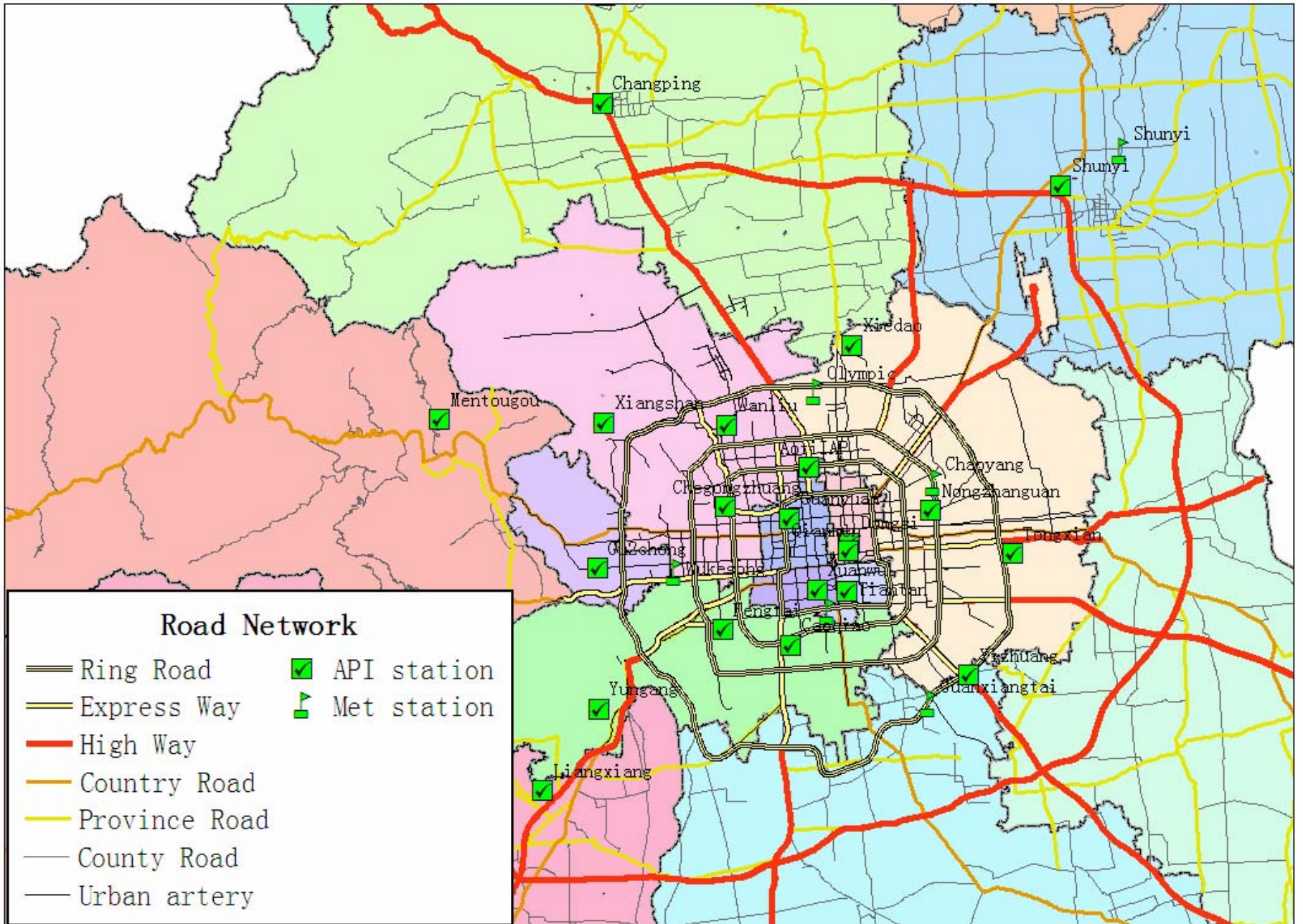
00:00:00 Group 1
06 Nov 07
1 of 49
Tuesday



Vis5D

Stations used for valuation model performance





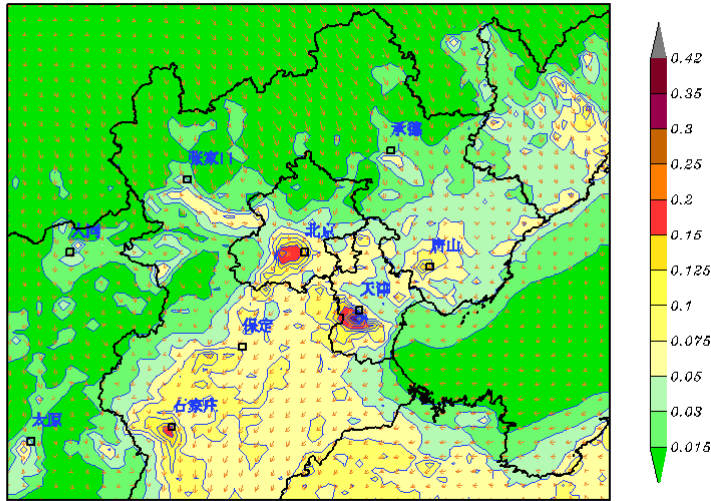
Output analysis

- The spatial distribution of air pollutant concentration (for real-time NAQPMS/CMAQ/CAMx, other models (Polyphemus, WRF-Chem) haven't finished for real-time)
- Ensemble forecasting with EnKF method

Ave PM10 in BJ09

NAQPMS

24-hour Mean Surface PM10 (mg/m³)
12Z15FEB2008-11Z16FEB2008(BJT)



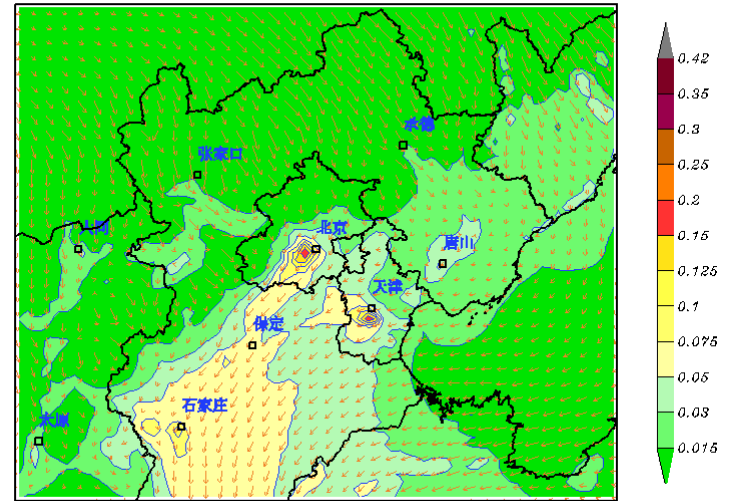
NAQPMS forecast

8

©Zifa.IAP

Model3/CMAQ

24-hour Mean Surface PM10 (mg/m³)
12Z15FEB2008-11Z16FEB2008(BJT)



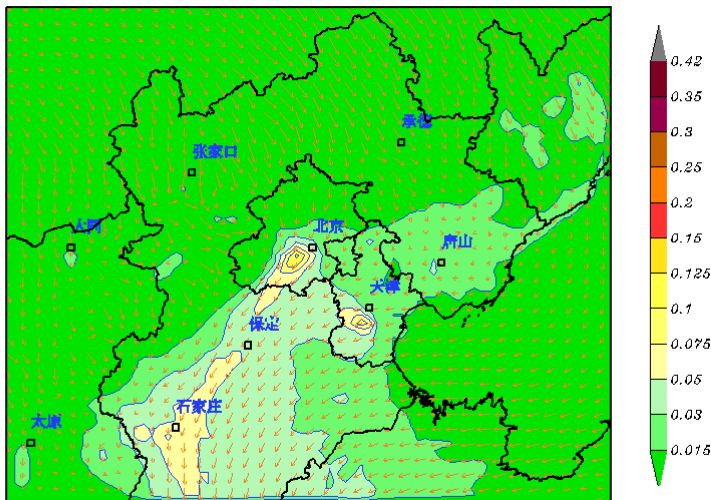
rCMAQ forecast

8

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CAMx

24-hour Mean Surface PM10 (mg/m³)
12Z15FEB2008-11Z16FEB2008(BJT)



CAMx forecast

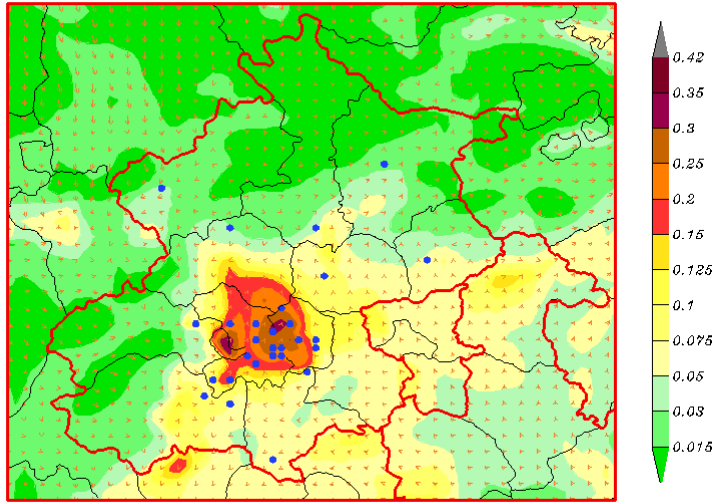
8

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PM10

NAQPMS

Surface PM10 (mg/m3) 13Z15FEB2008
BeiJing time 21Z15FEB2008



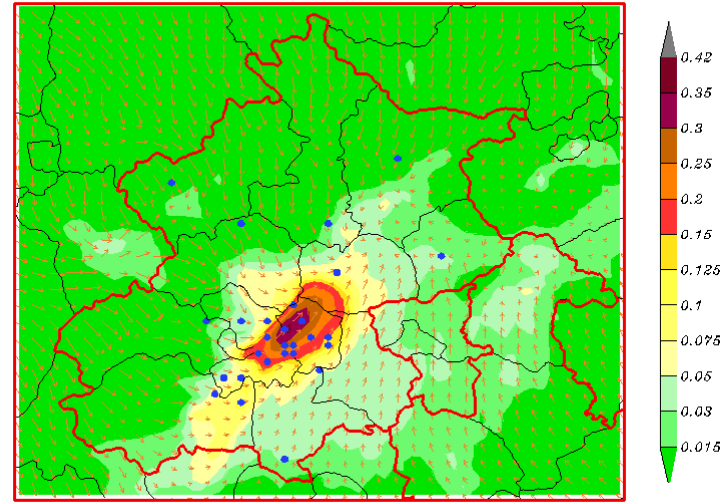
NAQPMS 01 hours forecast

10

@Zifa.IAP

Model3/CMAQ

Surface PM10 (mg/m3) 13Z15FEB2008
BeiJing time 21Z15FEB2008



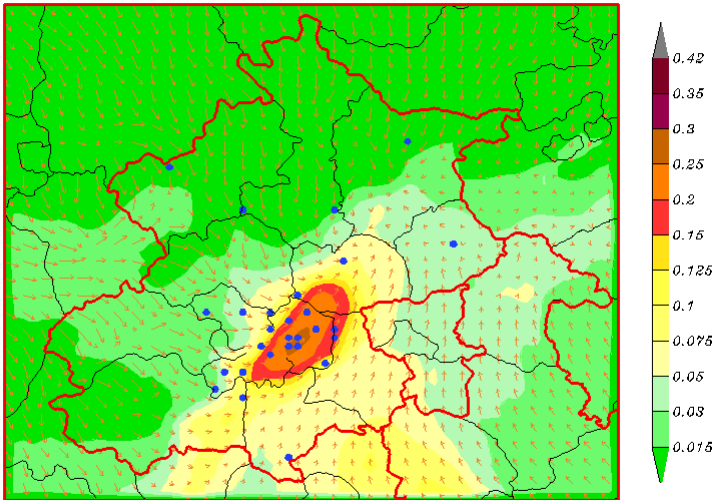
@Zifa.IAP rCMAQ 01 hours forecast

10

@Zifa.IAP

CAMx

Surface PM10 (mg/m3) 13Z15FEB2008
BeiJing time 21Z15FEB2008



PM₁₀ Ensemble Results

CAMx 01 hours forecast

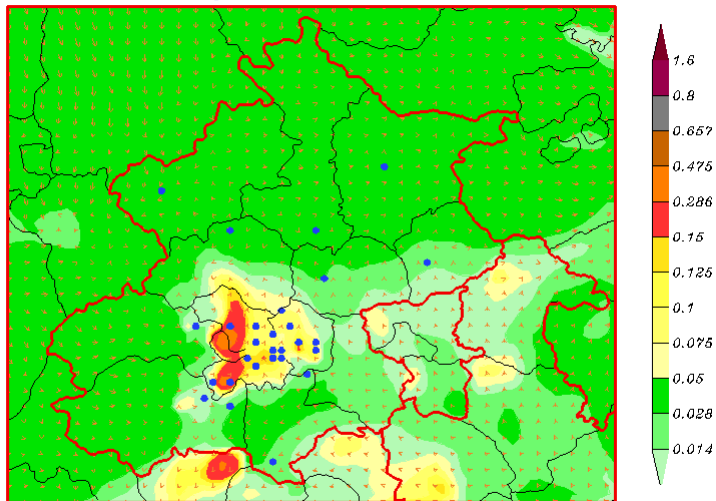
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@Zifa.IAP

SO₂

NAQPMS

Surface SO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



NAQPMS 01 hours forecast

$\overline{10}$

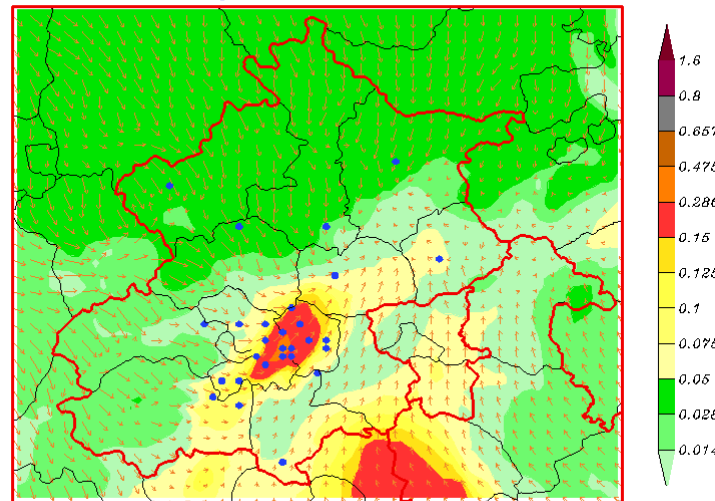
©Zifa.IAP rCMAQ 01 hours forecast

$\overline{10}$

©Robotalpha..

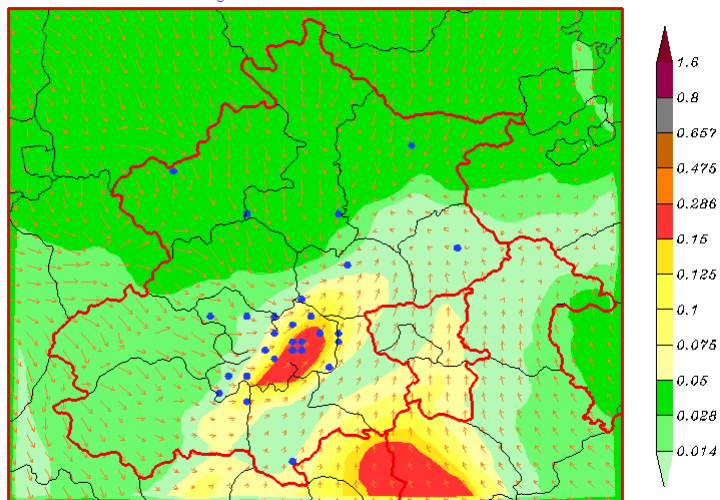
Model3/CMAQ

Surface SO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



CAMx

Surface SO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



rCAMx 01 hours forecast

$\overline{10}$

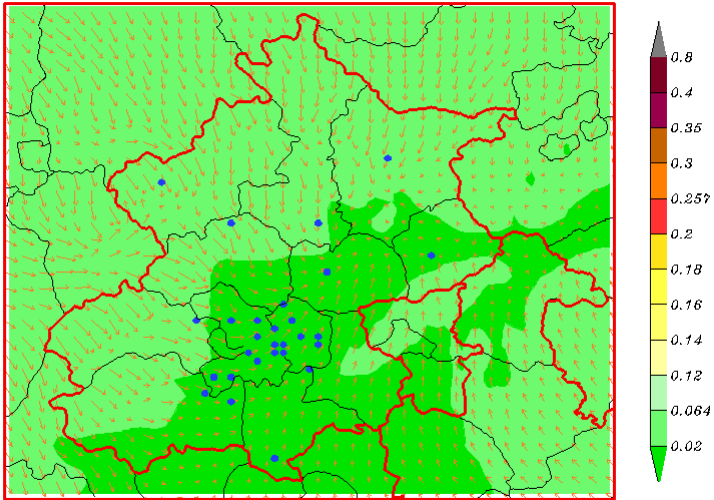
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SO₂ Ensemble Results

O₃

NAQPMS

Surface O₃ (mg/m³) 13Z15FEB2008
Beijing time 21Z15FEB2008



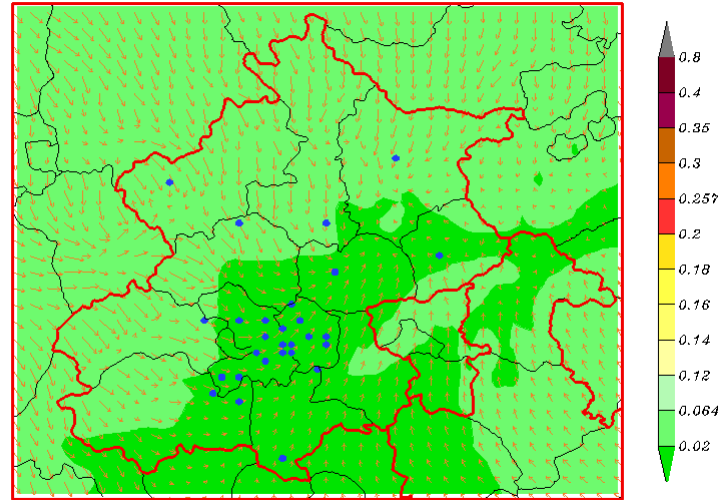
rcMAQ 01 hours forecast

70

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Model3/CMAQ

Surface O₃ (mg/m³) 13Z15FEB2008
Beijing time 21Z15FEB2008



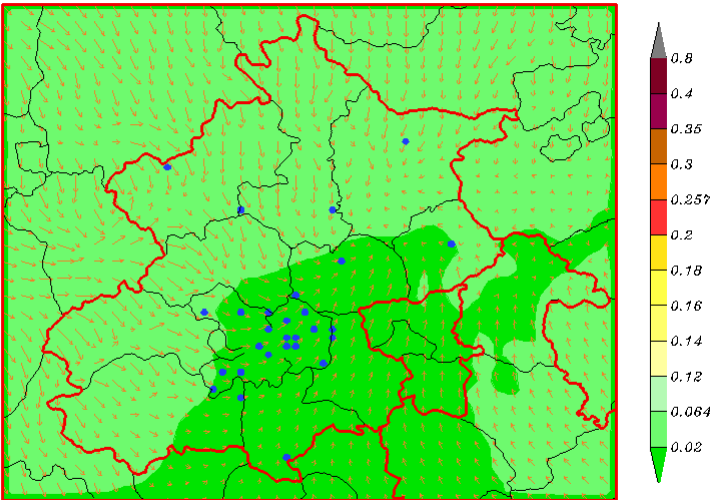
rcMAQ 01 hours forecast

70

@Zifa.IAP

Surface O₃ (mg/m³) 13Z15FEB2008
Beijing time 21Z15FEB2008

CAMx



CAMx 01 hours forecast

70

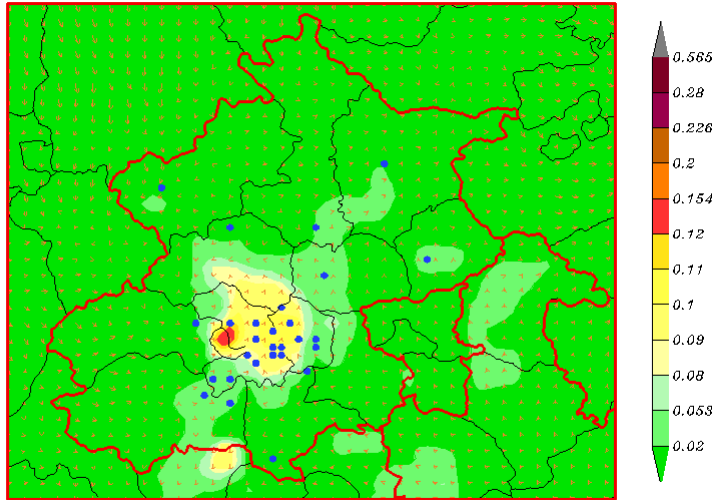
@Zifa.IAP

O₃ Ensemble Results

NO₂

NAQPMS

Surface NO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



NAQPMS 01 hours forecast

$\overline{70}$

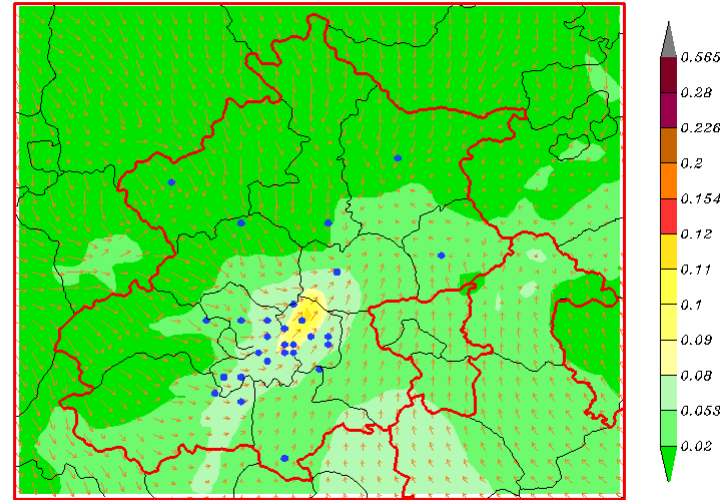
@Zifa.IAP rCMAQ 01 hours forecast

$\overline{70}$

@Zifa.IAP

Model3/CMAQ

Surface NO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



NAQPMS 01 hours forecast

$\overline{70}$

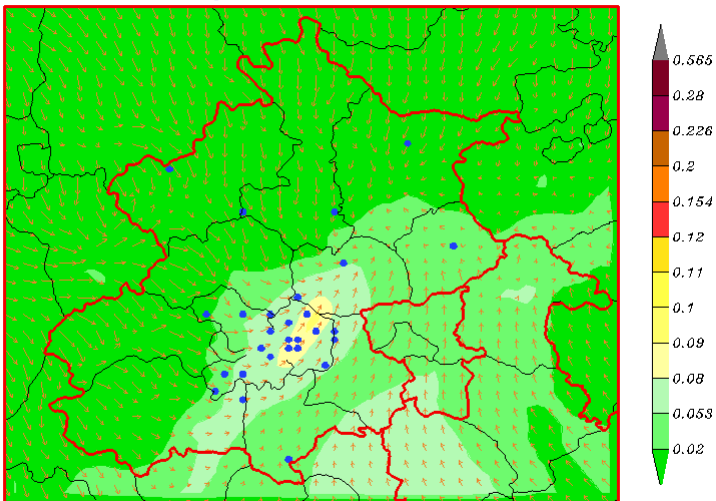
@Zifa.IAP rCMAQ 01 hours forecast

$\overline{70}$

@Zifa.IAP

CAMx

Surface NO₂ (mg/m³) 13Z15FEB2008
BeiJing time 21Z15FEB2008



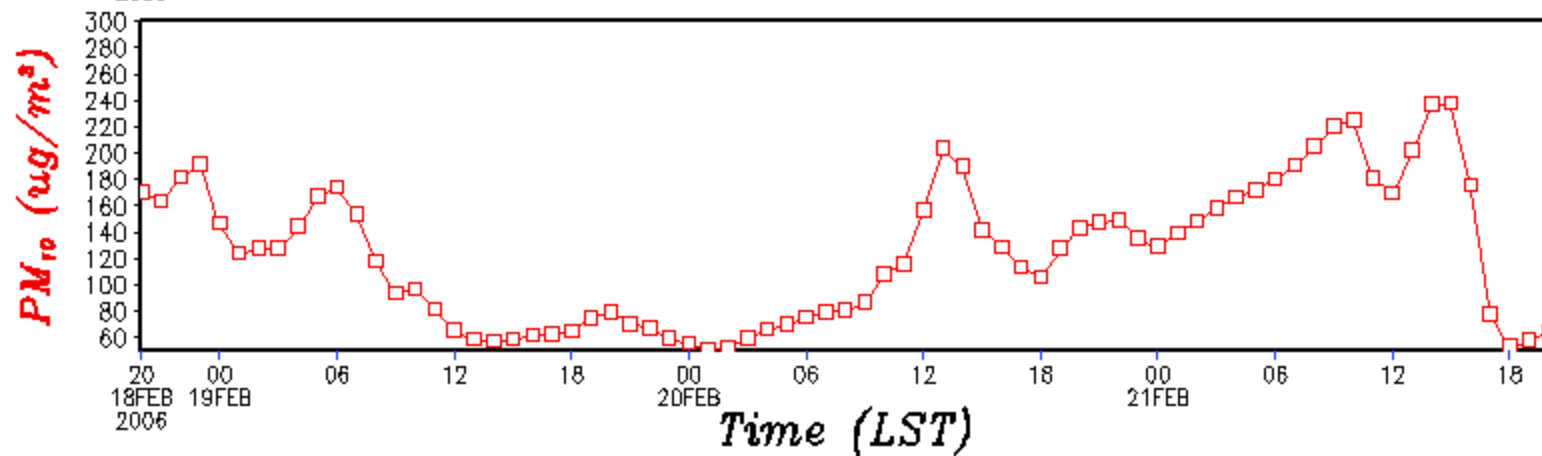
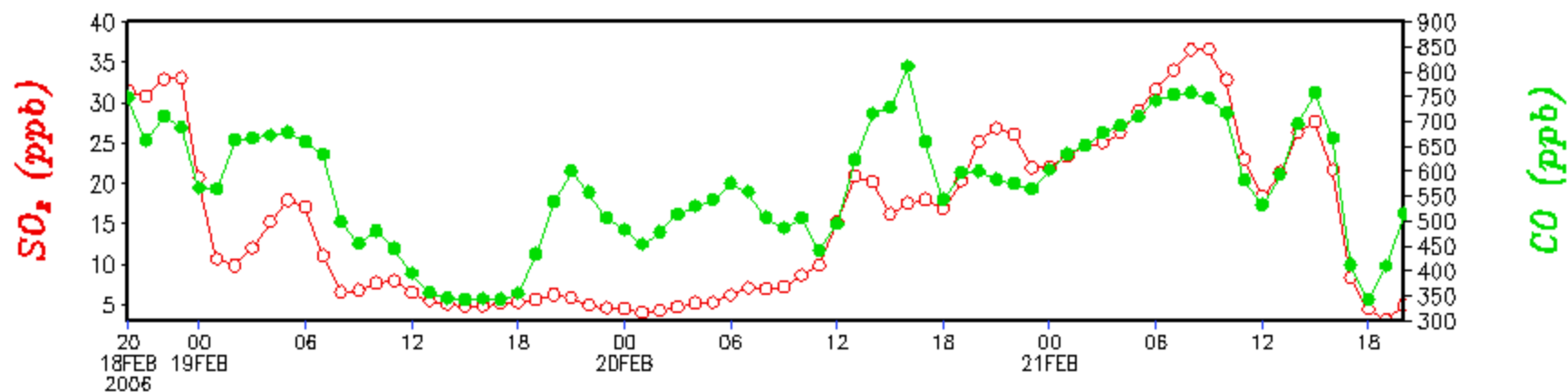
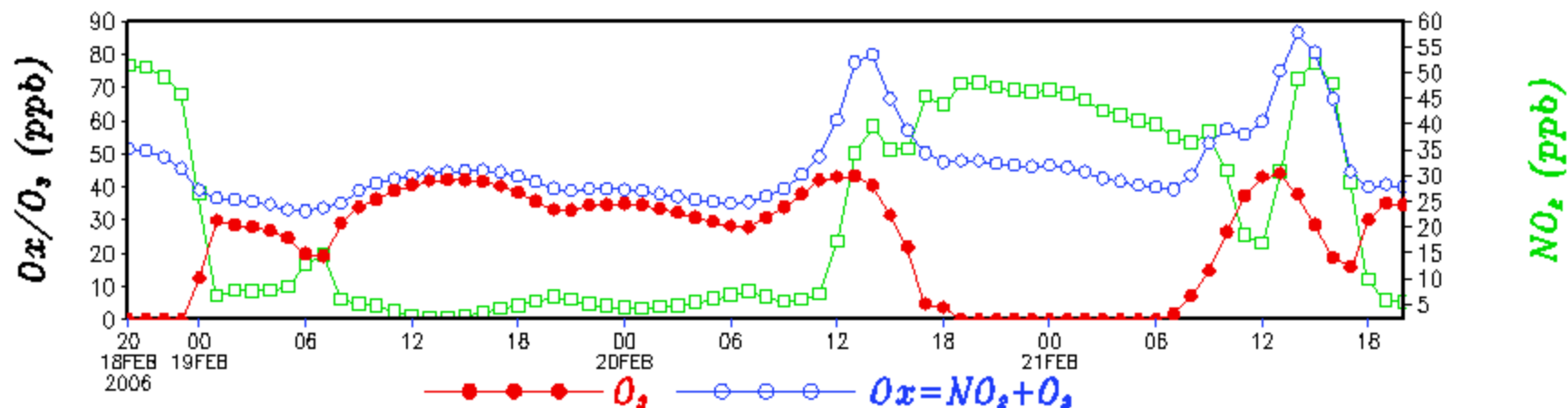
CAMx 01 hours forecast

$\overline{70}$

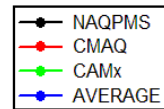
@Zifa.IAP

NO₂ Ensemble Results

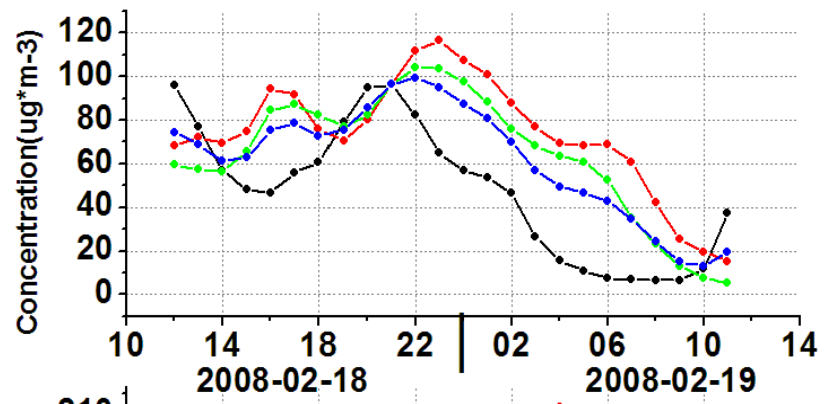
Aoti



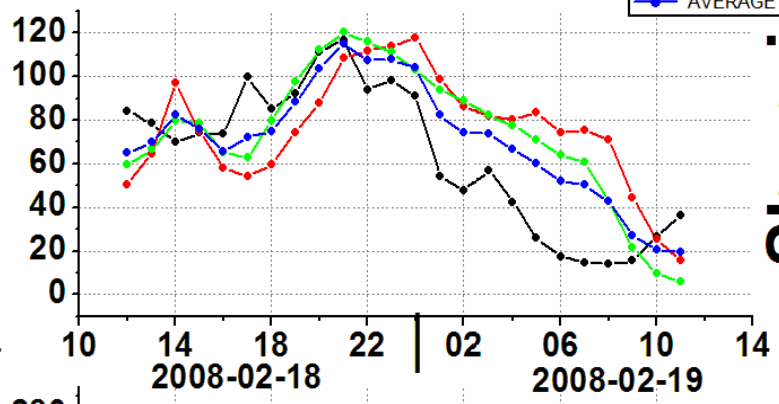
Station Forecast PM10



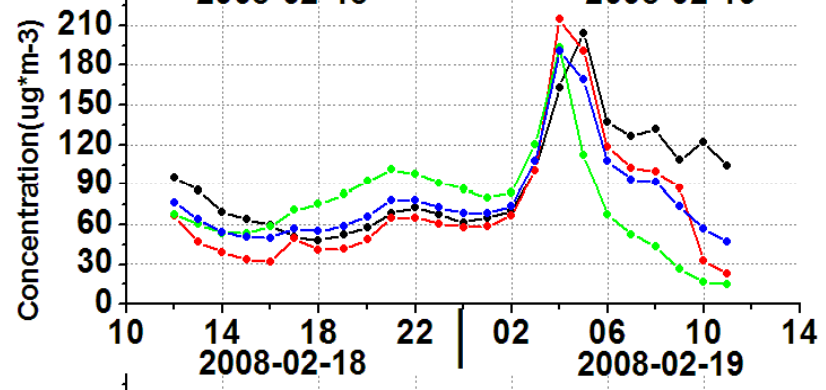
Huairou



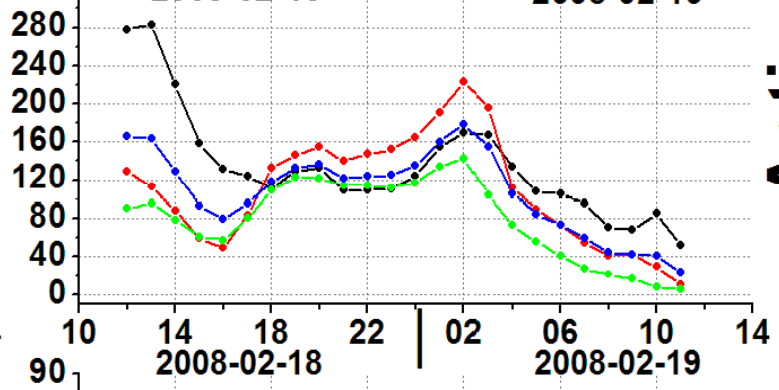
Shunyi



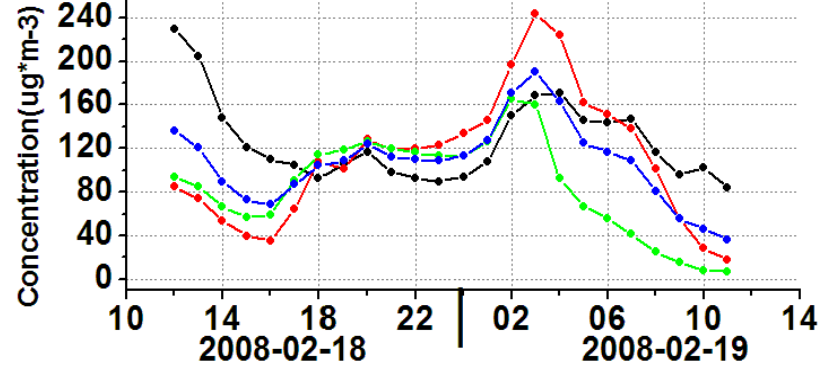
Yizhuang



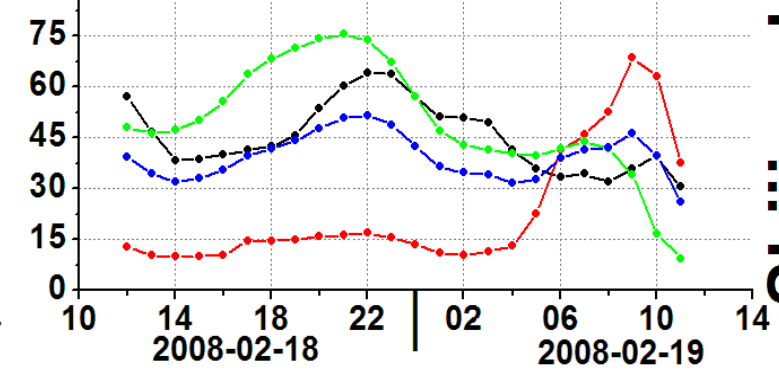
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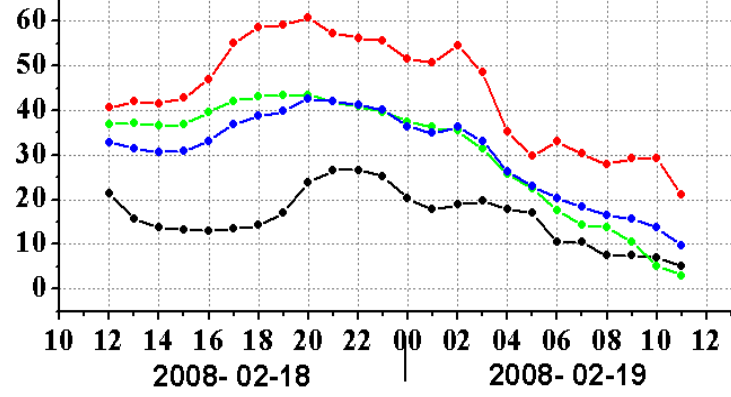
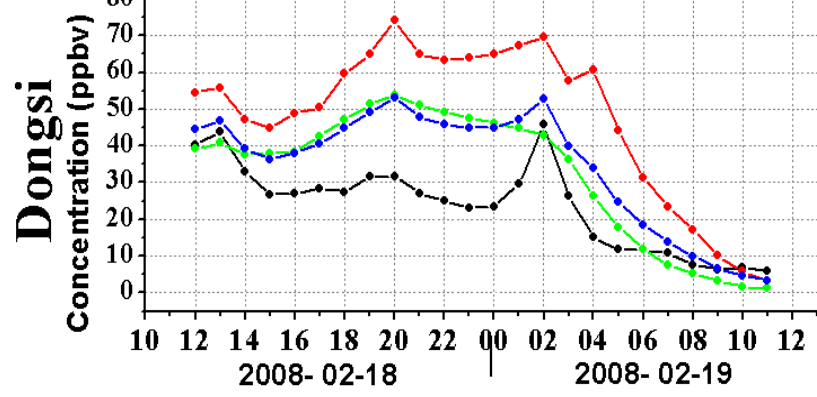
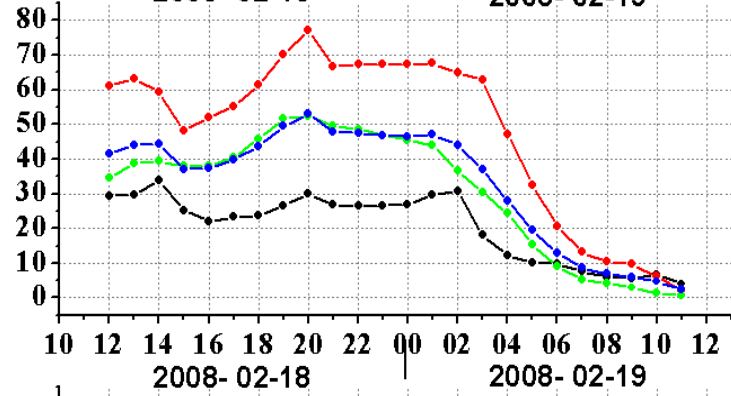
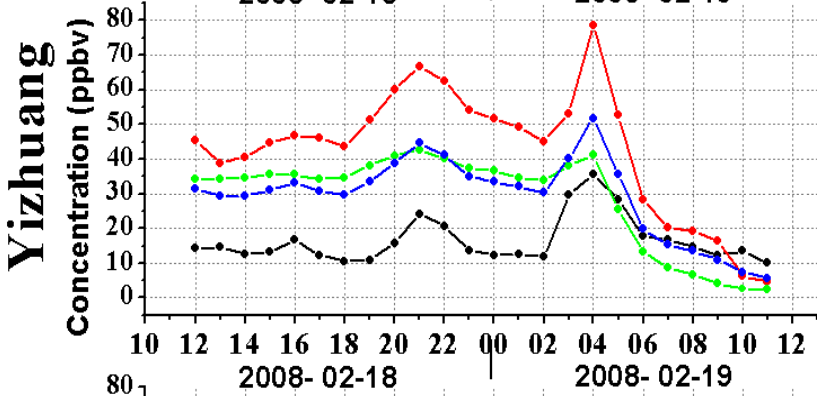
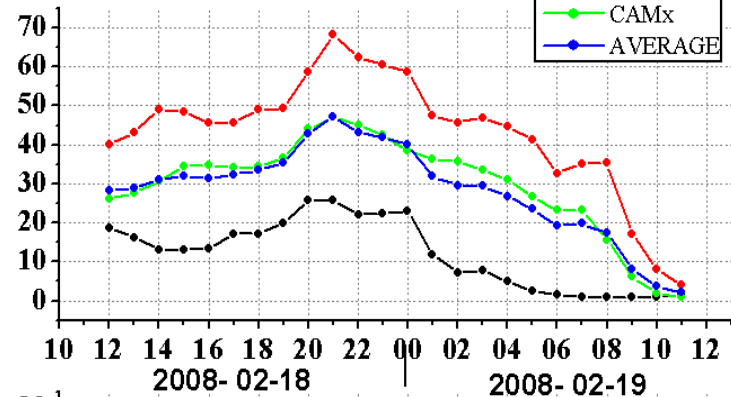
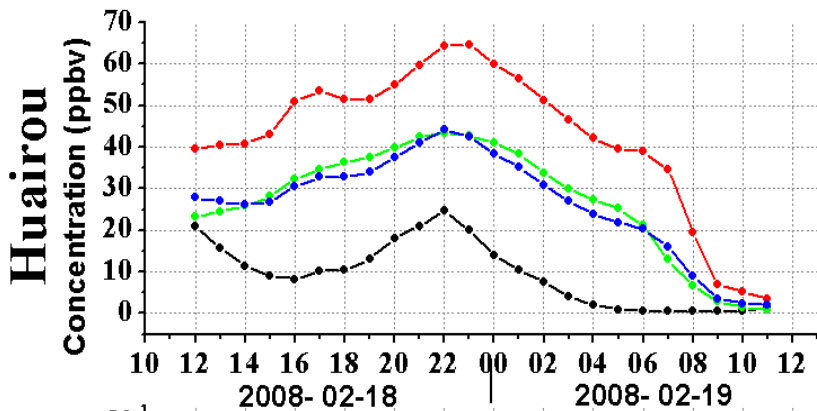
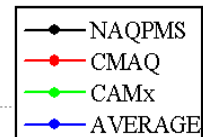
Dongsi



Shijingshan

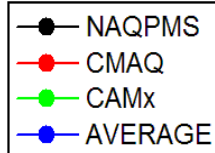


Station forecast: SO₂

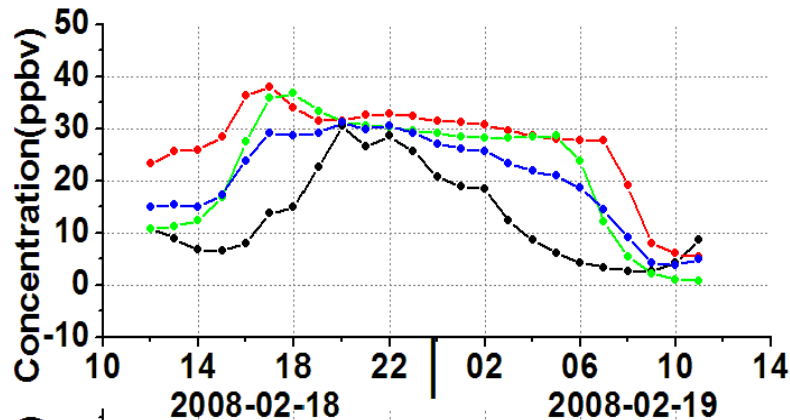


Beijing real-time forecast: Domain4 2008 BJT

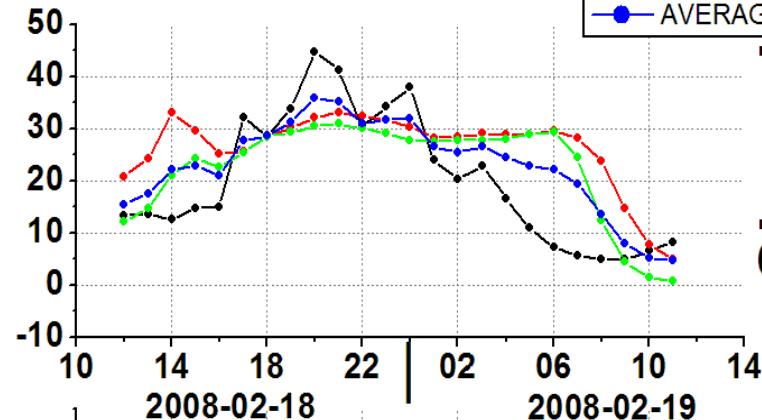
Station Forecast NO2



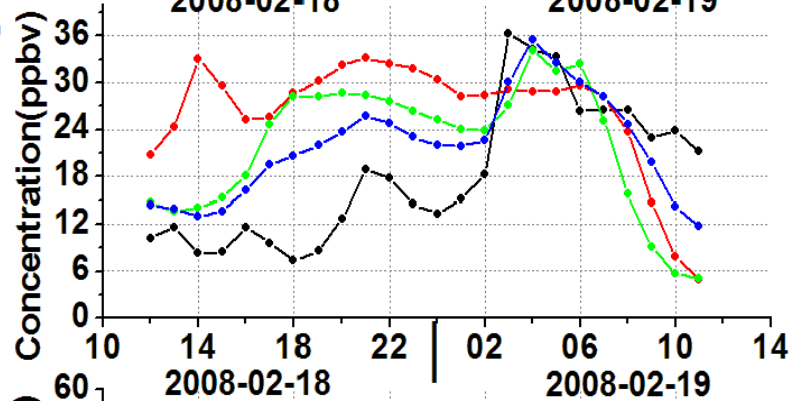
Huairou



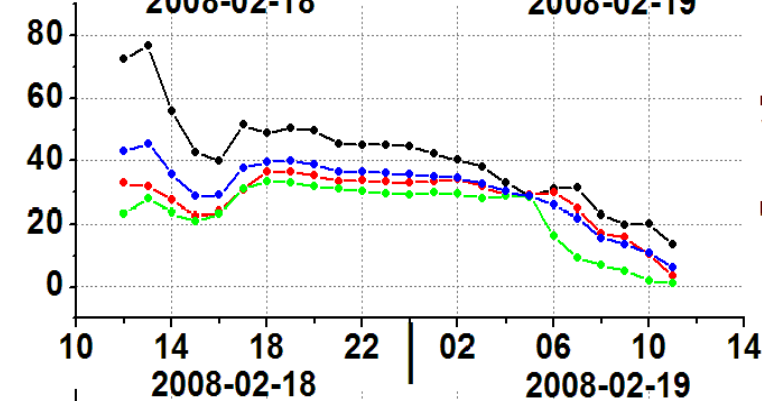
Shunyi



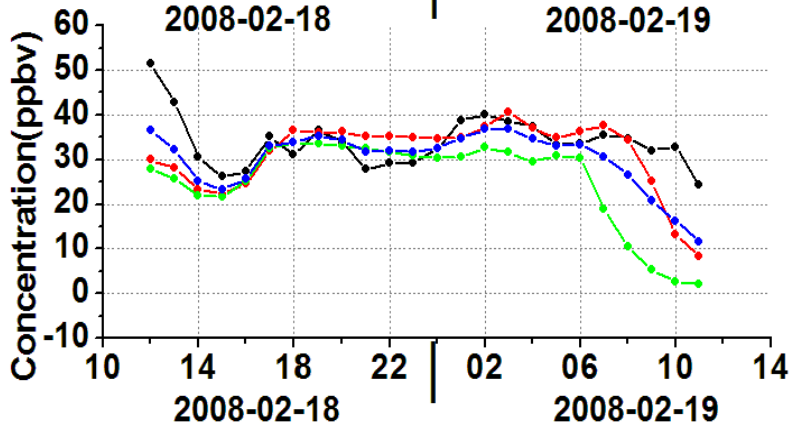
Yizhuang



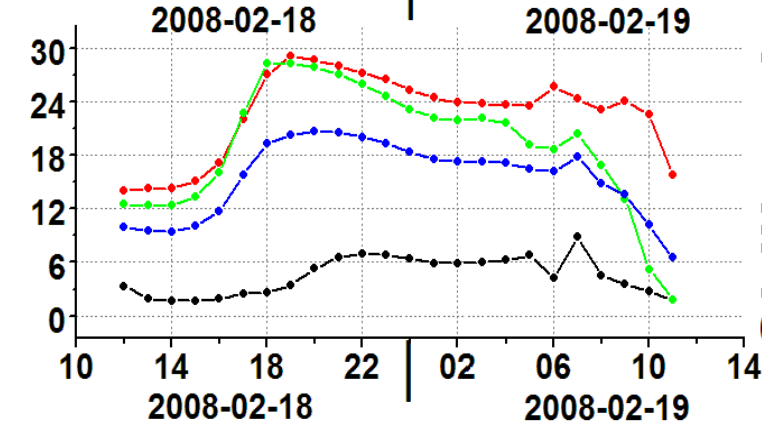
Aoti



Dongsi

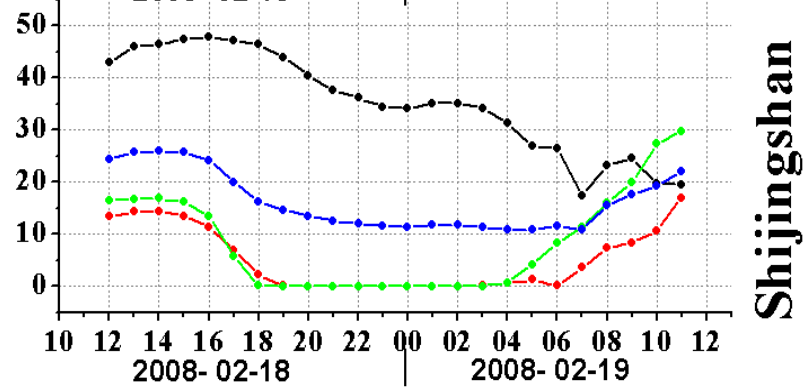
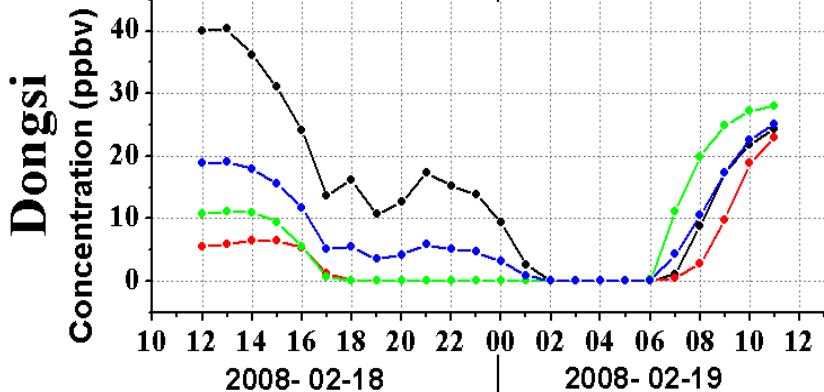
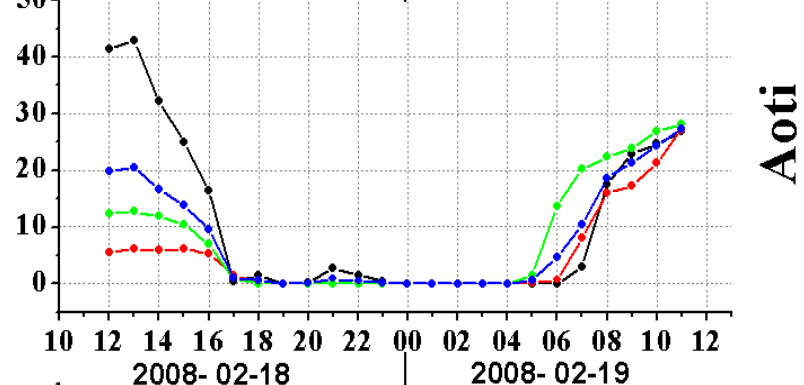
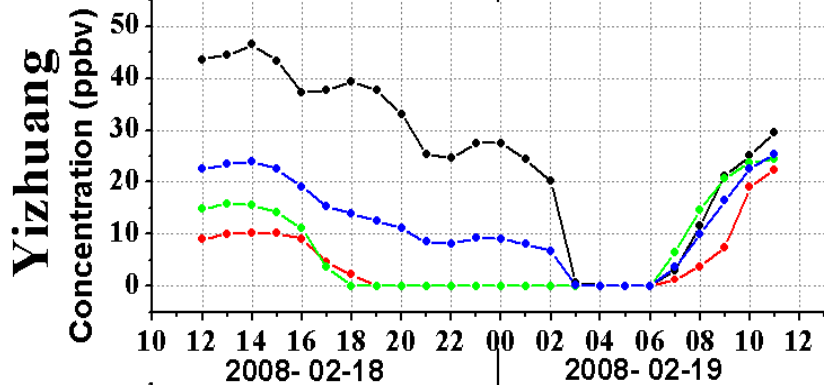
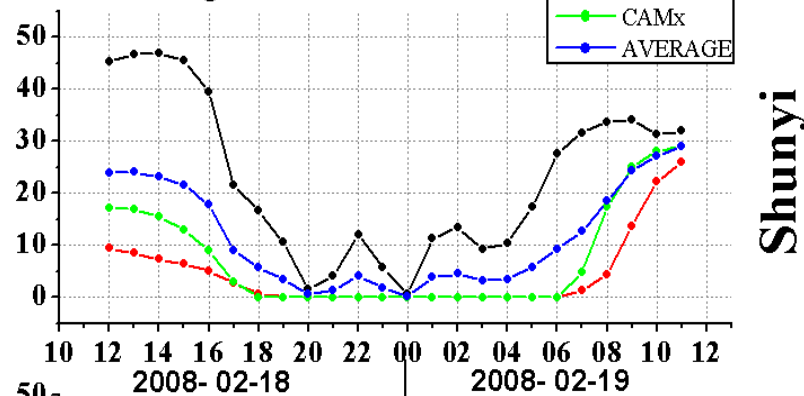
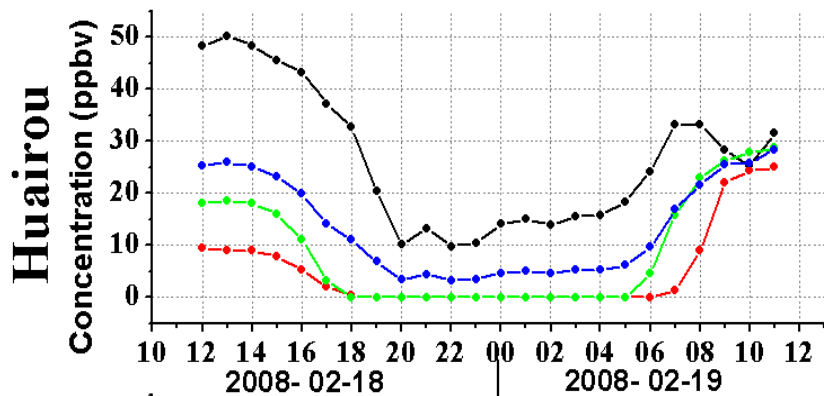
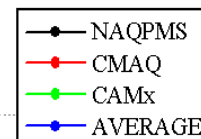


Shijingshan



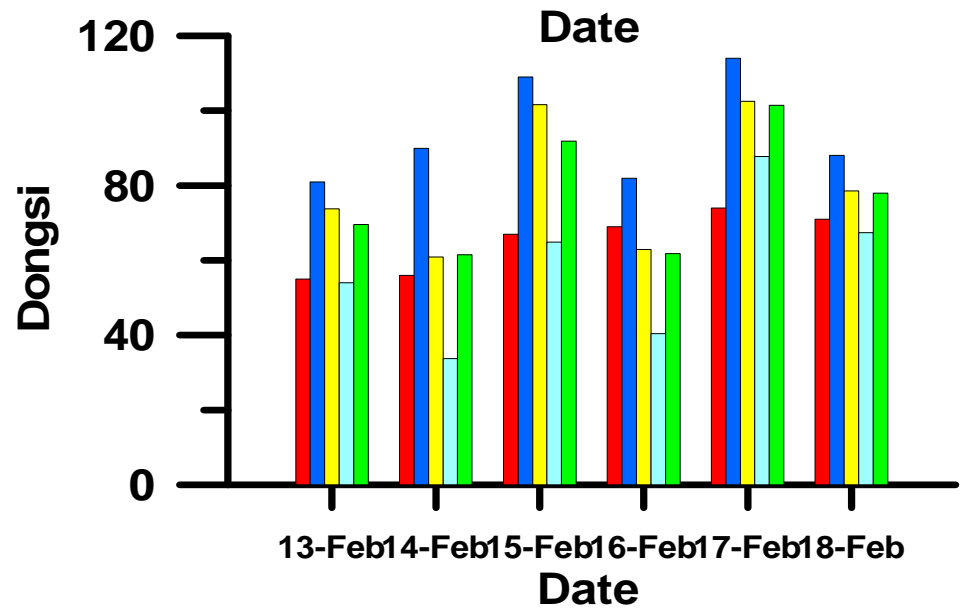
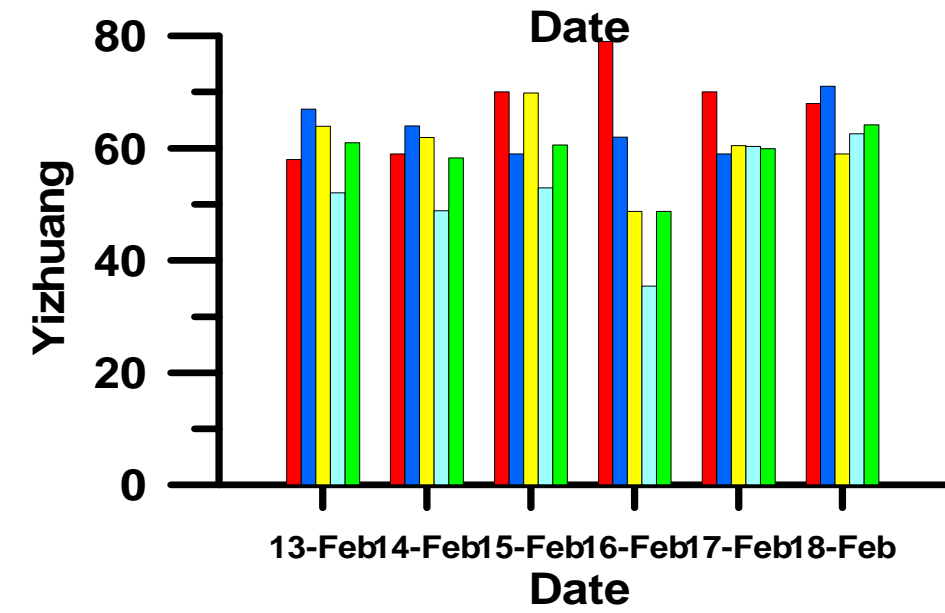
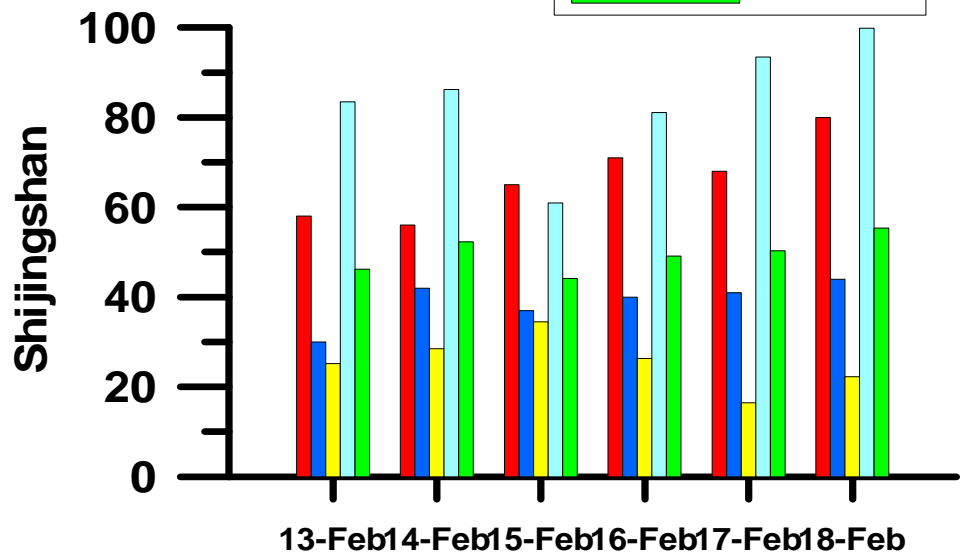
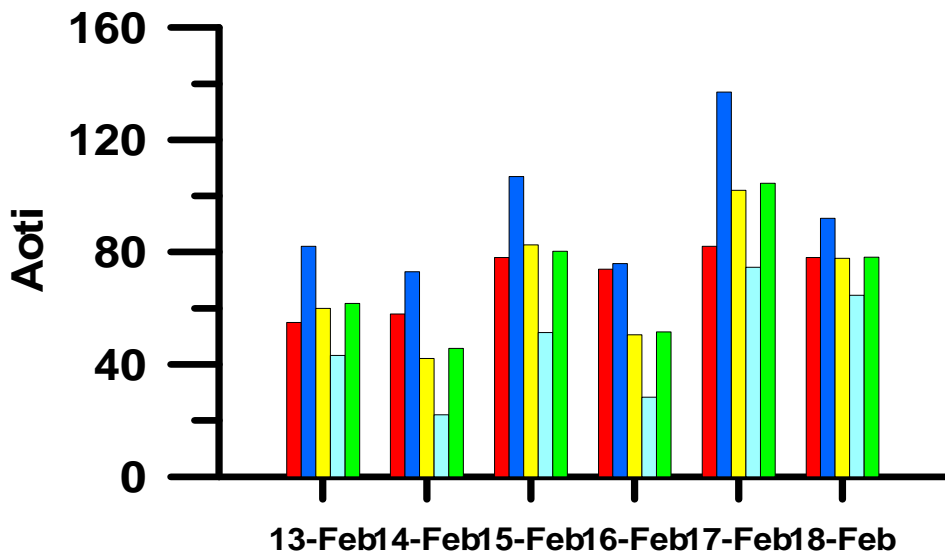
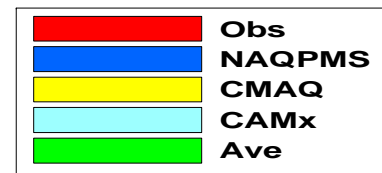
Beijing Real-time Forecast: Domain4 2008 BJT

Station forecast: O₃



Beijing real-time forecast: Domain4 2008 BJT

API in Obs,NAQPMS,CMAQ,CAMx and Model Ave

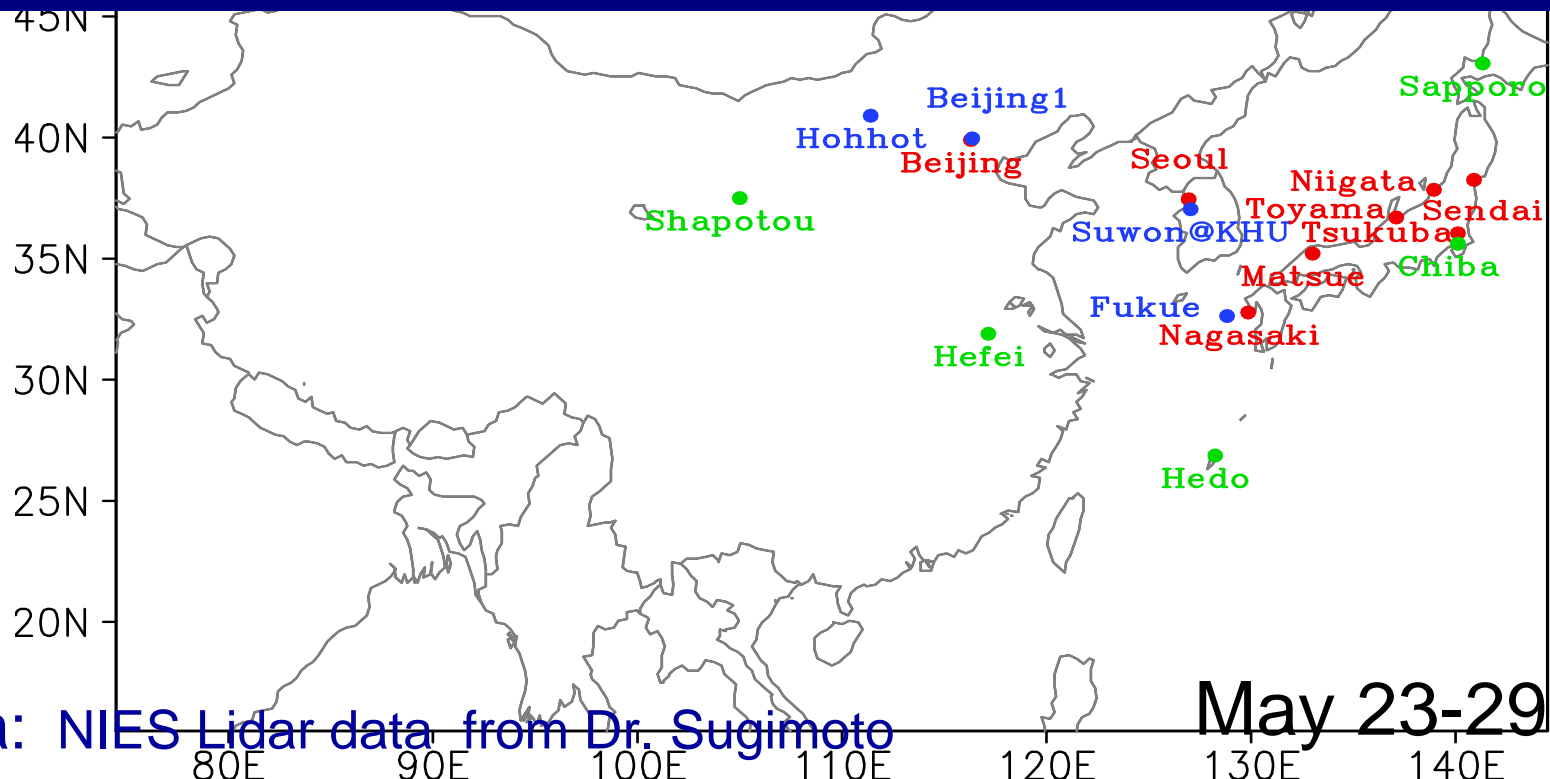


Data assimilation with Lidar data

EnKF data assimilation technique

Experimental Configuration

- **Considering model uncertainty by perturbing the emission intensity, deposition velocity, wind speed and wind direction using the Monte Carlo methods**
- **Observations assimilated every 3 hours**



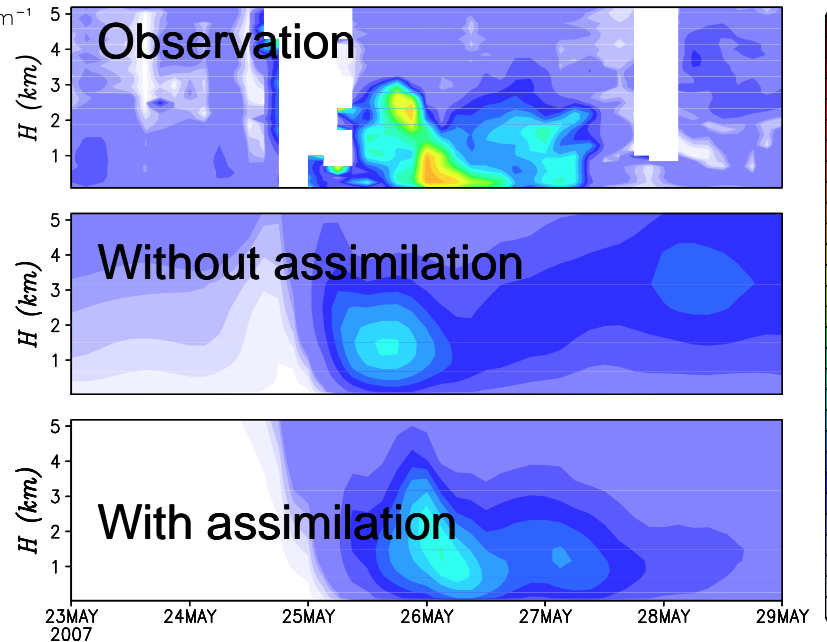
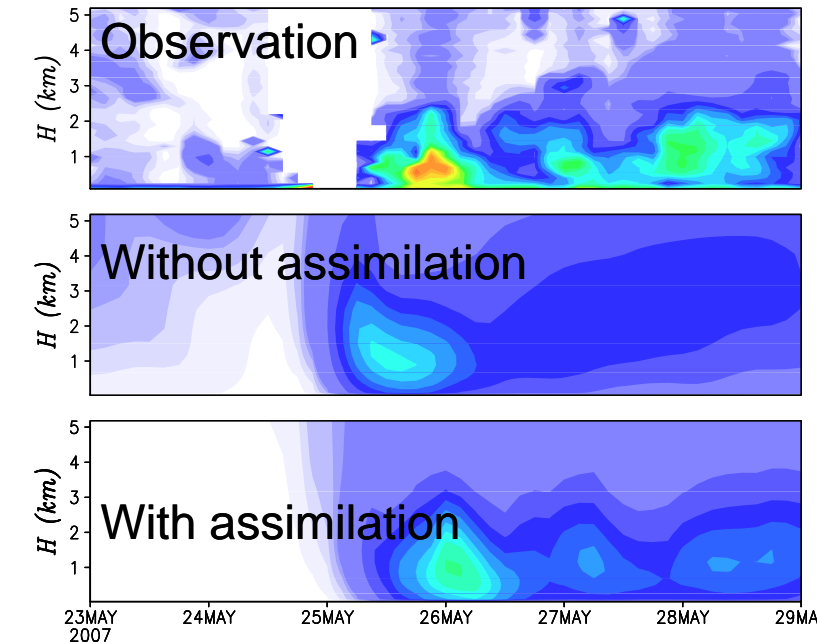
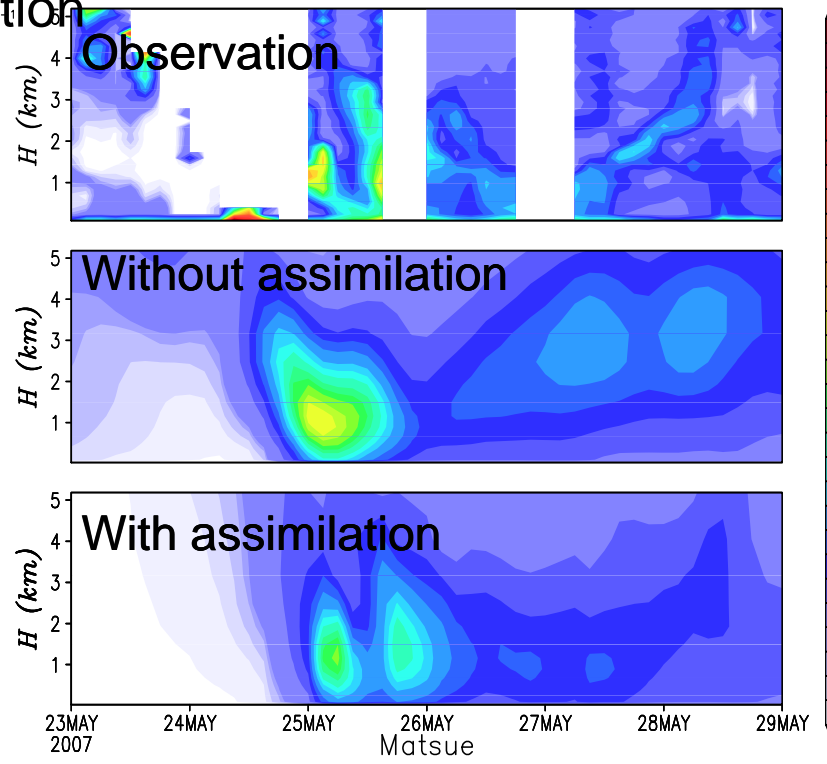
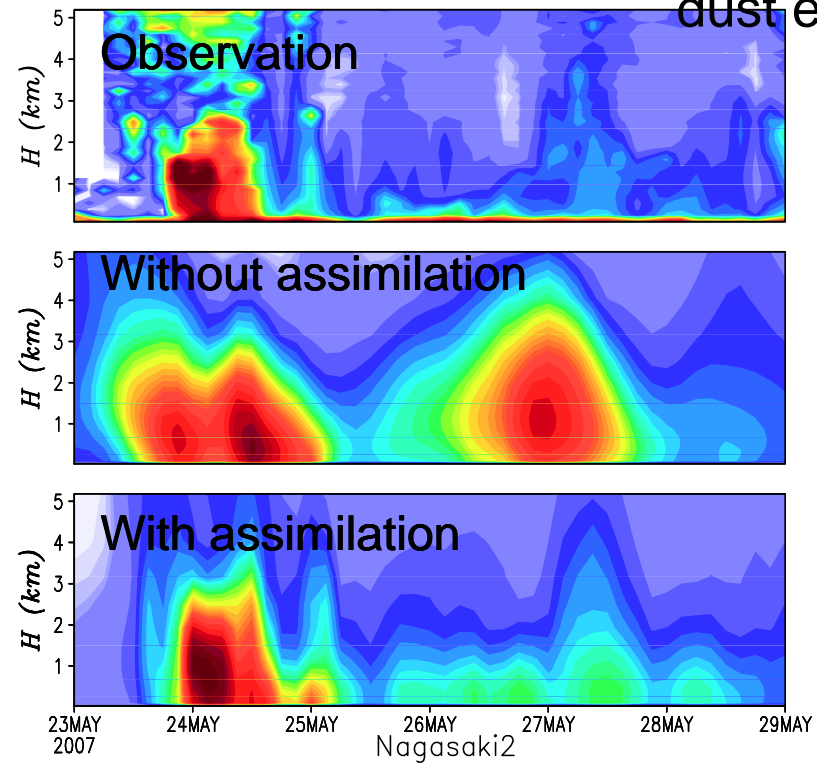
Data: NIES Lidar data from Dr. Sugimoto

May 23-29, 2007

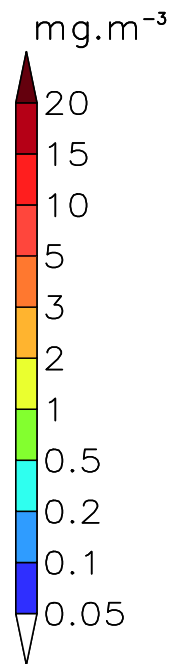
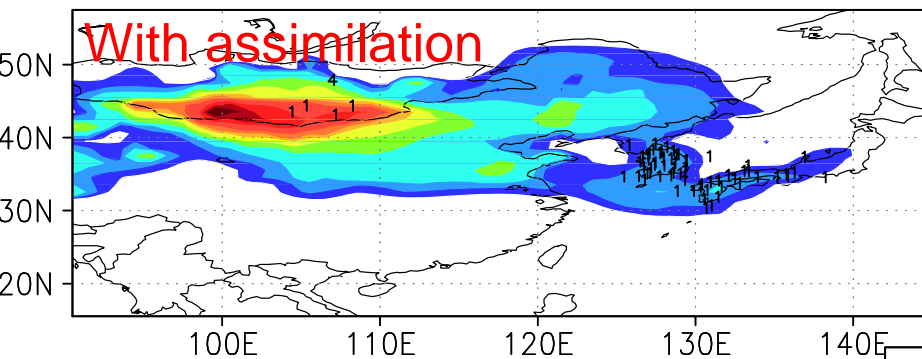
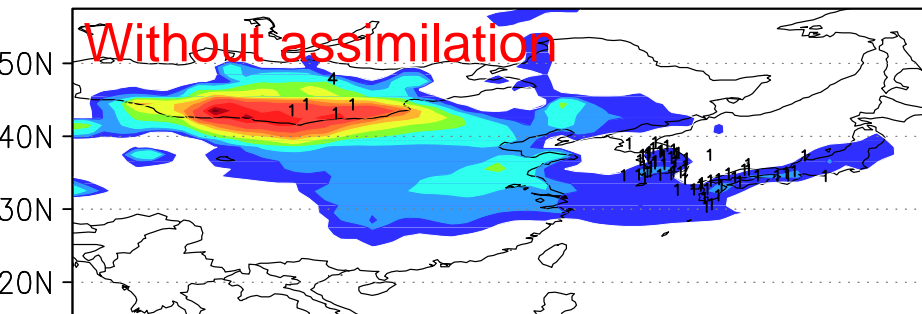
Beijing2

dust extinction

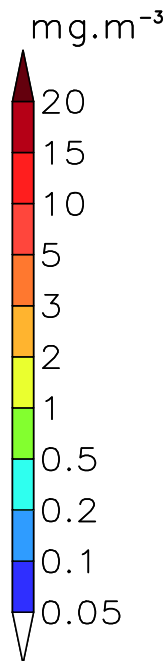
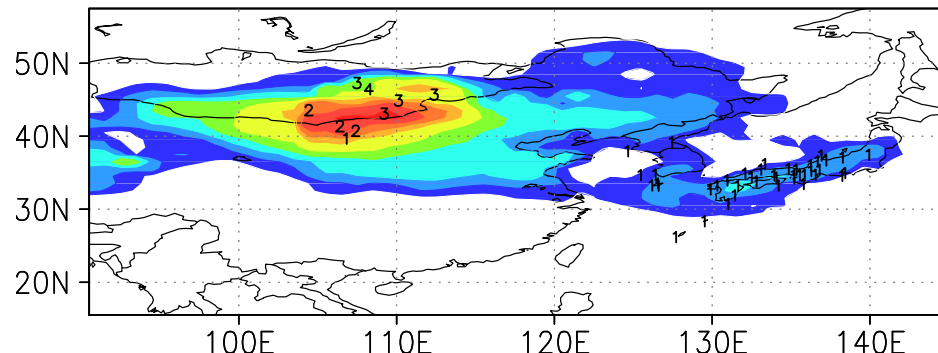
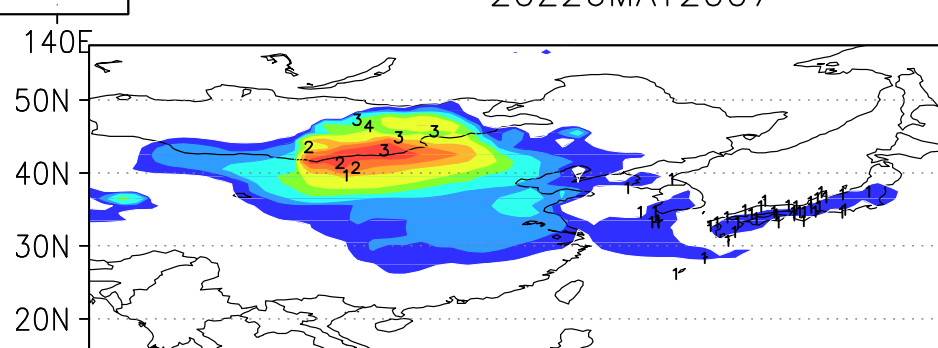
Seoul



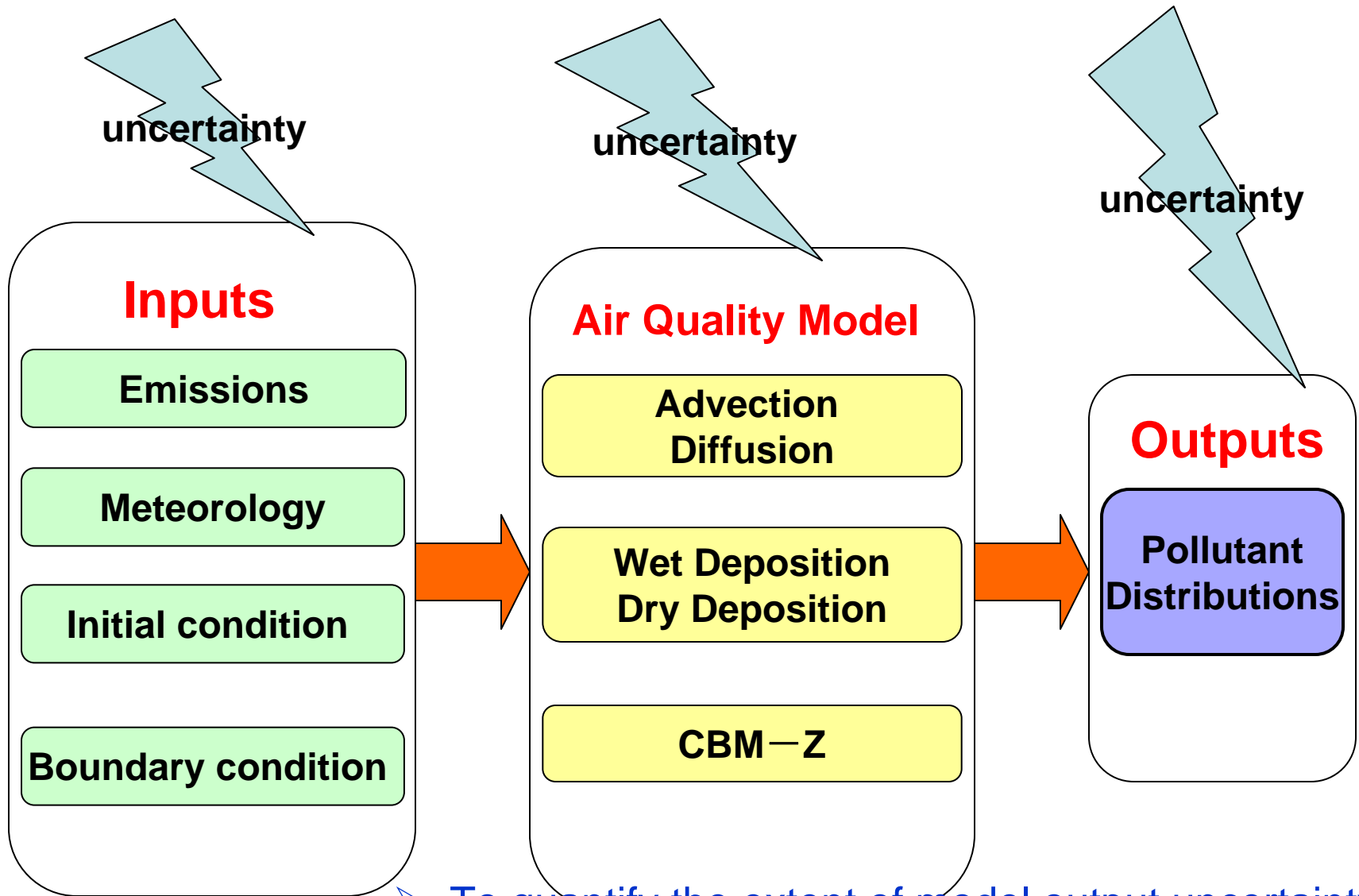
08Z26MAY2007



20Z26MAY2007



Model uncertainty analysis

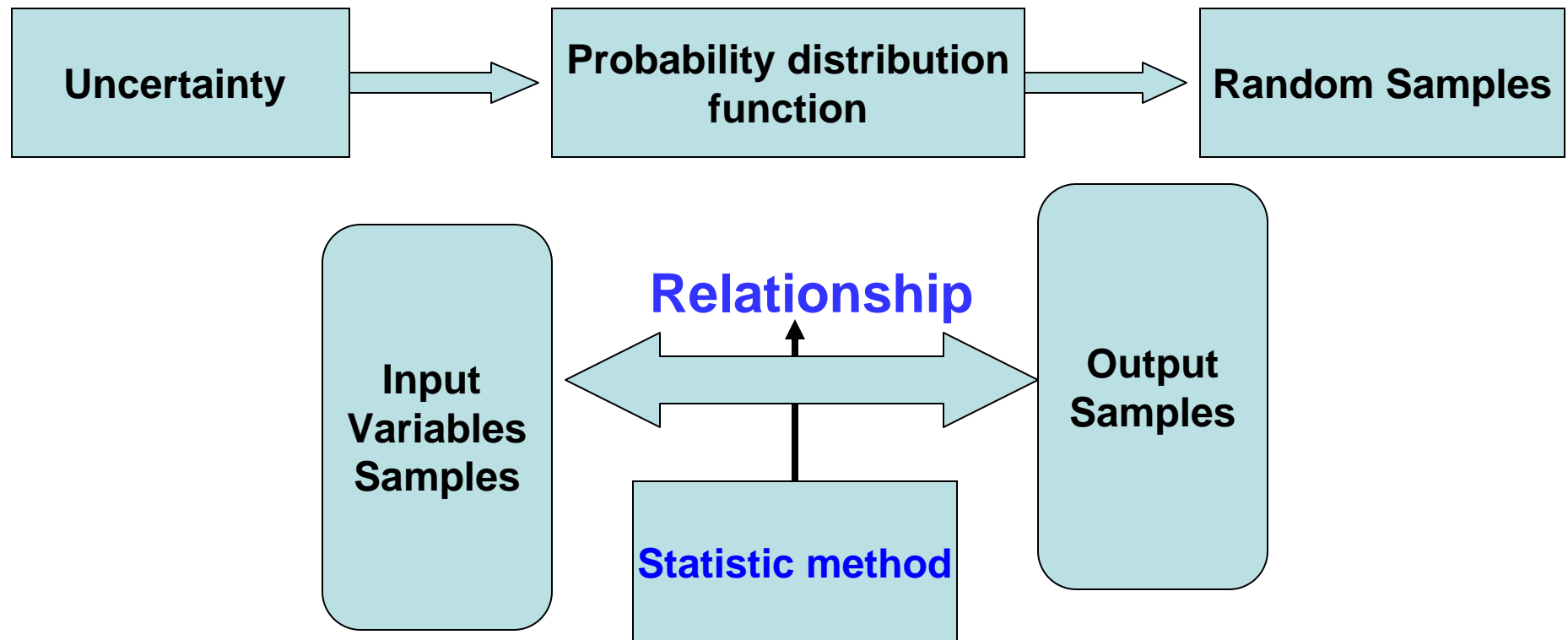


- To quantify the extent of model output uncertainty
- To identify the sources of model output uncertainty

Methodology: Monte Carlo Method

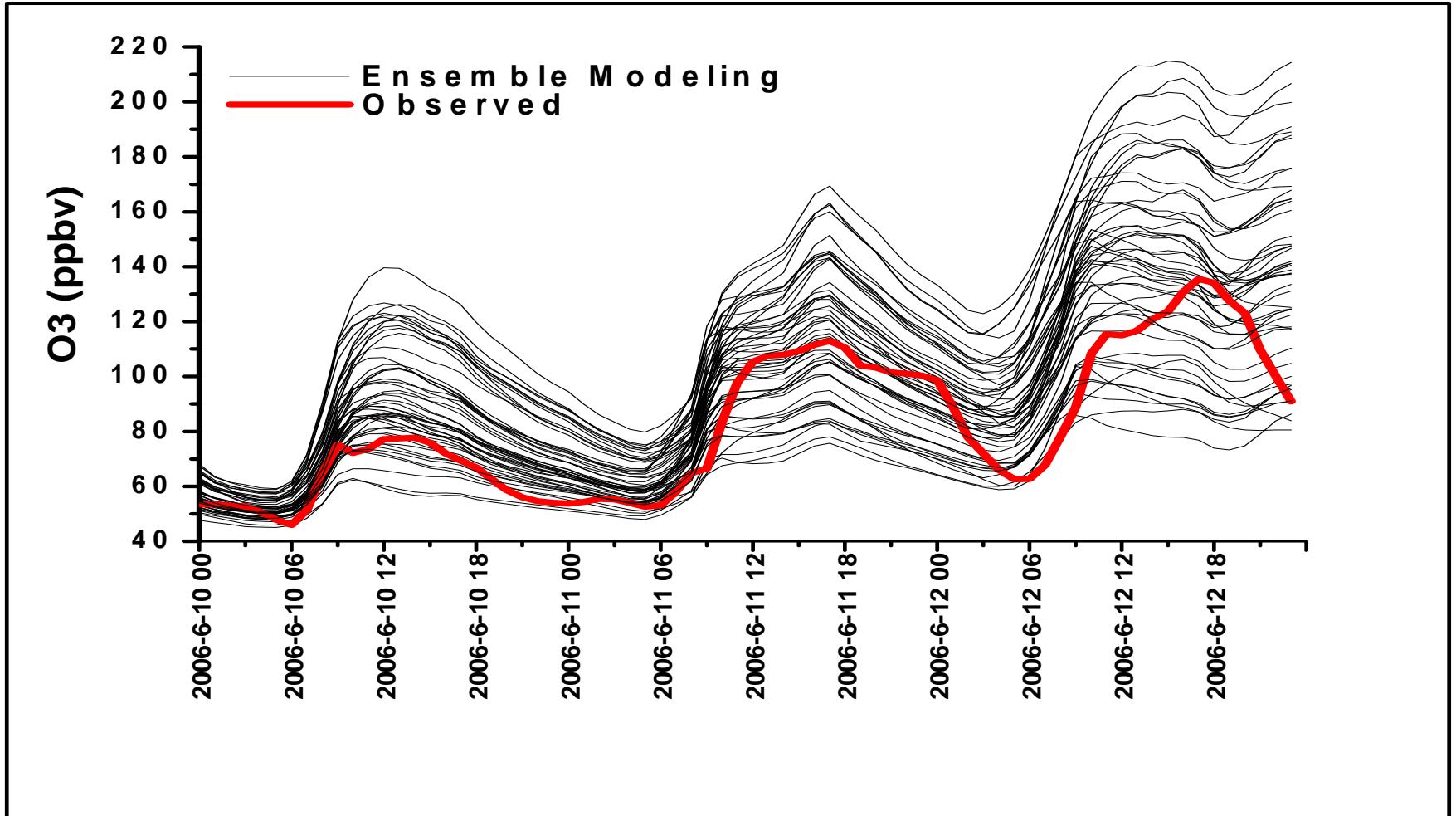
Advantages

- ✓ no tangent-linear and adjoint model
- ✓ Easy to deal with a set of about 100 or more input parameters (Hanna,1998)



Preliminary Result

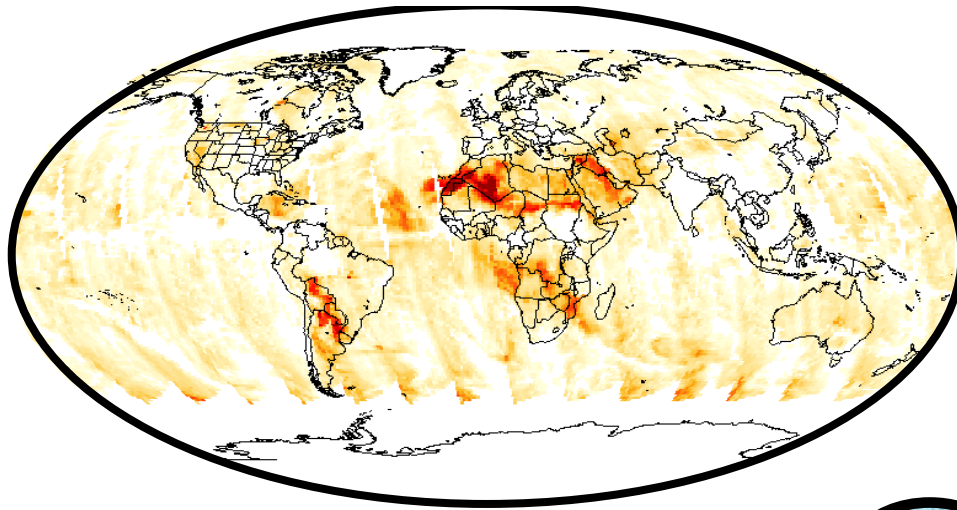
- Ensemble modeling (50 members of ensemble) VS observation





Our efforts on global modeling

Total Ozone Mapping Spectrometer
Global Aerosol Index: 2006-08-25



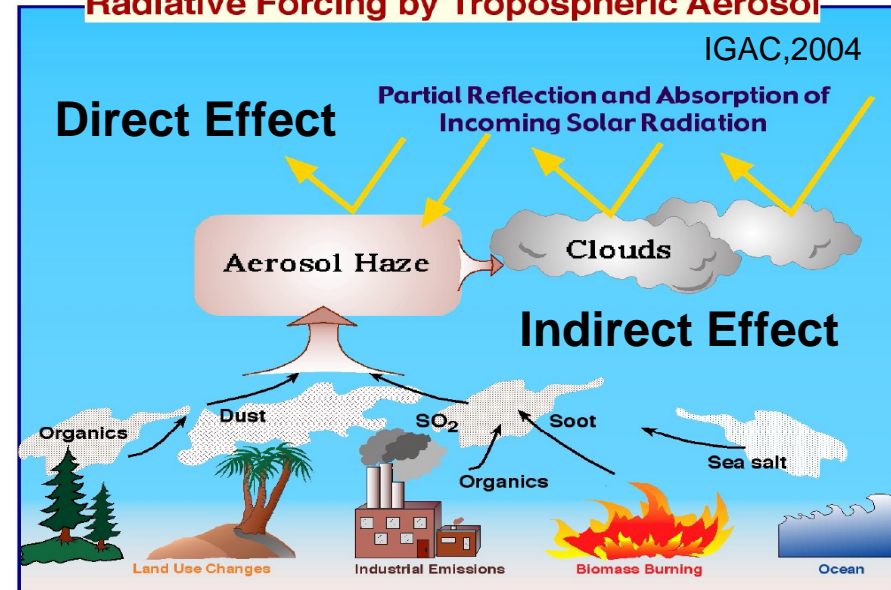
Regional → Global
? Global Change

Global → Regional
? Regional Environment

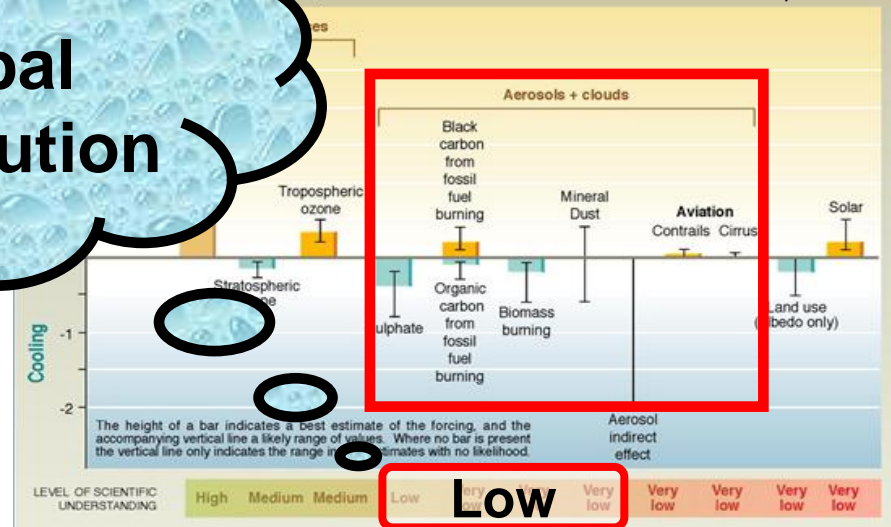


Radiative Forcing by Tropospheric Aerosol

IGAC, 2004



natural forcing of the climate for the year 2000, relative to 1750
IPCC, 2001



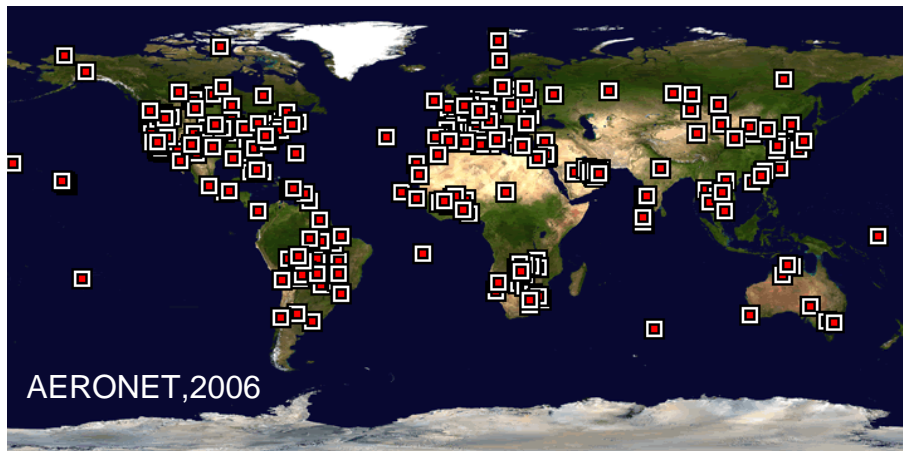
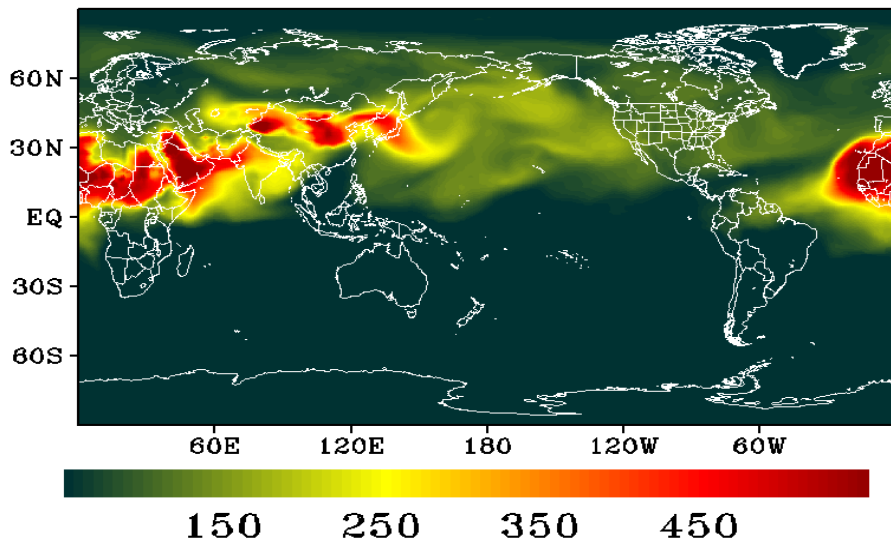


Methods

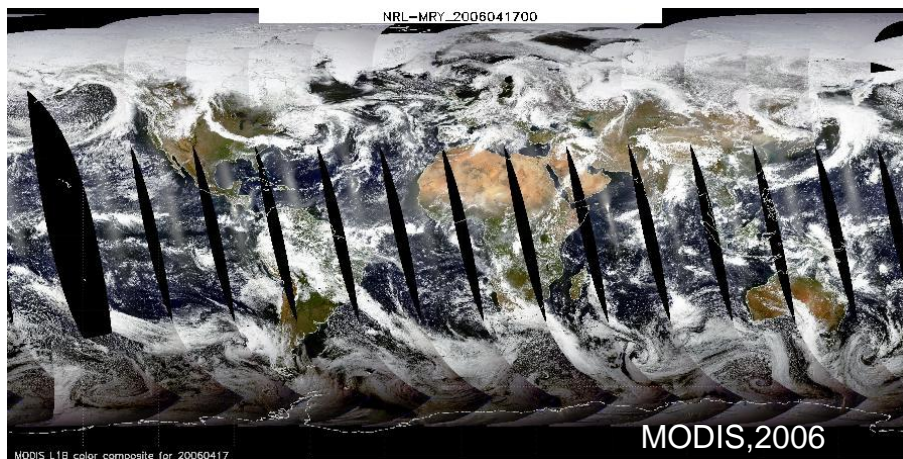
**To Obtain the Images
of the Global
Distribution of
Aerosols**

Model Simulation

Dust Column of GEATM: 2006-04-01



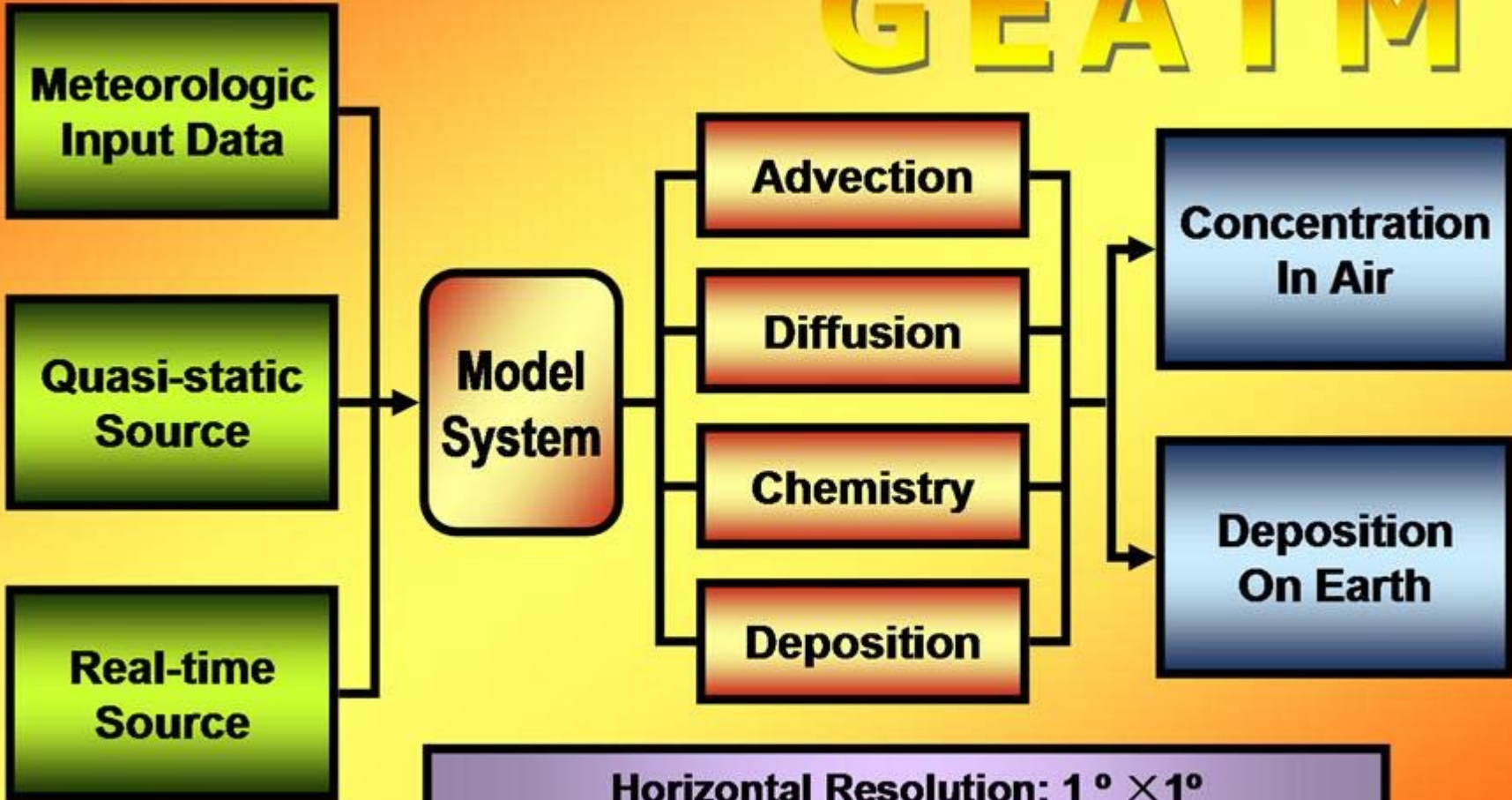
Surface Observation Network



Satellite Images



GEATM



Horizontal Resolution: $1^\circ \times 1^\circ$
Vertical Resolution: 20 Layers (0 ~ 15 km)



Meteorological input: **NCEP** data (2003.09 ~ 2004.12)

Quasi-static source: basic on **EDGAR, GEIA** ...

Real-time source:

Dust (**Luo and Wang, 2006**)

$$F = C_1 \cdot C_2 \cdot E \cdot u^{*2} \cdot \left(1 - \frac{u_t^*}{u^*}\right) \cdot \left(1 - \frac{RH_{2m}}{RH_t}\right)$$

Sea salt (**Gong et al. 1997**)

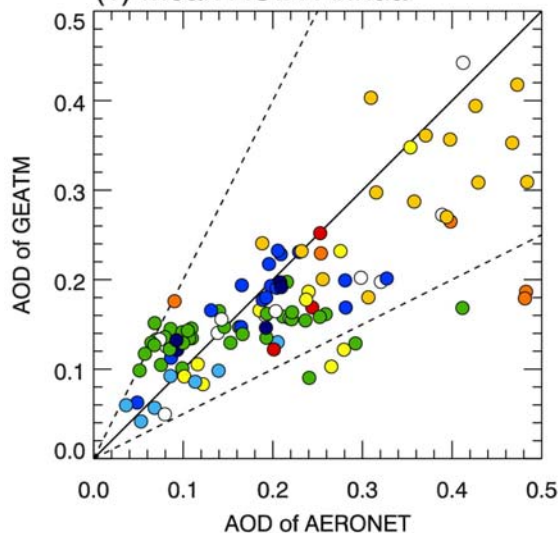
$$\frac{dF}{dr} = 1.373 u_{10}^{3.41} r^{-3} \left(1 + 0.057 r^{1.05}\right) \cdot 10^{1.19 \exp(-B^2)}$$

$$B = \frac{0.380 - \log r}{0.65}$$

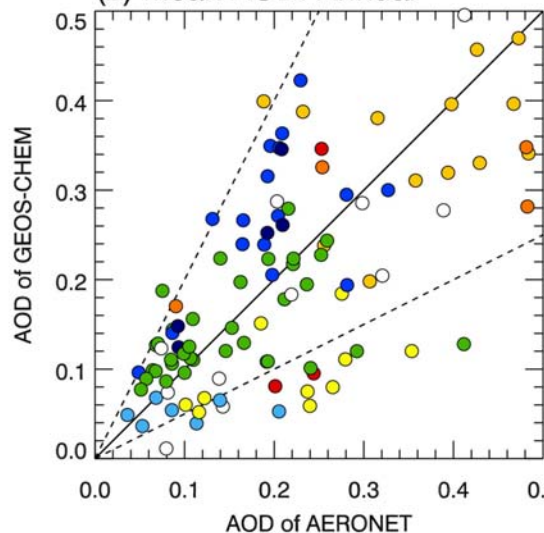


Comparison: AERONET

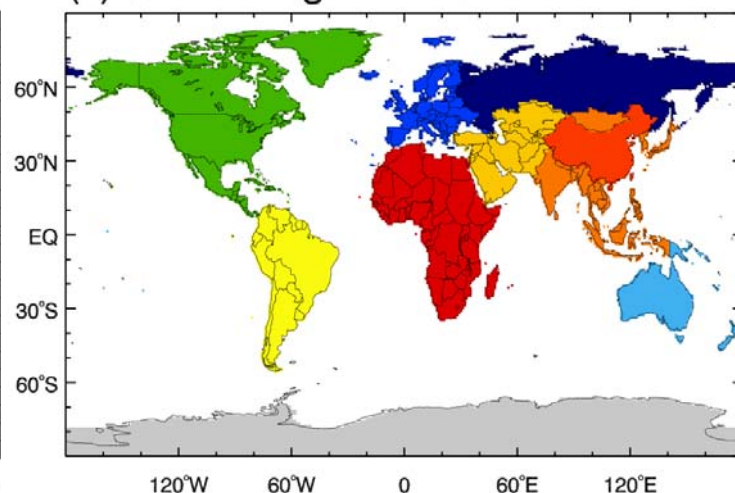
(1) Mean AOD: Annual



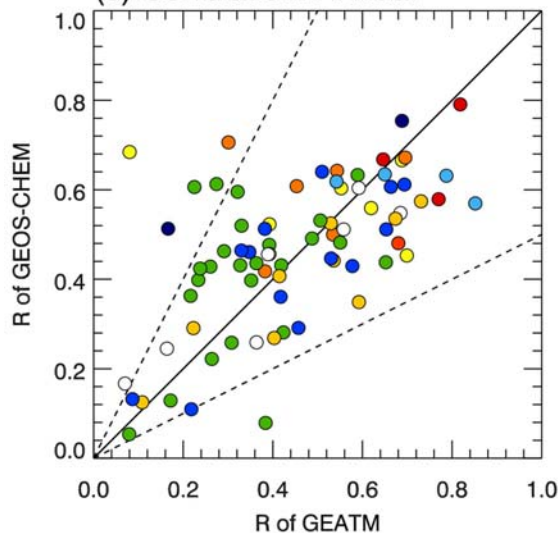
(2) Mean AOD: Annual



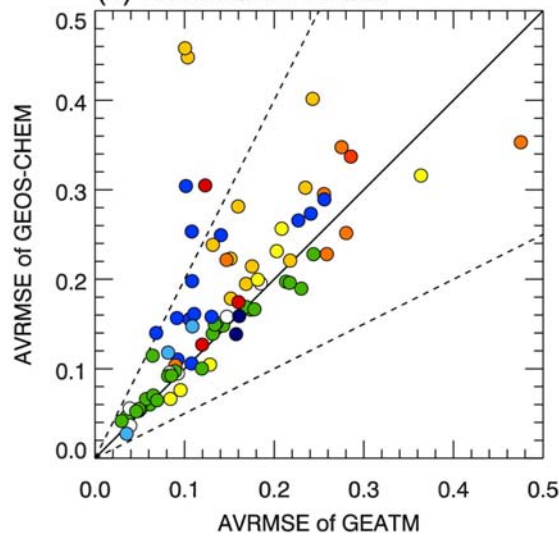
(1) Global Region Division



(3) Correlation: Annual



(4) AVRMSSE: Annual

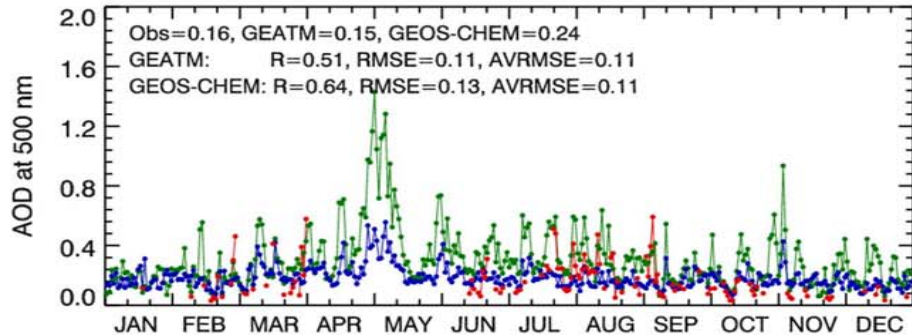


The different colors represent the different regions with the same color in the global region division

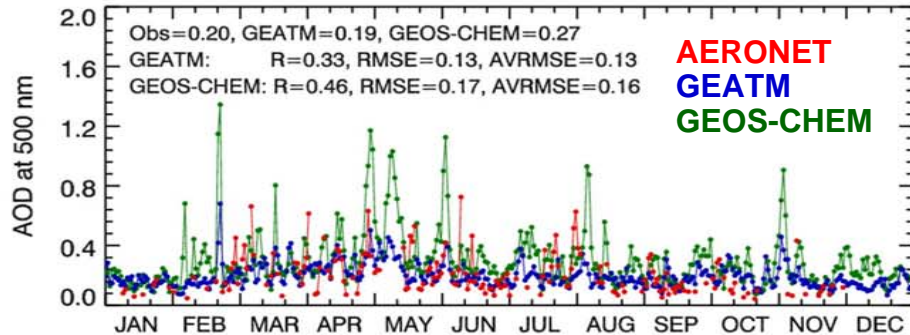


Sites: West Europe

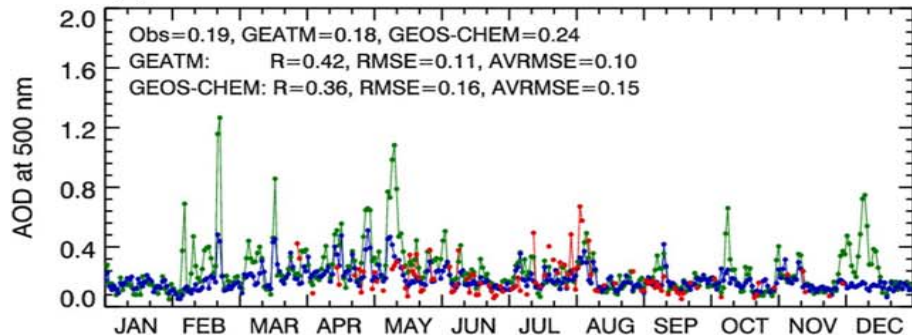
(1) AOD at Hamburg (10.0, 53.6): 115



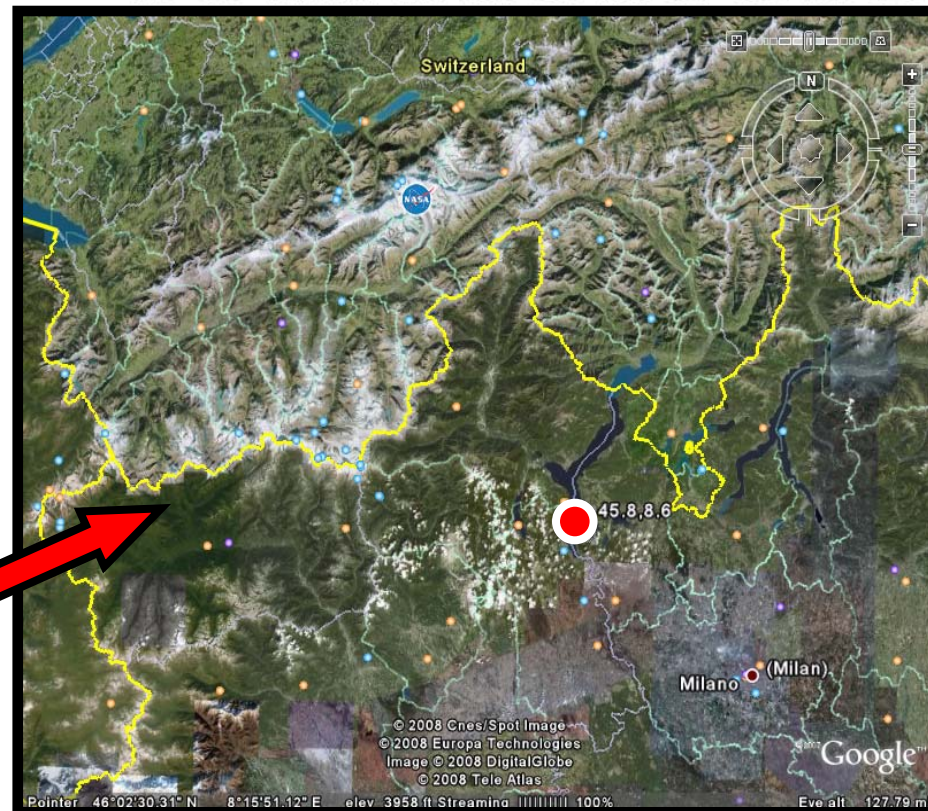
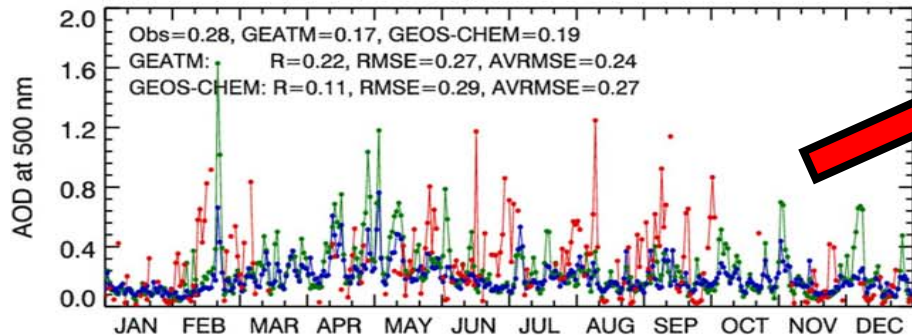
(2) AOD at Mainz (8.3, 50.0): 172



(3) AOD at Fontainebleau (2.7, 48.4): 106



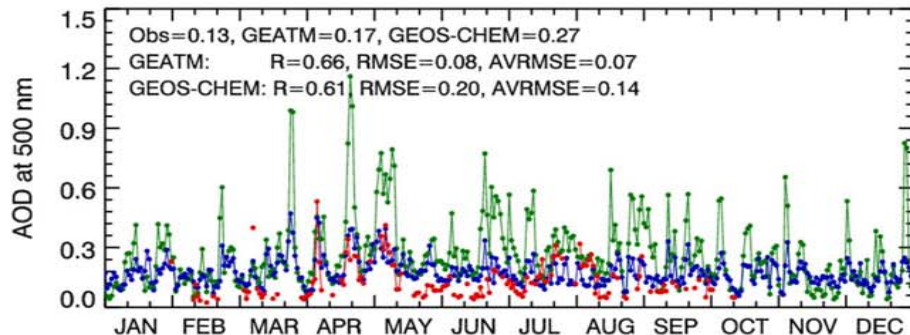
(5) AOD at Ispra (8.6, 45.8): 200



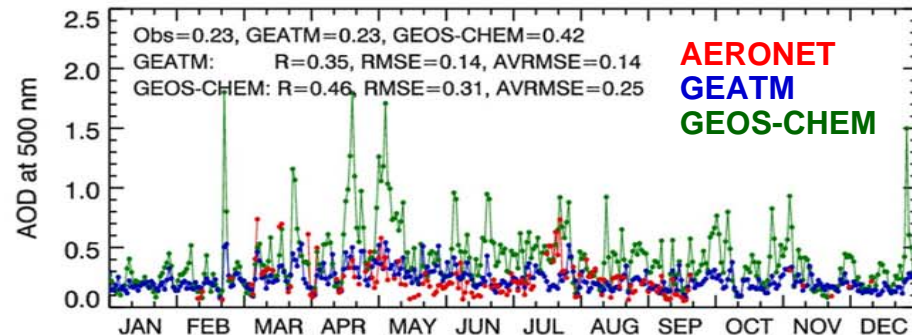


Sites: East Europe

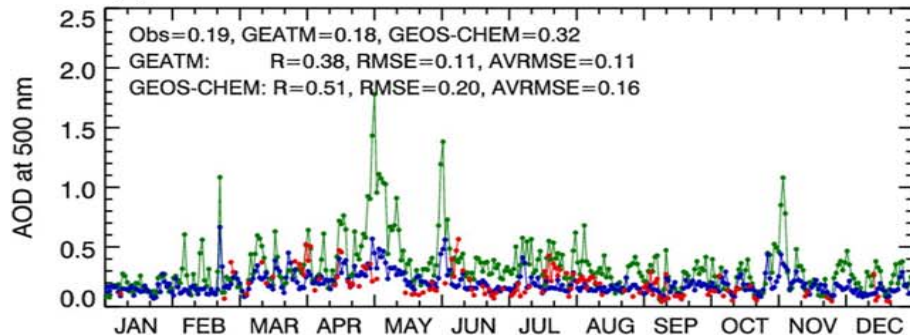
(1) AOD at Toravere (26.5, 58.3): 139



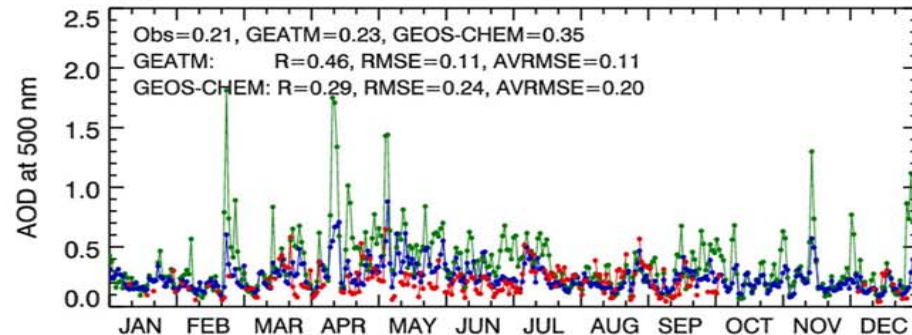
(2) AOD at Belsk (20.8, 51.8): 150



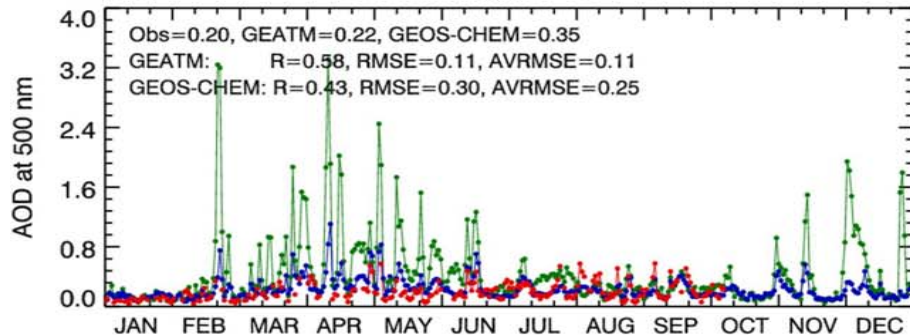
(3) AOD at IFT-Leipzig (12.4, 51.4): 129



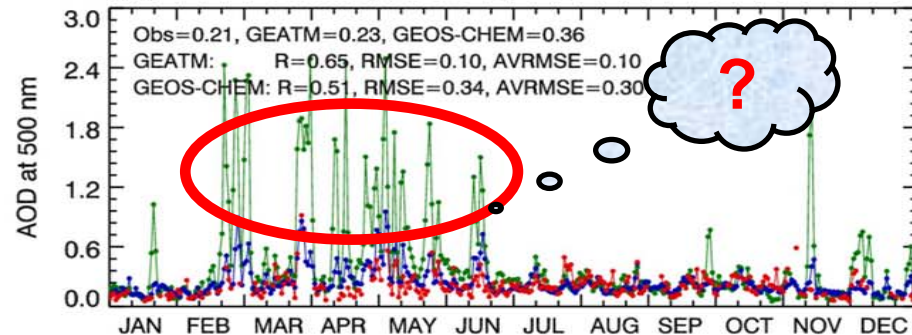
(4) AOD at Moldova (28.8, 47.0): 190



(5) AOD at Lecce_University (18.1, 40.3): 219



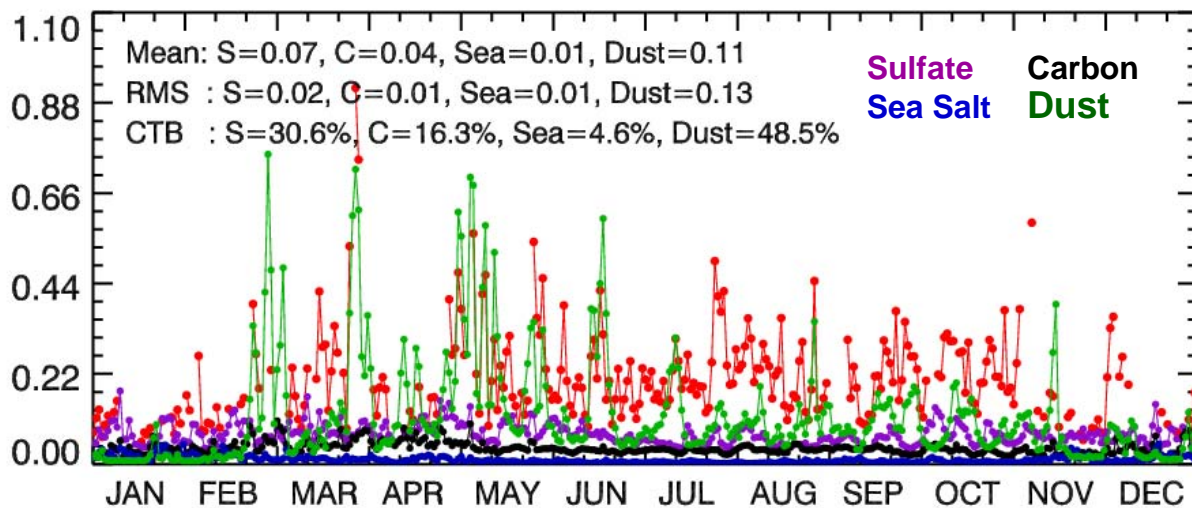
(6) AOD at FORTH_CRETE (25.3, 35.3): 272



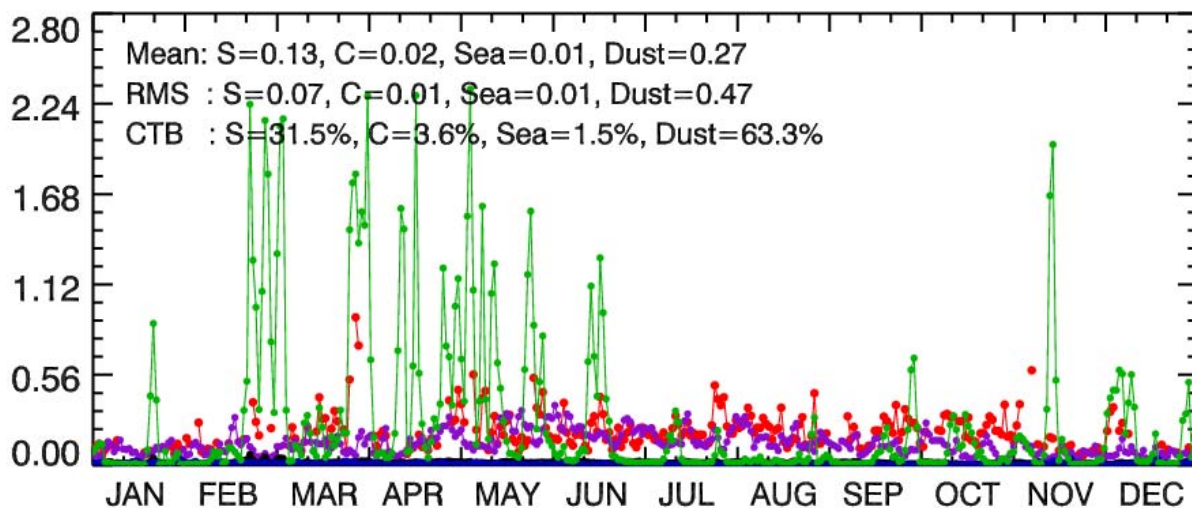


AOD at FORTH_CRETE

GEATM at FORTH_CRETE (25.3, 35.3): 272



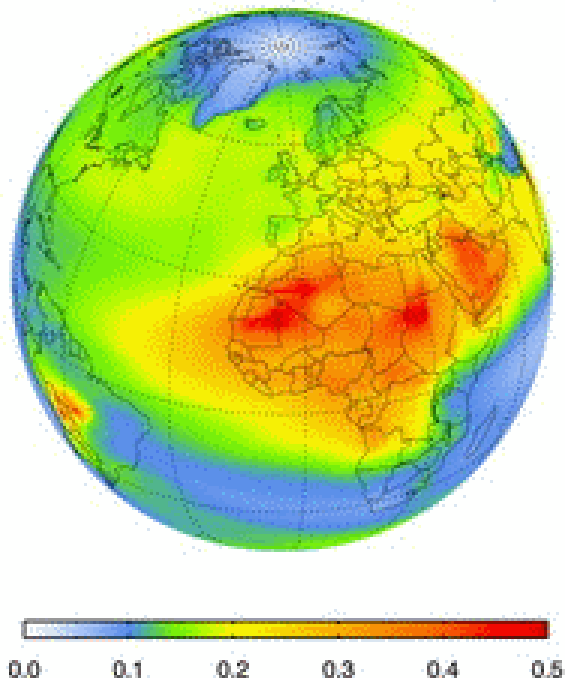
GEOS at FORTH_CRETE (25.3, 35.3): 272



Dust from Sahara can significantly impacts the AOD at FORTH_CRETE in spring time, however, GEOS-CHEM seems highly estimate this impacts

Global AOD

(1) GEATM: Annual, 2004

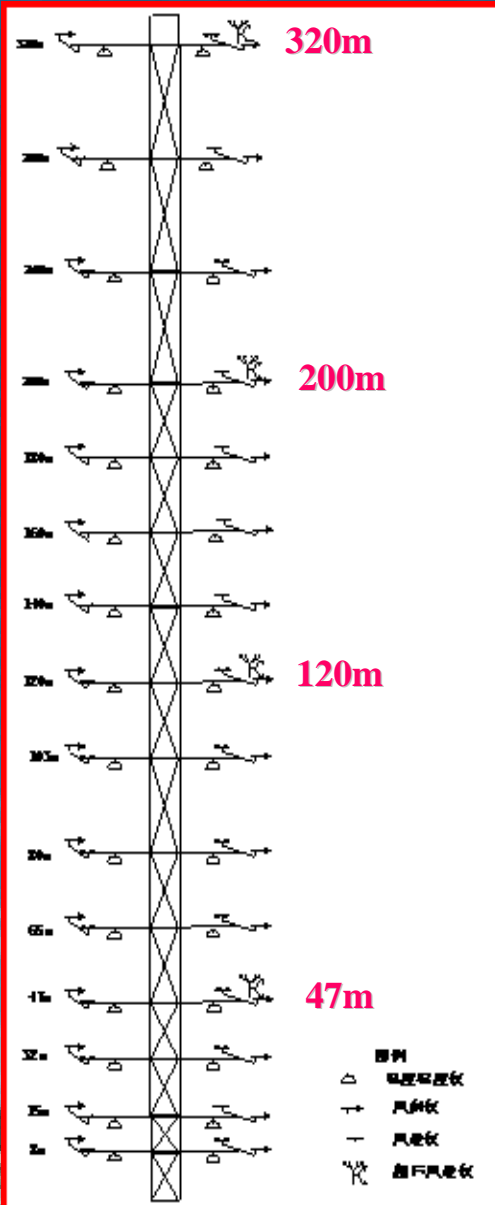


GEATM model can well simulate the global distributions of **aerosol optical depth**. It fully considers the contributions from **sulfate**, black carbon, organic carbon, **sea salt** and **dust**. Further validations will be presented in the near future

III. Comments on MICS-Asia Phase 3

- To perform all the models running at the same platform (hardware and software) with same emissions, same grids system
- To focus on the sources of the model uncertainties with EnKF method and its impacts on the source-receptor matrix

IAP 325m tower observational



Thank You