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第28届中国气象学会年会 CHINESE METEOROLOGICAL SOCIETY



Development of the Chinese Chemical Weather Forecasting System - CUACE and its Application in AQ Forecasts

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Environment Canada



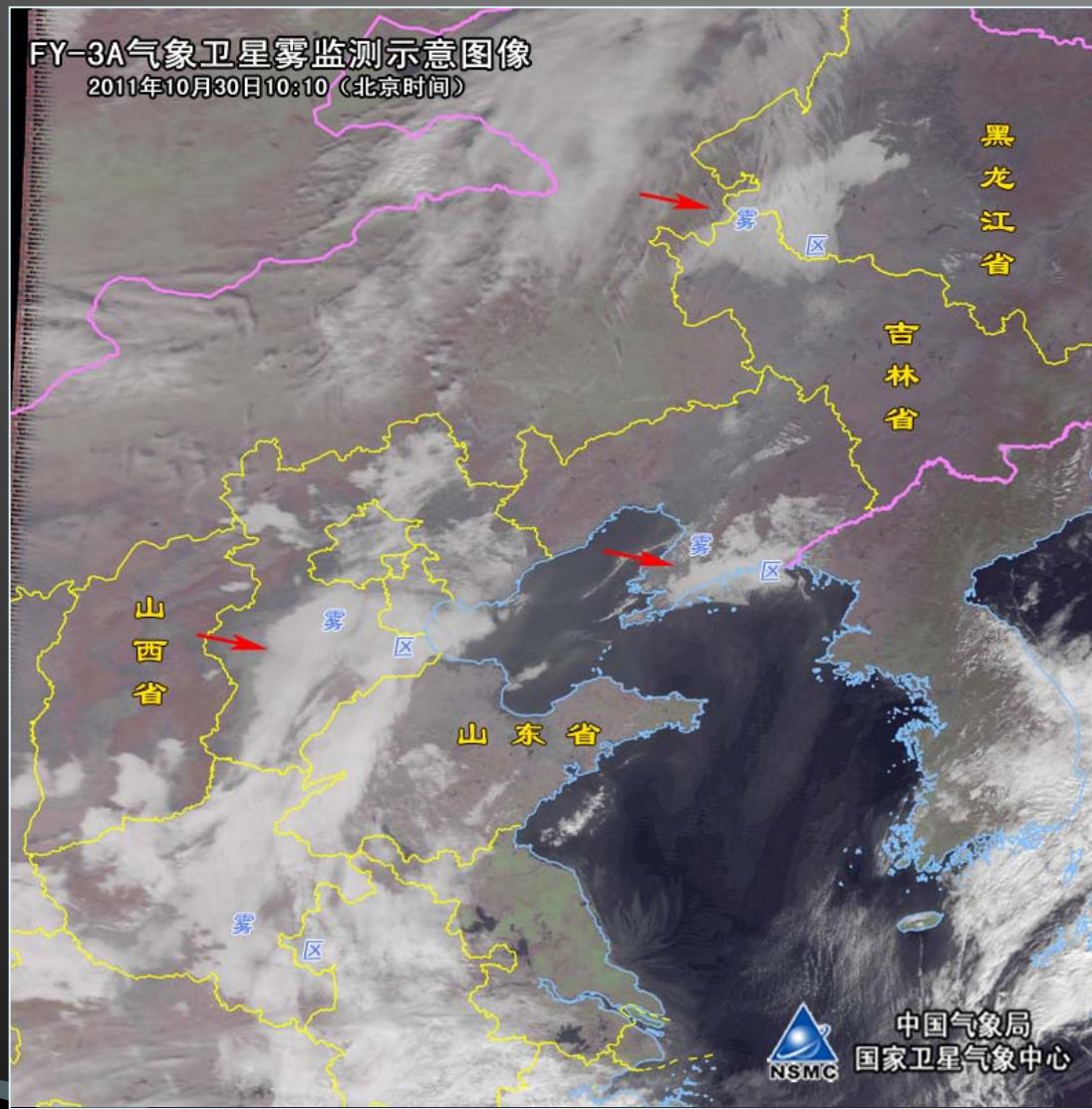
中国气象科学研究院
Chinese Academy of Meteorological Sciences

International Workshop on Air Quality Forecasting Research
Nov. 29-Dec. 1, 2011, Bolger Conference Center, Washington DC, USA

Chemical Weather Forecast – 化学天气预报 → Air Quality (AQ) NRT (near real time) Data – 近实时数据



2011/10/29 A wide range of fog and haze

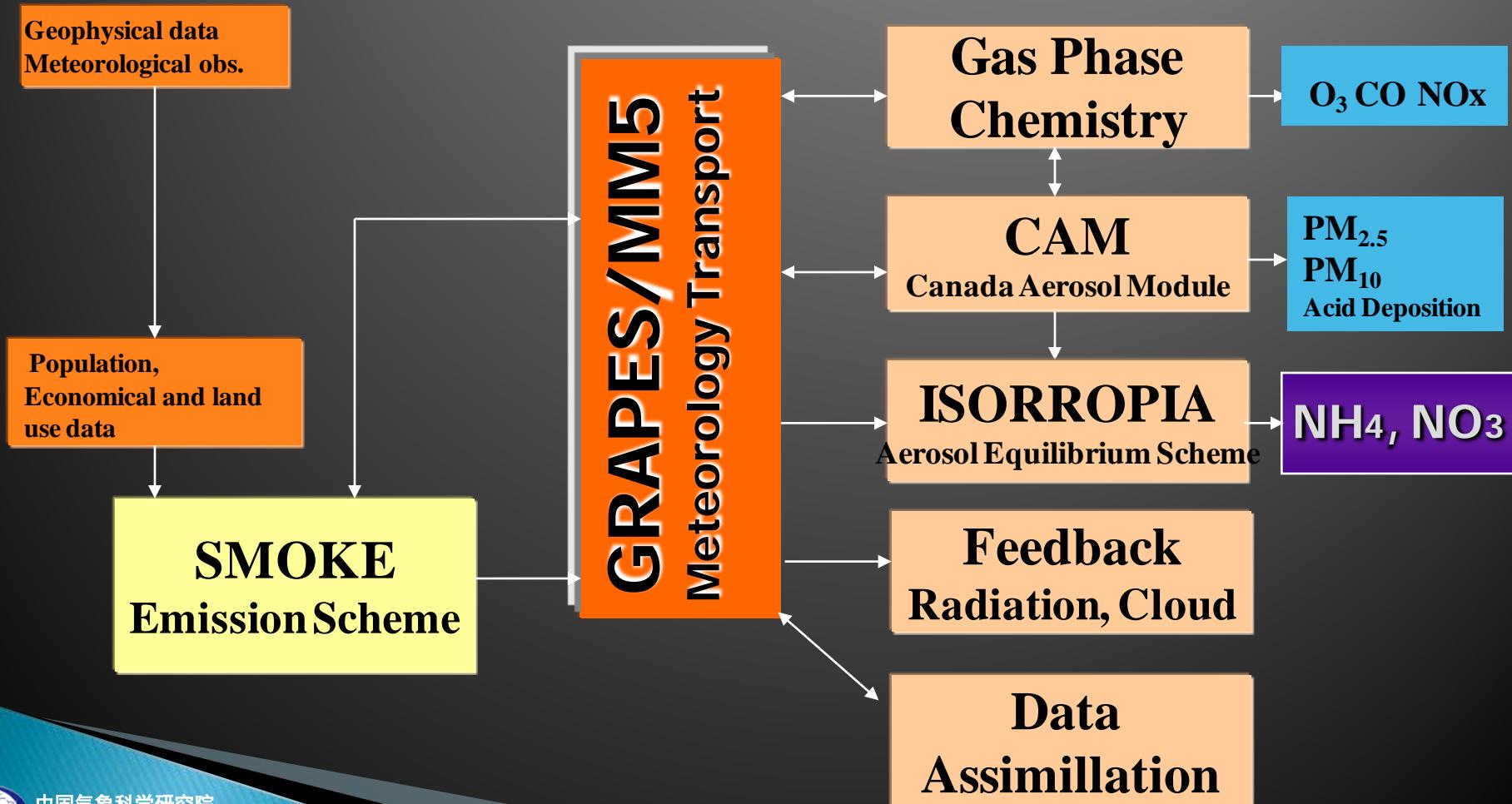


Development of the Chinese Chemical Weather Forecasting System – CUACE

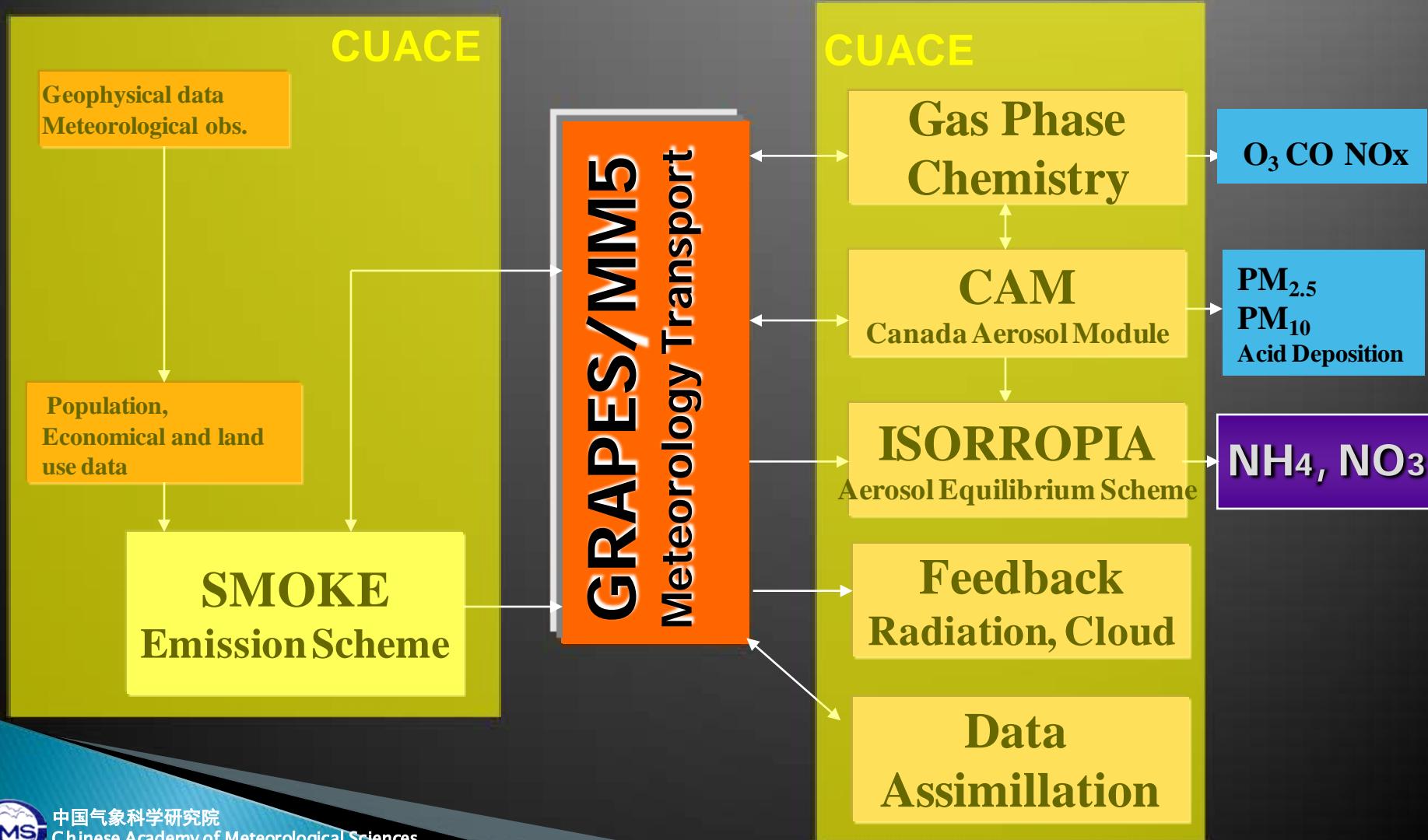
建立化学天气预报



CMA Chemical Weather Forecasting System



CMA Chemical Weather Forecasting System

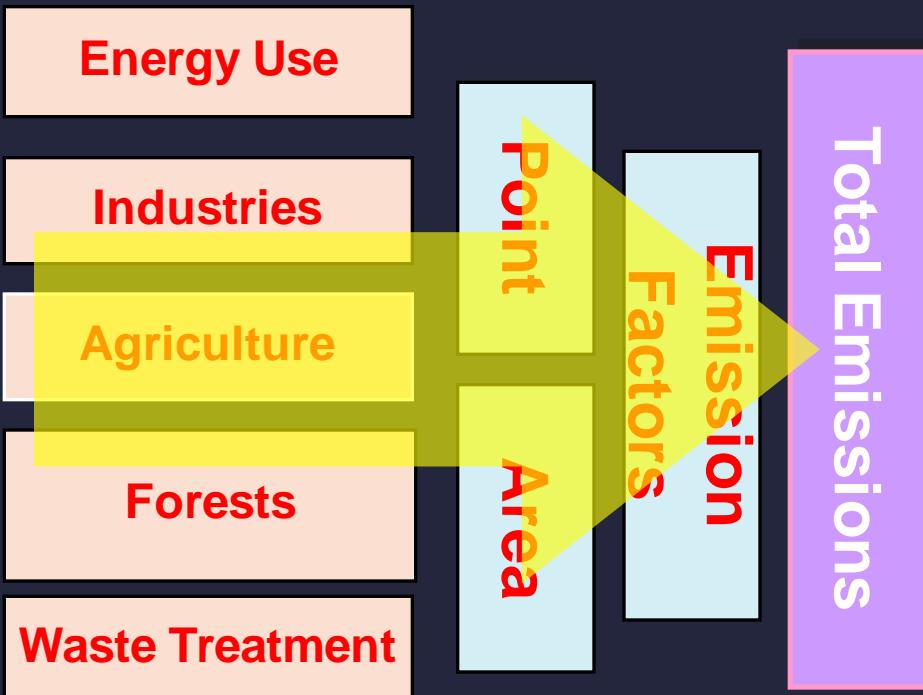


CUACE

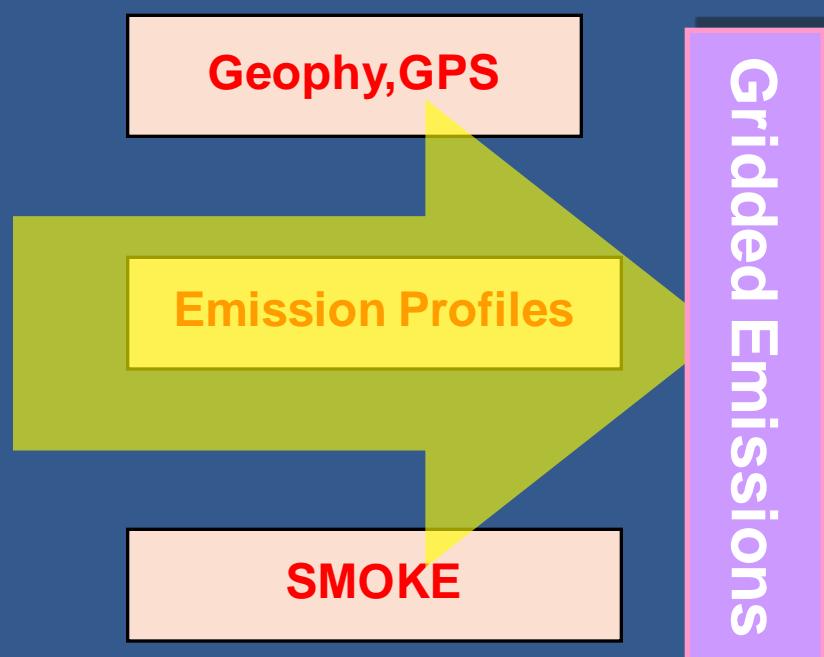
CMA Unified Atmospheric Chemistry Environment

Emission System

Inventories

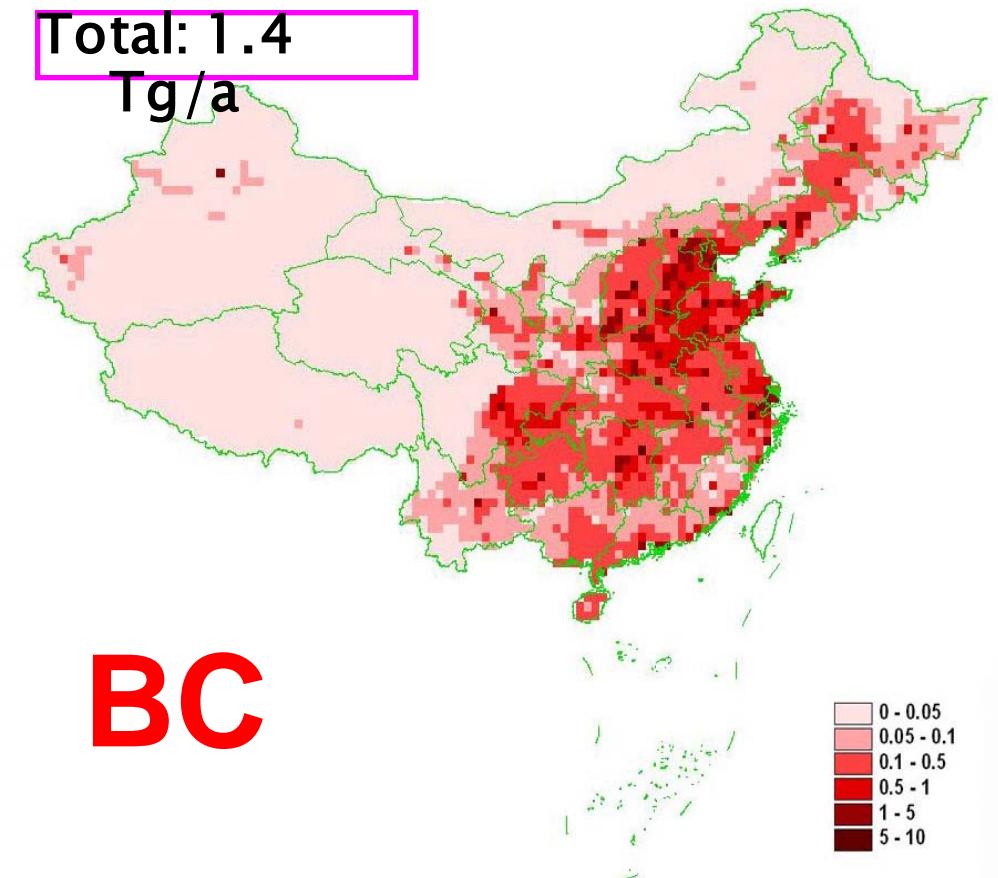


Processor



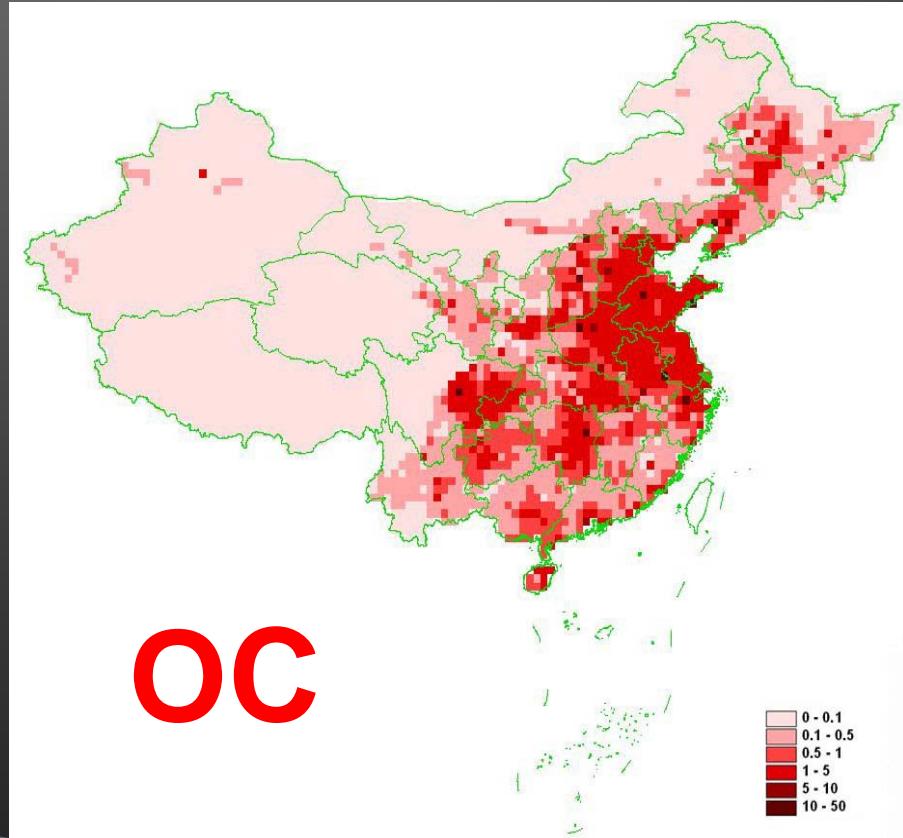
Gridded Emissions

Total: 1.4
Tg/a



0.5° × 0.5°

Total: 2.95 Tg/a



CUACE/Gas

Chemical Mechanism: radm2

- 66 Species, 5 SOA;
- 21 Photochemical reactions, 141 gas phase chemical reactions;
- A simplified SOA formation scheme;
- On-line dry and wet depositions.

Sectional Aerosol Approach

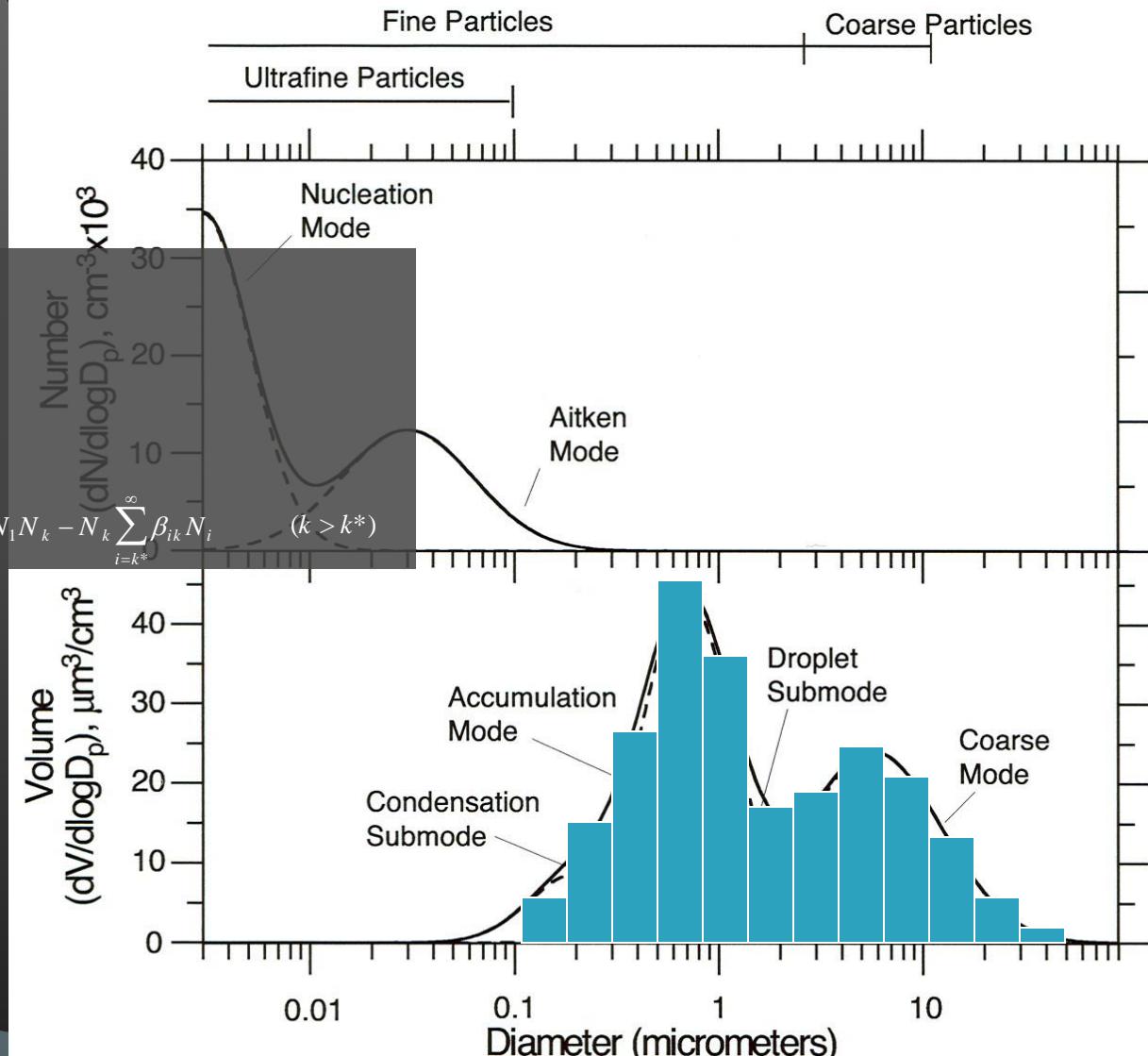
$$p(\tau) = \begin{cases} 0, & \tau < 0 \\ 1/(1 + (\beta/\alpha + 1)\tau^\alpha), & \tau \geq 0 \end{cases}$$

$$\frac{dN_1}{dt} = I_1 - k^* I_{k^*} - N_1 \sum_{i=k^*}^{\infty} \beta_{li} N_i$$

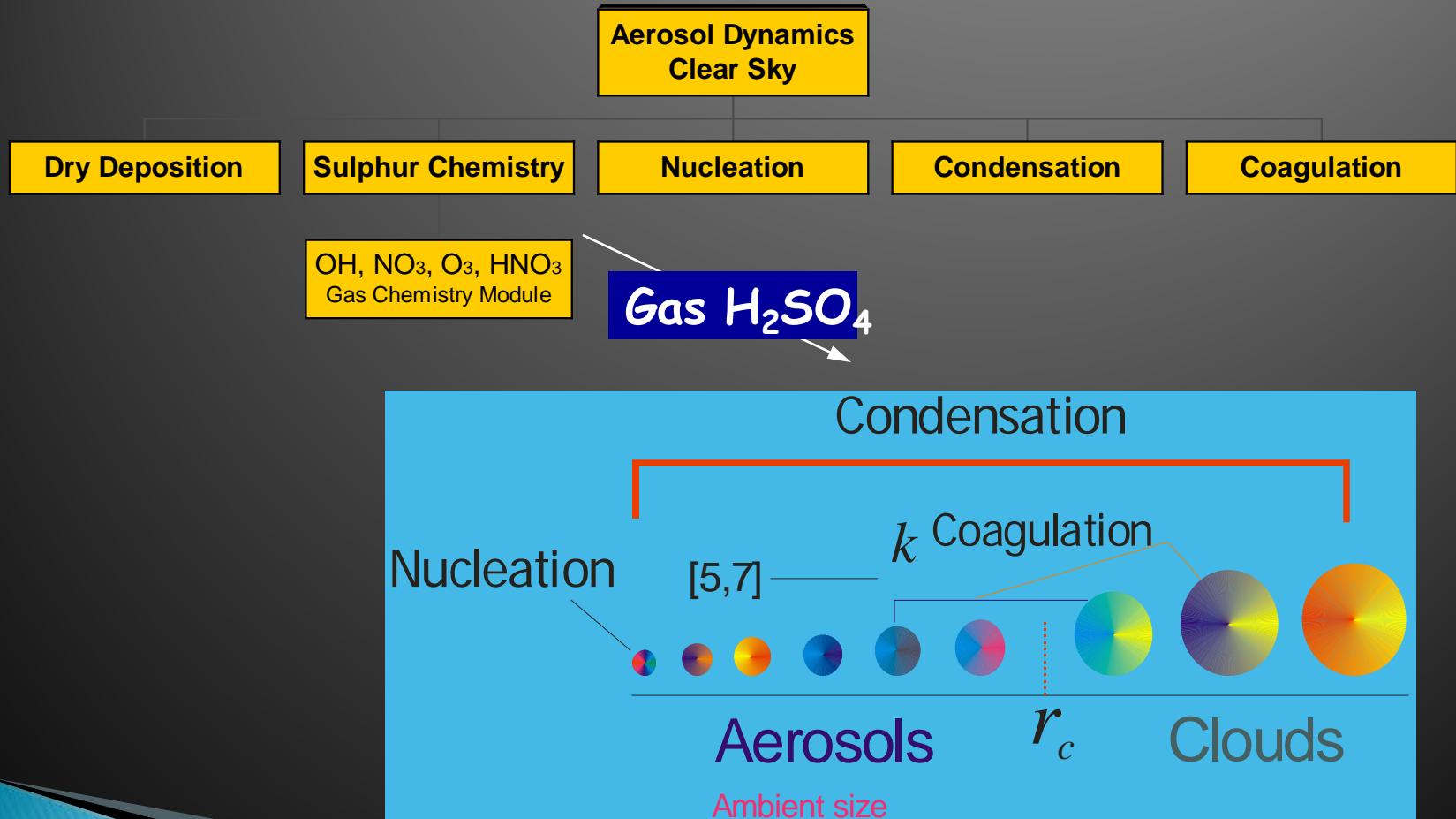
$$\frac{dN_{k^*}}{dt} = I_{k^*} - \beta_{1k^*} N_1 N_{k^*} - N_{k^*} \sum_{i=k^*}^{\infty} \beta_{k^*,i} N_{k^*} N_i$$

$$\frac{dN_k}{dt} = \beta_{1,k-1} N_1 N_{k-1} + \frac{1}{2} \sum_{i=k^*}^{k-1} \beta_{i,k-i} N_i N_{k-i} - \beta_{1k} N_1 N_k - N_k \sum_{i=k^*}^{\infty} \beta_{ik} N_i$$

Gong et al. 2003



CUACE/Aero

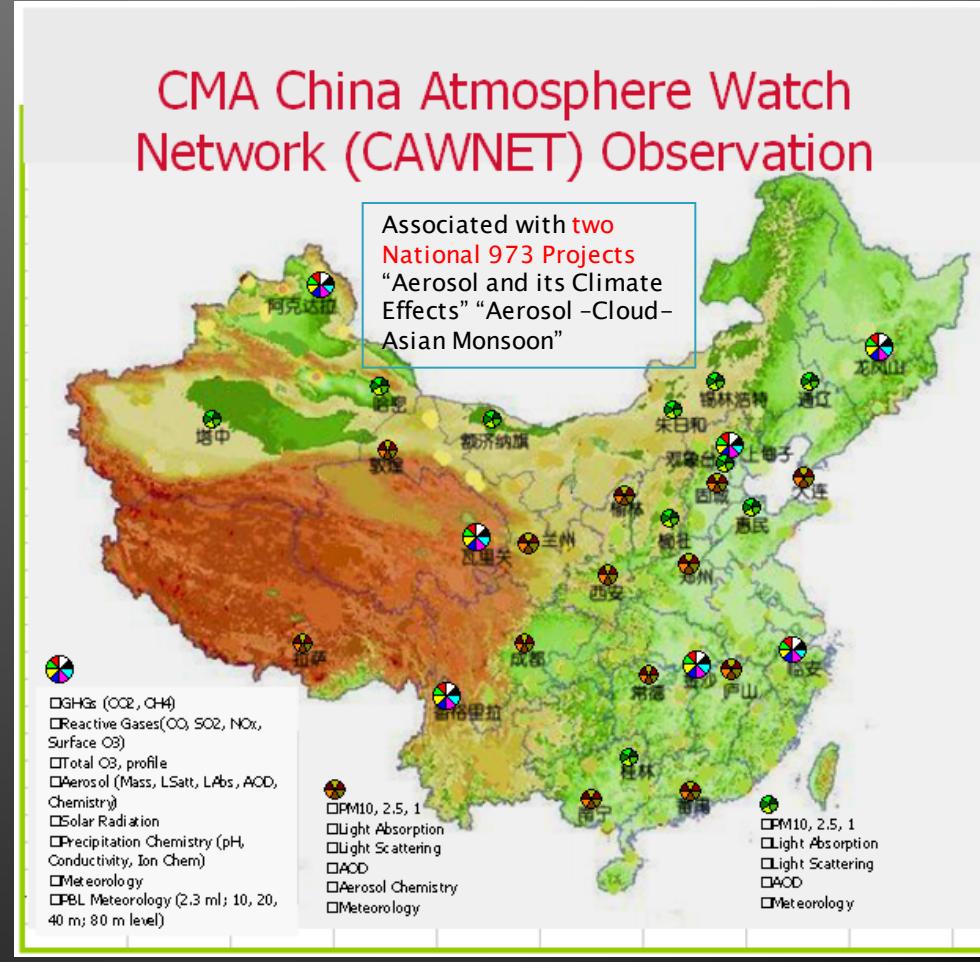
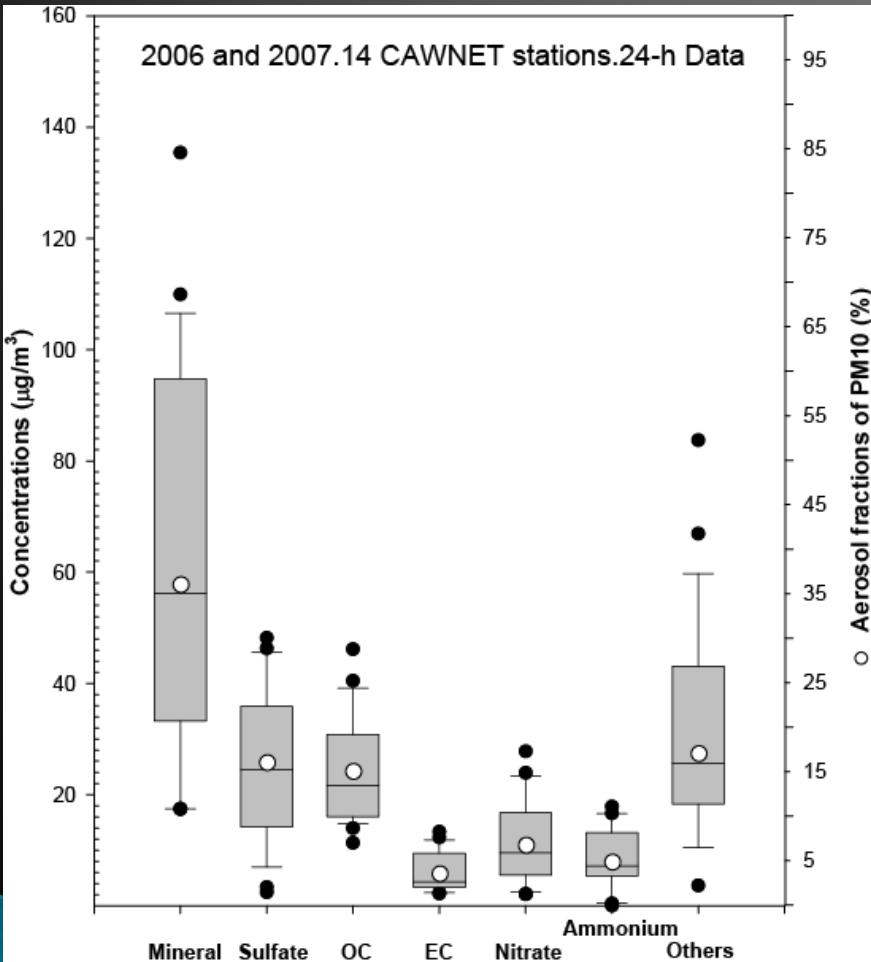


Challenges in AQ Forecasts

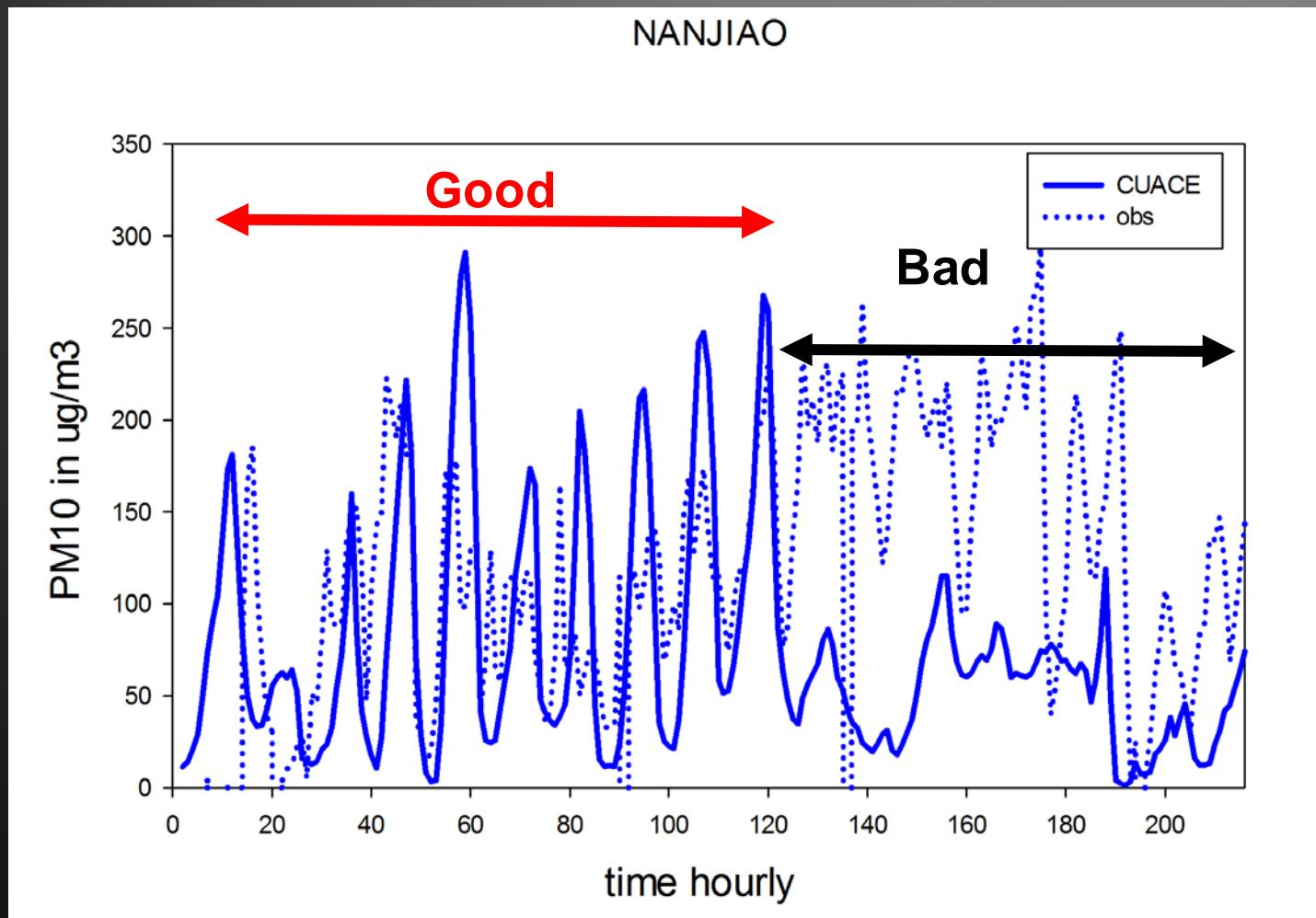
- **High concentrations with complex chemical compositions;**
- **Rapid changes in economy and hence difficulty to obtain timely emissions;**
- **Inaccurate statistics for emission inventory establishment;**
- **Modeling limitations and uncertainties.**

Feature of Chinese Aerosols

Zhang et al. 2011



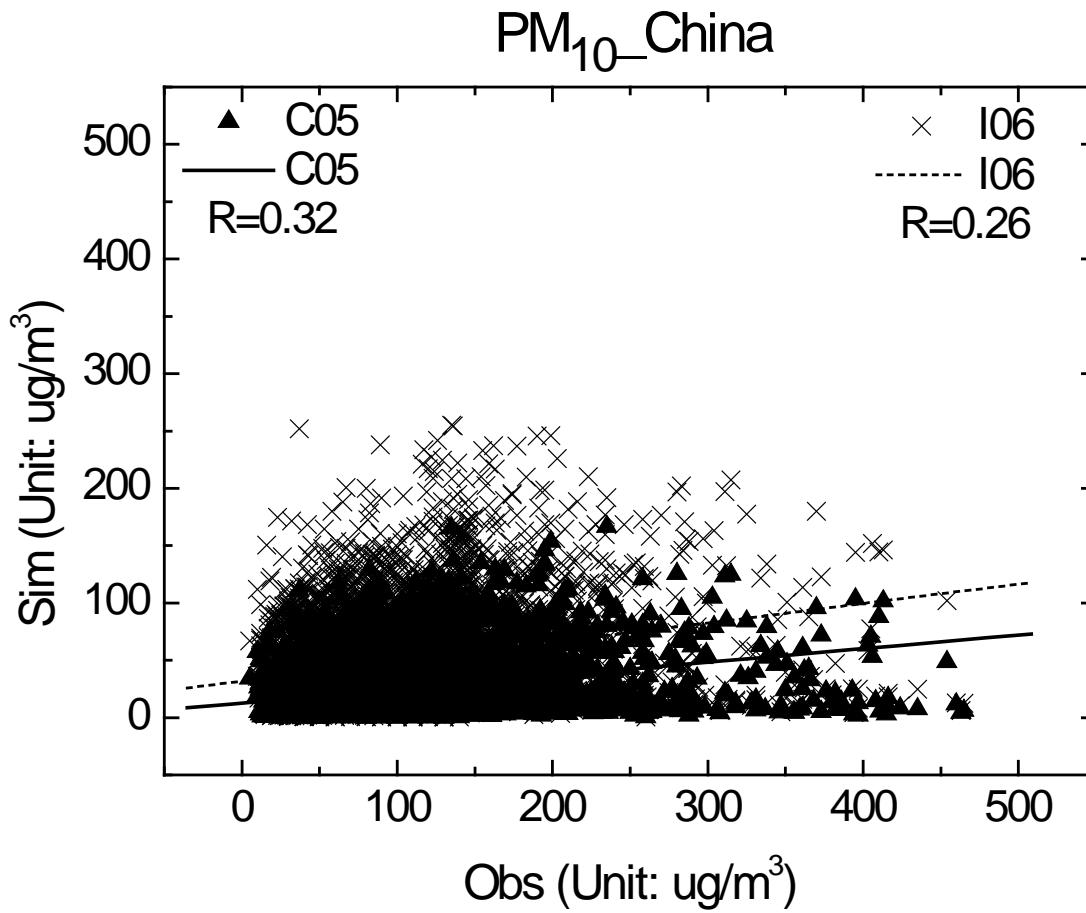
Model Predictions – CUACE



Zhou et al. 2011



Model Predictions – CMAQ



An et al. 2011



中国气象科学研究院
Chinese Academy of Meteorological Sciences

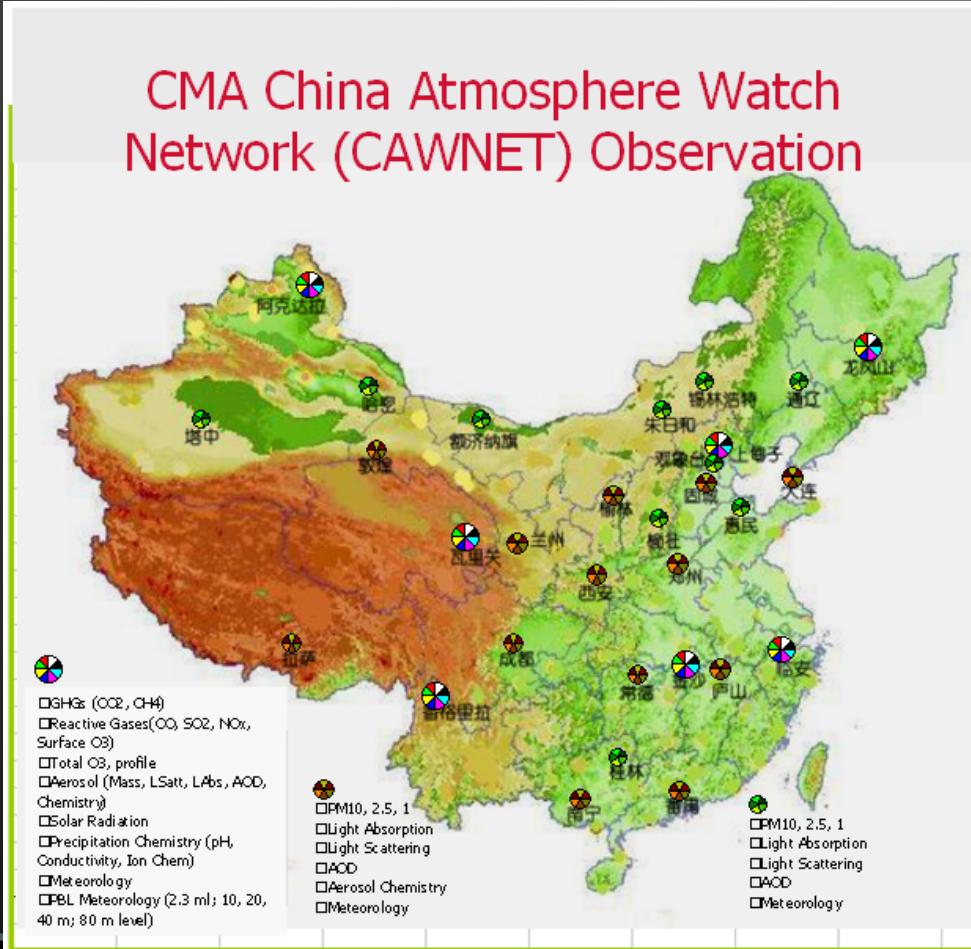
Improvement - 1

Acquiring Near Real Time Data



CAWNET

CMA Atmospheric Watch Network

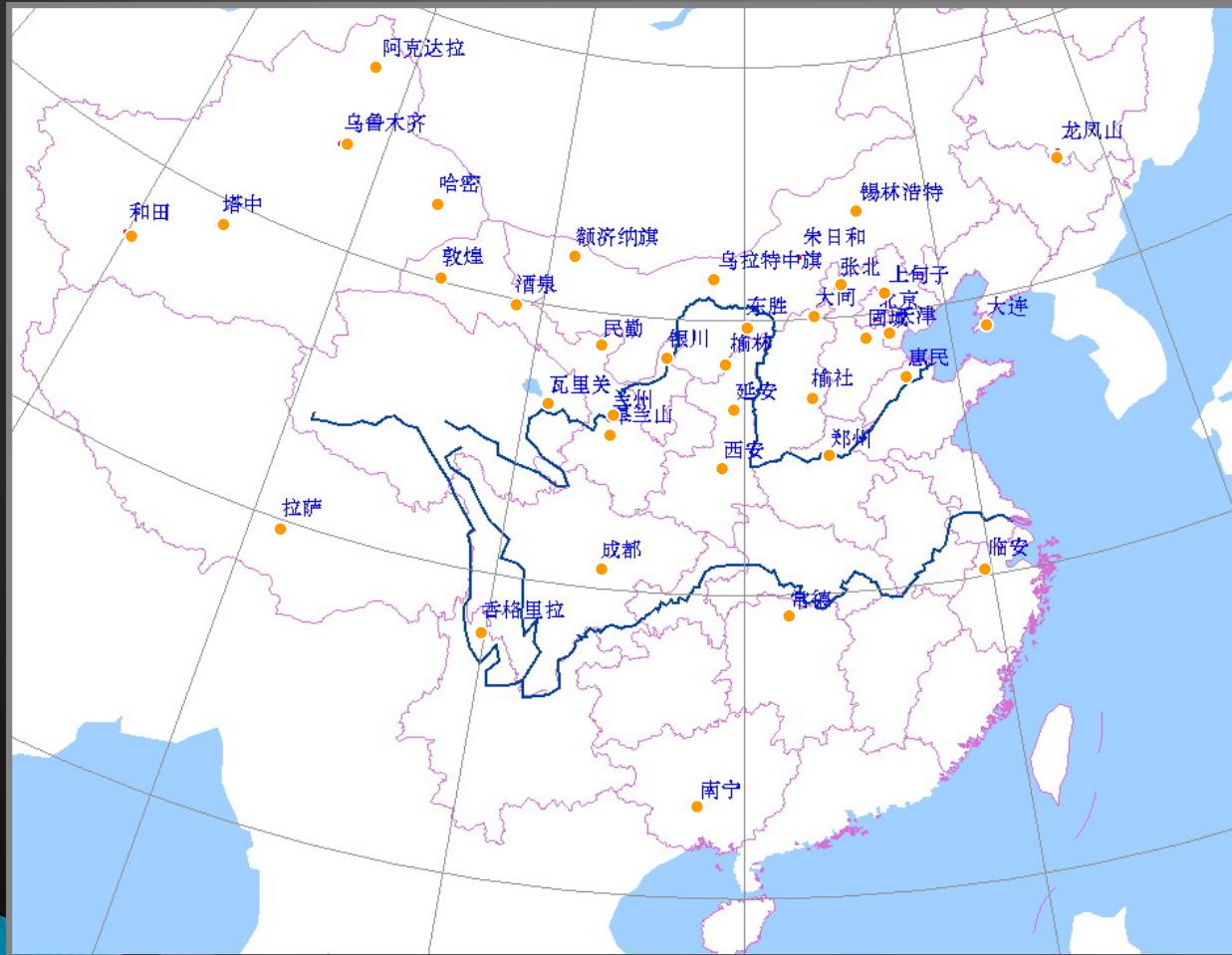


PM10
PM2.5
BC



CARSNET

CMA Aerosol Remote Sensing Network



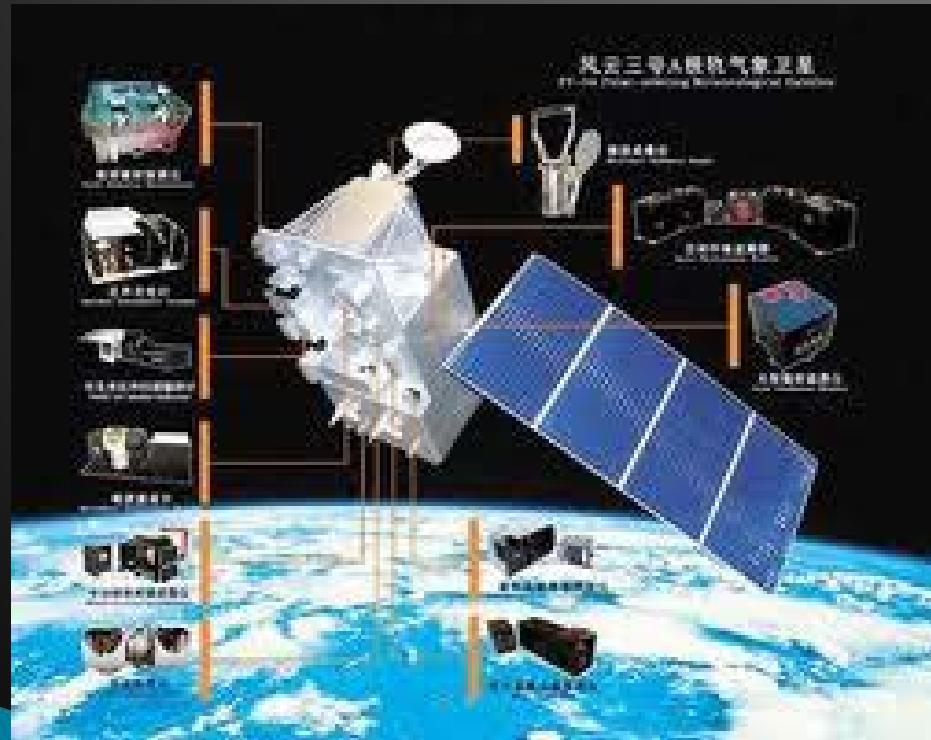
AOD



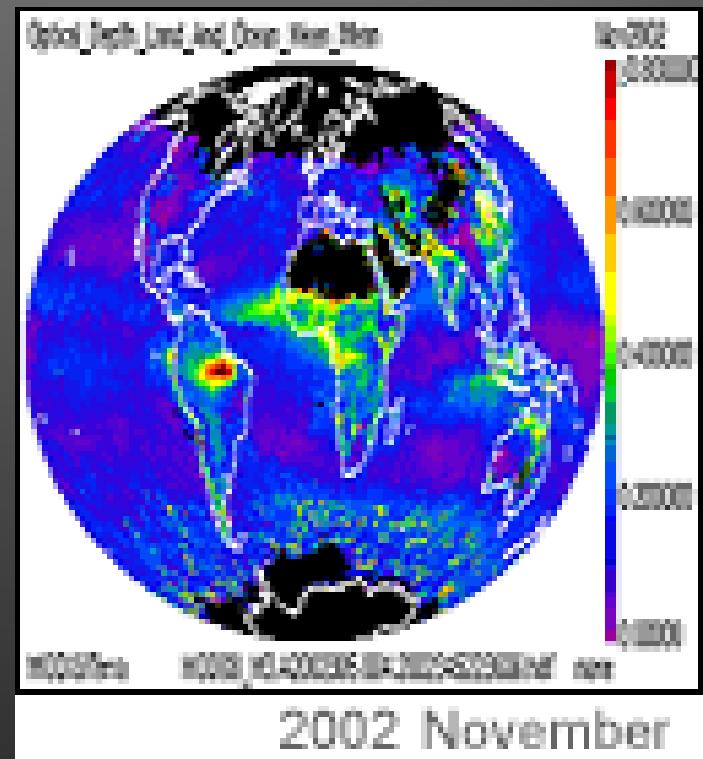
中国气象科学研究院
Chinese Academy of Meteorological Sciences

Satellites - AOD

FY-3A



MODIS



Product

**An on-line NRT data
collection system for
data assimilations and
model evaluations**

Improvement – 2

Data Assimilation using NRT Data



3D-Var Method

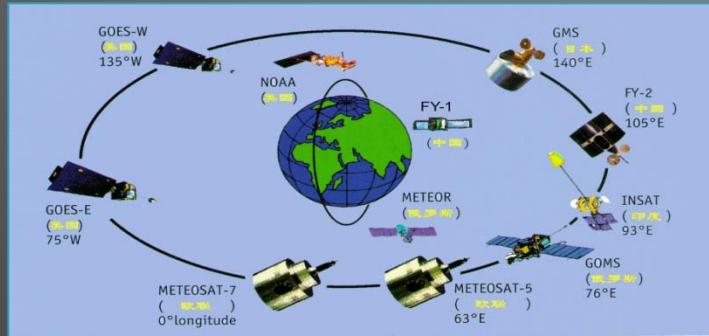
**3D-Var is to minimize the following function
(Lorenc,1986):**

$$J(x) = \frac{1}{2} \left[(x - x_b)^T \mathbf{B}^{-1} (x - x_b) + (H(x) - \mathbf{y}_o)^T \mathbf{O}^{-1} (H(x) - \mathbf{y}_o) \right]$$

**Using the observational data y_o to find
the solution of x that satisfies the
 $\min J(x) \rightarrow x_a$**

Dust Storm: CUACE/Dust

Satellite FY-2C 2D



SDS Observations



Data Assimilation

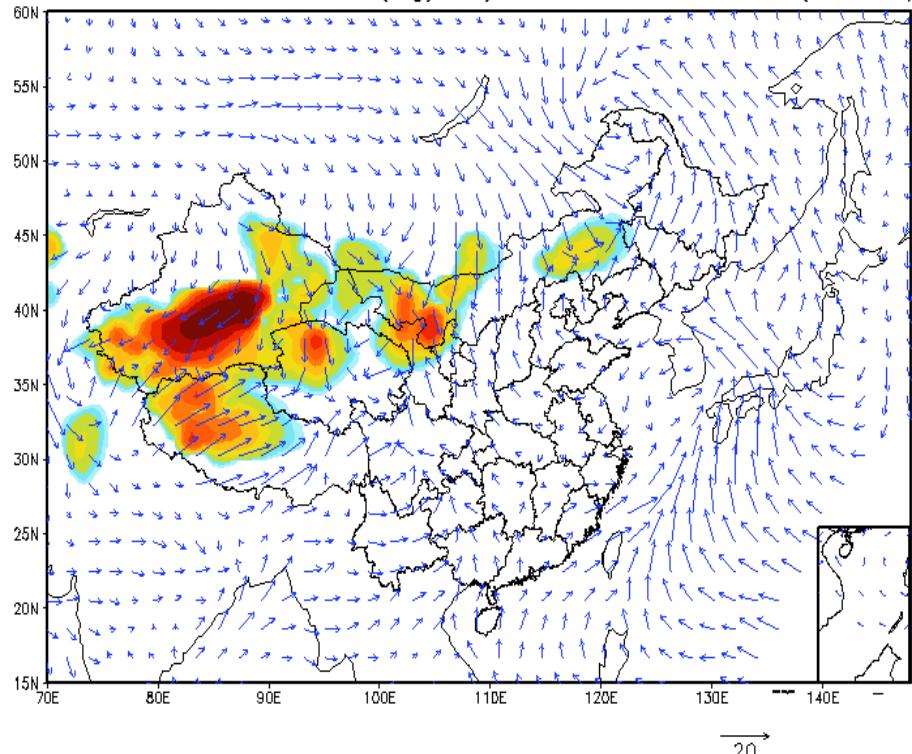
CUACE/Dust



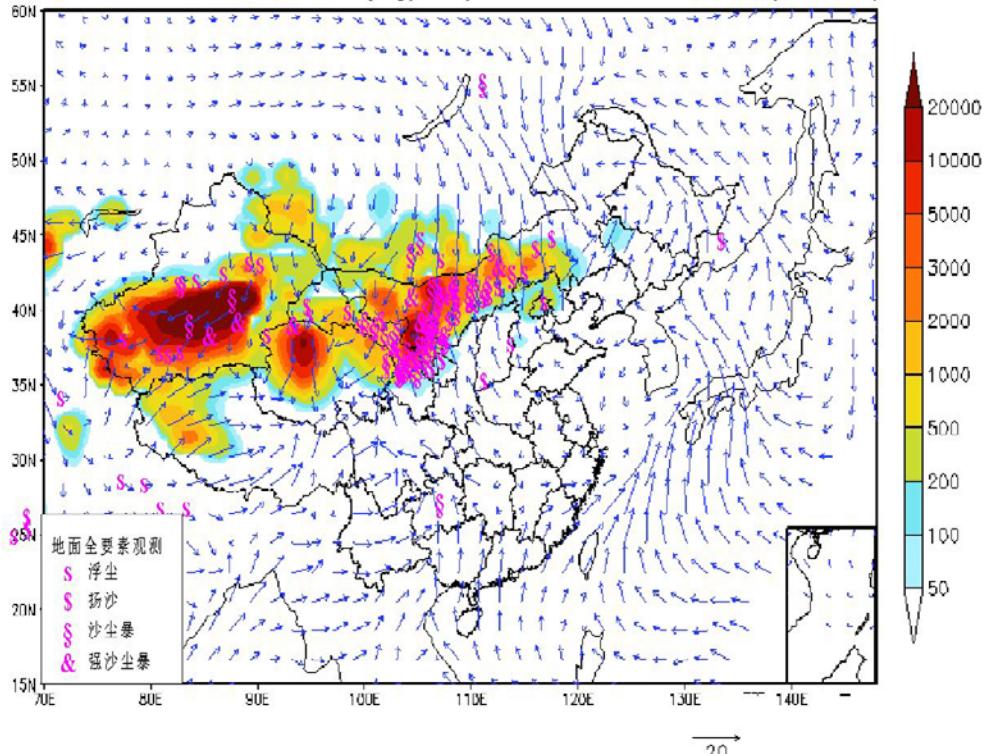
Gong and Zhang 2008, ACP

SDS Assimilation Results - 1

Surface Wind & Dust ($\mu\text{g}/\text{m}^3$) 06-04-10 20:00 (CAWAS)

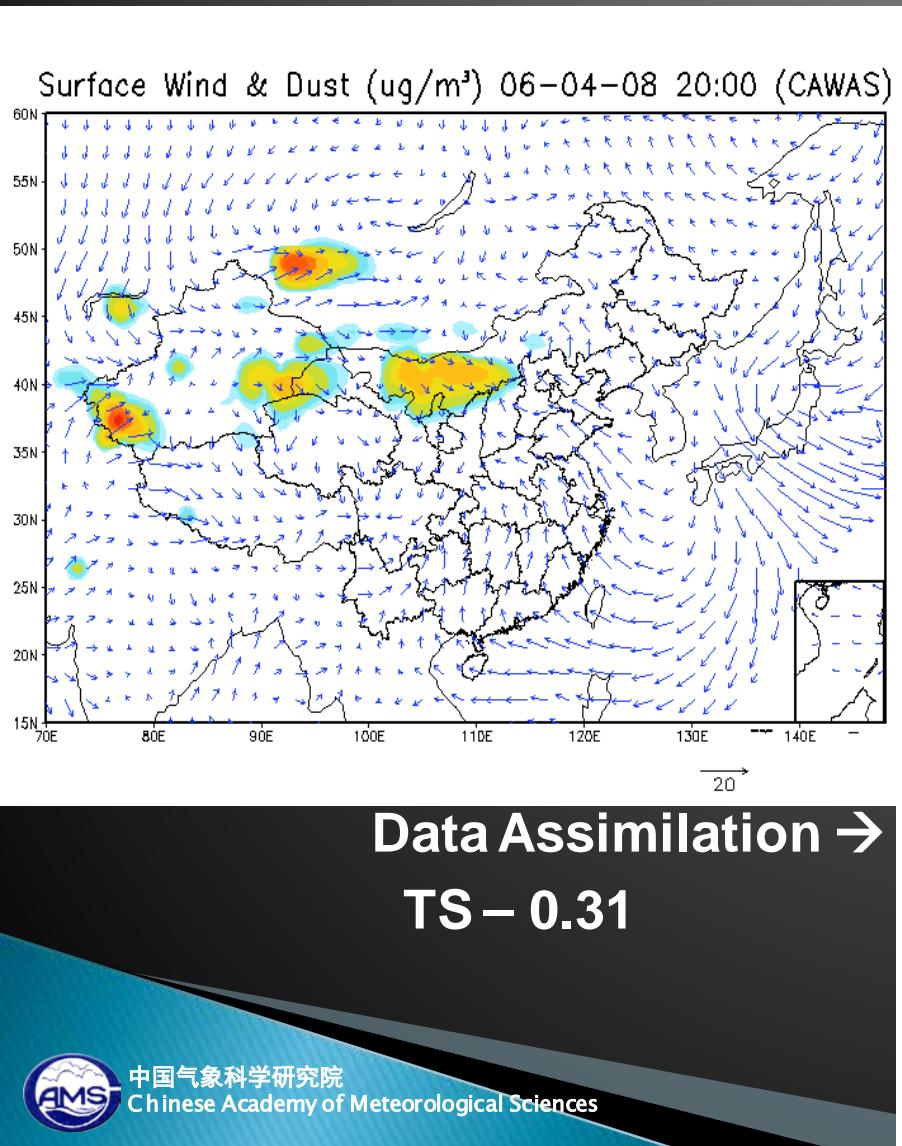


Surface Wind & Dust ($\mu\text{g}/\text{m}^3$) 06-04-10 20:00 (CAWAS)



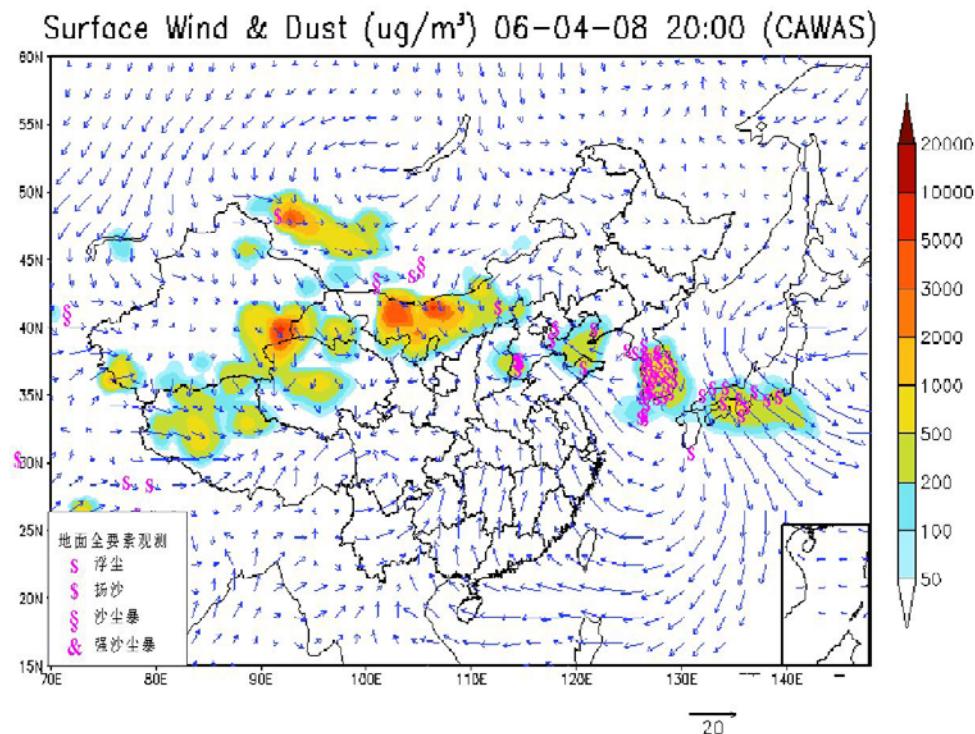
Comparisons of CUACE/Dust forecasting results for 10 April 2006 with and without data assimilation. The symbols of “S”, “\$”, “§”, “&” indicate floating dust, blowing dust, SDS, severe SDS, respectively, obtained from surface meteorological stations of CMA

SDS Assimilation Results - 2

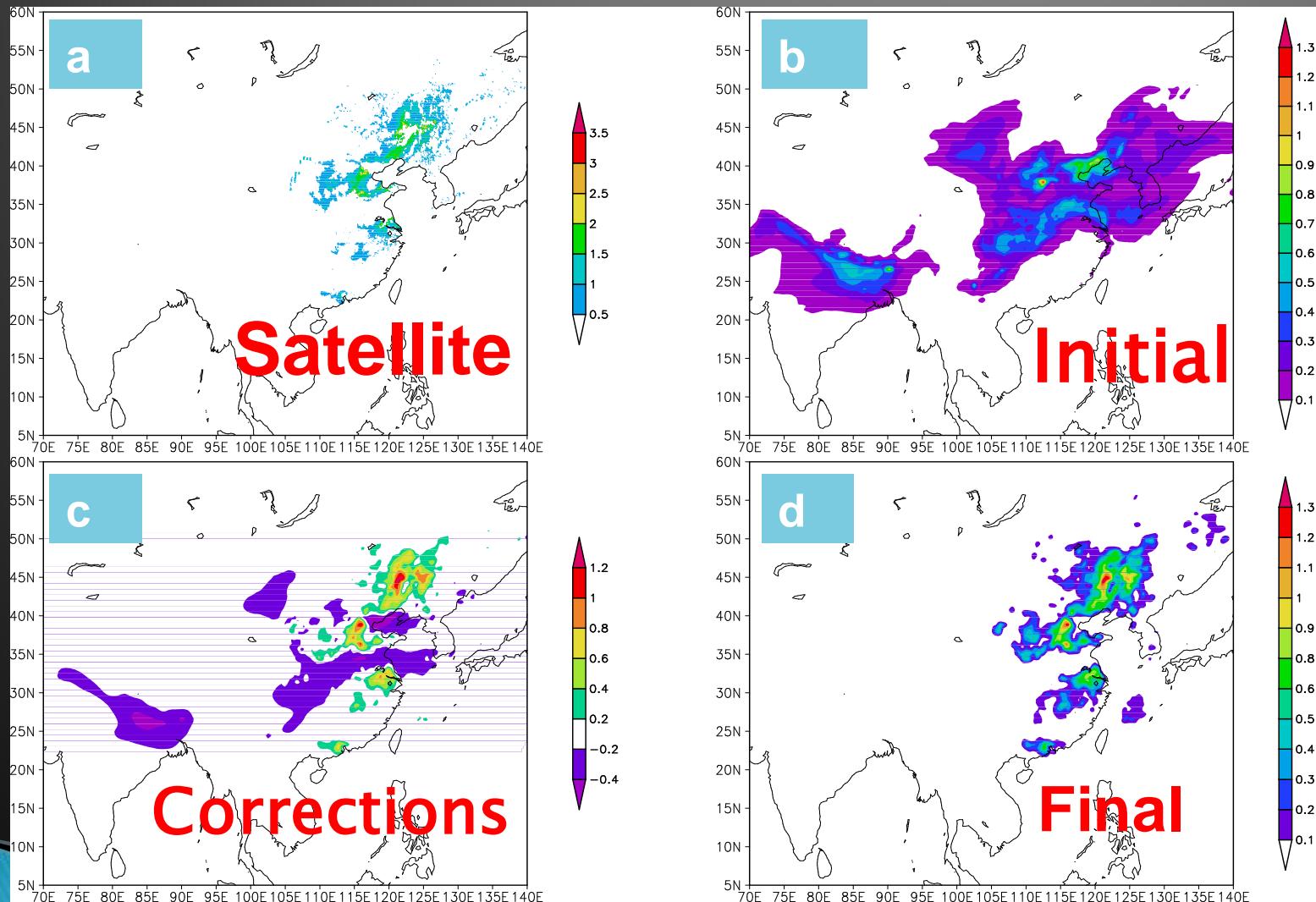


Nu et al. 2008, ACP

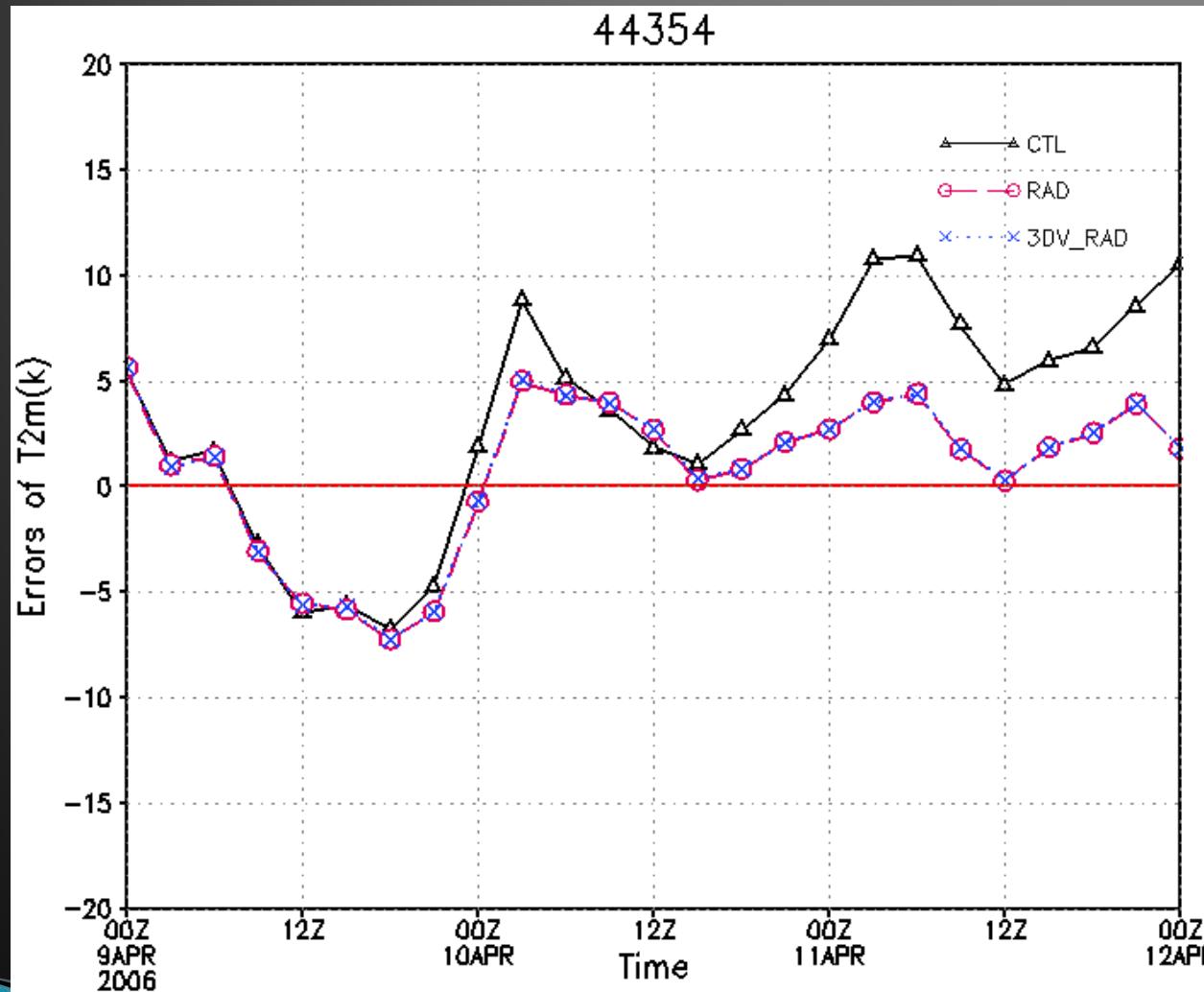
← No Data Assimilation
TS (Threat Score) – 0.22



AOD (FY-3A) Assimilation



Aerosol Feed back on weather



Wang et al. 2011 JGR



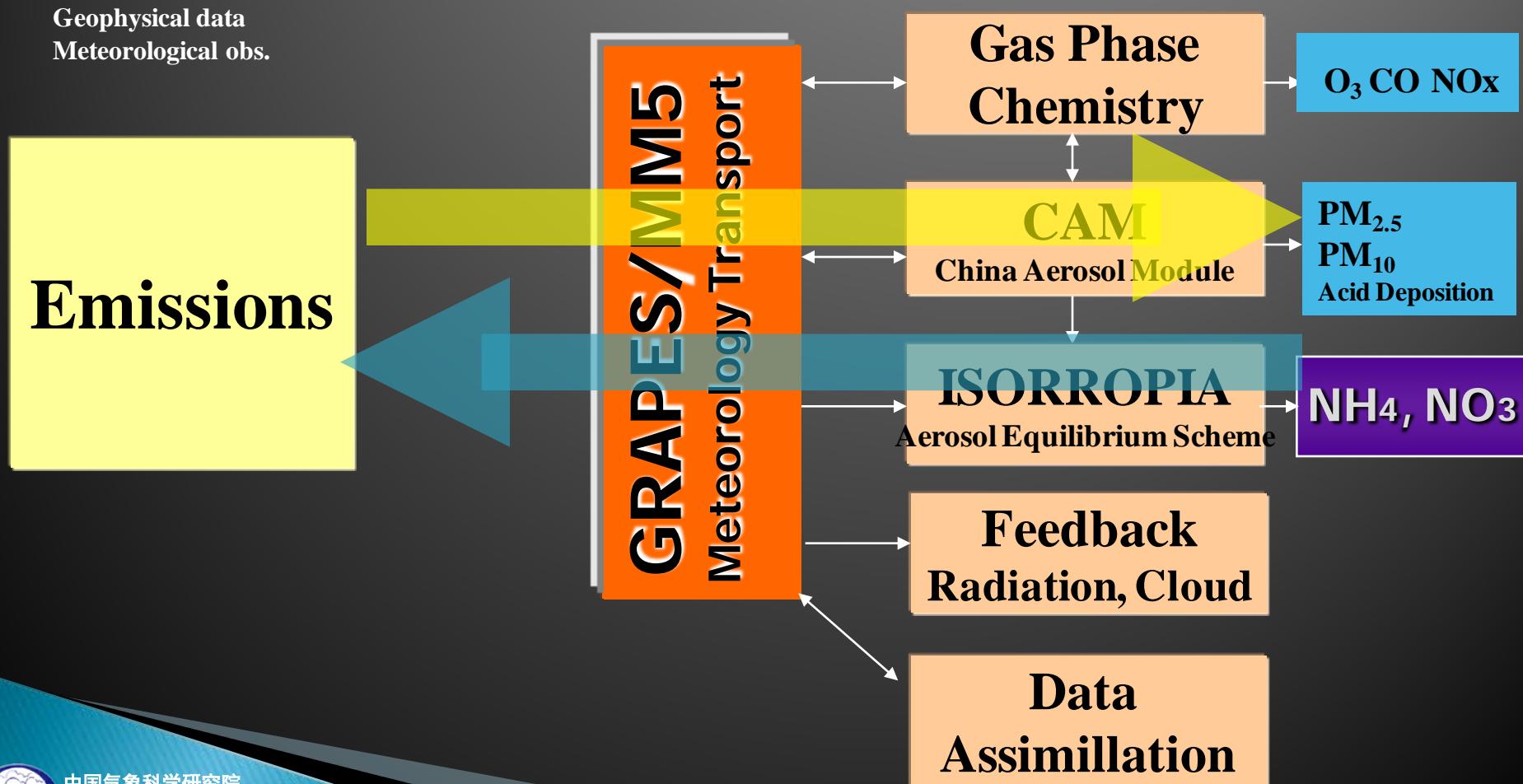
Product

An AQ forecasting
system with data
assimilation capacity
using the NRT time in
China.

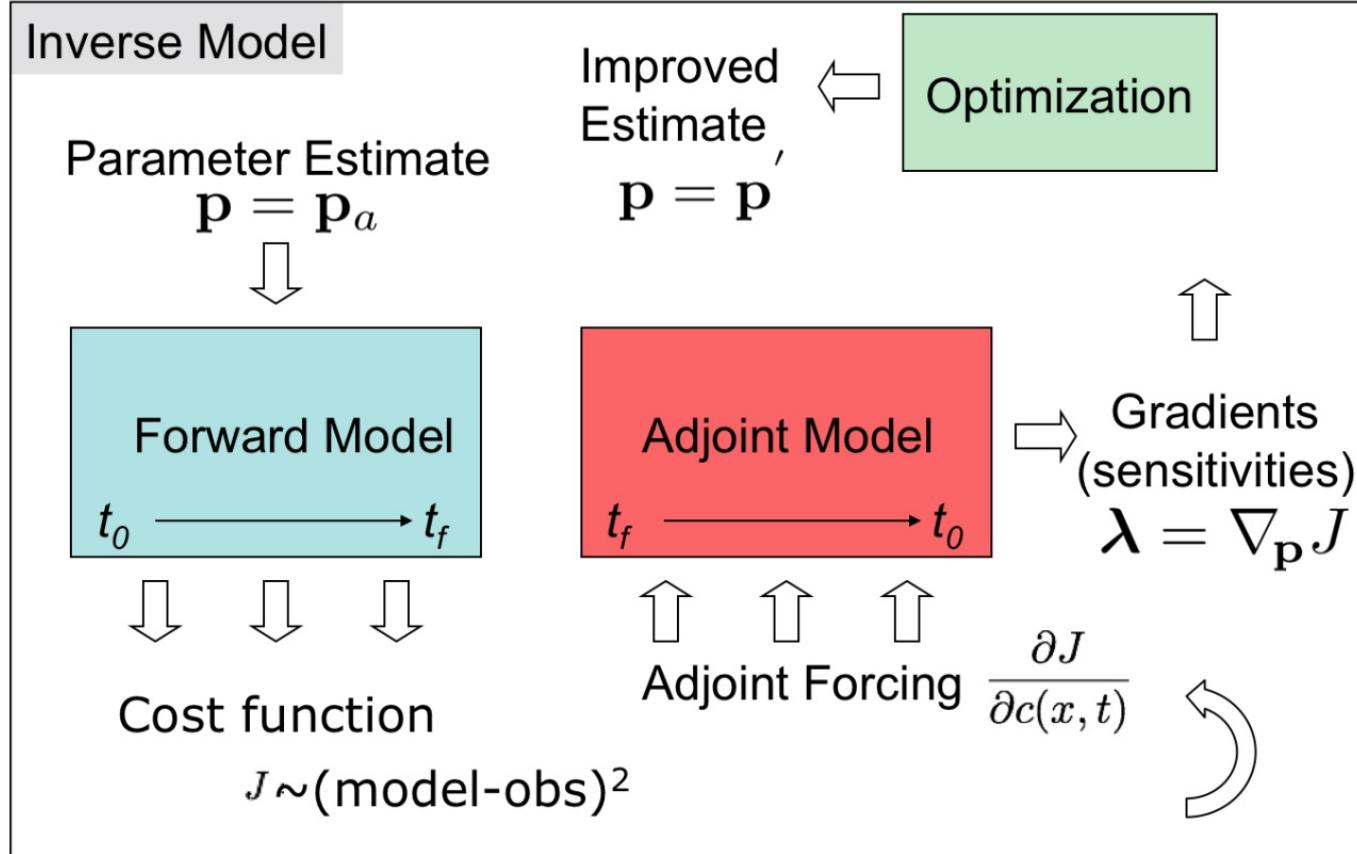
Improvement – 3

Inverse Modeling of Emissions

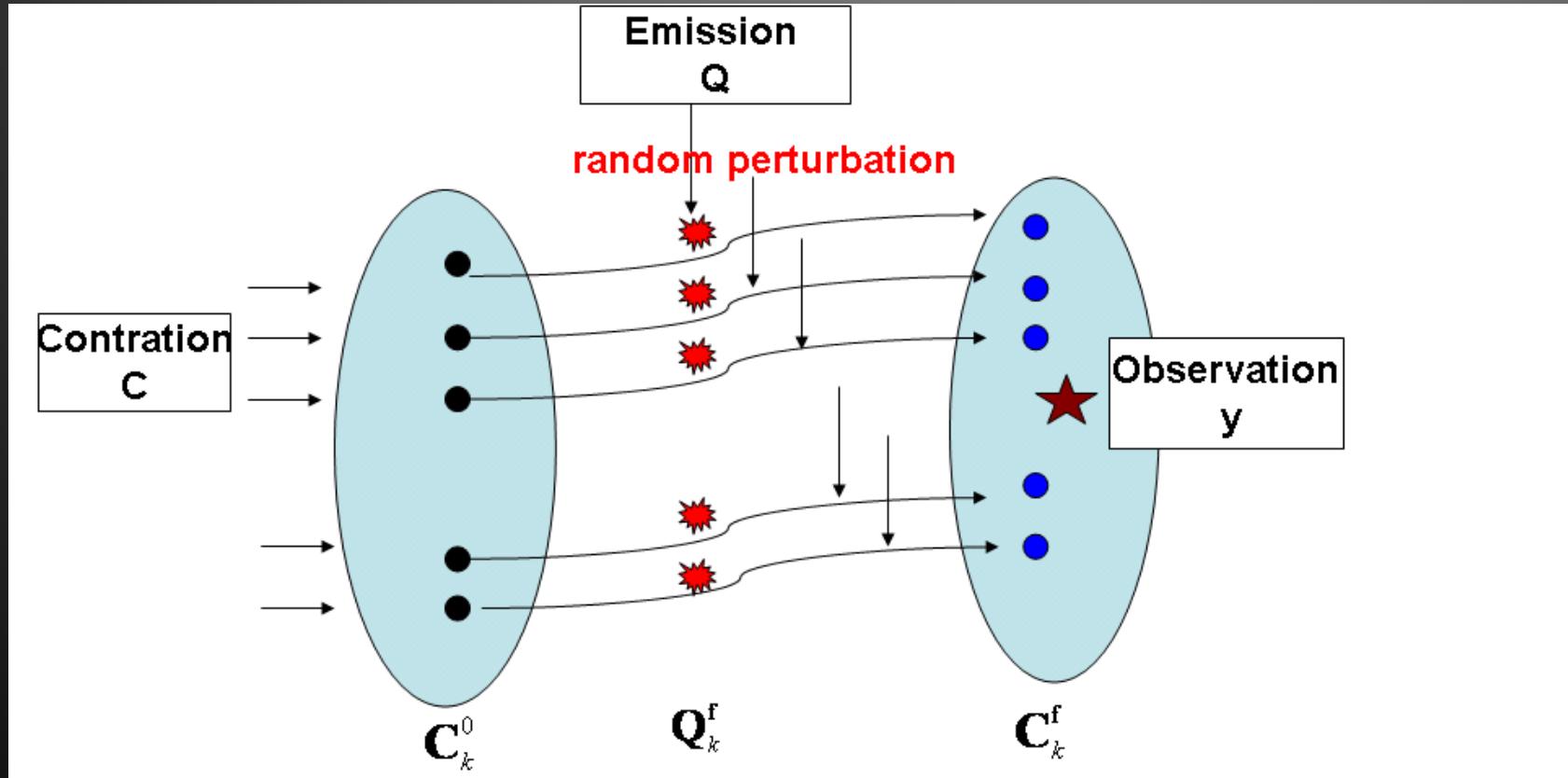
CMA Chemical Weather Forecasting System



(1) Adjoint Model



(2) Ensemble Kaman Filter Model

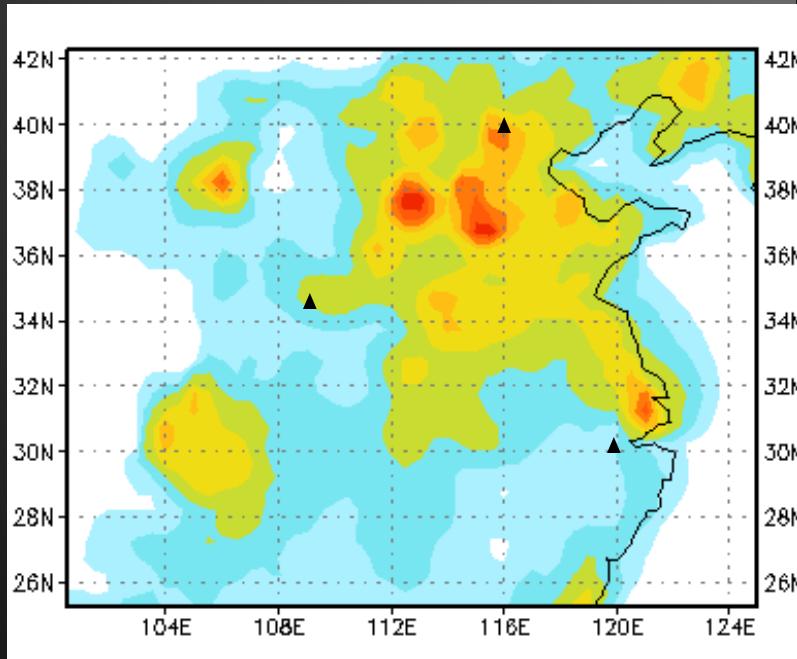


EnKF



BC Conc. ($\mu\text{g m}^{-3}$)

Forecasted

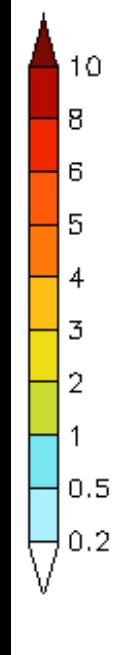


Observations:

Beijing : 7.0

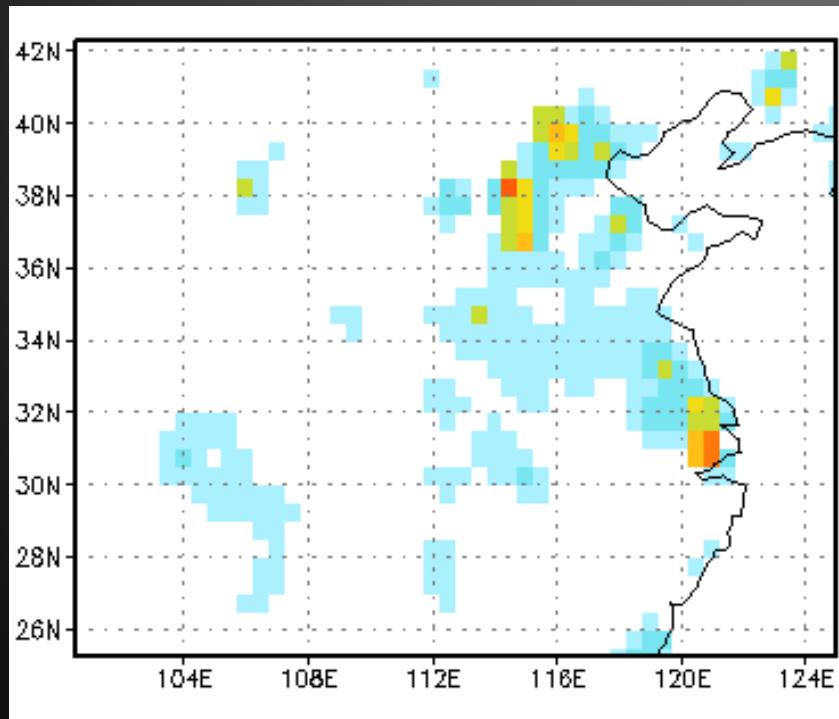
XI'an: 0.09

Lin An: 1.03

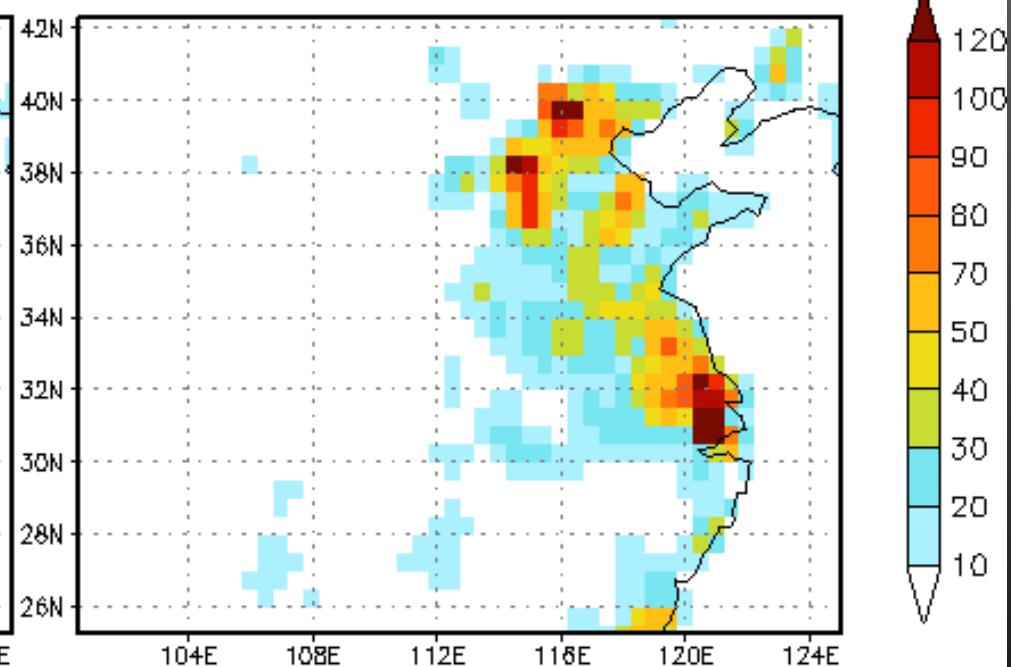


BC Emission Strength ($\mu\text{g m}^{-2} \text{s}^{-1}$)

Original



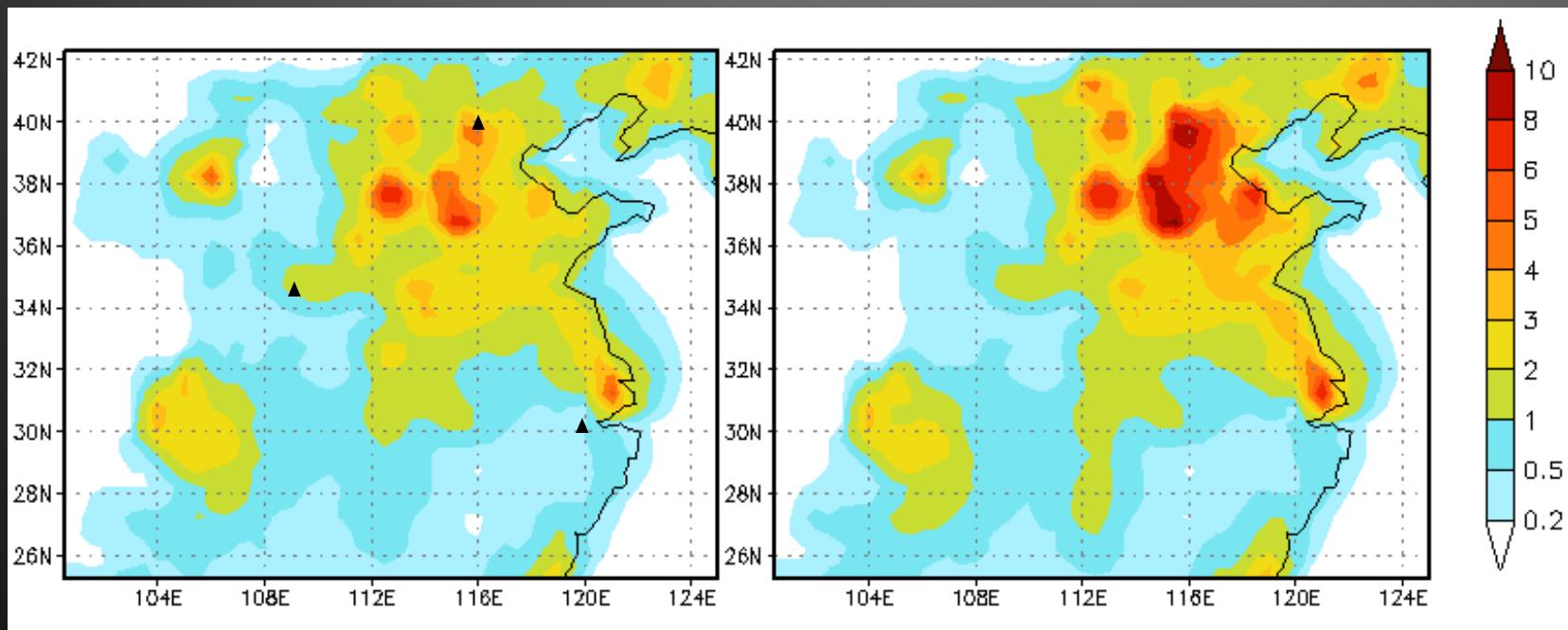
After Adjustment



BC Conc. ($\mu\text{g m}^{-3}$)

Original Forecasting

After Adjustment

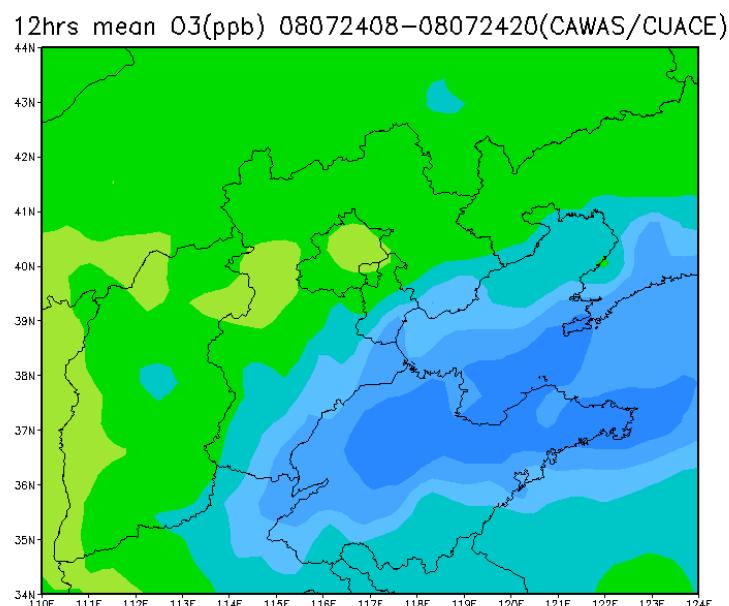
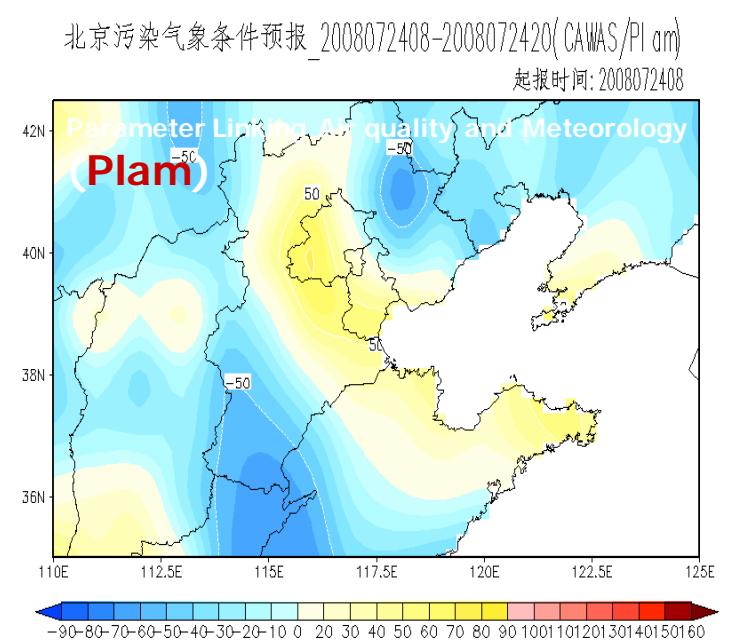
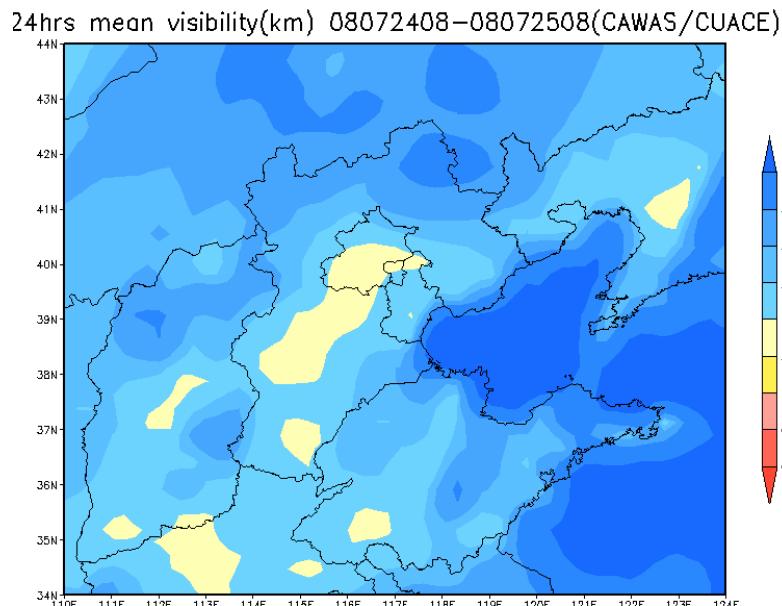
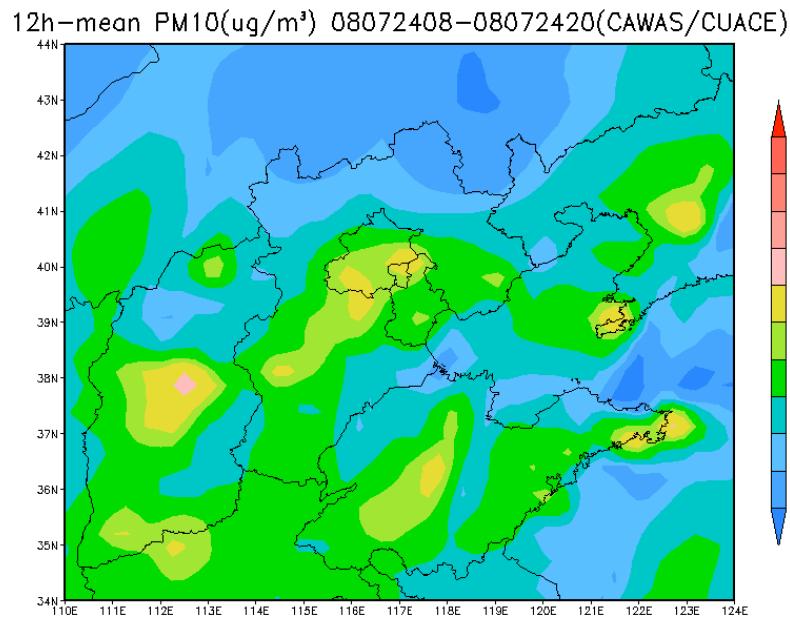


Beijing : 7.0, XI'an: 0.09, Lin An: 1.03

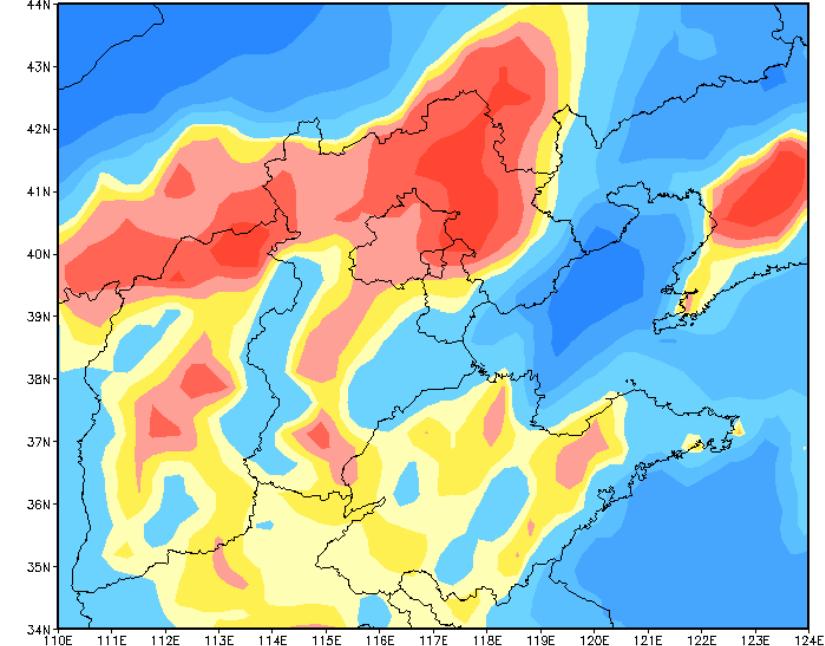
Product

An emission inventory that combines the bottom-up approach with the inversed modeling emissions, that can get better AQ forecasting results.

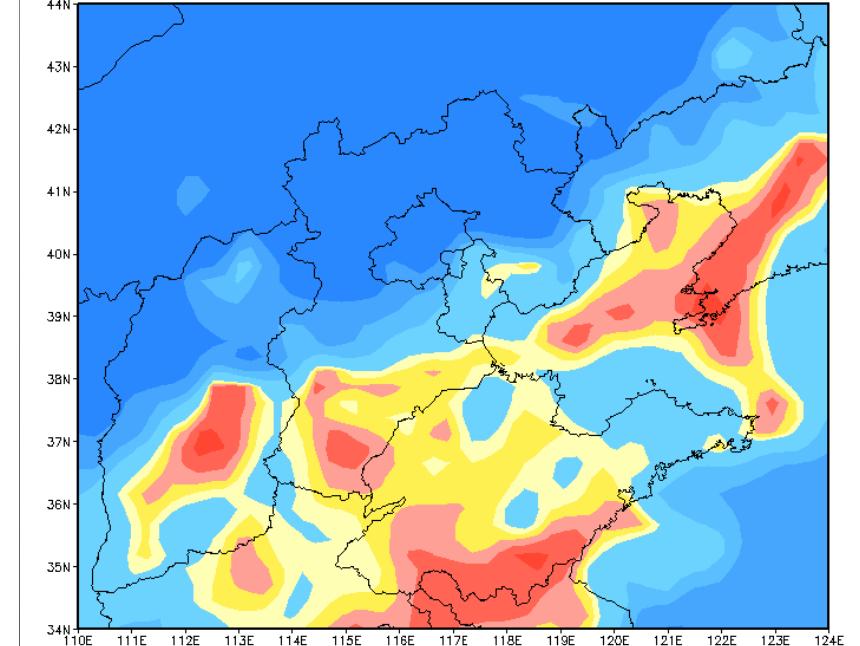
Before and during the Beijing Olympic Games, the CMA provided 2-day forecasts of PM10, visibility and O₃ to BMG and subsequently provided to Beijing Meteorological Bureau (BMB) and Beijing Municipal Environmental Protection Bureau (BMEPB).



12hrs mean visibility(km) 09093008–09093020(CAWAS/CUACE)



12hrs mean visibility(km) 09100108–09100120(CAWAS/CUACE)

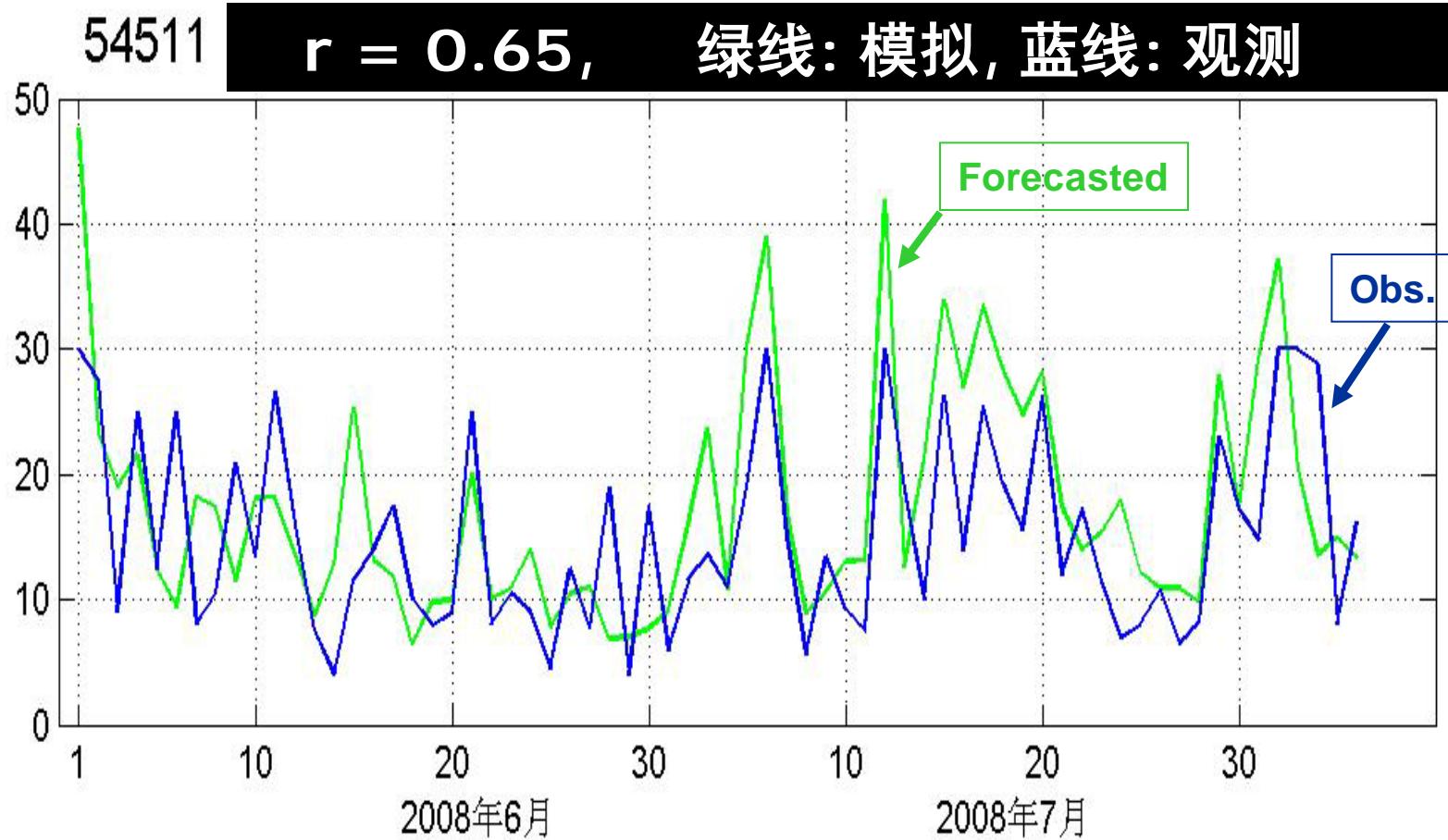


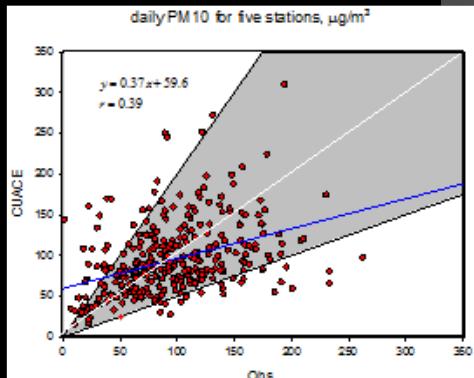
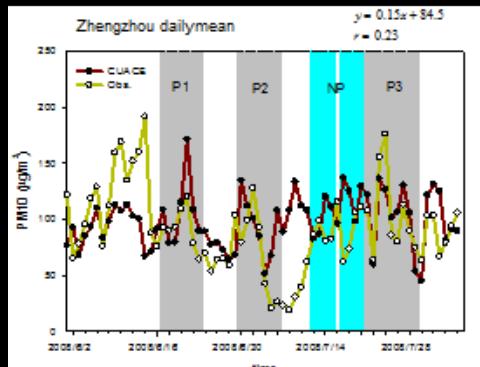
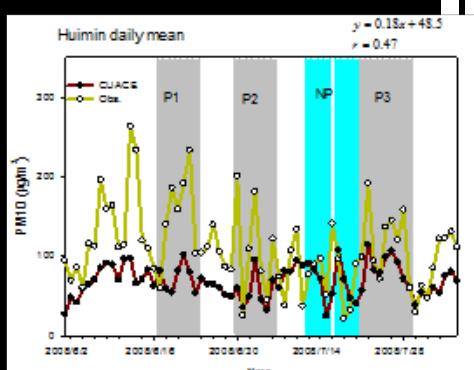
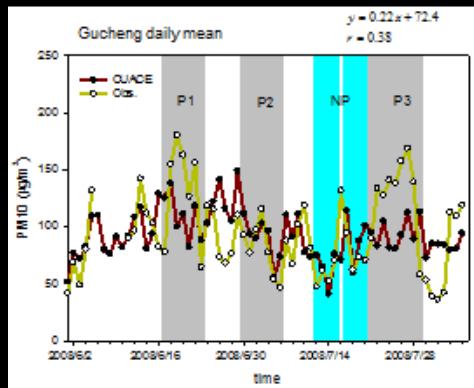
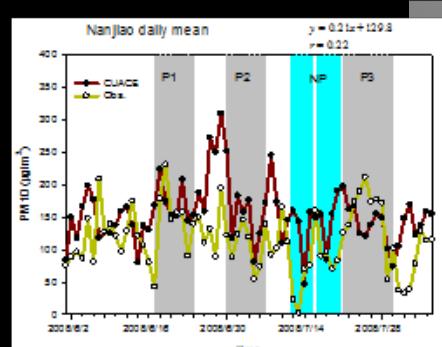
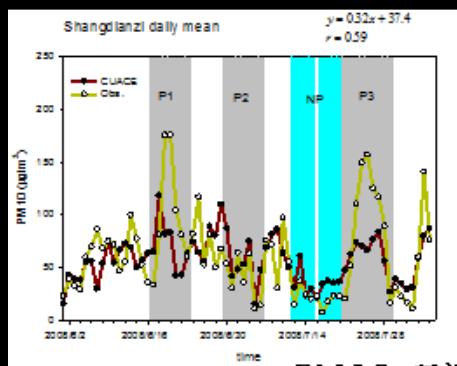
Visibility Forecast for National 60th anniversary
参加了国家级团队的60周年大庆预报服务



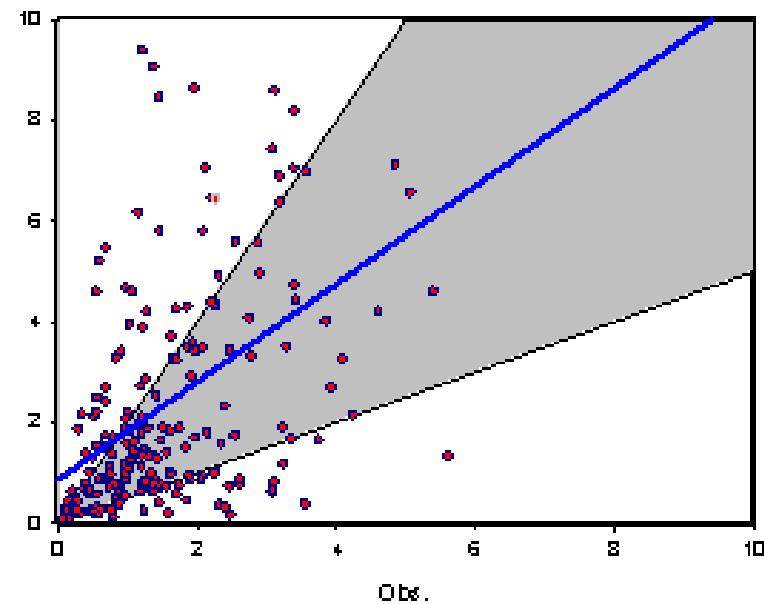
08奥运期间能见度模拟和观测对比

Comparison between Forecasted and Observed Visibility



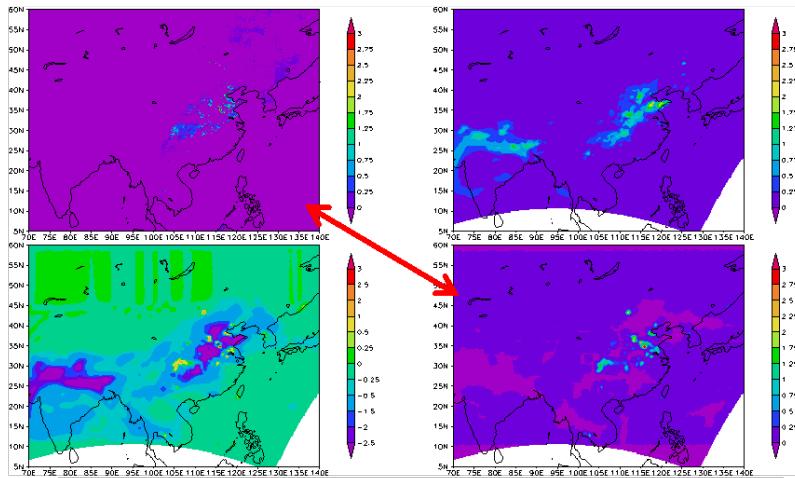


AOD-440 nm for all stations



Aerosol Data Assimilation (AOD):

AOD of China Geostationary Satellite: FY-3A



upleft: satellite AOD;
 downleft: increment by DA;

upright: initial model
 downright: updated initial



Conclusions

- A chemical weather forecasting system has been developed within the Chinese weather forecasting model - GRAPES.
- The NRT data can be used to improve the accuracy of the AQ forecasts through the data assimilation for the realistic initial conditions and inverse modeling for a timely and accurate emissions.
- Chemical weather forecast can not only forecast AQ but also improve the conventional weather forecasts through the feedback of aerosols.

Thank you!