The Design and Application of the Fine-Resolution Road Weather Information System to Improve Special Meteorological Services over the Greater Beijing Metropolitan Area in North China

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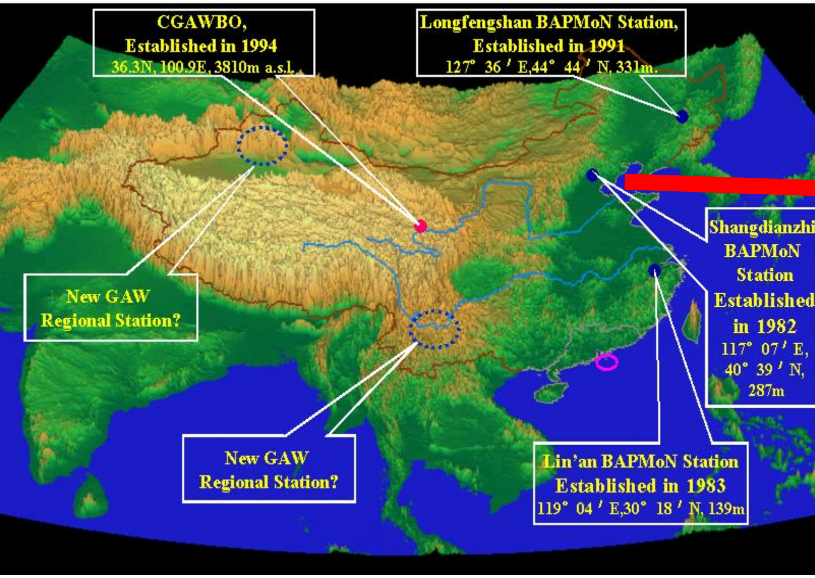
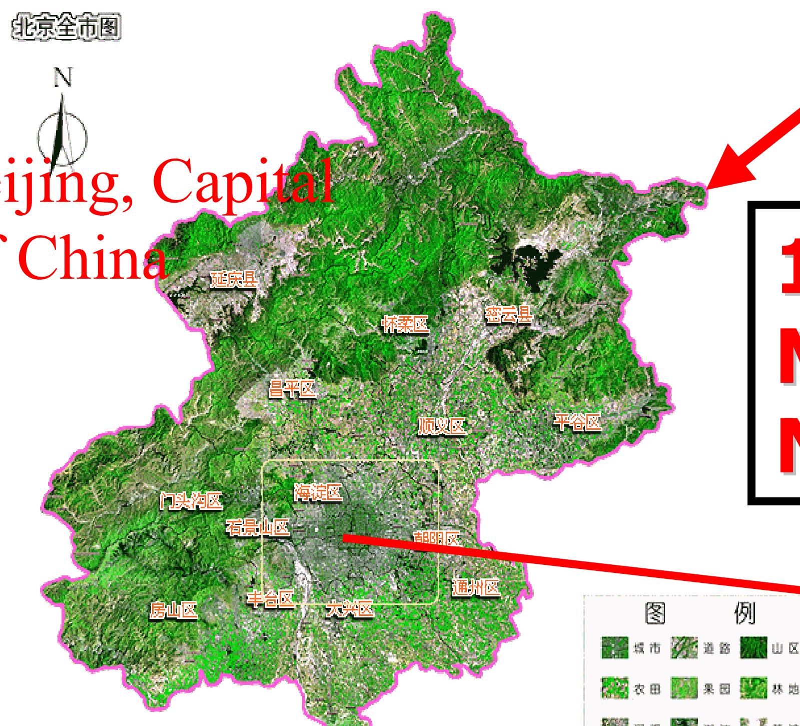
P.R China



The Great Beijing metropolitan Area

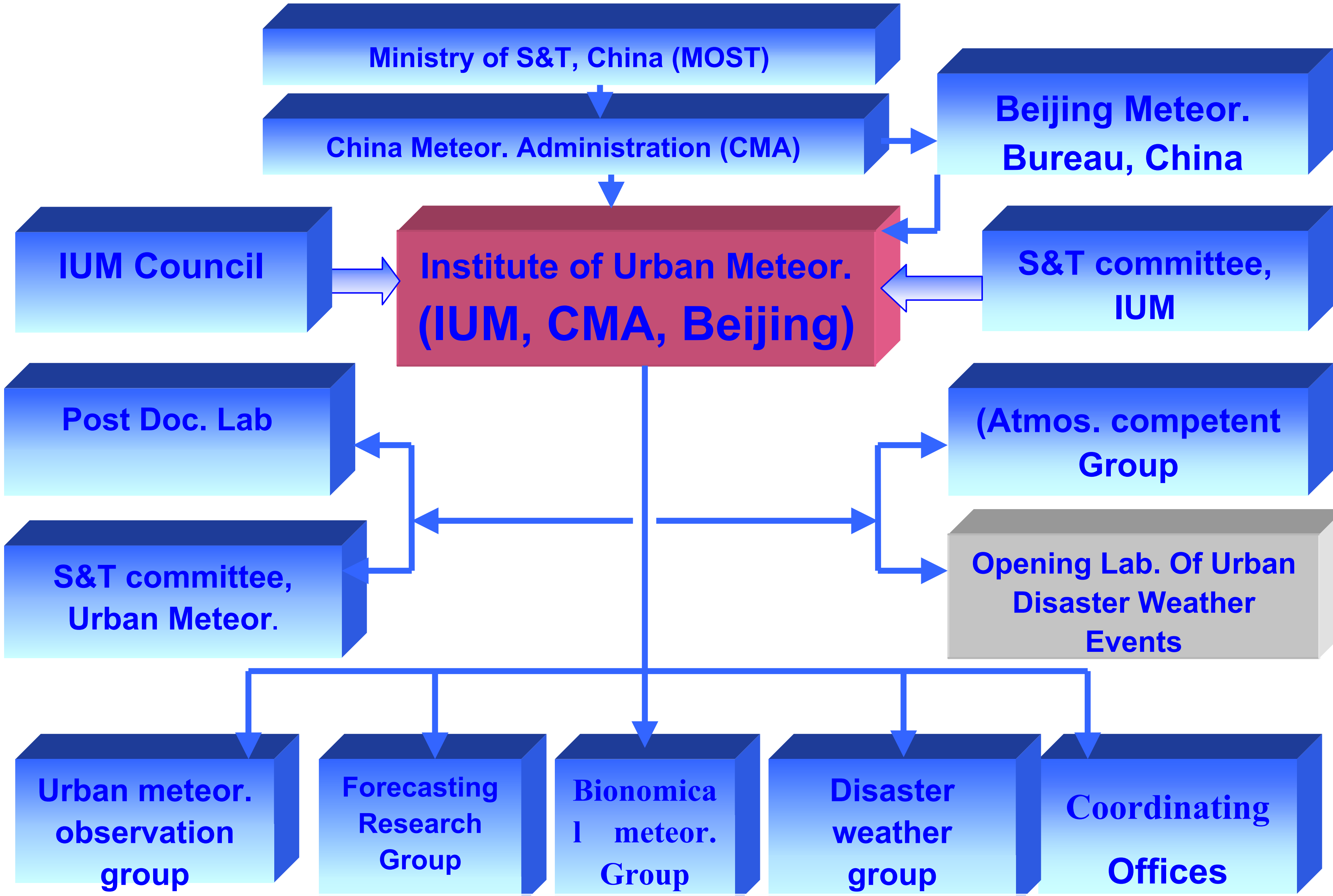


1. On the Greater Beijing Metropolitan Area in North China

Downtown

Density expressway network
around the greater Beijing metropolitan area

2. Brief Introduction to IUM



IUM is one of eight special meteor. institutes supported by MOST of China. And its aims focus on R&D of urban meteor. application.

3. R&D Background

With rapid expansion of both urban area and expressway network, road weather information and fine resolution NWP forecasting are becoming two high impact factors on urban security system of the Great Beijing metropolitan area, and on large public services as 2008 Olympics.

A local light-snow (1.8mm/24h) event on 7 Dec 2001 of Beijing caused a heavy traffic jam lasted 8 hours. And about 10 thousand townspeople went back home on foot.

Expressways are closed for a heavy fog over Beijing-Tianjin-Hebei areas on 17 Feb 2007

All flights are cancelled for a snow over the greater beijing metropolitan area
on 15 Feb 2005

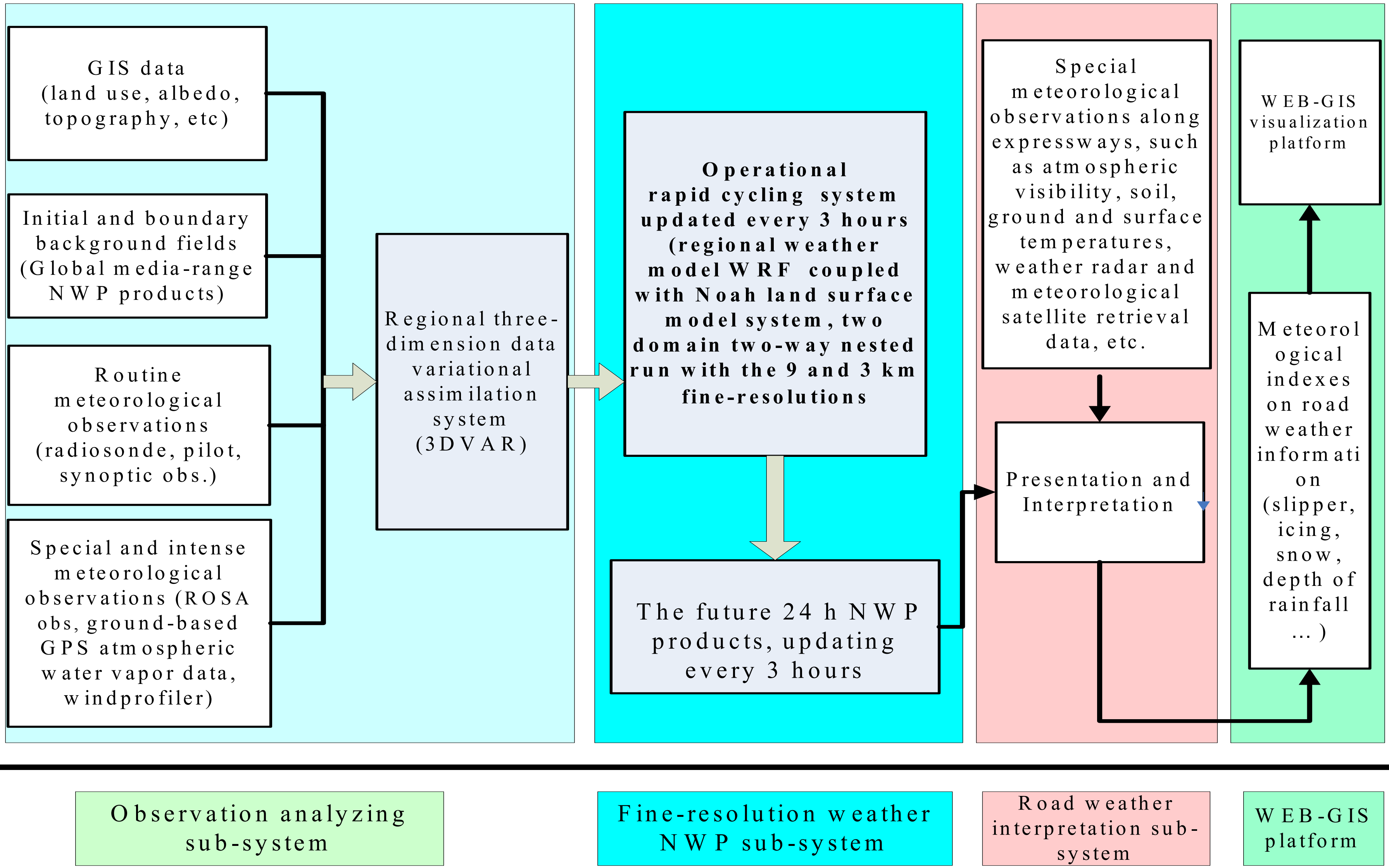
It is in a urgent need to establish road weather condition monitoring and forecasting system for 2008 Olympics and other public services….., especially for low atmospheric visibility events.

A local heavy rainfall event (over 100mm/6h) occurred in downtown area of Beijng on 10 Jul 2004, resulted in serious problem on the public transportation and life.

4. Design&Application to Fine-Resolution Road Weather Information System

- Design of the Fine-Resolution Road Weather Information System
- Road Meteor. Monitoring Network and operational NWP system
- Observational Characteristics of Atmospheric Visibility
- Improvement on the fine-resolution numerical prediction system
- The sophistical presentation&interpretation method: nonlinear support vector machines SVM
- WEB-GIS Visualization Operational Ppatform

Design of the Fine-Resolution Road Weather Information System



–Road Meteor. Monitoring Network

Special weather obs. network

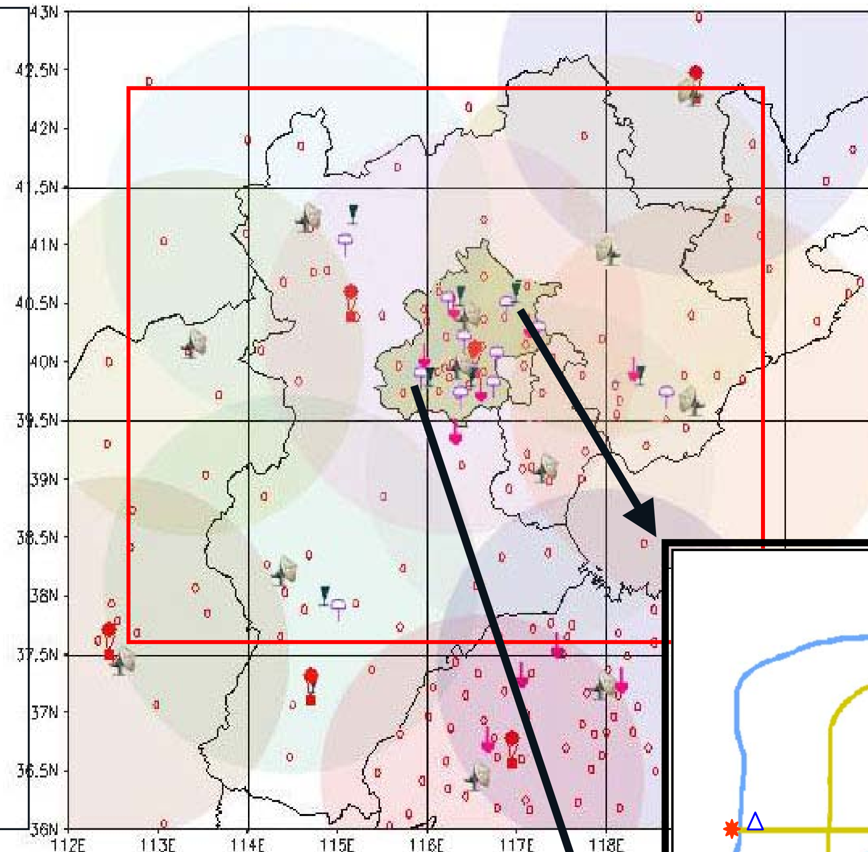
GPS-Met : 48

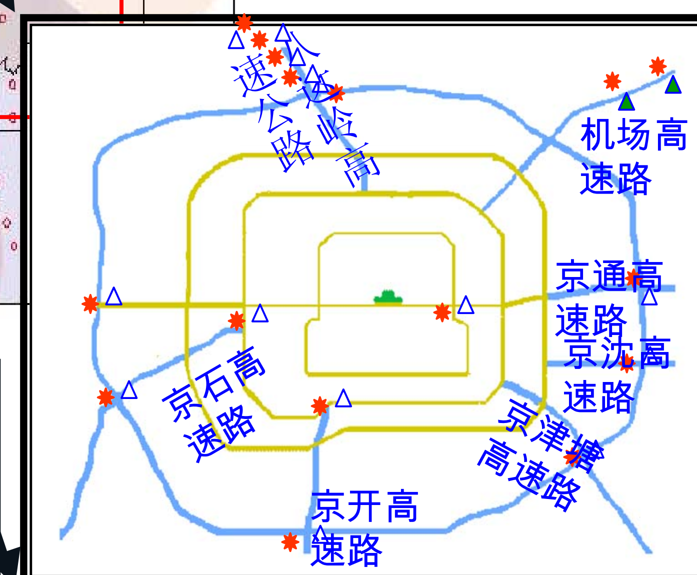
Radar : 5

Wind profilers: 5

Radiometric : 5

Mobile Environment meteorological observations: 2





Ring-roads and Density obs. within Beijing city

AWS: 167

ROSA:18

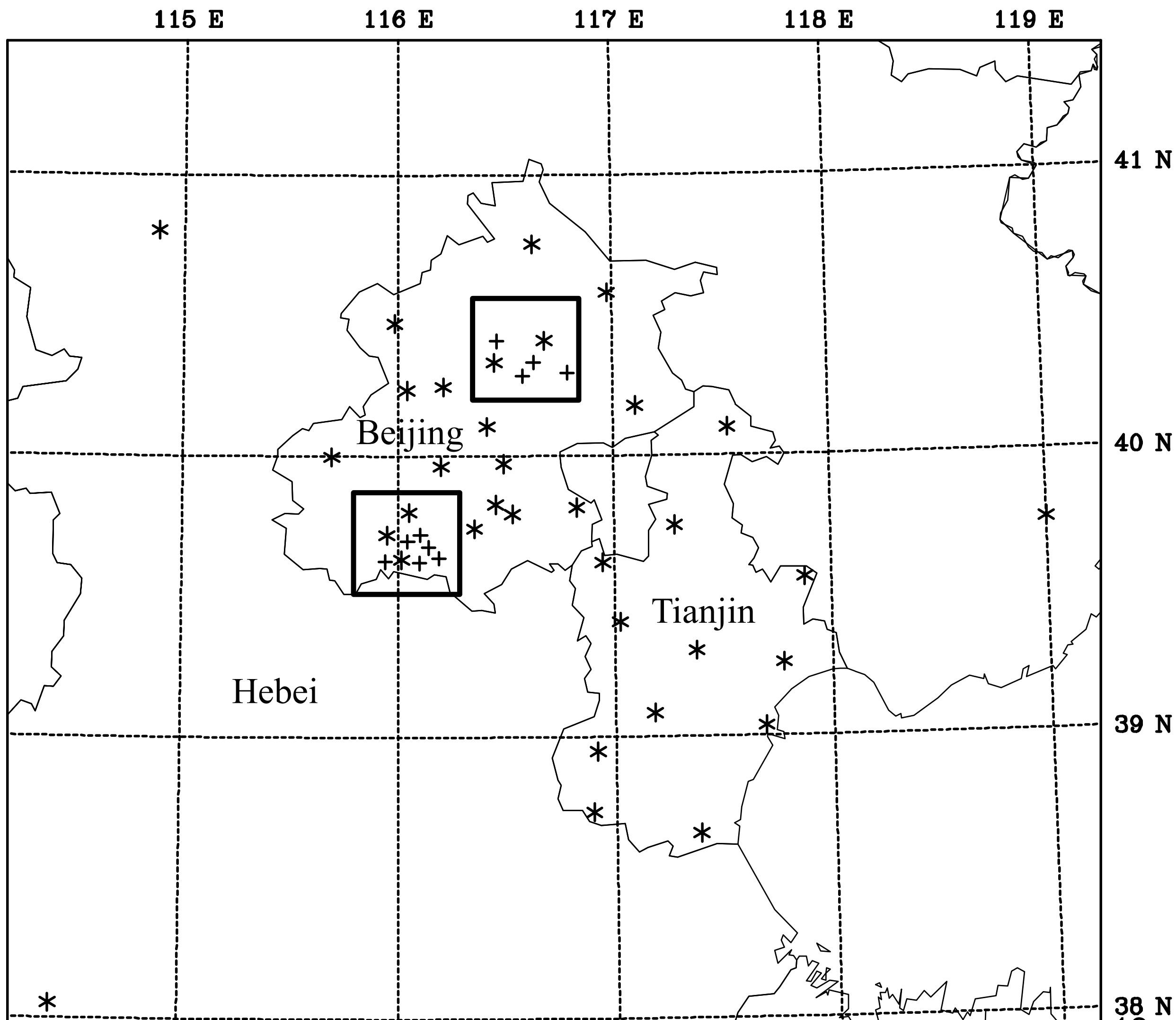
Visibility: 11

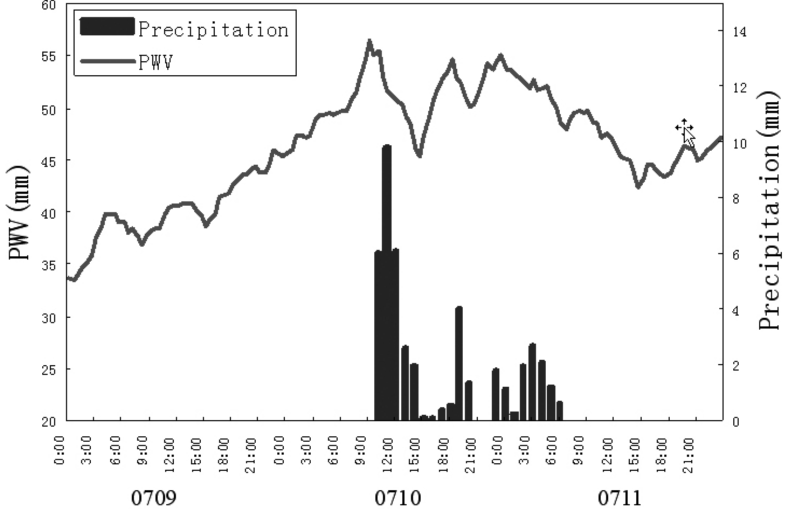
ROSA station, imported from Finland

Auto visibility station, made in BMB,China

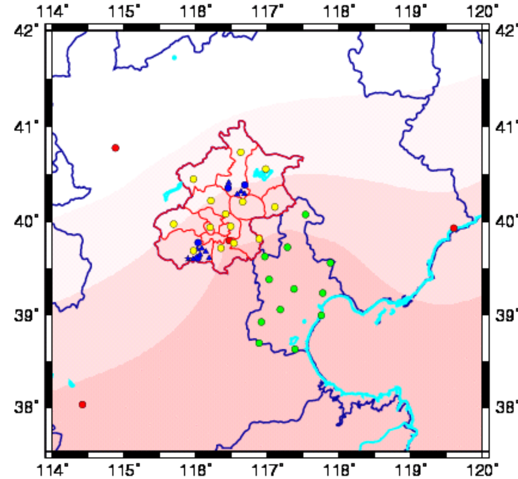
–Ground-based GPS-MET Network

Distribution of the ground-based GPS network for atmospheric water vapour. Single- and dual-frequency GPS station denotes with asterisk and plus sign, respectively. Tow bold squares highlight the intense observation sub-networks over the sensitive area to sever weather events (especially heavy rainfall) within Beijing using the mixed single- and dual-frequency ground-based GPS receivers.

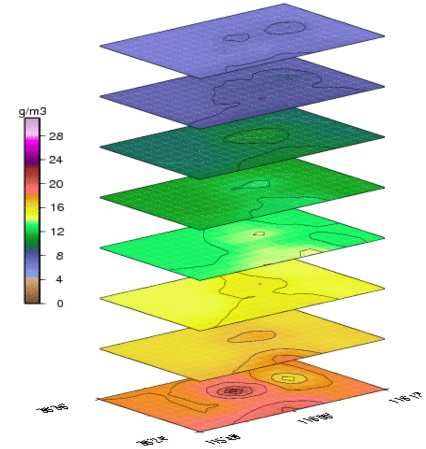




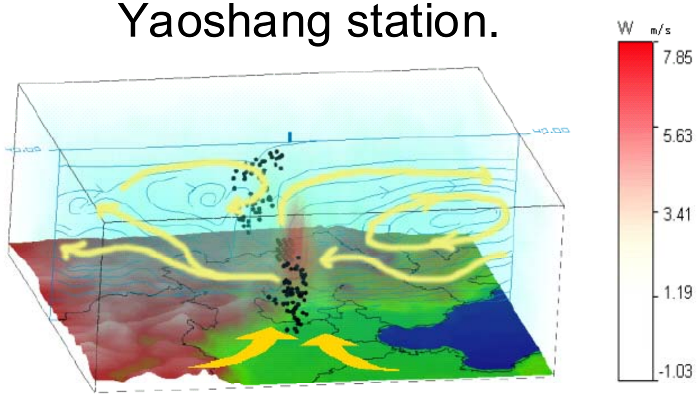
Change of PWV (black curve) and hourly accumulated rainfall amount time during the period from 9 to 11 of July at Yaoshang station.



PWV at 200608151230 (BJT)



tomography products

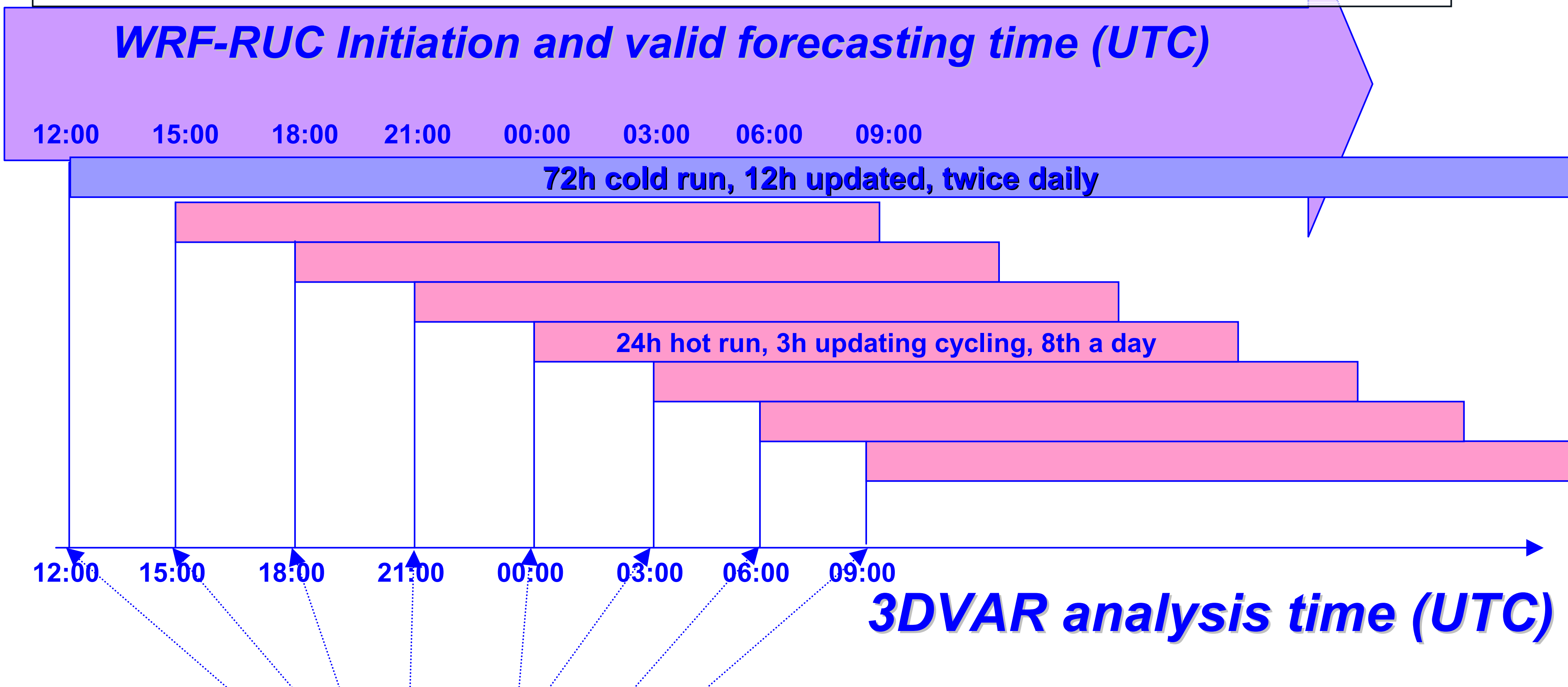


operational application to short-rang NWP with the 3DVAR method

List of near real-time GPS operational products

Description	Update	Format	Station/region
Atmospheric pressure at sea surface level	30 min	Table list and 24h time serial chart for each station	each station
Surface temeprature	30 min	Table list and 24h time serial chart for each station	each station
Surface relative humidity	30 min	Table list and Table list and 24h time serial chart for each station	each station
PWV at the zenith direction	30 min	24h time serial chart for each station	each station
PWV at the zenith direction	30 min	2D chart for whole region	region
Tomography product	15 min	3D chart for whole region	region

–operational NWP system



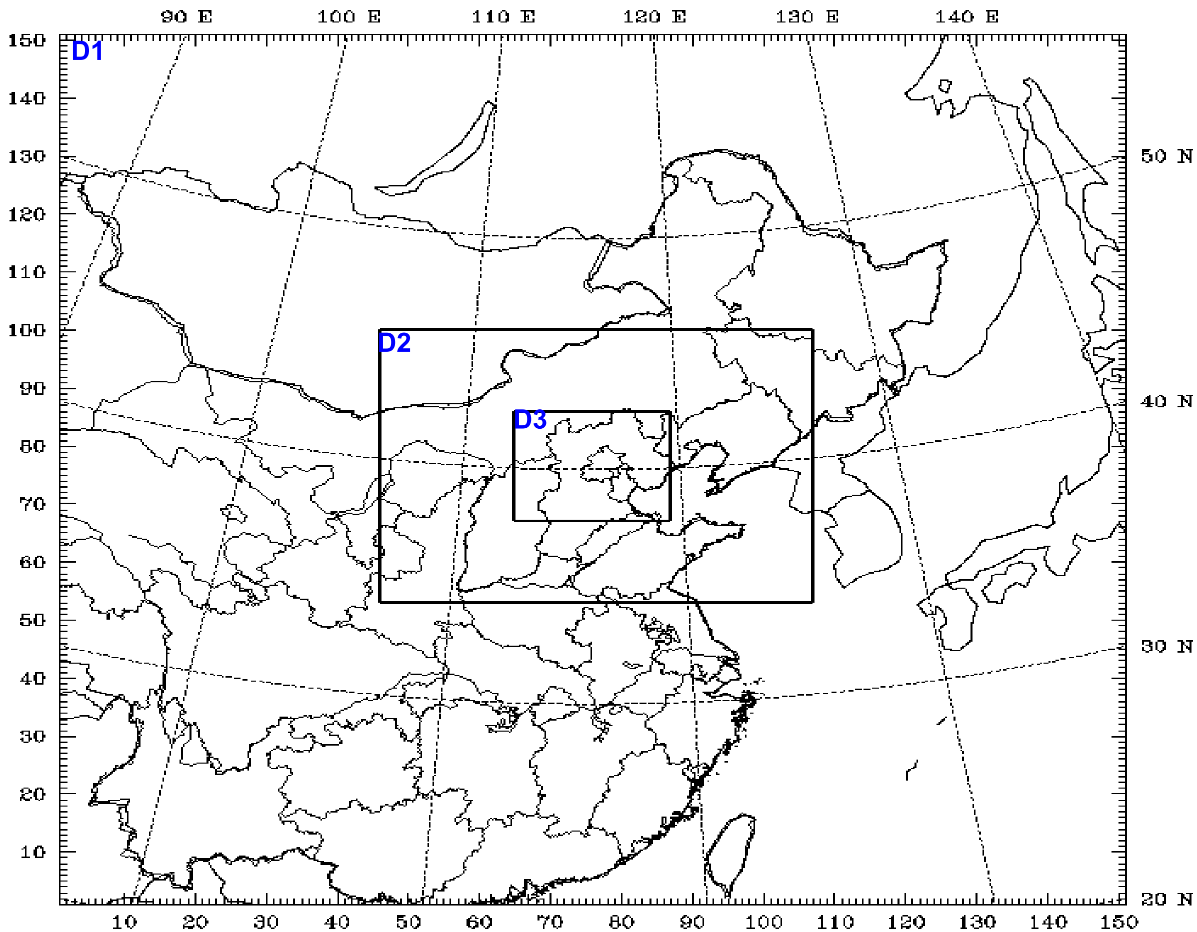
- GTS observations, e.g. Synopic, radiosonde, AWS, pilot, ship, airrep…
- **Local intensity observations (ROSA, AWS, AWS, GPS-PWV, etc.)**

3km horizontal resolution over the Beijing area on HPC IBM-blue moon 9.728TFlops.

Operational flowchart of regional WRF-RUC system

NWP Model Domains 27:9:3km

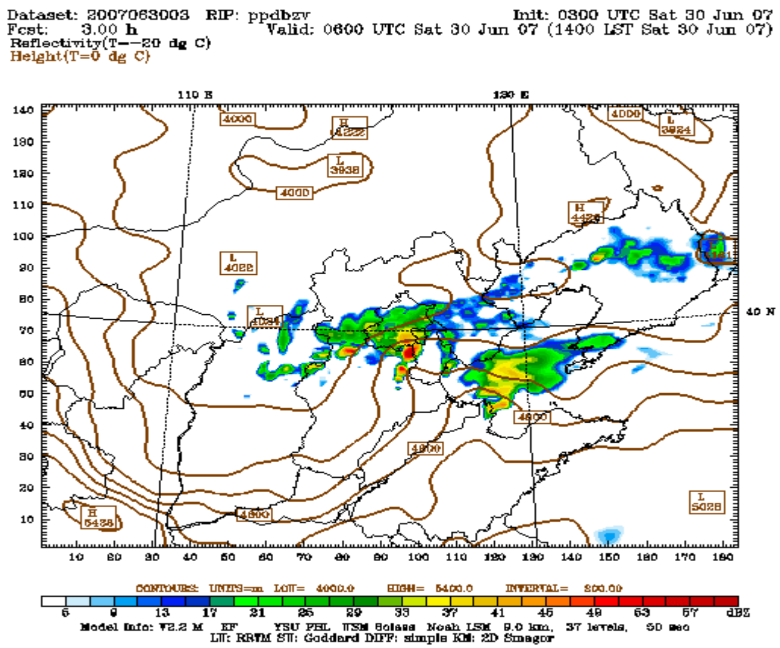
The WRF meso-scale weather operational system coupled with the Noah land surface model with the 27, 9, and 3km resolution.

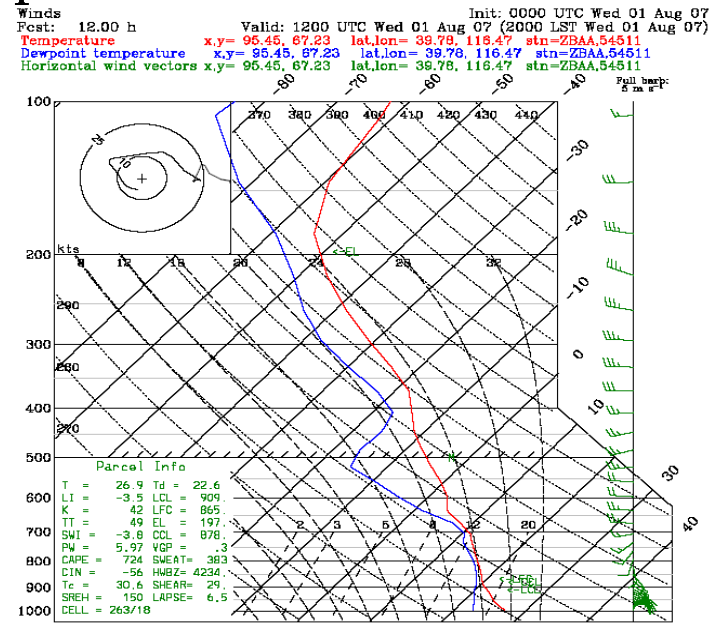


Full atmospheric physical processes , and two-way tow nested run

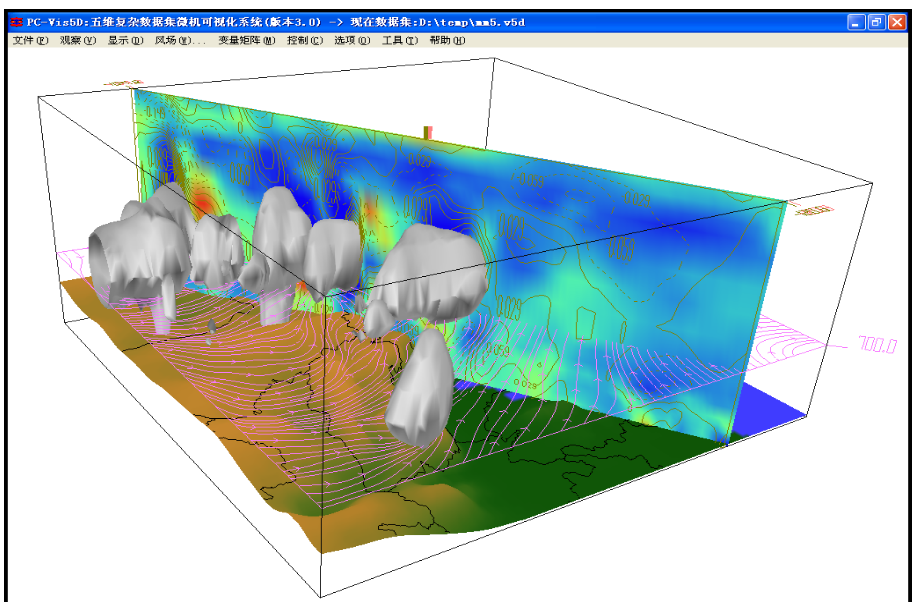
Horizontal grids for the three nest domain: 151X151，142X184，172X199，211X211

Operational NWP products

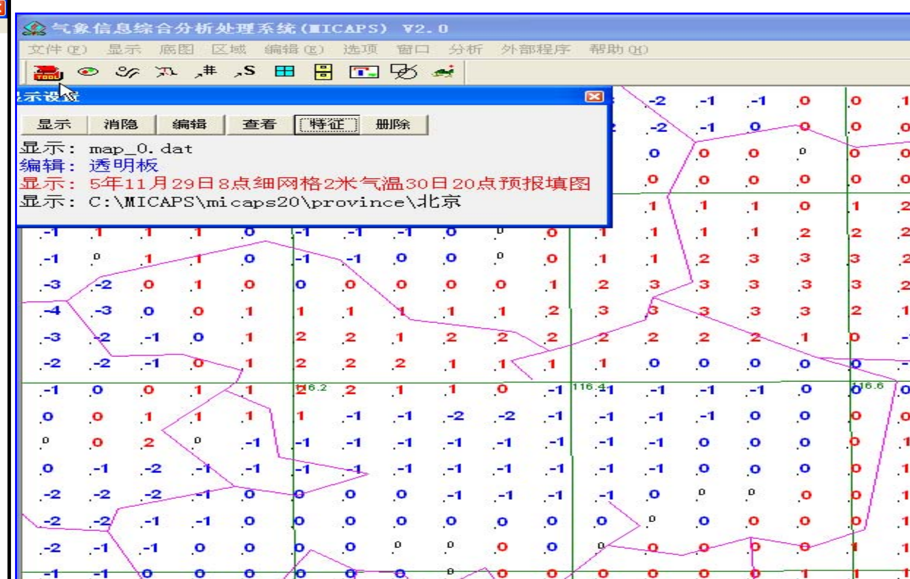




T-logP skew

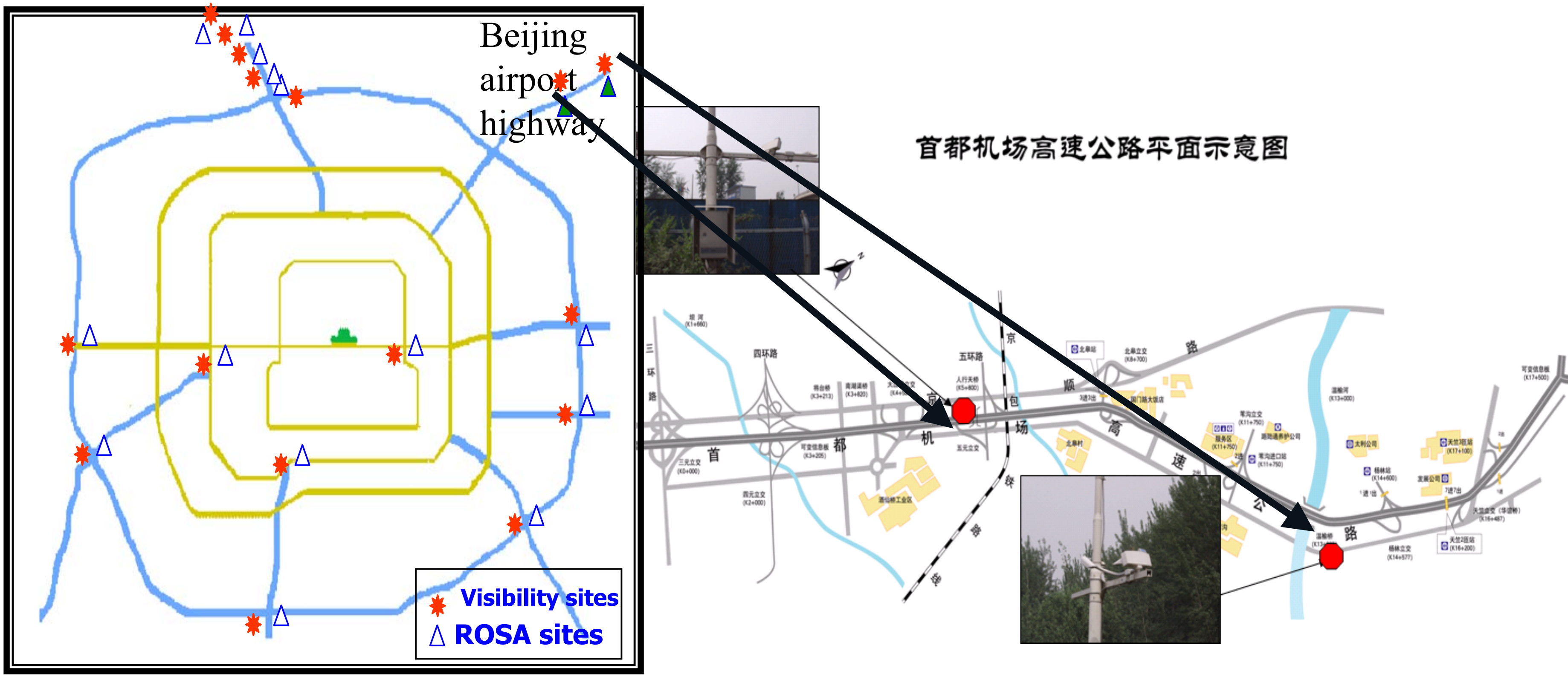


5D visualization



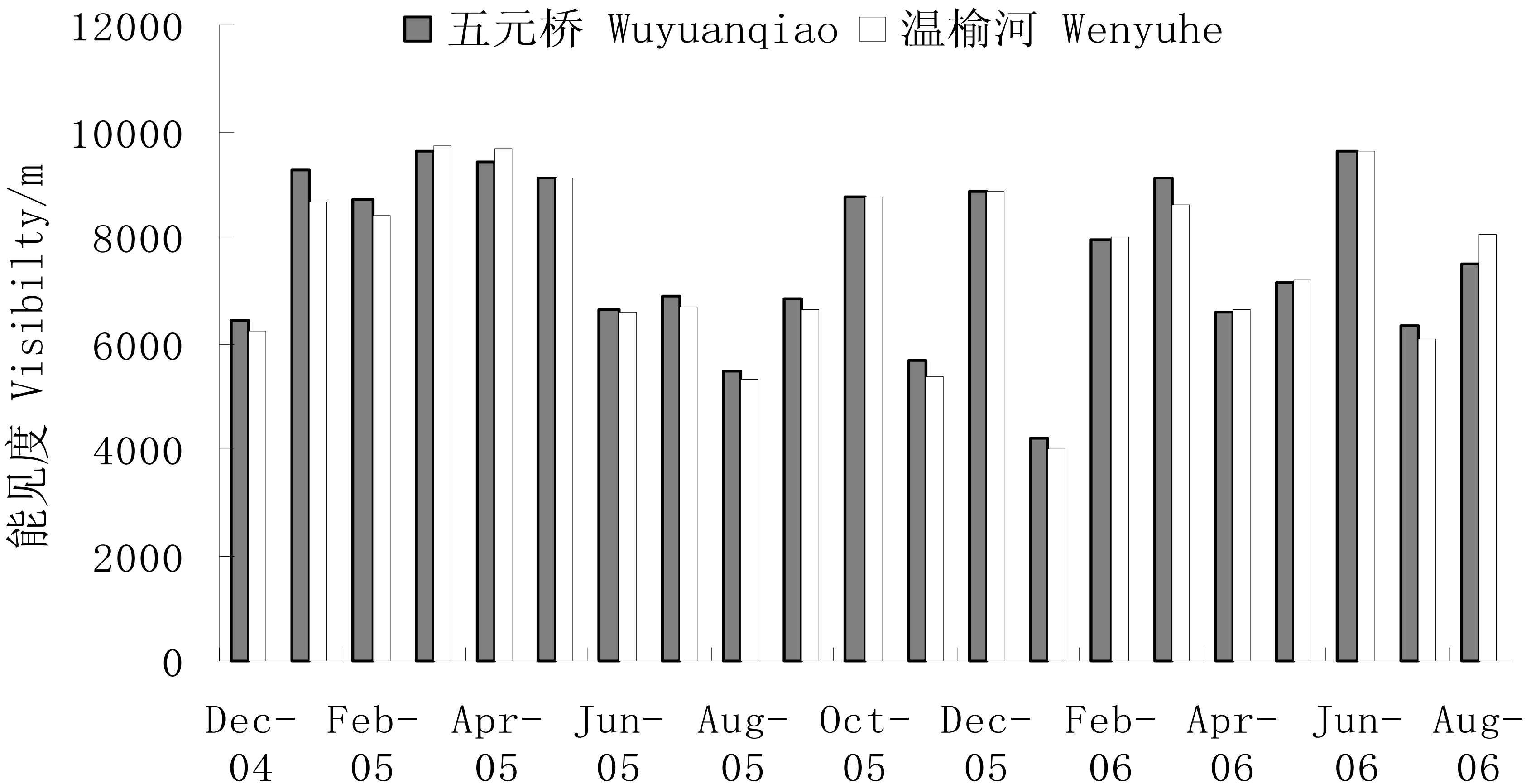
T2m

Observational Characteristics of Atmospheric Visibility (data)



Atmospheric visibility Observations from two ROSA stations at Beijing airport highway (highlighted with red dot in the top left figures), 21-month data observed every 5-min from Dec 2004 to AUG 2006

–Observational Characteristics of Atmospheric Visibility (monthly)

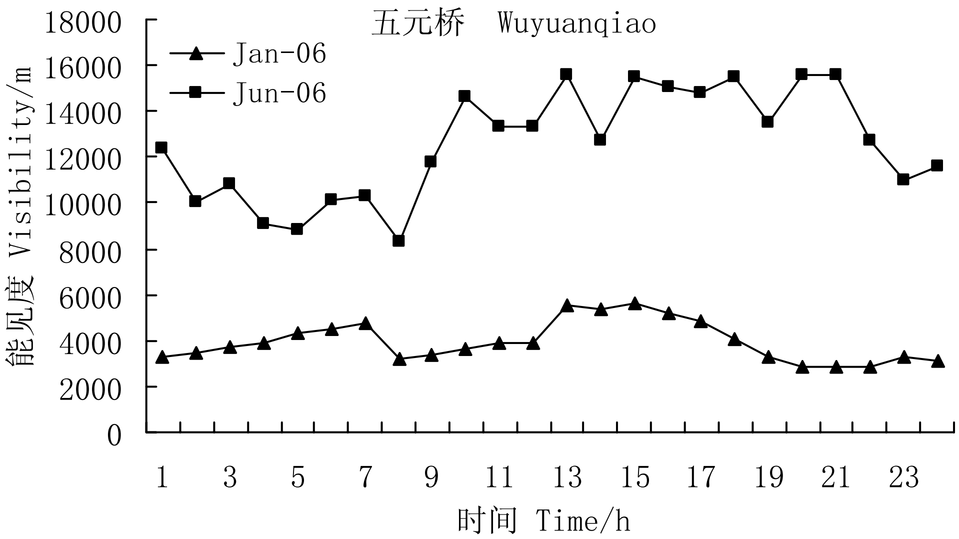


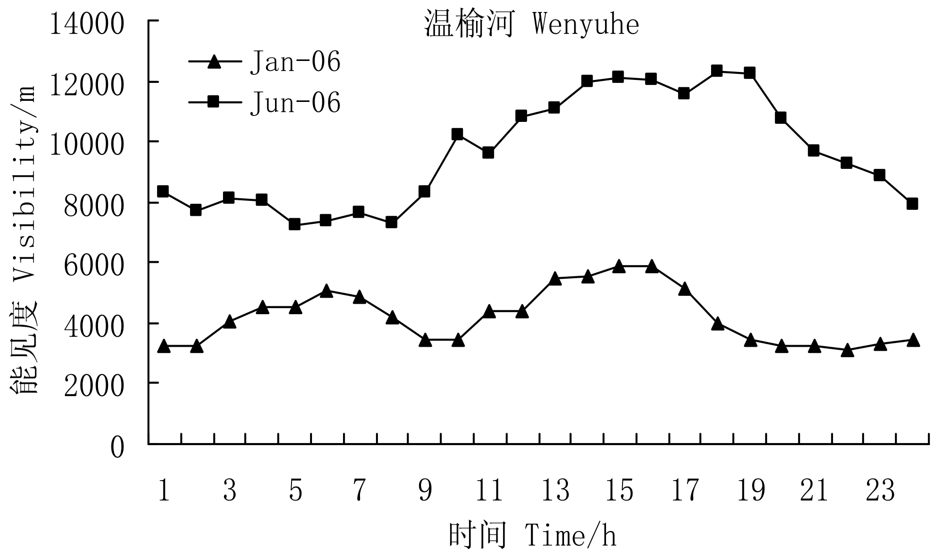
Monthly variation of visibility at Beijing airport highway, 21-month data observed every 5-min from Dec 2004 to AUG 2006

Spring lowest

Summer highest

–Observational Characteristics of Atmospheric Visibility (daily)



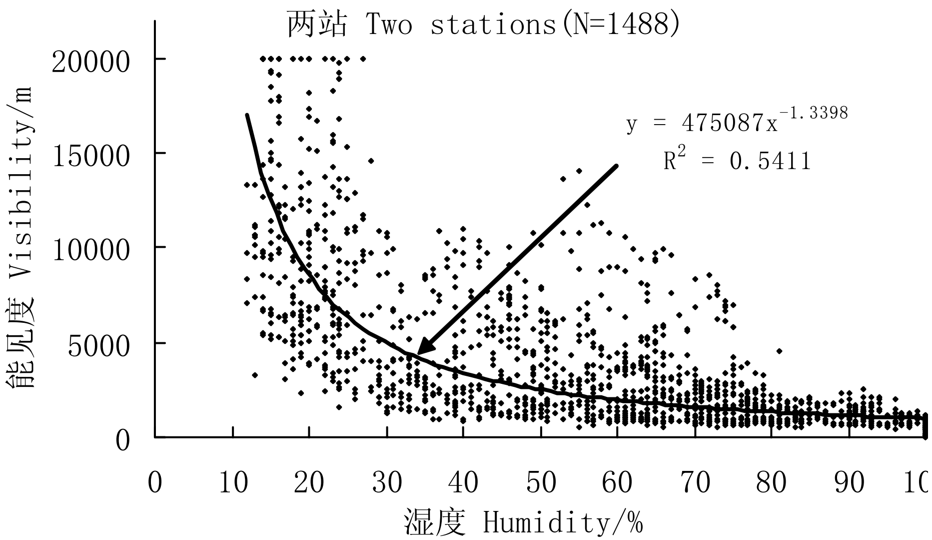


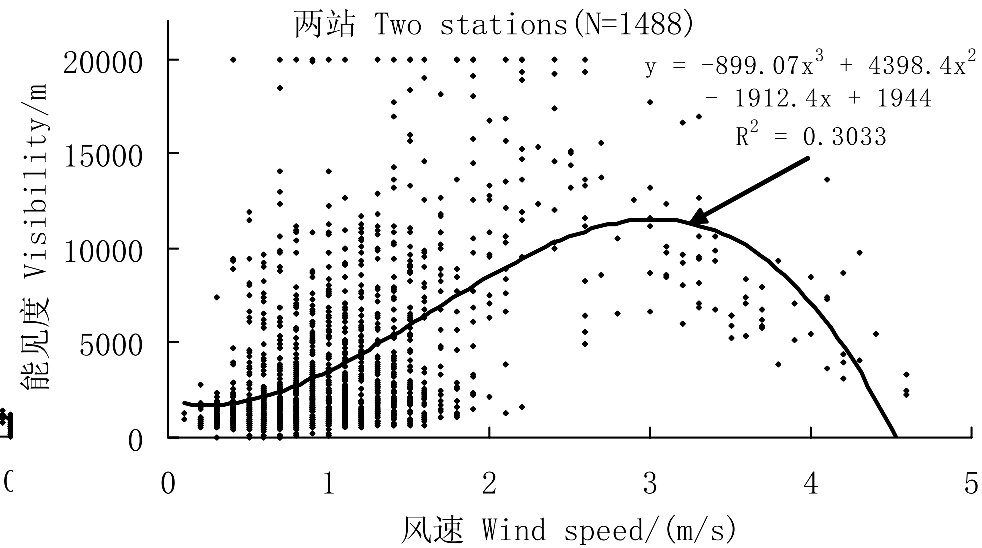
Daily variation of the two stations at Beijing airport highway in January and in June, 2006

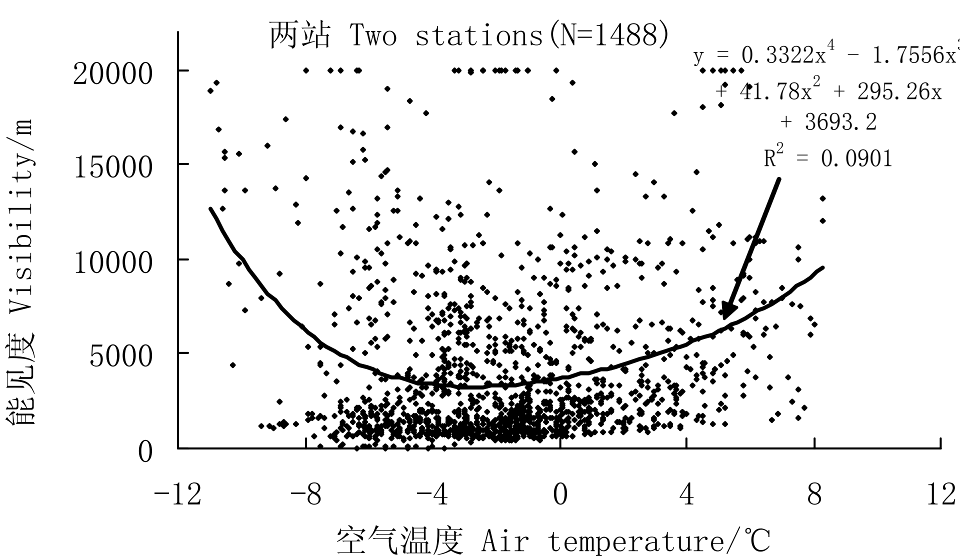
14:00 LST hightest

lowest time is uncertain

–Observational Characteristics of Atmospheric Visibility (nonlinear)







Complex nonlinear relationships with surface obs. , as partly shown for the Jan in the spring 2006:

visibility – humidity: power

visibility – wind speed: bell shape

visibility – T2m: U shape

Low visibility is closely related with low air temperature and low wind speed, and high relative humidity.

Times of visibility less than 4000 m as well as the corresponding distribution of humidity

Visibility/m	Total Times	Humidity100%		Humidity95%～100%		Humidity90%～100%	
		Times	Frequency	Times	Frequency	Times	Frequency
V＜50	84	81	96%	83	99%	83	99%
50≤V＜200	230	211	92%	230	100%	230	100%
200≤V＜1000	21706	7124	33%	11029	51%	13664	63%
1000≤V＜4000	121560	13539	11%	23555	19%	33559	28%

- visibility below 200 m happens mostly on the conditions that relative humidity of atmosphere is close to 100% (fog weather phenomenon)

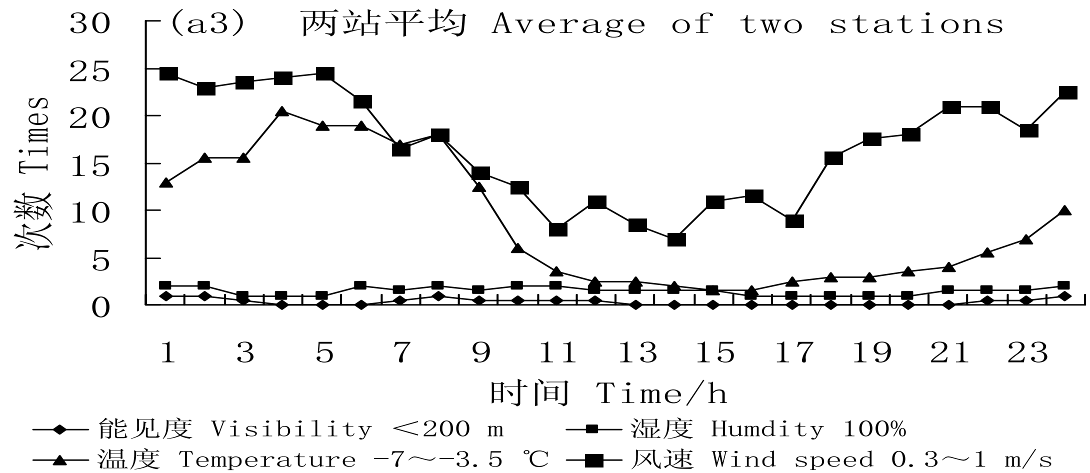
- about 50% of visibility between 200 m and 1 000 m happens in the case of fog, and about 30% of 1 ~ 4km visibility is caused by fog.

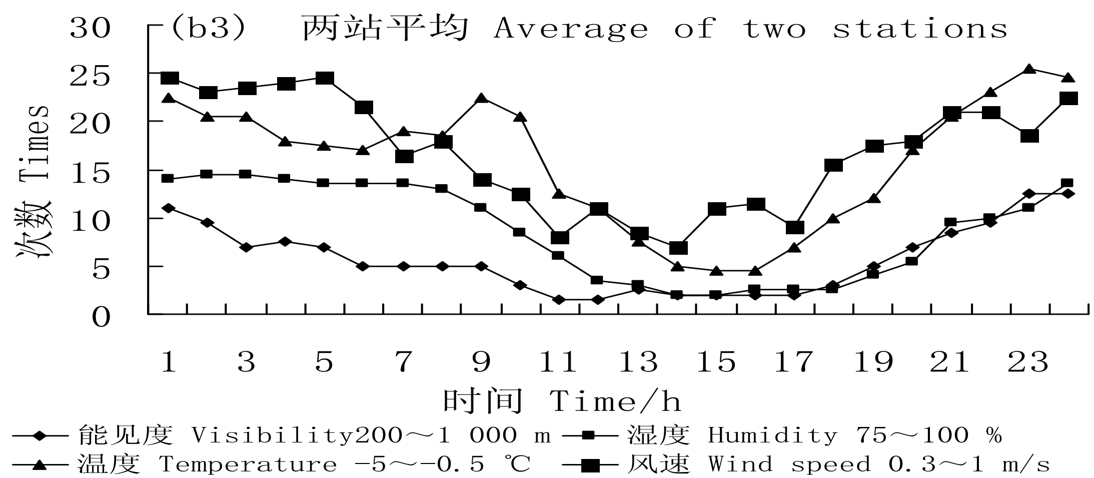
- 1 ~ 4 km visibility mainly result from haze, sand storm and other weather phenomena.

Times of the low visibility 0～200m（a）,200～1 000m (b) and the times of their corresponding meteorological factors respectively

•The visibility below 1000 m appears on the conditions that temperature is very low, humidity is very high, and the wind speed is very small

but it is only the essential condition not the full condition, especially for the heavy fog which visibility is below 200 m





Relative Physic Processes on Visibility Reduction

- By humidity through the water vapor's Rayleigh scattering and the fog's Mie scattering

- By the aerosol through the pressure resistance from the wind

- By the water phase change through the Bergeron three-phase processes when the temperature is around 0℃.

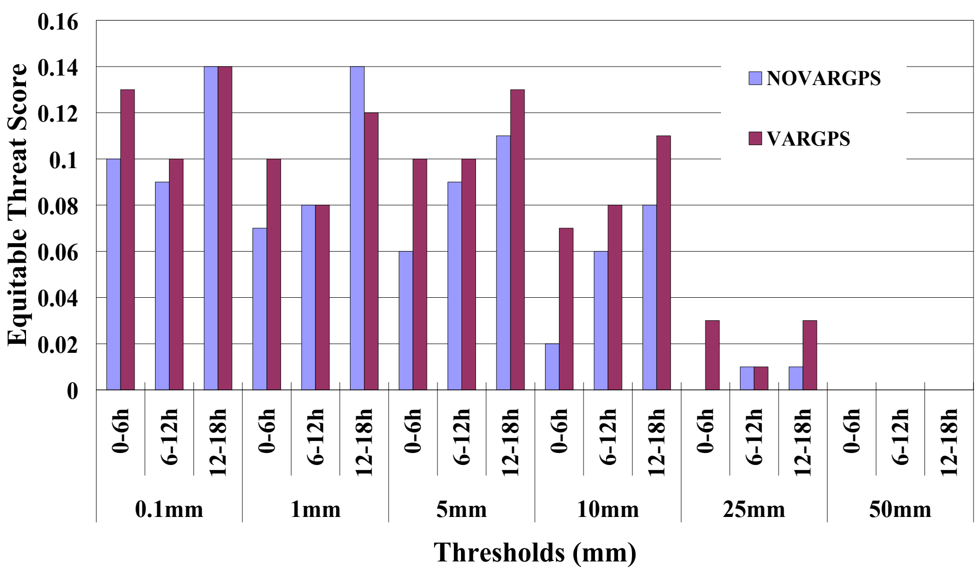
– Improvement on the fine-resolution numerical prediction system

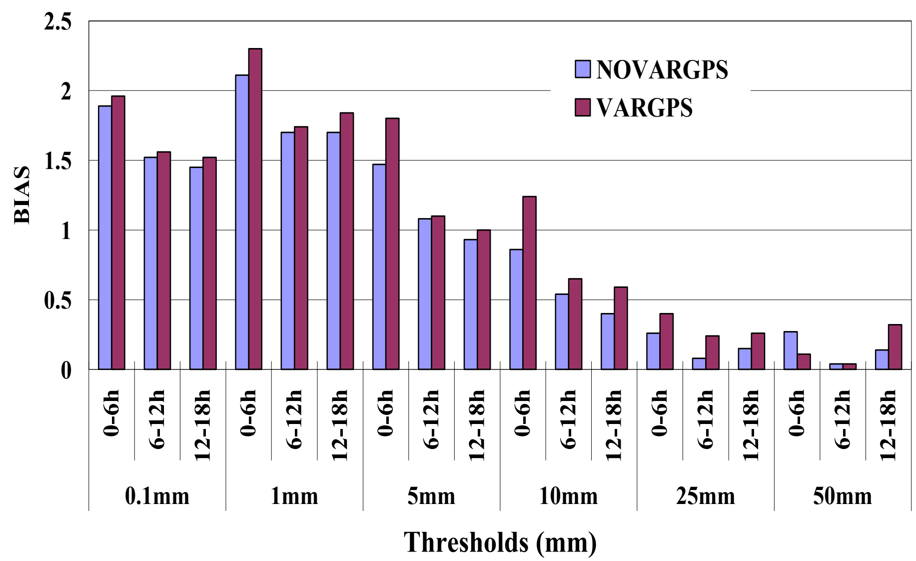
•Topography effects (zhang et al., 2005, PNS)

•Fine-resolution urban land use data (zhang et al., 2007, CJGR)

•3DVAR assimilation on density local observations GPS-IPW, AWS, and conventional weather reports. (zhang et at., AMS, 2006; ISPRS2008, 2008; Chen et al., 2008)

…….





– The sophistical presentation&interpretation method: nonlinear support vector machines SVM

•Owing to the observational relationship between the visibility and the meteorological factors is the complex nonlinear correlation

•The SVM method is a nonlinear and a few samples study method base on the statistic learning theory (Vapnik, 1998; 2000)

•The final decision-function of SVM is only confirmed by a few of support vectors, and the complication of calculation depends on the number of support vectors rather than the dimension of sample space.

•The method is available to deal with nonlinear mathematical and physical problems.

In operational application we use SVM nonlinear regression method

$$f(X) = \sum_{\text{support vector}} (\alpha_i - \alpha_i^*) K(X, X_i) + b$$

$$= \sum_{\text{support vector}} (\alpha_i - \alpha_i^*) \exp(-r \|X - X_i\|^2) + b$$

and select radial basis function as kernel function

$$K(X, X_i) = \exp(-r \|X - X_i\|^2)$$

X_i is sample factors of support vector, X is pre forecast vector's factors, α_i, α_i^*, b are pending coefficients of founding SVM model, r is kernel parameter.

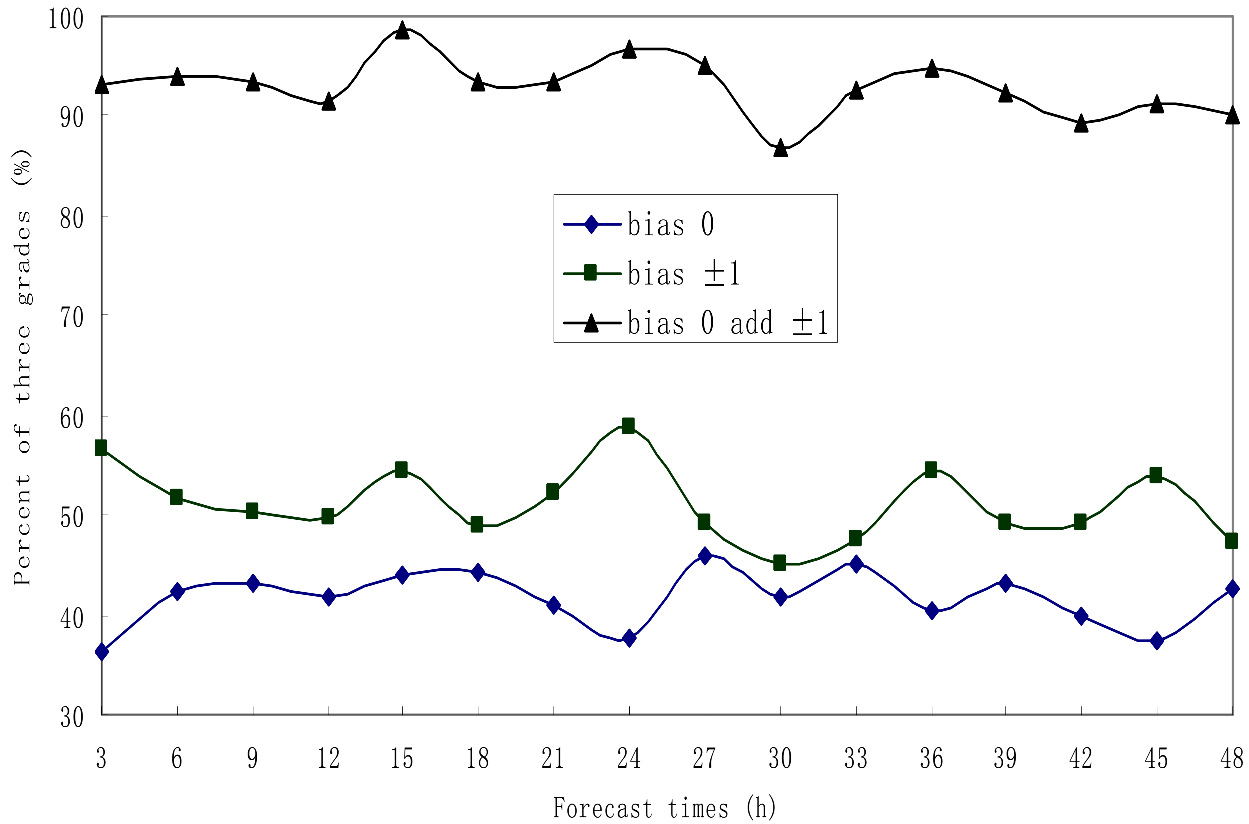
- **Use the visibility data (ROSA station Wuyuanqiao at 39°59´45"N , 116°29´30"E), the NWP operational results of meso-scale model in Beijing areas, and the auto weather station (AWS) data as experimental data.**

- **Data of spring 2006 (March to May) has been used to modelling the forecasting method of atmospheric visibility classification**

- **Data of spring 2007 used to verification**

- **Atmospheric visibility is classificated into six grades ($V < 50$ $50 \le V < 200$ $200 \le V < 1000$ $1000 \le V < 4000$ $4000 \le V < 10000$ $V \ge 10000$).**

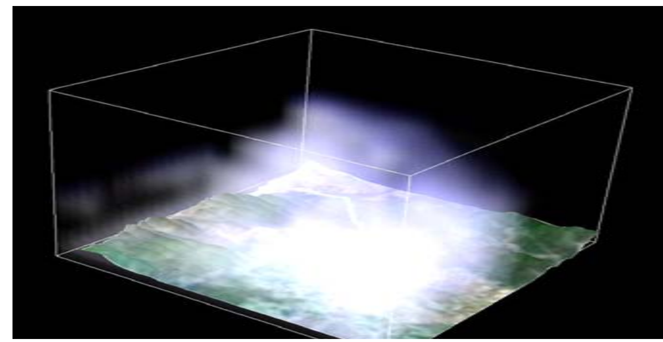
•40 percent of atmospheric visibility classification forecast agree with the observing data
•more than 90 percent forecast classification's errors are within one level(include equal).
•the performance of 3–48 hours atmospheric visibility forecast is stable.

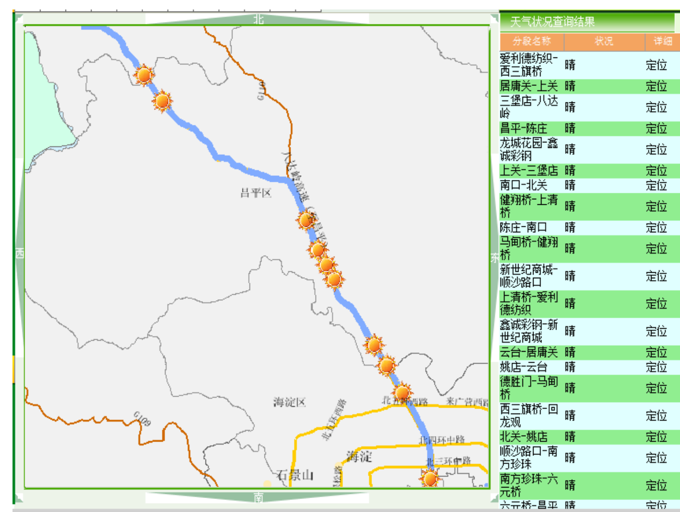


•**<u>The verification of 03-48h visibility classification forecast</u> of Wuyuanqiao station in spring 2007.**
•**The bias results have been divided into three kinds: the same classification (classification bias is 0), discrepancy is 1 (classification bias is ±1) and same classification add discrepancy is 1. Count the number of each verification score to get the percent of three forecasting skills in total forecast data.**

– WEB-GIS Visualization Operational Platform

Observation, forecasting and point, 2-D and 3-D visualization products available, statistical info. available





Future plans

•Further investigations on special models of road temperature and depth of accumulated rainfall amount are still necessary in the future.

•To improve the downscaling accuracy of the presentation&interpretation of the urban fine-resolution NWP system, lots of things need to do……, especially on the data assimilation both of weather radars and GPS slant path water vapor obs.

Questions or comments are welcome!

Thank you