WMO/CIMO TECO-2018

Megacities Experiment on Integrated Meteorological Observation in China

(MEMO)

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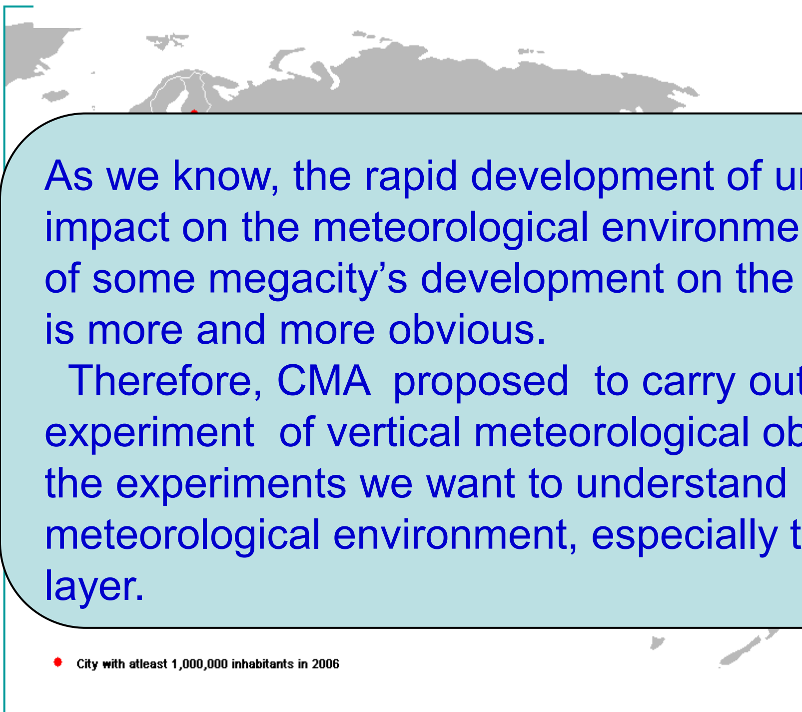
outline

1. Scientific backgrounds
2. Necessities of MEMO
3. Observation experimental design
4. Tasks and scientific issues
5. Preliminary progress and analysis

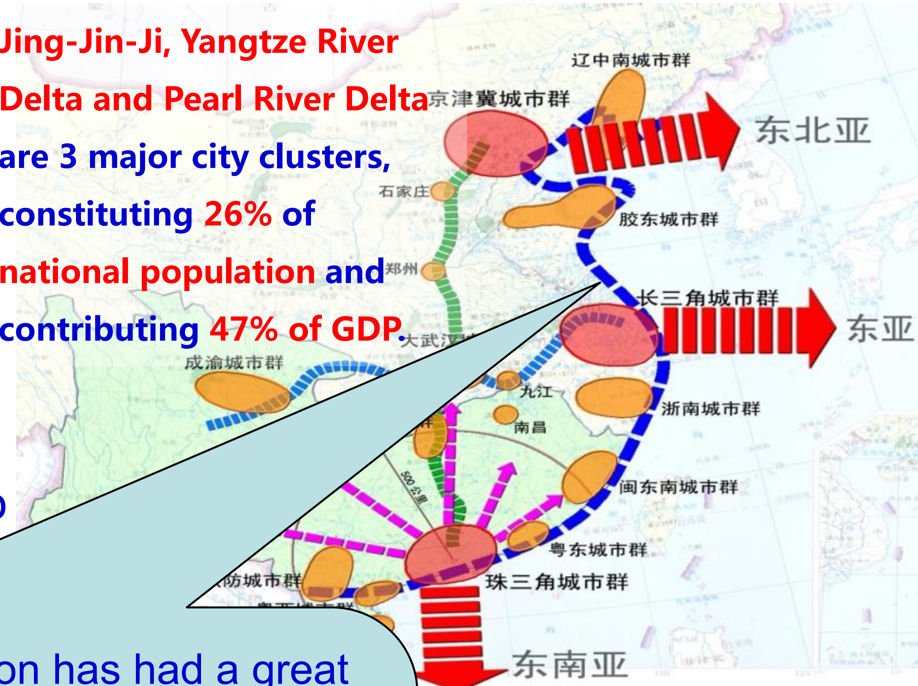
Scientific backgrounds (1/5)

■ Rapid development of urbanization

Urbanization rate has reached 60% in east coastal region of China, the most dense region worldwide.



Jing-Jin-Ji, Yangtze River Delta and Pearl River Delta are 3 major city clusters, constituting 26% of national population and contributing 47% of GDP.



As we know, the rapid development of urbanization has had a great impact on the meteorological environment , especially the influence of some megacity's development on the atmospheric boundary layer is more and more obvious.

Therefore, CMA proposed to carry out the integrated observation experiment of vertical meteorological observation of megacities . By the experiments we want to understand how megacities affect the meteorological environment, especially the atmospheric boundary layer.

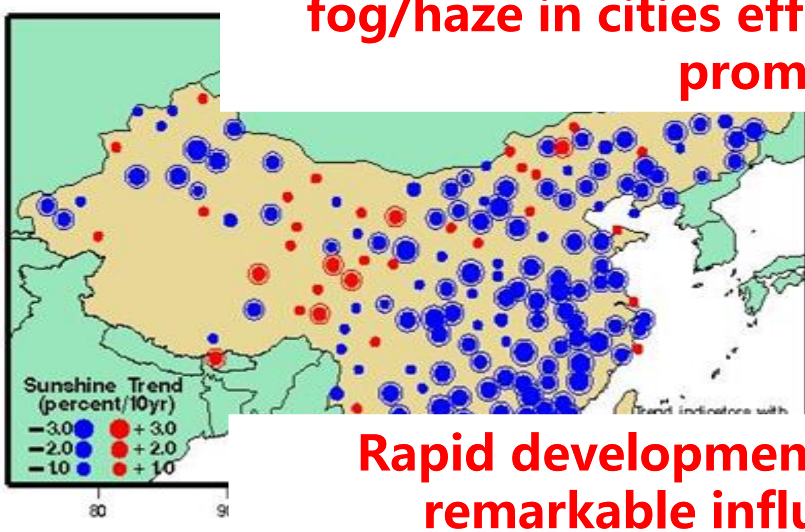
...: major motivation and ...onomic development

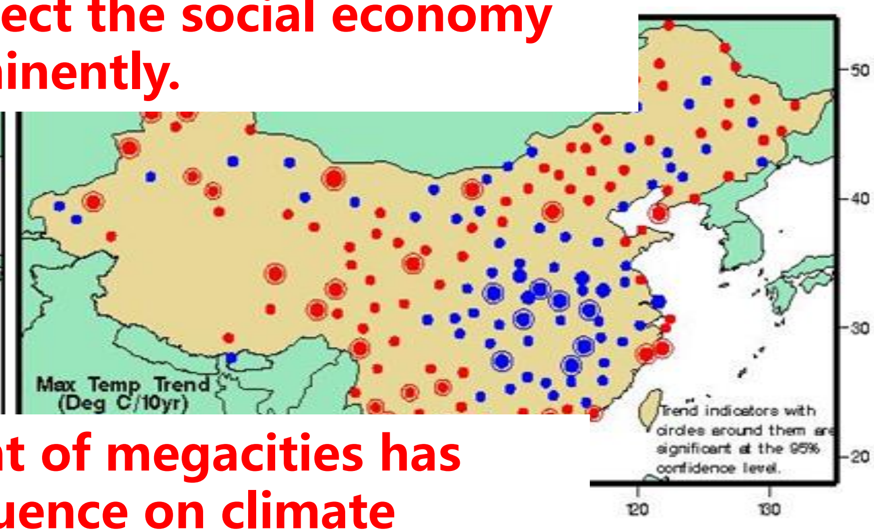
...meteorological ...prediction services are imperative!

Scientific backgrounds (2/5)

■ Frequent disasters often occurred in megacities

Frequent and enhanced occurrence of flood and fog/haze in cities effect the social economy prominently.



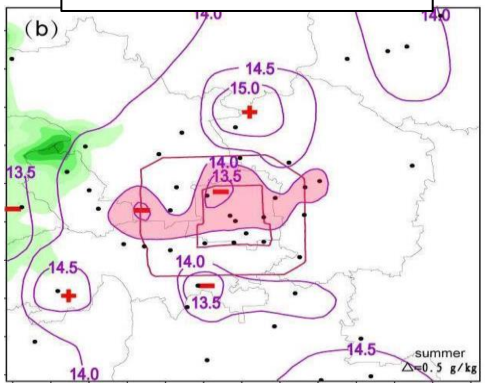


Rapid development of megacities has remarkable influence on climate

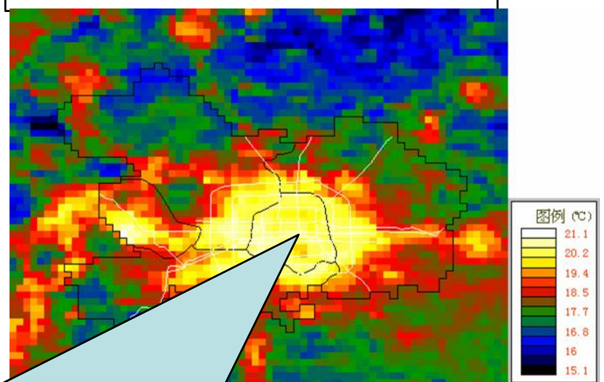
Scientific backgrounds (3/5)

■ Scientific issues arisen from observations

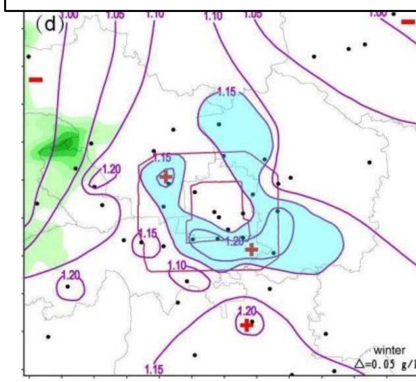
Urban Dry Island Effect in summer



Thermo observation in urban and outskirts Beijing

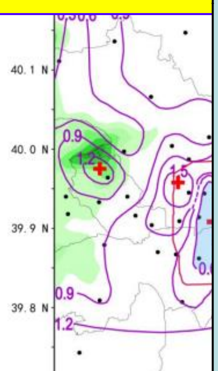


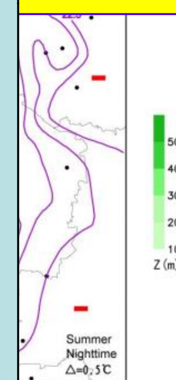
Urban Moisture Island Effect in winter



Meso-micro scale m... al environment in cities have set higher

r...





Due to the acceleration of China urbanization , the impacts on the meteorological environment is more and more significant. For example of Beijing , long-term observation shows : in Summer, Beijing Urban area presents as a dry island and in winter, it presents as a wet island, and the average wind speed in urban areas is obviously lower than suburban. At same time, the distribution of cloud and precipitation in urban region is malddistribution. In summer, the heat island effect of megacity become more significant .

Smaller win... a...

...ng due ...ties

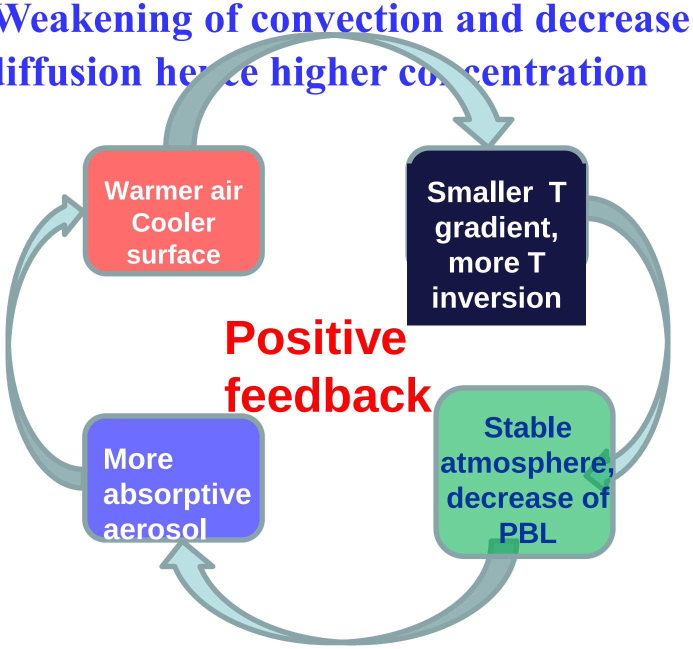
Scientific backgrounds （4/5）

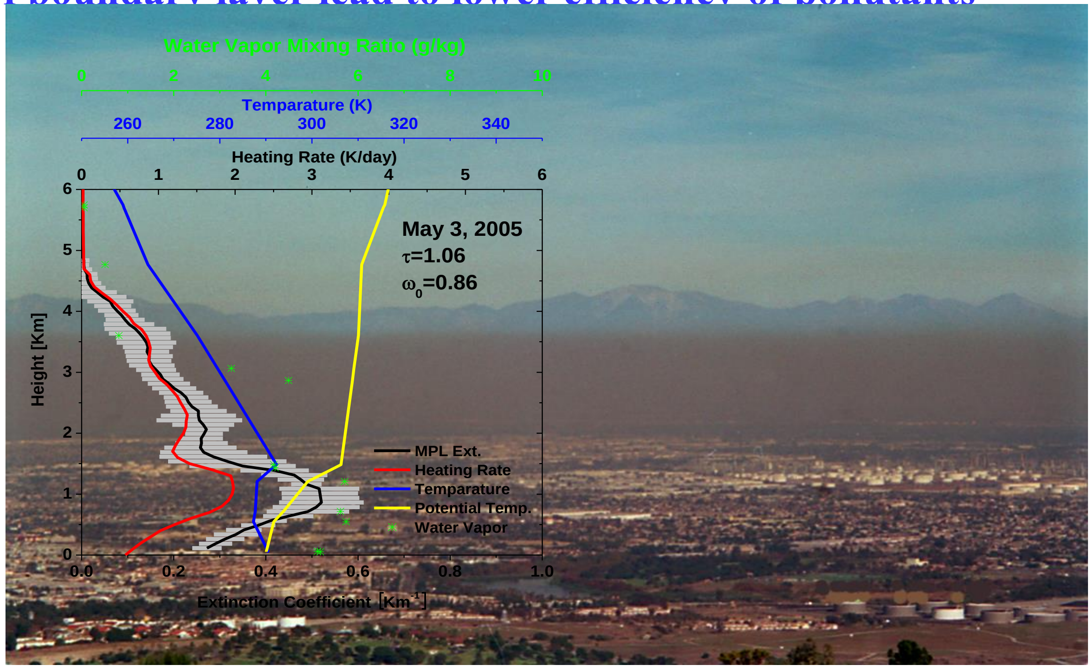
- **Long-term observation shows that aerosol , fog-haze events and their effects is increasing in megacities. The mian functions are as follows**

- **Reduction of surface solar radiation and latent heat flux restrain the occurrence and development of convection**

- **Aerosol absorption of solar radiation increases atmospheric stability and temperature inversion in boundary layer**

- **Weakening of convection and decrease of boundary layer lead to lower efficiency of pollutants diffusion hence higher concentration**



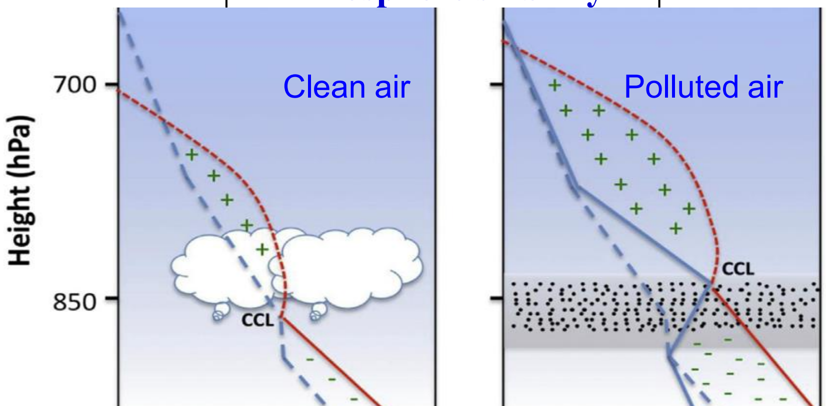


Interaction mechanism of aerosol-boundary layer

Scientific backgrounds (5/5)

■ Aerosol , fog-haze events and their effects

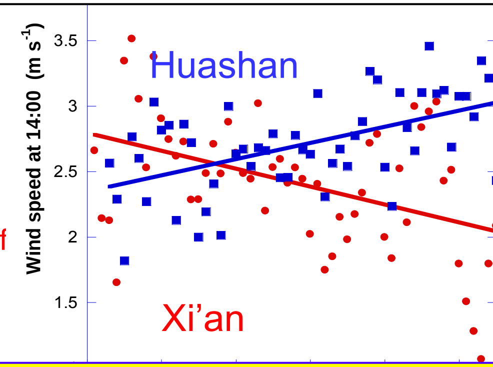
Aerosol's influence on atmosphere stability



Unstable free air, increase of ws and convective cloud

Stable PBL, decrease of surface ws and convective cloud

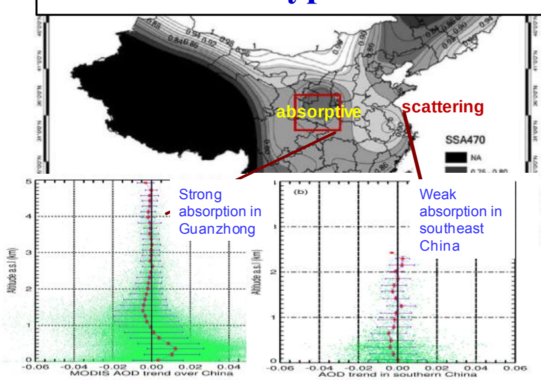
Aerosol can reduce surface wind speed, hindering the cleaning of pollutants



Wind speed variation

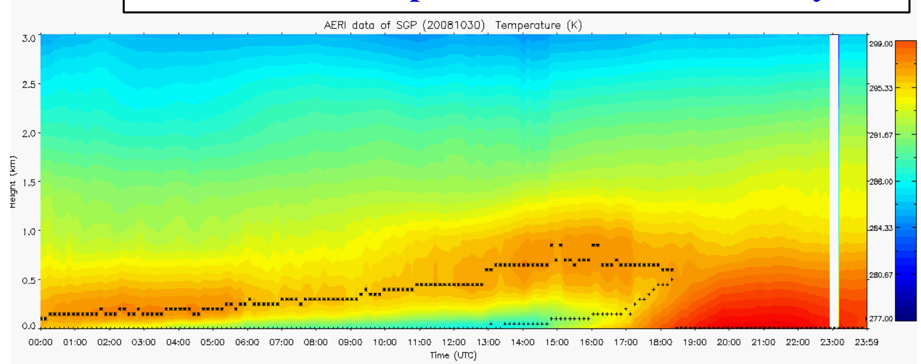
Increased aerosols and haze have led to higher boundary layer height and greater atmospheric stability in megacities.

Inhomogeneous distribution of aerosol types in China



AOD trend

Influence on T profile and T inversion layer



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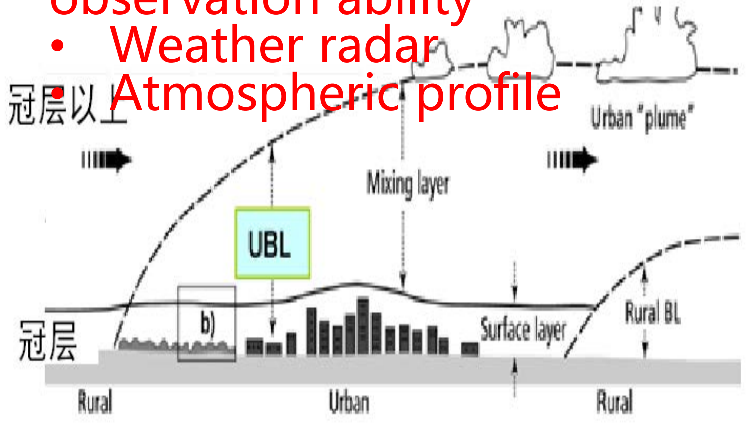
Developing urbanization and its effects

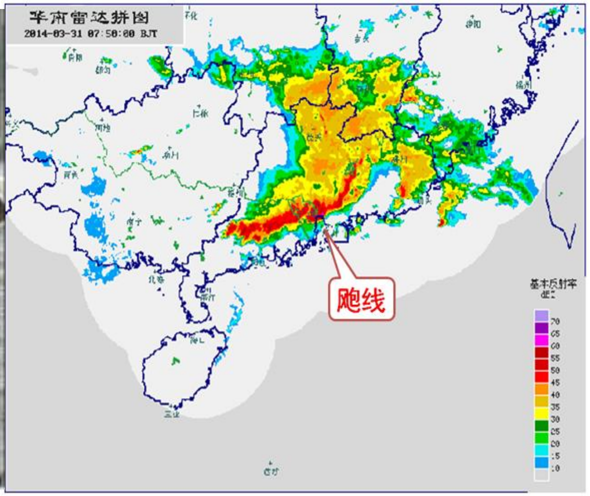
- **Disasters in megacities have caused great loss of life and property**
  - Strong convective weather(e.g., strong precipitation, squall line)
  - Fog-haze, photochemical pollution
- **Must know more about effects of nature on mankind**

Urgent to improve the vertical observation ability

- Weather radar
- Atmospheric profile

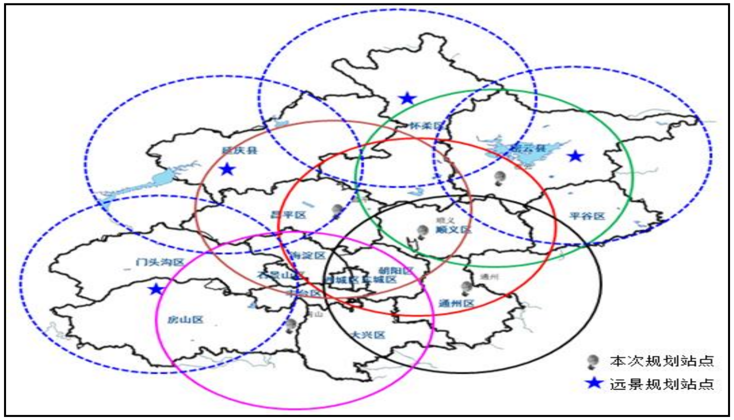


Another reason to carry out MEMO



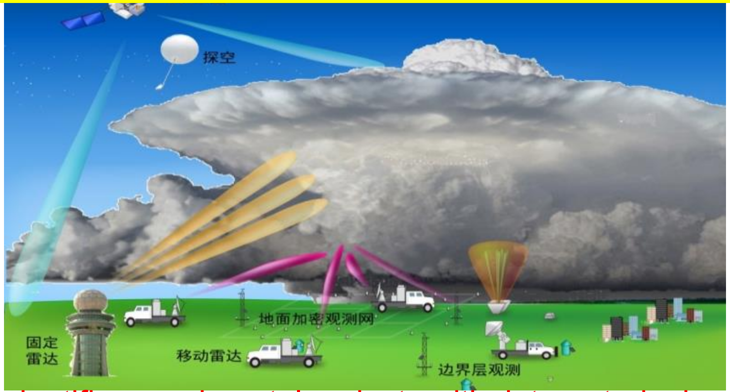
The foundation for carrying out integrated observation experiment of megacities. The main basic conditions are as follows:

1. X band Doppler weather radar network had been established in Beijing

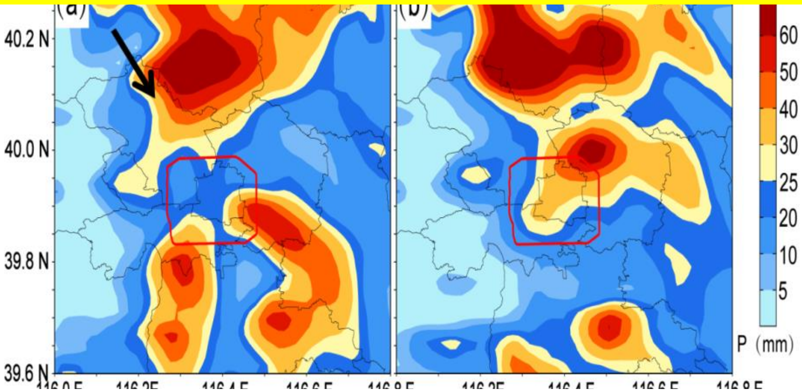


2. The integrated vertical meteorological observation station has been built by using various remote sensing observation techniques, and some practical experience has been obtained

Related studies have been carried out by CAS IAP and other institutes, which provide solid foundation for further research



Some scientific experimental projects with integrated observations have been carried out and some results have been achieved

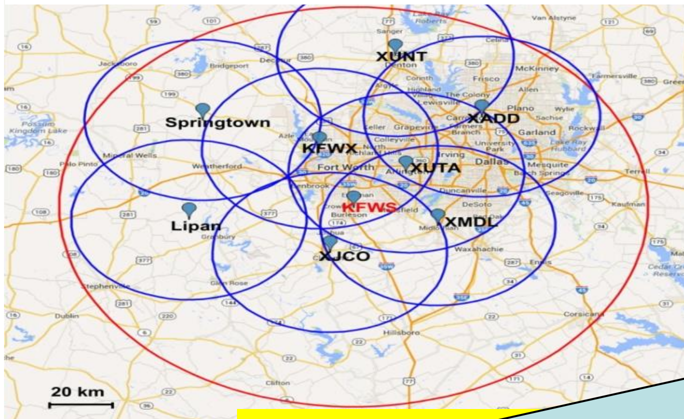


Simulations of some weather processes have also been carried out

Scheme design of MEMO benefits from successful experiments abroad

■ Typical intensive observation networks abroad

Dalas USA: collaborative observation with multiple radars, improving observation precision of urban rainfall



Europe: laser lidar calibration system with high standards, improving data accuracy and applying in numerical prediction

No net... ...tegrated observation for

The NYS Ea...

New ...
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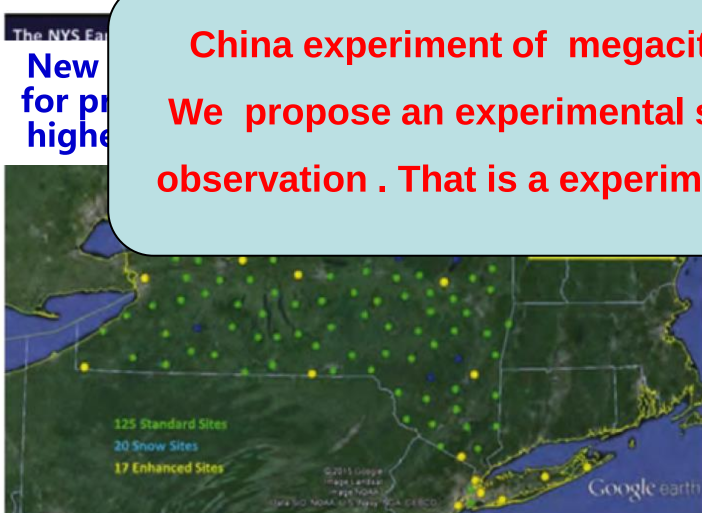

China experiment of megacities is based on the design of foreign cities.

We propose an experimental scheme for integrated vertical meteorological observation . That is a experimental scheme of 5 profiles of remote-sensing .

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Observation Experimental design

Feature 1: To establish 5 profilers observation of remote-sensing

With respect to the design of megacity observation network , we design a integrated remote-sensing observation station, every integrated observation station has built a X band Doppler dual-pro weather radar,a Lband wind profiler radar , aerosol Lidar and micro wave radiometer. Five vertical profile of temperature,wind ,humidity , hydrometeor and aerosol.

Research on key techniques of improving remote sensing data quality, realize the data fusion products which can be validated and compared with each other, solve the simplification problem of observation of

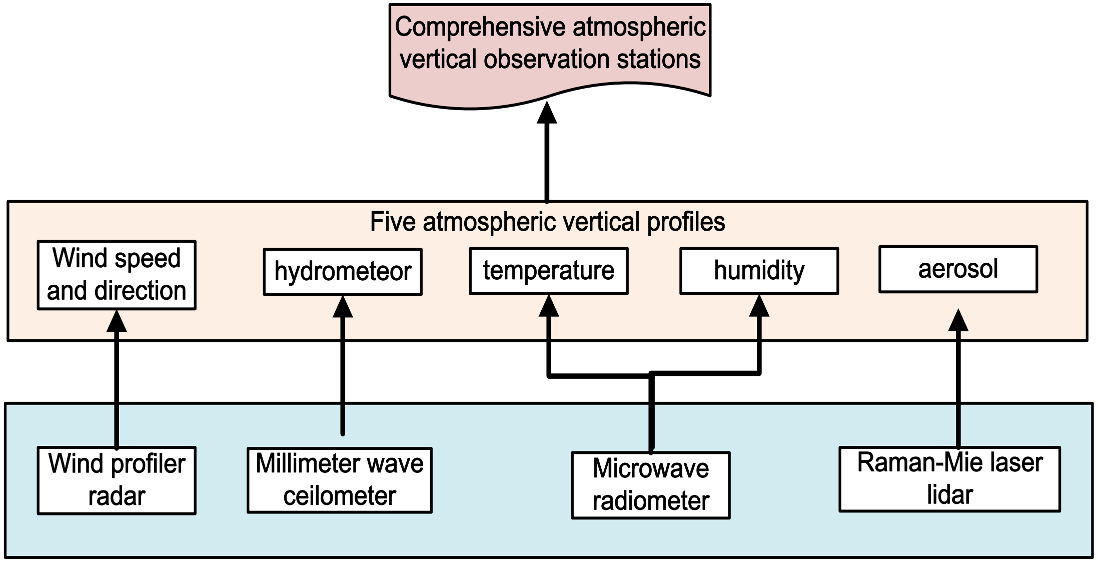
➢ Establish the ground based remote sensing observation of integrated atmosphere profiles

5 profiles:

- **Temperature & humidity**
- **Wind**
- **hydrometeor**
- **aerosol**

5 equipments:

- **millimeter-wave cloud radar**
- **X band Dual-polarization Radar**
- **Microwave radiometer**
- **Wind profiler**
- **Raman-Mie laser lidar**



Integrated profiles network in Beijing

This is layout map of Beijing Experiment region. By establishing seven vertical observation stations, a three-dimensional observation network is formed

High-perforemance equipments for Megacity Integrated Meteorological Observation Experiment

Wind profiler

Frequency: 1.360GHz
Antenna gain: ⩾30dB
Beam width: ⩽4.0°
Peak power: 9.21kW
Noise factor: ⩽1.5dB
Pulse width: 0.80μs 6.35μs 12.70μs

Lidar

Wave length : 355nm/532nm
Mode: observation vertically
Max Detection altitude: ⩾5km
Range resolution: 10M
Temporal resolution: 5～30min
Range accuracy: ⩽10m
Peak power: ⩽1.5KW

X-band Dual Polarization radar

Detection range : 150KM
Azimuth scanning range: 0° ～360°
Elevation scanning range: -2° ～+90°
Detection accuracy: ⩽1dBz ⩽2.5m/s
Detection range: -15～+75dBz
-48m/s～+48m/s

Microwave radiometer

Detection range : 0～400K
Detection accuracy: ±1K
Stability: ⩽0.1K/month
Temperature vertical resolution: ⩽50m
Humidity vertical resolution: ⩽100m
Temporal resolution: 0.01～2.5s

Millimeter-wave cloud radar

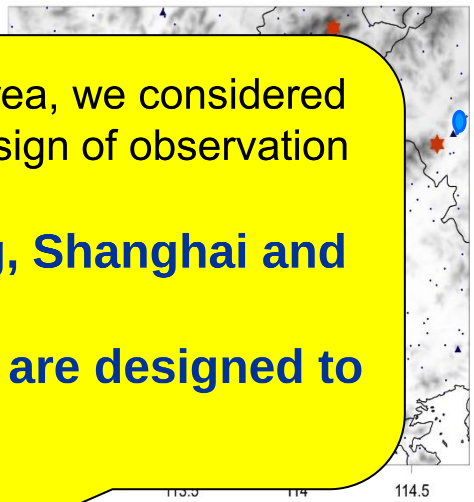
Frequency: 35GHz
Range resolution: 30m
Reflectivity detection range:
-40～40dBz
Mode: observation vertically
Product accuracy: 1dBz

Feature2:To design the intercompersion between urban and suburb ->In order to verify Urban Effect

Beijing

Shanghai

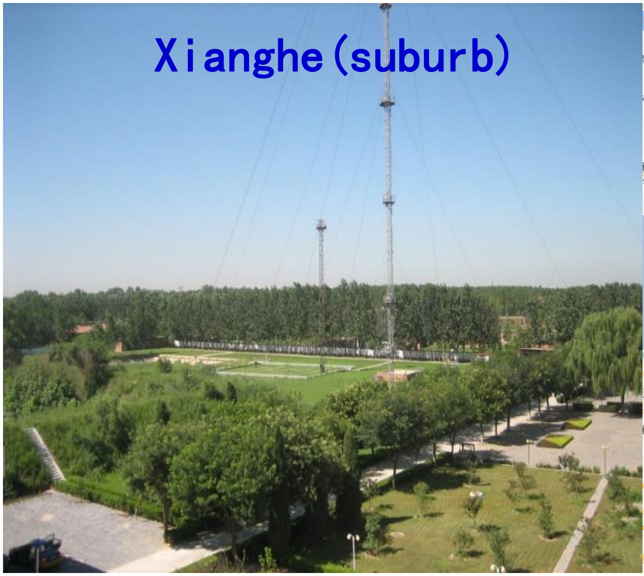
Guangzhou



In order to make a comparison between urban area and suburban area, we considered the construction of suburban integrated observation station in the design of observation plan.

- **Integrated profile observation stations in urban Beijing, Shanghai and Guangzhou**
- **Intercomparison observation in urban-suburb stations are designed to verify the Urban Effect**

Xianghe(suburb)

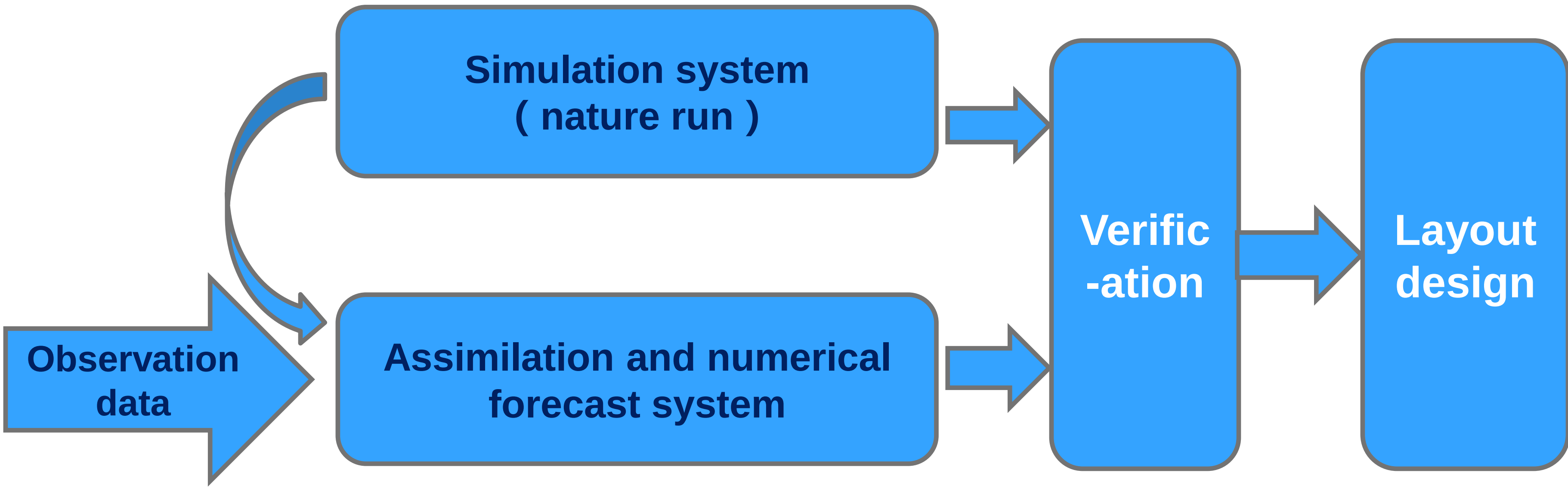


Chongming(suburb)

Longmen(suburb)

Feature 3: To carry out scientific layout design of MEMO

- Implement **vertical observation** simulation experiment including profiles of wind, temperature and hydrometeor
- Achieve the **observation network layout optimization** in megacities by means of
  - Observation system experiment(OSEs)
  - Observation system simulation experiment(OSSEs)
  - Forecast Sensitivity to Observation (FSO).



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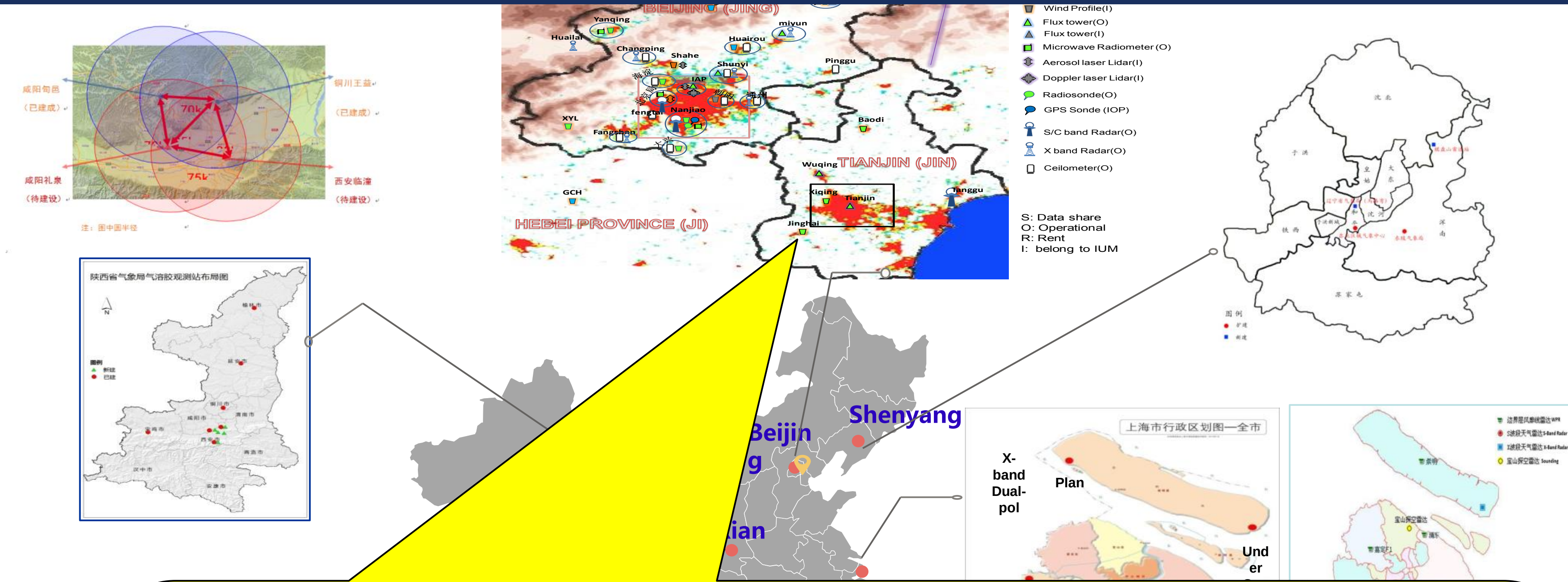
Tasks of MEMO: 2016—2022, 5 profiles

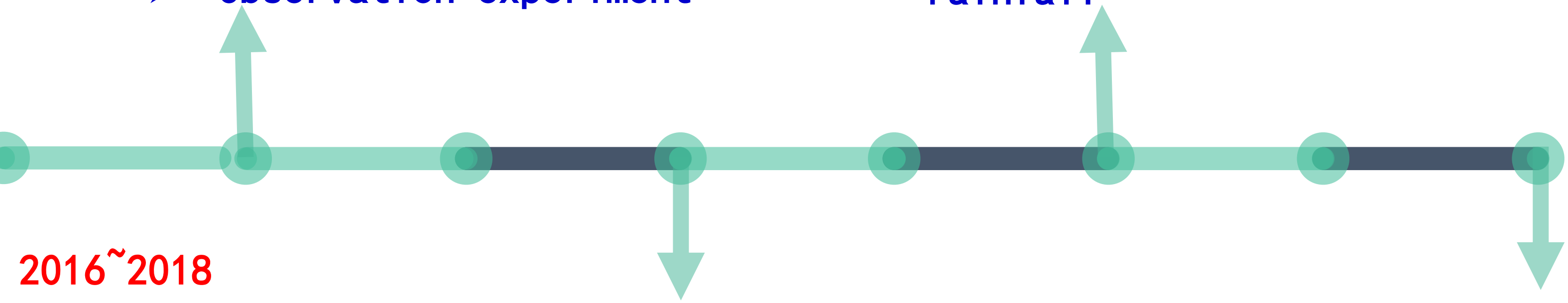


Main Tasks are as follows

- To Obtain 5 profilers from 2018 to 2022
- To research the mechanism of the effect of megacities on meteorological environment and boundary layer
- To carry out observation methods and quality control researches
- To establish some regulations of megacities vertical meteorological observation

Carry … **e, hydrometeor and atmospheric composition, utilizing the new technology equipments of wind profile radar, ceilometer, aerosol laser lidar and microwave radiometer.**

Timeline of MEMO



2016~2018

- Scheme design
- preperation

2018.1—2018.12

- Research on network layout
- Research on calibration and quality control
- Observation experiment

2019.1—2019.12

- Integrated and intensive observation in BJ

2020.1-2021.12

- Observation in BJ, SH and GZ, consecutive dataset
- Research on observation technique of cloud, temperature, humidity and wind; research on influence mechanism of aerosol-cloud-rainfall

2022.1-2022.12

- Research on data assimilation and fusion technique
- Inspection and evaluation of 3-D real-time analysis field
- Project acceptance

Key technical and scientific issues to be solved by MEMO

3 Scientific issues

Reach the maximum observation benefit with the minimum layout scale

Study the aerosol-PBL interaction with integrated observation

Reveal the influence mechanism of aerosol, T and wind on cloud-rainfall

Scientific Issue 1
Scientific layout of vertical observation

Scientific Issue 2
Structural characteristic and variation pattern of aerosol

Scientific Issue 3
Heterogeneous structure and influence mechanism of cloud-rainfall

Main Research contents

Technical Issue 1
Eliminate influence of cloud and rainfall on profile inversion

Technical Issue 2
Collaborative observation, data assimilation and fusion technique

Technical Issue 3
Set up methods for inspection and evaluation of observation data and fusion

Technical Issue 4
Verification and validation of ground based remote sensing and satellite observation

Improve the operational level of vertical observation remote sensing tech

Develop fusion algorithm for multi-parameters, achieve the collaborative assimilation

Ground calibration system based on insitu remote sensing

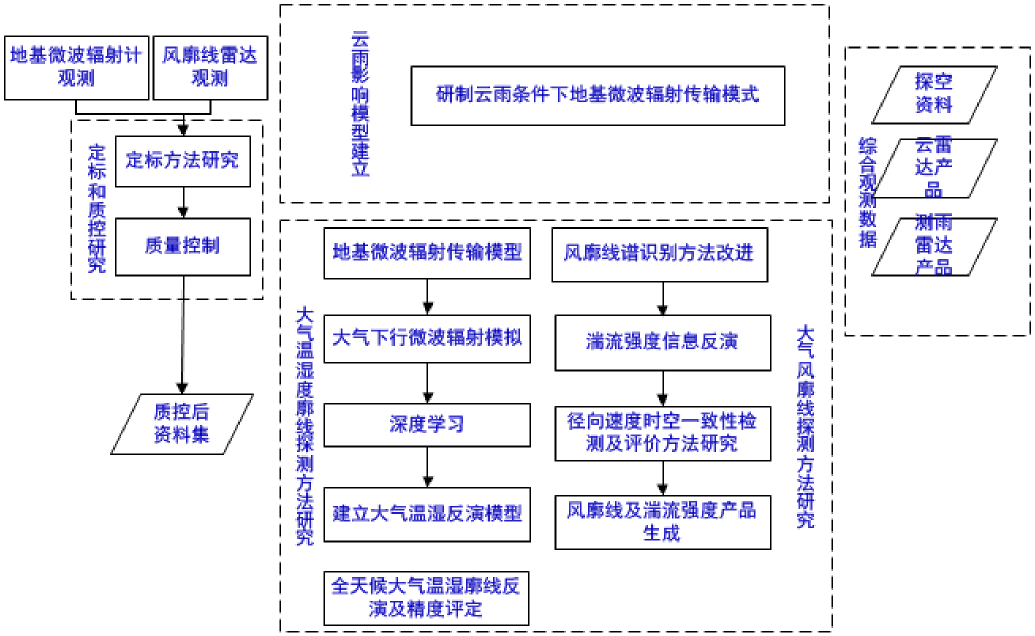
obs quality inspection & evaluation methods

4 Technical issues

The idea and the solution to issue 1

- **Eliminate influence of cloud and rainfall on profile inversion**

Quality control → **Setup model** → **Intercomparison and validation**



Improve vertical observation precision of T, humidity and wind profiles under existence of cloud and rainfall, combined with surface observation and cloud radar and based on equipments calibration,

Key techniques :

◆optimization of MonoRTM microwave radiation transfer model, set up of inversion model under cloud and rainfall

◆ base level quality control (brightness T, spectrum)

◆ intersectional quality control methods

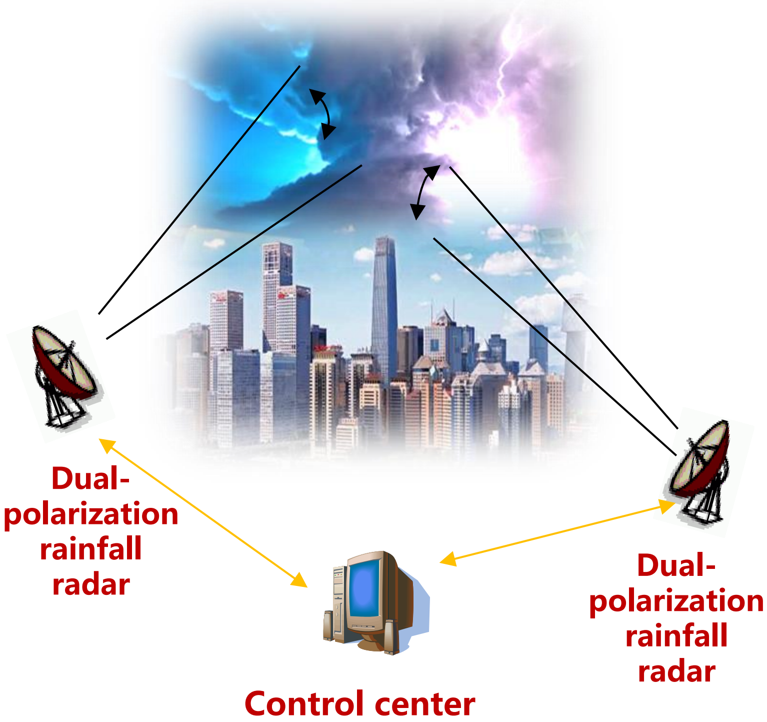
Innovation :

◆quantified application of refined cloud parameters on inversion of profiles of T and humidity

◆quantified analysis of calibration and obs errors

The idea and the solution to issue 2

■ Integrated and collaborative remote sensing observation



Technical design

雷达单元探测数据预处理

⬇

综合识别

⬇

确定重点观测区域AOI

⬇

根据AOI优先等级制定并优化扫描策略

⬇

分发控制

⬇

协同自适应观测

Key techniques：

- Networked radar observation modes
- Temporal and spatial synchronization
- Real-time adjustment of networked radar adaptation parameters
- Quality control

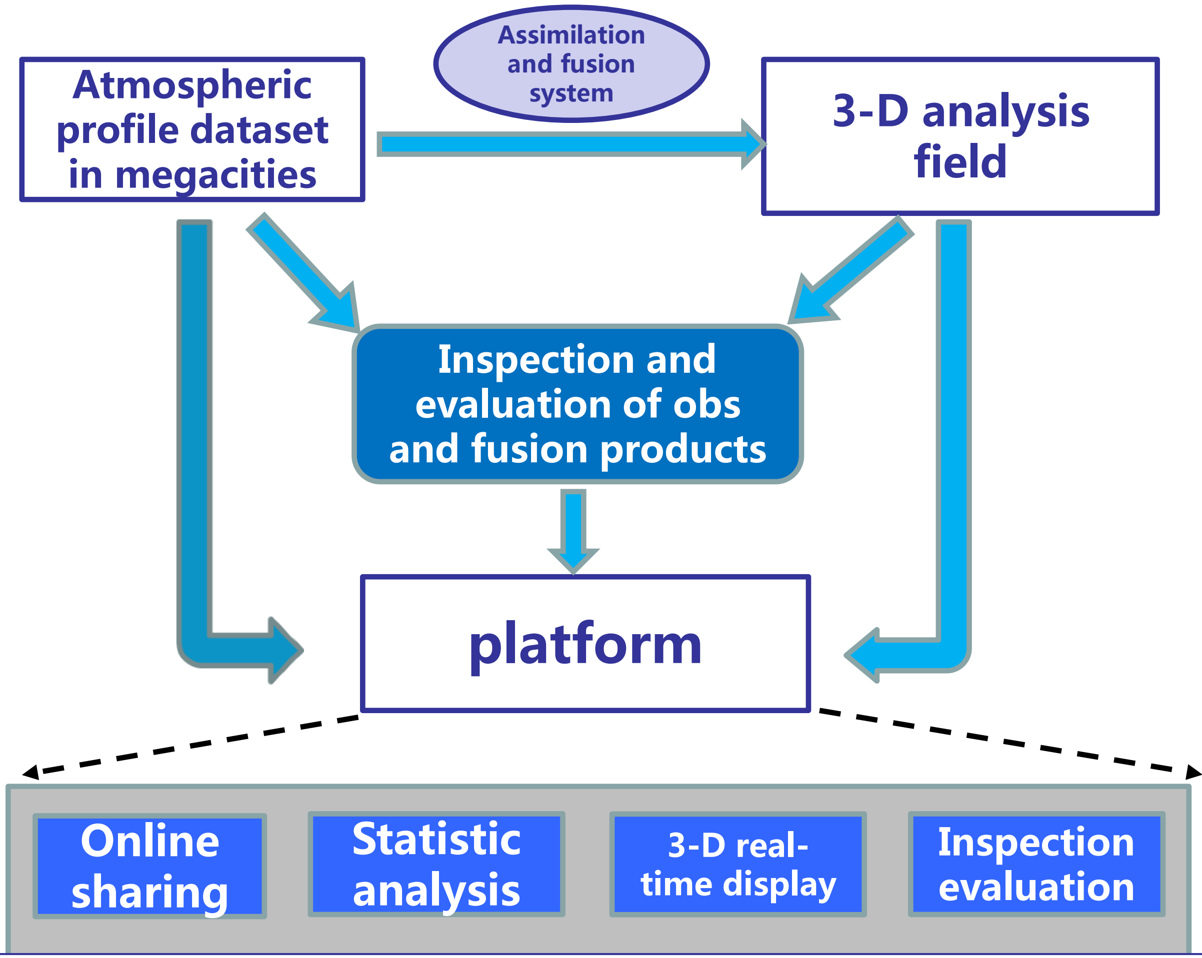
Innovation：

- Integrated and collaborative observation of cloud and rainfall with radars at various (X-, C- and S-) bands, first time in China

Maximum efficiency in obtaining refined vertical structural characteristics of cloud and rainfall, with limit-scaled obs network and networked collaborative obs technique

The idea and the solution to issue 3

■ Inspection and evaluation of observation data and fusion products



Production of 3-D analysis field and evaluation application adopting the advanced assimilation model technique , combined with conventional observation and integrated vertical observation data in megacities

Key techniques ：

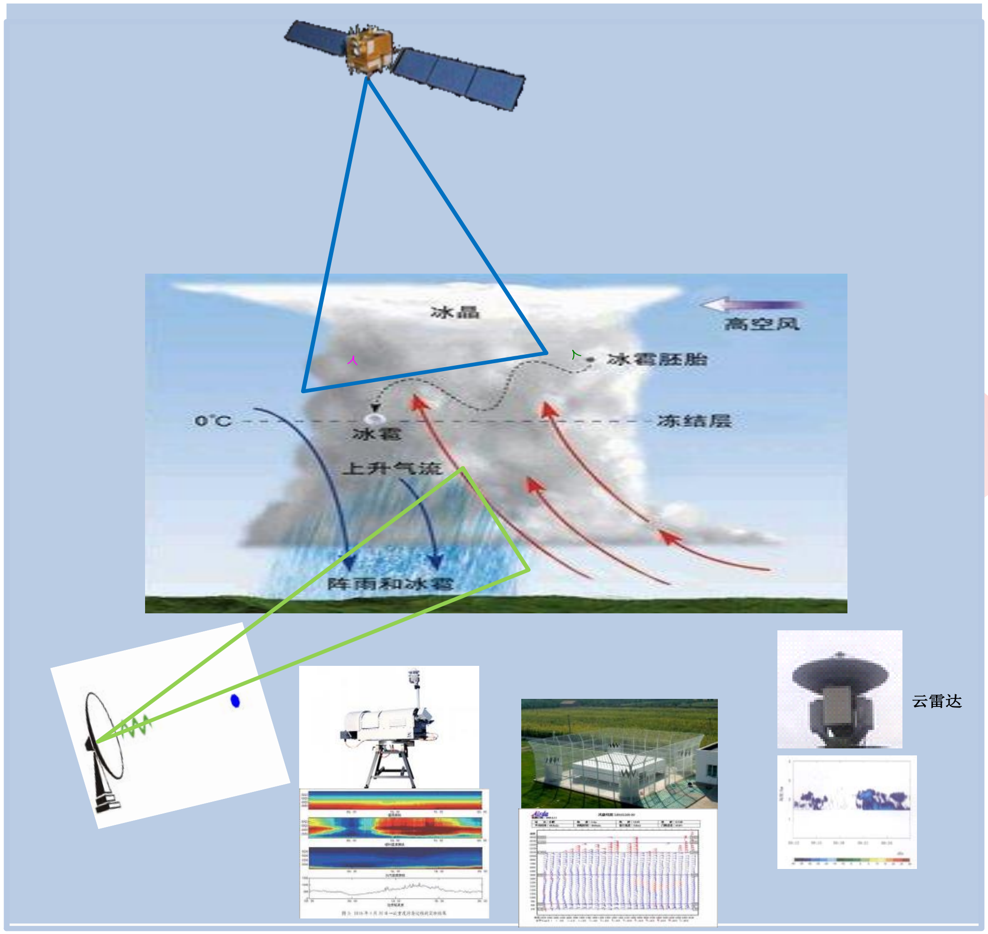
- Fusion technique of temperature, humidity, wind and rainfall data
- Evaluation quality and forecast influence of data fusion product

Innovation ：

- Coordinated assimilation of integrated vertical observation data

The idea and the solution to issue 4

- **Verification and validation of ground-based remote sensing and satellite observation**



Key techniques :

- Comparison of T profile of microwave radiometer and infrared channel of satellite
- Comparison of PR of ground rainfall radar and satellite-borne radar
- Comparison of cloud base height and cloud top height

Innovation :

- Regional quality improvement based on limited ground calibration

Intercomparison and validation of ground observed vertical profiles of wind, T, humidity, hydrometeor and aerosol with satellite observations

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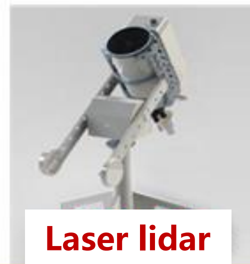
1) Experimental equipments progress

■ To realize Higher resolution for vertical observation

Cloud radar



Laser lidar

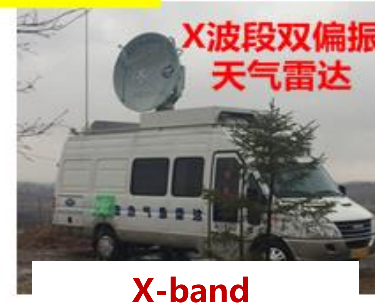
Laser lidar

We have gathered a large number of new remote-sensing equipments for MEMO

- ✓To calibrate and comparison before the experimental observation
- ✓To testing and maintenance to all of equipments

Microwave radiometer

X-band dual-polarization radar



X-band dual-polarization radar

These are all of equipments for MEMO

#	types	names	BJ	SH	GZ	total	remarks
(1)		In operational equipments					
1	Remote sensing equipments	Wind profiler	7	6	6	19	
2		Microwave radiometer	2	2	1	5	
3		Doppler laser wind radar	3		1	4	
4		S-band Doppler radar	1	2	1	4	
5		C-band dual-polarization radar	1		1	2	
6		X-band radar	5		4	9	
7	Conventional observation equipments	L-band sounding system	1	1	1	3	
8		RS41 sounding system	1	1	1	3	
9		ceilometer	10	3	10	23	
10		AWS	379	260	260	899	8 atmospheric watch stations in Shanghai
(2)		Additional new equipments					35 new equipments
1	MEMO, CMA	Cloud radar	7	3	3	13	
2		Aerosol laser lidar	7			7	
3		Microwave radiometer	7		1		
4	Comrehensive stations in Xianghe, Xujiahui and	Wind profiler	1	1			
5		Microwave radiometer	1				

Total equipments :

>50 equipment companies

>10 institutes

>60 types of equipments

>1000 sets of equipments

>500 participants

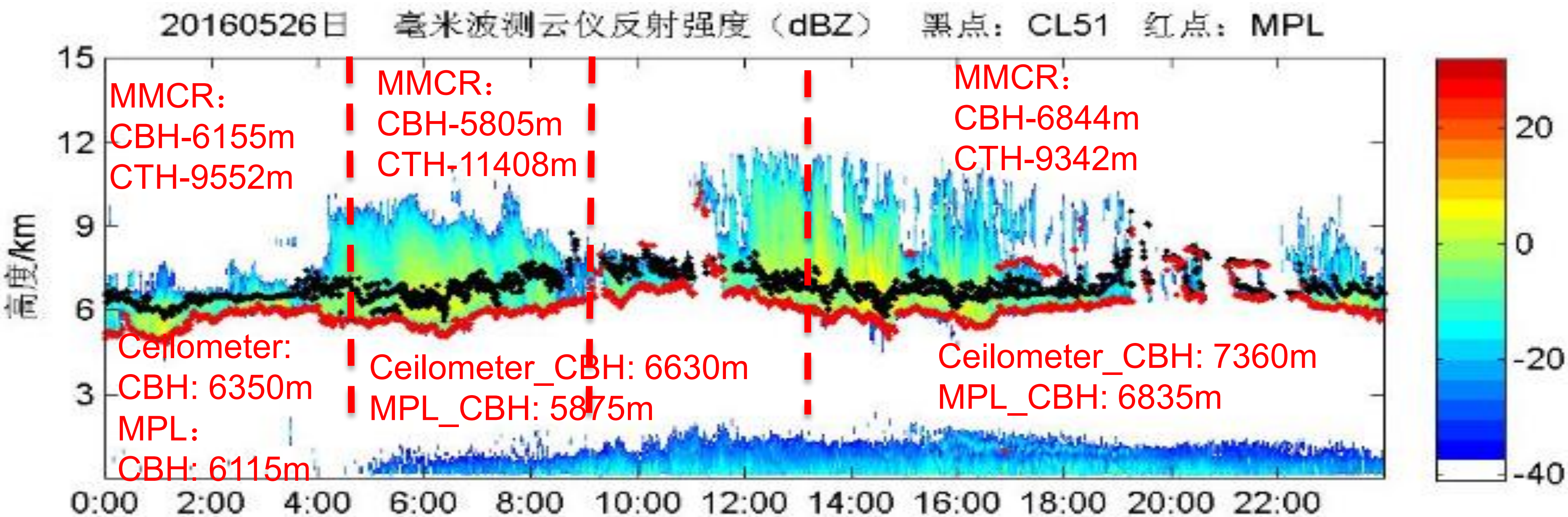
In the process of the megacities experiment, we not only use operational network equipments, but also some new equipments for observation

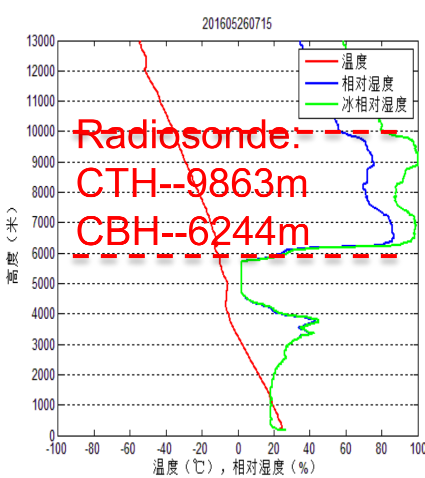
2) Progress of MEMO Intensive Observation period in 2018

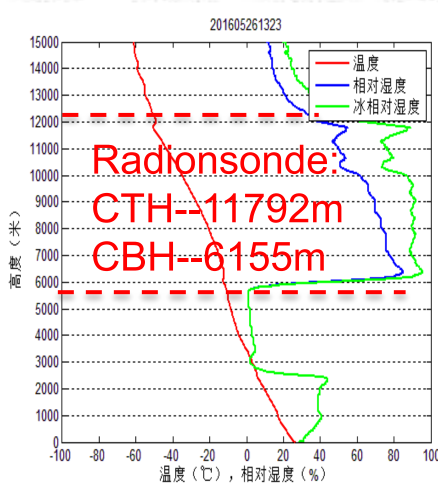
- To establish metadata standards and data bases
- To complete testing and calibration for all of equip
- To carry out comparison for some equipments
- To carry out the experiment of Intensive Observation period for 3 months

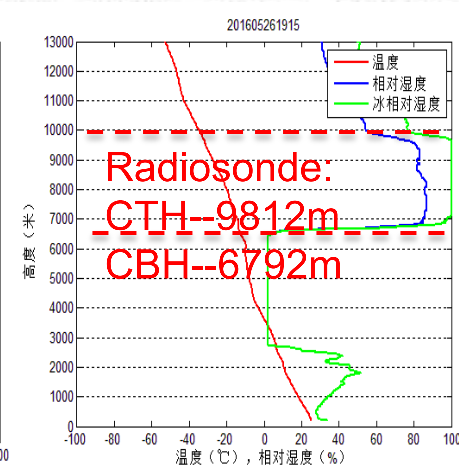
To carry out Comparison between MMCR and other equips

Observations of Cloud-top heights (CTHs) and Cloud-base heights (CBHs) by Millimeter-wave cloud radar (MMCR) are **consistent** with those by radiosondes, ceilometers and Micro Pulse Lidars (MPL).



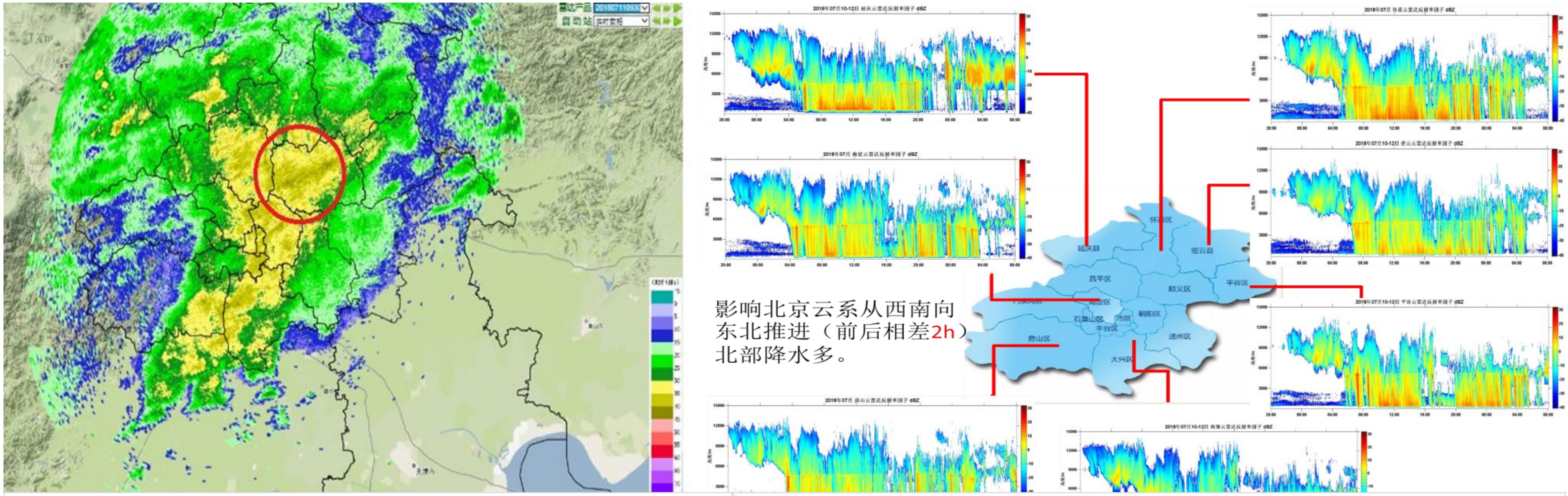


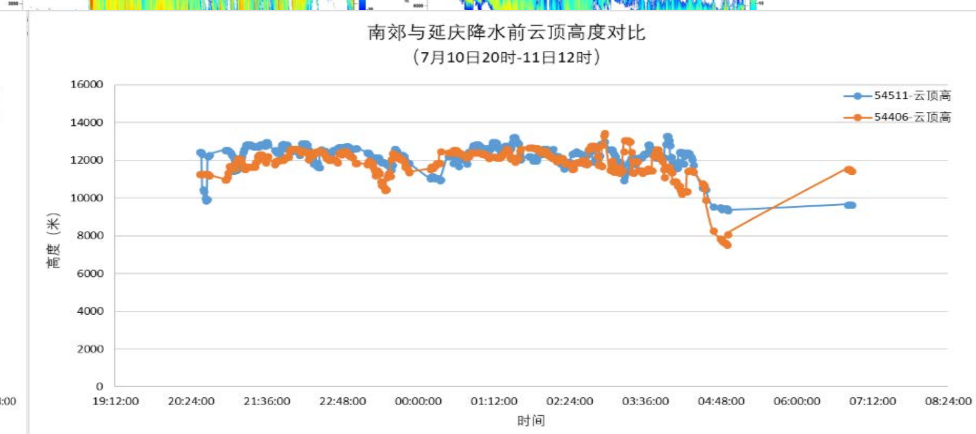




Mean of CBHs		
Radion sonde	MMCR	Relative error
6674	6641	-0.5%
Mean of CTHs		
Radion sonde	MMC R	Relative error
8957	8963	0.1%

To carry out continuous observation of precipitation process



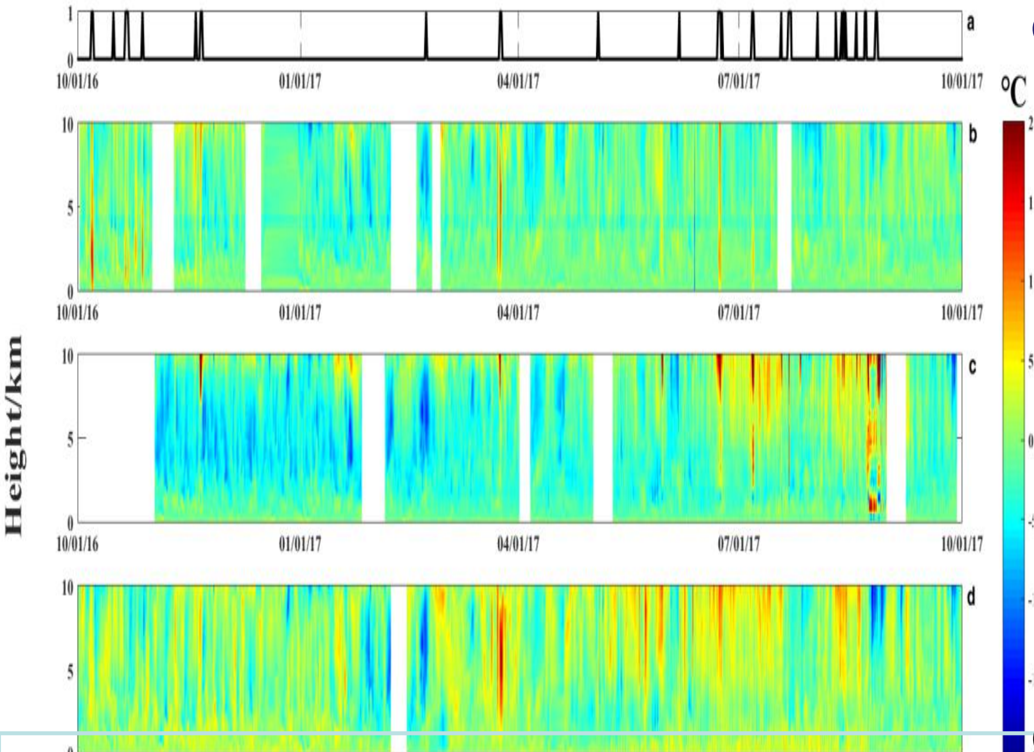


- CBHS derived by MMCR gradually decrease from 10 km since 2000 BJT on 10 July, 2018, while CTHs have been maintained at 12 km, which indicates that vapor are increasing continually and precipitation clouds are moving from southwest to northeast of Beijing.

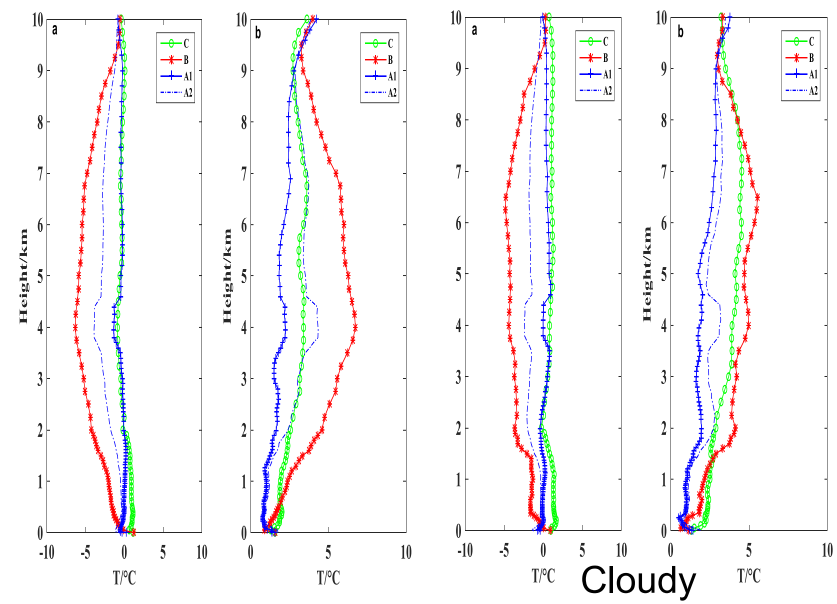
To carry out comparison between radiosonde and microwave radiometer

3 types Microwave Radiometer VS Radiosonde: Measured Temperature Deviation

a-Precipitation Flag，b-RPG，c-MP3000，d-MWP967KV



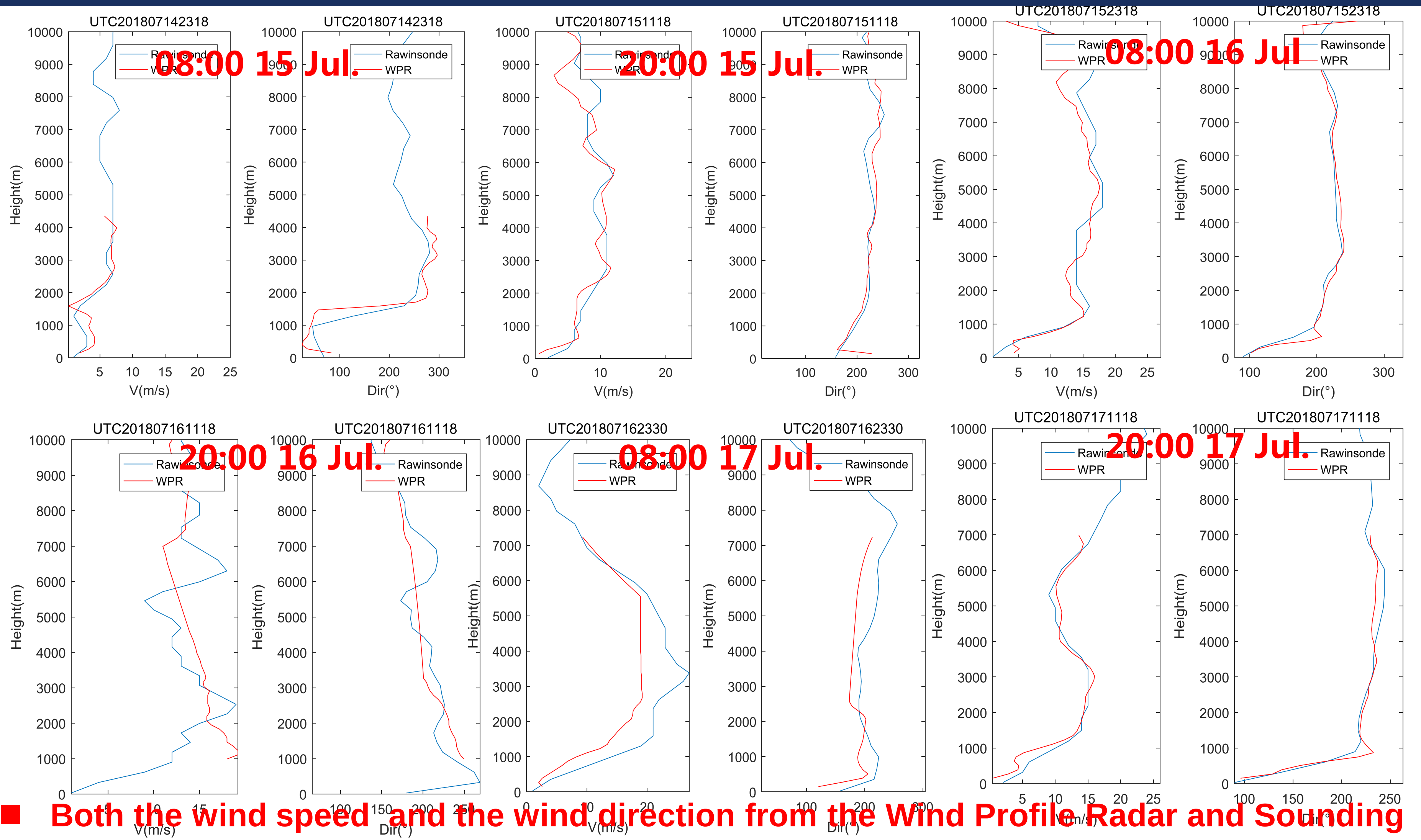
Quantitative Temperature Deviation Profile



(a) Average Deviation (b)Root Mean Square

- Temperature measured by the RPG is stable and closer to that measured by the Radiosonde; Temperature deviations increase with the height (Wang et al., 2018);
- Before 2017.07, measured temperature deviation between the MP3000 and the radiosonde was about -4℃， the deviation goes above 0 ℃ after then after utilizing a new algorithm model;
- Domestic microwave radiometers still have gaps with foreign instruments in terms of observation performance;
- The temperature deviation of the three devices increase under precipitation conditions.

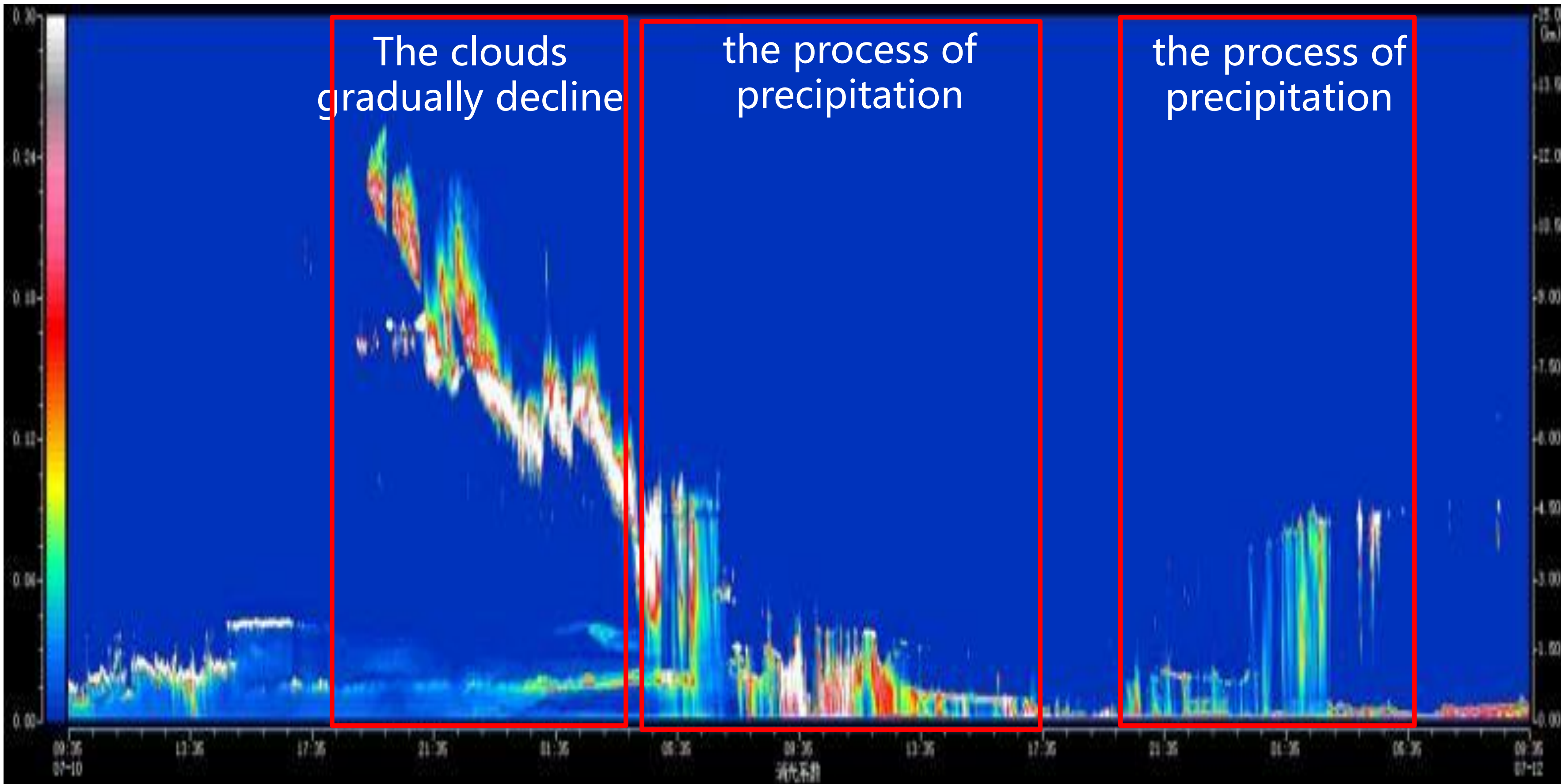
To carry out Comparison of Wind Profile Radar with Sounding during 15-17 Jul. 2018



■ **Both the wind speed and the wind direction from the Wind Profile Radar and Sounding showed good agreement during the whole precipitation process.**

■ **Wind Profile Radar performed well during this kind of precipitation process because the atmosphere was well mixed and the signal was strong.**

To observe the change of aerosol before and after of precipitation



July 10th-12th, pseudo color map of 48h extinction coeff. from lidar

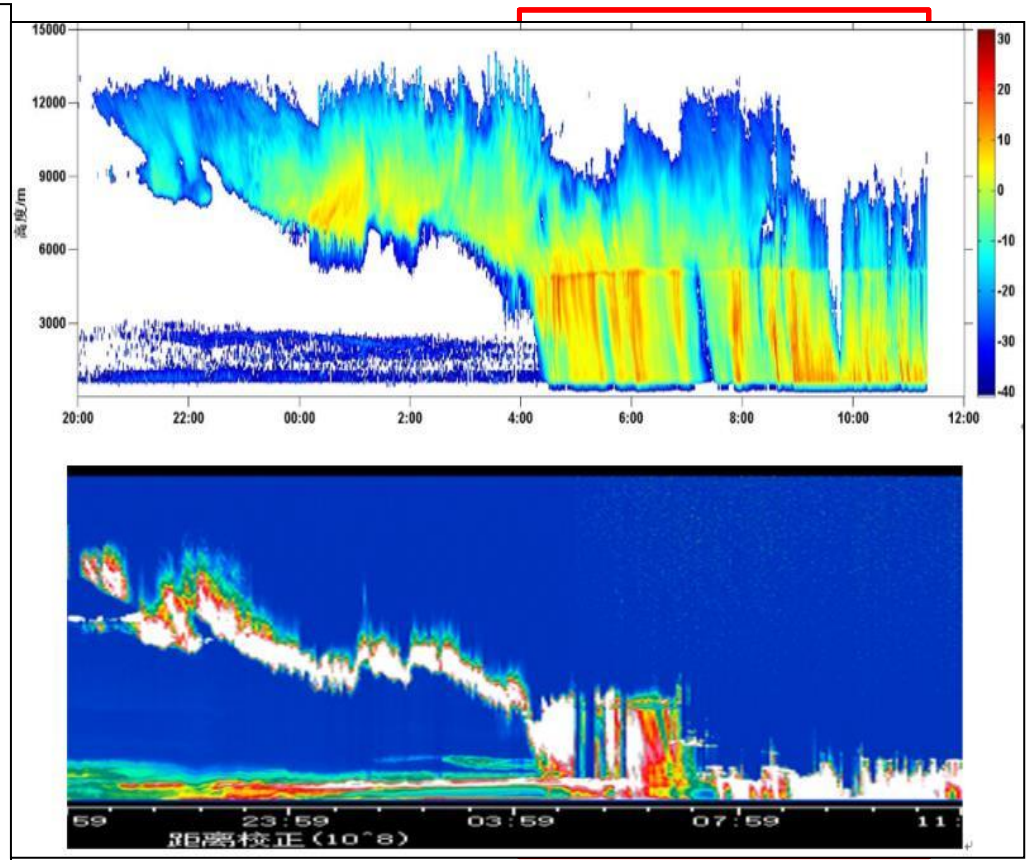
To carry out comparison between millimeter wave Radar and Lidar

In comparison with the Ka band millimeter wave radar, the analysis of precipitation data shows that：

1. The cloud bottom shapes and the beginning time of precipitation detected by two methods are obtained good consistency；

2. The stratification of lower aerosol measured by lidar is more obvious；

3、When the precipitation is enhanced, aerosol lidar can not penetrate the precipitation, and the detection height is significantly reduced.



Thanks you for your attention!

Recommendations are most welcome