Megacities Experiment on integrated Meteorological Observation in China

(MEMO)

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MEMO

Challenges:

◆ Capability of high-resolution monitoring and forecasting
  ● short-time forecasting, nowcasting
  ● precise time and area of torrential rain, hail, heavy snow
  ● Application of new datasets to numerical model

◆ Precise weather services
  ● fog and haze, urban citizen health
  ● thunder and lightening, severe convective weather……

◆ Capability of vertical observation
  ● 4-D real-time observation data cannot be assimilated by numerical model
  ● Constraints on forecasting precision, difficulty in the verification of weather prediction

Advantages:

◆ Comprehensive observation network
  ● Regular surface, radiosound, radar, satellite, meteorological observations
  ● atmospheric composition detections

◆ Capability of urban weather prediction
  ● Reanalysis, assimilation and modeling
  ● Ability to implement experiment on Observation-Assimilation-Prediction

◆ Experience of specialized urban meteorological services
  ● CMA gave refined meteorological services to Beijing Olympic 2008, Shanghai EXPO 2010……

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Outline

- A Brief Introduction of MEMO
- Scientific and Operational Objectives
- MEMO Design Scheme
- Introduction of Experiment A
- Introduction of Experiment B
- Expected Achievements
MEMO is initiated by China Meteorological Administration (CMA) and organized by CMA Meteorological Observation Centre (MOC). The experiment takes place in Beijing (and also the Jing-Jin-Ji region), Shanghai, Guangzhou, Chengdu, Shenyang, Xi'an and Shenzhen. Over a period of three years (2016~2018) of the trial, it will effectively improve the overall quality of meteorological observation data and model assimilation rate, and establish the interaction mechanism of observation and forecast, solve the key technical problems in the short term forecasting, nowcasting and the environment weather service as well.

- **MOC:** systematic design, technical support and coordinate
- **Achieve the observation modernization in 7 megacities**
- **Improve quality of meteorological observation data and assimilation rate**
- **Invite professional companies to provide high-tech instruments, test-run and compete the performance of new equipments in MEMO**
- **Invite universities and research institutes to participate, jointly work on research and data sharing**
- **All technical departments are, great cooperation and collaboration lead to technological innovation**
Reveal the characteristic of atmosphere structure in megacities: put emphasis on vertical and horizontal distribution structure, to build seasonal conceptual model of structure of urban heat island and pollutants in fog/haze events.

Promote the advanced application of comprehensive urban observation data in numerical model: to build operational assimilation system of synthetical meteorological observation data, and improve the prediction ability.

Improve the combination of integrated urban observation and nowcasting: to build real-time operational system from observation to nowcasting.

Comprehensive operational observation system: to build complete set of work flow, specifications and standards.

Scientific and reasonable Integrated Meteorological Observation Network: able to implement observation on study of characteristics in megacities.
The experiment is decomposed into two sub-experiments A and B to make the implementation more specific:

**Experiment A on coordination of observation and forecast**

Based on the experiment, the integrated observation of new observing technologies and equipments would promote the collaboration of observation and forecast, improve the quality of integrated ground-based remote sensing observation and make important contribution to the local numerical forecast.

**Experiment B on vertical observation of fog and haze**

Realize the vertical detection of aerosols under the boundary layer. Promote the synergy between the observation and the fog/haze forecast, and improve the level of the fog/haze forecast.
Carry out the observation of boundary layer height, vertical profile of wind vector, temperature, hydrometeor and atmospheric composition, utilizing the new technology equipments of wind profile radar, ceilometer, microwave radiometer and aerosol laser lidar.
Objective:

- To promote the collaboration of observation and forecast, establish the high-resolution delicate 3-D objective analysis fields over the metropolis and fulfill the modernization of comprehensive observation in megacities.
- To improve the quality of integrated ground-based remote sensing observation and make important contribution to the local numerical forecast.
- To provide technical support to fine-grid forecast in cities, meteorological services for air pollution, drainage, waterlogging prevention, traffic and tourism.
Experiment A:

Intercomparison of fine prediction products and real-time observation, evaluation and verification of numerical model output with ground-based remote sensing measurements.

- Observation network layout optimization test
- Evaluation and experiment on output of forecast model
- Generation technique and experiment on 3D real-time analysis field
- New equipment, new technology operation observation experiment
- Satellite observation application experiment
- Experiment on improving observation operation

Sub-experiment design

To establish the high-resolution delicate 3-D digital atmosphere over the metropolis; assimilation of new type observation data.

- To establish the comprehensive data application platform of FY, GF and foreign satellites
- To apply the achievements in operation, data sharing platform of SEMO

The assessment of existing observation network and optimization suggestions, including OSEs, OSSEs and FSO.
Experiment A: Technical problems we focus on:

1. Solve the key techniques to improve the data quality of ground-based remote sensing, accomplish the intercomparison and internal verification of fusion data.

   Through the joint efforts between observation and forecast, the improvement of numerical assimilation of comprehensive vertical profile observation of atmosphere is expected, the digitalized and high-resolution atmosphere can be established based on data fusion technique of multiple ground-based remote sensing observation methods and platforms.

   • "5 key elements of vertical profiles": wind vector, temperature, humidity, hydrometeor and aerosol
   • "6 kinds of observation instruments": Millimeter-wave cloud radar, Microwave radiometer, Wind profiler, Raman-Mie lidar, Phased-array radar, Dual Polarization radar
2. Expand the observation in megacities from 1-dimentional to multi-dimentional and optimize the comprehensive and vertical observation layout:
   • Establish the top-level design and technical platform of meteorological observation system
   • 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) and Forecast Sensitivity to Observation (FSO).
3. Key Technologies of Ground Remote Sensing

**Experiment A:**

- Improve the detection capability of low clouds
- Eliminate clear-sky echo effects
- Improve the ability of recognition of cloud base in precipitation
- Establish quality control method

Increase the signal-to-noise ratio and improve the detection capability of low clouds by increasing the transmission power and optimization of antenna structure.

Eliminate the influence of clear-sky echo to millimeter wave cloud radar by developing clear-sky echo recognition algorithm and real-time software.
Equipment improvement of microwave radiometer

Improve brightness temperature forward model parameter scheme

Improve of temperature and humidity profile retrieval algorithm under the condition of cloud

Evaluation method of temperature and humidity profile

Establish quality control process

The deviation between the measured brightness temperature and the simulated brightness temperature is obviously decreased after the improvement of the forward model.
Experiment A:

5. Wind profiler

- Improve the wind observation in precipitation
- Optimization of quality control
- Application and verification of propulsion model

Technical method

In precipitation, the wind profiler radar can detect the atmospheric turbulence echo and the raindrop scattering echo signal, which will bring error to the subsequent atmospheric wind field inversion.

Technical method

Determine the average noise power of wind profiler radar and cloud radar, and then the two are shifted to the same benchmark, subtracted result is the turbulence spectrum.
6. Strengthen the verification of satellite products with ground-based observation, establish the satellite products verification operation system to improve the satellite data quality operation level.
Carry out **vertical observation of aerosol under PBL**, get knowledge of vertical distribution characteristic of aerosol in fog/haze and boundary layer height, build the **3-D objective analysis fields of aerosol PM**, enhance the coordination of observation and forecast of fog/haze and improve the local fog/haze forecast ability.
Experiment B:

Syntetical analysis of vertical profile data of multiple observation methods; study on structure of urban aerosol and variation characteristic of PBL; research on formation and development of haze and fog events in megacities; study on interaction mechanism of PBL and aerosol pollution.

Improvement of prediction and assessment of chemical weather forecast result.

Comprehensive analysis of in situ and vertical observation of aerosol in haze and fog events.

Experiment on vertical observation of fog and haze.

Generation technique of 3-D objective analysis fields of aerosol PM under PBL.

Operational observation of newly developed technology.

Layout of haze and fog observation operation.

Carry out observation and intercomparison of Raman-Mie laser lidar, hyperspectral lidar, unmanned aerial vehicles, MAX-DOAS, sun photometer etc.
**Experiment B:**

**Technical problems we focus on:**

1. **Vertical profile observation of aerosol in megacities**

- **Vertical observation network in Beijing:** Raman-Mie laser lidar (5~7 units), micropulse laser lidar (3), MAX-DOAS (1~2)
- **Observation layout:** According to the air pollutants transportation channel in Beijing, Raman-Mie laser lidar will be located along the channel from south-west to north-east and also its perpendicular path, aiming to get vertical distribution and variation characteristic along these two paths.

**Distribution plan of Raman-Mie laser lidar**

**Observation stations in and around Beijing**
**Experiment B:**

Technical problems we focus on:

2. Operational experiment of Raman-Mie laser lidar:
   - Establish the quantitative and operational vertical observation technique of haze and fog
   - Set up quality control system and operational work flow of Raman-Mie laser lidar

1. Raman-Mie laser lidar calibration test compared with sun photometer
2. Raman-Mie laser lidar calibration test compared with visibility meter

Tower

100m

200m

Extinction/Visibility observation
Inversion algorithm based on ground visibility observation
Extinction/Visibility observation

**Tower**

Raman-Mie laser lidar

Intercomparison

4. Verification of laser lidar with unmanned aerial vehicles

3. Intercomparison of Raman-Mie laser lidar and hyperspectral lidar

sun photometer

Intercomparison

**Hyper-spectral lidar**

Data analysis, transmission/distribution, quality control, product design and development

Numerical model application

Experiment B:

3. Intercomparison of Raman-Mie laser lidar and hyperspectral lidar

4. Verification of laser lidar with unmanned aerial vehicles

5. Data analysis and product development

1. Raman-Mie laser lidar calibration test compared with sun photometer
2. Raman-Mie laser lidar calibration test compared with visibility meter

100m

200m

Tower

Extinction calculation based on combination of particle distribution measurement of unmanned aerial vehicles and Mie scattering model

Inversion algorithm based on ground visibility observation

**Tower**

Extinction/Visibility observation

Raman-Mie laser lidar

Data analysis, transmission/distribution, quality control, product design and development

Numerical model application
Several ‘Observing findings’: 
• Vertical characteristics of atmospheric boundary layer
• ‘5 profiles’: wind vector, temperature, humidity, hydrometeor and aerosol
• Urban heat island effect

Operational generation system of real-time atmosphere 3-D objective analysis fields

After the assimilation of newly produced and improved data, make important contribution to forecast result of numerical models

Technical standards, specifications and processes of cooperative observation
Application of new technology on MEMO

Focus on continuous observation of multiple weather conditions, including clear sky, precipitation and fog/haze events.

Satellite verification

Propose to establish the verification and calibration system of operational satellite and ground-based remote sensing technology in megacities, laying foundations of remote sensing application.

Integrated observation

Establish the super integrated observation stations, consisting of Millimeter-wave cloud radar, Microwave radiometer, tropospheric wind profiler, Raman-Mie laser lidar and weather lidar.

Focus

• Temporal-spatial synchronized observation of multiple elements and parameters of atmosphere
• Observation of accurate vertical profiles of 5 key elements: temperature, humidity, wind vector, hydrometeor and aerosol

Aims
THANK YOU

LOOKING FORWARD TO SUGGESTIONS AND WORLDWIDE COOPERATION