Shanghai City MHEWS and Urban Integrated Observation

Jianguo TAN
Jianguot@21cn.com
Shanghai Institute of Meteorological Science
Shanghai Meteorological Service, CMA
Background

★ Megacity of Shanghai: high exposure and vulnerability

4 centers
Strategic Positioning
Financial, Trade, Transportation, and Shipping Center of China

- 24+ million dense Population
- 2+ million Civil vehicles/congested traffic
- Productive economic activities.

Critical locations
Downtown, bund, airports, ports, etc. are highly sensitive to weather events.
The frequent disasters occurred in Shanghai include **typhoon**, **rainstorm**, **lightning**, and **gale**.

- **Magnification Effect:**
  Even slight weather events can trigger significant loss of life and property due to high population density and critical economic activities.

- **Domino Effect:**
  Natural hazards can lead to accidents, life and economic losses. Secondary and tertiary effects of weather-induced disasters can have severe short and **LONG TERM** consequences.

### Impacts of meteorological disasters on Shanghai during 1984-2009

<table>
<thead>
<tr>
<th>Type of disasters</th>
<th>Number of deaths (people)</th>
<th>Number of injuries (people)</th>
<th>Collapsed building (houses)</th>
<th>Direct economic losses (million CNY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainstorm/flood</td>
<td>28</td>
<td>56</td>
<td>788</td>
<td>237</td>
</tr>
<tr>
<td>Typhoon</td>
<td>54</td>
<td>394</td>
<td>26030</td>
<td>650</td>
</tr>
<tr>
<td>Thunderstorm</td>
<td>85</td>
<td>58</td>
<td>108</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>312</strong></td>
<td><strong>1928</strong></td>
<td><strong>38290</strong></td>
<td><strong>1082</strong></td>
</tr>
</tbody>
</table>
Main task of Shanghai MHEWS

WMO identified the Shanghai MHEWS as Demonstration Project in 2007

Weather and climate hazards:
- Typhoon
- Severe Convective Weather
- Rain storm
- Heat wave
- Drought

Weather and climate related hazard:
- Storm Surge
- Urban Inundation
- Human Health
- Epidemic Diseases
- Air Pollution

Other hazards:
- Earthquake
- Other Emergencies

Emergency Response:
- Fire accident
- Chemical gas leak
Shanghai has established a Multi-Hazard Early Warning System (WMO showcase project)
An integrated weather and services for public health system in Shanghai has developed, with multi-department cooperation.
Benefit

Case 1: Heat wave warning for EXPO 2010

- Tailored heat wave warning were issued based on different tourists requirements.
- Cooling measures were taken: spraying of mist on groups of people queuing to enter pavilions (waiting time to enter popular pavilions often exceeded 5 hours!)

<table>
<thead>
<tr>
<th>Date</th>
<th>NET</th>
<th>HI</th>
<th>PT</th>
<th>PT</th>
<th>Humidex</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-22</td>
<td>23</td>
<td>91</td>
<td>27</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>9-23</td>
<td>17</td>
<td>75</td>
<td>26</td>
<td>27</td>
<td>30</td>
</tr>
</tbody>
</table>
Benefit

Case 2: Typhoon ‘Haikui’

- Typhoon ‘Haikui’ attacked Shanghai on the 7th August 2012
  Max gale: Level 14, Max rainfall: 246.2mm.

- The warning Signals were issued ahead of the disasters through every channel, both to the decision makers and general public.

- The MHEWS played a key role in protecting people’s lives and property through triggering sectors response measures.
  - 6,000+ vessels called back to ports
  - 374,000+ residents relocated to safe areas
  - 8,000+ construction sites inspected
  - 93,000+ trees protected
  - 6,899 outdoor billboards’ firmness examined

- Accurate forecast and warning, high efficient multi-agency cooperation were the KEY factors for the successful disaster reduction.
Why Establishing Shanghai IUWCS

Objectives

► Observation design and practices
► Forecasting and warnings across all time scales
► Impact based weather forecasts and multi-hazard risk analysis and reduction
► Urban framework for climate services

Challenges

• On-going urbanization
• Expected increase of weather and climate extremes

Experiences

• MHEWS
• WENS
• GURME
• TLFDP

WMO CAS、CBS Priorities, GFCS
Proposal

Objectives & Development Plan

Identification of end user needs, hazards and partners

Weather Service ↔ Climate Service

Assessment

Impact-based Forecast and Risk Warning

Numerical Forecast R & D and Application

Urban Integrated Meteorological Observation and Application

Research and Development

Capacity Development
Main task of Shanghai Integrated Urban Weather and Climate Service: Two integrations

1. Integration of weather forecast and climate prediction

- Fined nowcasting for 0-12h
- Extended range forecast and short-term climate prediction
- Urban Meteorological Integrated Observation
- High resolution regional weather forecasting systems

2. Integration of weather forecast and risk management

- Impact-based Forecasting and Warning
- Urban climate services
- Early-warning triggered service for decision making and department response

a seamless forecast system

impact-based weather forecasting and risk warning system
Case 1: Impact-based Forecasting and Warning: urban flooding

- The threshold for Flooding risk warning is docked with community four-level response and linkage standards.
- Flooding Risk products released to the public, community manager and shared with flood control sector.
- Cooperation with the Civil Affairs Department and flood control sector

Rainstorm waterlogging simulation (50mm/h)
Case 2: Impact-based Forecasting and Warning: Human health

- SMS Issues impacts forecasts for respiratory diseases, such as common cold, children’s asthma and COPD (Chronic Obstructive Pulmonary Disease) in cooperation with Shanghai municipal center for disease control and prevention.

- WeChat ‘jiankangqixiang’ is used to release health forecasting service. It has over 70,000 followers till now.

The influence of PM2.5 on the sensitivity of primary pollutants in different age groups.

health forecast in hospitals
Case 3: Impact-based Forecasting and Warning: environment

- Jointly issue the AQI prediction and warning with Shanghai Environment Protection Bureau.
- Extend the air quality forecast to 10d for emergent emission reduction to mitigate severe air pollution events.
- Evaluate the cost effect of local clean air action plan to support the decision making for emission control.
Case 4: Impact-based Forecasting and Warning: ocean meteorology

- The WMO Coastal Inundation Forecast Demonstration Project – Shanghai Subproject (CIFDP-S) is being implemented as national sub-project since 2013.
- Cooperation with Hydrology (Shanghai Water Authority), Oceanography (East China Sea Branch of State Oceanic Administration), Emergency Management (Shanghai Emergency Response Center) and Coastal Planning (Shanghai Maritime Safety Administration).
Case 5: Impact-based Forecasting and Warning: traffic meteorology

- Cooperation with Shanghai Metro to carry out the risk warning forecast of rail transport
- Cooperative development of rail transport impact forecast and risk warning platform
- According to the risk warning products, line 16 and line 2 suspend operations during the period of typhoon ‘chan-hom’ in Shanghai.
Case 6 Impact-based Forecasting and Warning: aviation meteorology

- Preliminary aviation weather service is issued to support airport and Airlines etc.
- Based on high resolution numerical weather prediction model, aviation index including icing and clear air turbulence has been developed.
- Developed high impacted weather analysis and forecast platform for aviation mete service.
Technical progress: Enhancement of the Urban Integrated Meteorological Observation

- Experimental studies on adaptive layout of the synoptic network in Yangtze River Delta.

- Establishment of the integrated meteorological observation system, enhance the city's meteorological disaster monitoring, early warning.
The goal of Urban Met-Observation is to provide the measurements for all the processes that influence urban weather/climate and environments with multi-scales in terms of time and space.

These measurements on multi-processes, including those from free atmosphere, the boundary layer, and underlying surface features, are linked and impacted one another, therefore, the urban Met-observation should be an integrated system.
Characters of Urban Integrated observation:

1. **Multi-purpose/multi-function**: Weather/climate, environment forecast, Met-service, research, etc.
2. **Multi-scale**: macro/meso-scale, urban scale, neighbourhood scale, street, building.
3. **Multi-variable**: thermal, dynamic, chemical, biometeological, ecological, ...
4. **Multi-platforms**: radar, wind profiler, photo, ground-based, aero-borne, satellite based, in-situ observation or sampling, etc.;
5. **Multi-linked**: linkages between all platforms, Integration of all platforms and techniques;

With:
- **Data acquisition Management** to facilitate exchange of data and information
- Ability to improve coordination of strategies and instruments and to identify gaps in observations based on science- and user-driven requirements
- **Capability to intelligently combine observations** from a variety of platforms with different models to produce the best estimate of the current state of the urban atmosphere

---

Shanghai Urban Integrated Meteorological Observation Network (SUIMON)

Wind profiler

Lightning positioning System

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Count</th>
<th>Update Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS (5 – 6 km)</td>
<td>256</td>
<td>1 min</td>
</tr>
<tr>
<td>Weather radar</td>
<td>2</td>
<td>6 min</td>
</tr>
<tr>
<td>Wind profiler</td>
<td>10</td>
<td>30 min</td>
</tr>
<tr>
<td>Met-towers</td>
<td>13</td>
<td>1 min</td>
</tr>
<tr>
<td>L-band radiosonde</td>
<td>1</td>
<td>6 h</td>
</tr>
<tr>
<td>Lightning positioning system</td>
<td>7</td>
<td>1 s</td>
</tr>
<tr>
<td>GPS/MET</td>
<td>31</td>
<td>30 min</td>
</tr>
<tr>
<td>Satellite receivers</td>
<td>9</td>
<td>30m/1h</td>
</tr>
<tr>
<td>Atmospheric component</td>
<td>10</td>
<td>1 min</td>
</tr>
<tr>
<td>Urban FLUX</td>
<td>3</td>
<td>30Hz</td>
</tr>
<tr>
<td>Mobile observation</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

1 GPS-met network consisting of 14 reference stations

weather radar (WSR-88D)
In-situ sites (10) for atmospheric chemistry measurements, monitoring air pollution level under different kind of emission impacts.
Urban Effects on Weather/Climate/Environment

- **Urban “Forcing” Factors**
  - Roughness
  - Albedo
  - Permeability
  - Thermal conductivity
  - Volumetric heat capacity
  - Anthropogenic heat flux
  - Emissivity

- **Atmospheric Impacts (“response”)**
  - Turbulence intensity
  - Stability
  - Mixing height
  - Wind speed, direction, shear
  - Cloudiness
  - Energy fluxes
  - Runoff
  - Temperature
  - Solar and UV radiation
  - Visibility
  - Air quality
  - Precipitation

- **Some Urban Phenomena:**
  - Pedestrian weather: winds; temperature; humidity; insolation
  - Street canyon winds
  - Urban weather modification (inadvertent) and convection
  - Heat island
  - Flooding
  - Air quality (e.g. PM2.5)
  - Dispersion
  - Visibility
  - Heat-AQ stresses

Urbanization alters the “Forcing” Factor such as roughness, albedo, permeability, emissivity…etc. and impacts the atmospheric (Turbulence intensity, stability, mixing height…, etc. results the special urban phenomena (heat island, air pollution…. etc.)
Multi-platform

- Surface/in situ observation
- Met Tower
- Ground-based Remote sensing (weather radar, Wind Profile, RASS, Sodar, Lidar)
- Aeroborne sample/remote sensing
- Satellite based remote sensing
- Wind Tunnel, water tank experiment ....
Priority of Urban Environment Measurement Needs

Planetary Boundary Layer (PBL) and the upper subsurface (~2m) need attention

• **First-priority needs:**
  – Height (and structure) of the PBL
  – Soil moisture and temperature profiles
  – Hi-resolution vertical profiles of atmospheric humidity
  – Air quality concentrations above the atmospheric surface layer

• **second-priority needs:**
  – Solar radiation (direct and diffuse)
  – Vertical profiles of wind
  – Icing near the surface
  – Vertical profiles of temperature
  – Surface turbulence parameters
PBL observation: Physics & Chemistry

- AWS: 220
- Doppler radar: 1+1
- Wind profile: 8 + 1
- Lightening position: 6
- GPS/Met :18
- Tower: 13
- Mobile: 3+1+1
- Total sky imager: 16

- Atmospheric chemistry: 10

Physics instruments: in-situ obs & remote sensing

Chemistry instruments: Sampling & remote sensing
Key point: horizontal measurement

(1) Representative in different environments

(2) Layout at different scale

Shanghai megacity
~ hundred of kilometers

Shanghai downtown
~ tens kilometers

Expo garden
~ kilometers
Key point: vertical measurement

(1) Extend from the surface to the top of the Earth

- ~100m
- ~3000m
- ~6000m
- ~10000m
- ~30000m
- the Earth's top

(2) Integrated observation including dynamical, thermal and chemical
Technical progress: High Resolution Regional Weather Forecasting Technology

- **Rapid updated cycling analysis and forecasting system** (SMS-WARR2.0). Assimilate multi-source observational data and add additional meso-scale and micro-scale weather information in the initial fields.

- **Tropical cyclone modeling system**. Assimilate multi-source observational data and optimize the NCEP vortex initialization technique.

- **Urban model and Air quality forecasting system**. Improve Chemical transformation process of pollutants and optimizing gas phase chemistry and aerosol schemes.

- **Ocean modeling system**. Achieve high resolution forecasts in key areas.
Numerical Weather Prediction
----Urban meteorology and chemistry aspect

Met data assimilation (ADAS)

WRF/DUST (24km)

SMB-WARMS(9km)

WRF/CMAQ (9km/3km, off-line)

HYSPLIT/CFD

Trajectory, emergency response

Chemical data assimilation (GSI)

WRF/ CHEM (6km, on-line)

Highly-impacted chemical weather & health (O3, PM, haze, et al.)

Dust
Summary

- **Multi-purpose**: forecasts, research, service
- **Multi-function**: High impact weather, Urban Boundary layer and air quality, special end user needs
- **Multi-scale**: macro/mesoscale, urban, neighbourhood, street canyons, buildings
- **Multi-variable**: thermal, dynamic, chemical, biometeorological, ecological
- **Multi-platform**: radar, wind profiler, ground-based, airborne, satellite based, in situ observation, sampling;
- **Multi-linked**: linkages between all platforms

  with

  - Management to facilitate exchange of data and information
  - Ability to improve coordination of strategies and instruments and identify gaps in observations based on science- and user-driven requirements
  - **Capability to combine observations across platforms with model system to produce the best estimate of the current state of the urban atmosphere**
Thank you for your attention!