Shanghai’s Urban Integrated Meteorological Observation Network (SUIMON): Case studies of application

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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.
Outline

- Characteristics of SUIMON
- Case studies of application
Shanghai has a long history in urban meteorological observation. Early in 1865, temperature, humidity and precipitation measurements began at the Dongjiadu Church using advanced instruments for that time brought from France by missionaries (Fig. left).

In 1872 Shanghai established a multi-function observatory, Xujiahui ("Zikawei" in Shanghai dialect), one of a small group of urban stations with long (>100 years) continuous records (fig. right).
A high dense urban monitoring network covering whole of Shanghai and nearby seashores

<table>
<thead>
<tr>
<th>Instrument</th>
<th>AWS (5–6 km)</th>
<th>Weather radar</th>
<th>Wind profiler</th>
<th>Met-towers</th>
<th>L-band radiosonde</th>
<th>Lightning positioning system</th>
<th>GPS/MET</th>
<th>Satellite receivers</th>
<th>Atmospheric component</th>
<th>Urban FLUX</th>
<th>Mobile observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>256</td>
<td>2</td>
<td>10</td>
<td>13</td>
<td>1</td>
<td>7</td>
<td>31</td>
<td>9</td>
<td>10</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Data collection interval</td>
<td>1 min</td>
<td>6 min</td>
<td>30 min</td>
<td>1 min</td>
<td>6 h</td>
<td>1 s</td>
<td>30 min</td>
<td>30m/1h</td>
<td>1 min</td>
<td>30Hz</td>
<td></td>
</tr>
</tbody>
</table>
In-situ sites (10) for atmospheric chemistry measurements, monitoring air pollution level under different kind of emission impacts.
Characters of SUIMON:

1. **Multi-purpose:** Weather/climate, environment forecast, Met-service, research, etc.
2. **Multi-scale:** macro/meso-scale, urban scale, neighbourhood scale, street, building.
3. **Various parameters:** thermal, dynamic, chemical, biometeological, ecological, ...
4. **Various platforms:** radar, wind profiler, photo, ground-based, aero-borne, satellite based, in-situ observation or sampling, etc.;
5. **Integration of** all platforms and techniques;
6. **Data acquisition management** to facilitate exchange of data and information;
7. **Capability to intelligently combine observations** from a variety of platforms by using a data assimilation system.

Applications

1. Urban Analysis:
   - Urban boundary wind-Based on AWS, Mete-tower, WP
   - Surface Temperature/ air Temperature downscaling
   - Urban heat island, Sea breeze and thermal convection
   - Boundary Height

2. Model Urbanization:
   - Urban Flux and Model localization

3. Urban impact-based forecast and Service:
   - Wind risk assessment
convergence and divergence at the UBL relates with convective weather
A mass-consistent model (MATHEW model) has been used for boundary wind fields based on AWS, Met-tower and Wind Profilers.
Case 2

2013.9.13

vertical section at 121.4E

13:00~14:00 precipitation

divergence at 1500m (10^{-3}s^{-1})
2. Surface Temperature/ air Temperature downscaling

A simple downscaling model based on OHM (Objective Hysteresis Model) and force-restore method is developed to simulate surface temperature and air temperature.
Simulated surface temperature (Aug. 12th, 2013)
Simulated air temperature distribution (Aug. 12th 2013)
Simulated air temperature distribution (cont.) (Aug. 12th 2013)
Urban heat island, Sea breeze and thermal convection

- Interaction between urban heat island and sea breeze circulations
- Determining the precipitation falling region

Temperature at 13:00 Aug. 15th, 2012

Wind field and convergence at 13:00 Aug. 15th, 2012

Precipitation of 14:00-18:00 Aug. 15th, 2012
Comparison of different methods for boundary layer based on Ceilometer, Lidar and radio sounding.

POSTER 22: Peng J, Tan JG, Grimmond CSB. Ceilometer based retrieval of Shanghai’s Boundary Layer height
II. Model Urbanization

UCM can be integrated into WRF through LSM

Noah LSM in NCEP Eta, MM5 and WRF Models
Surface parameters in Shanghai

- Building height ($Z_R$)
- Land cover friction ($f_i$)
- Roughness ($z_0$)
Albedo

- Sunny
- Cloudy
- Mixed

Albedo

- K down
- K up
- L down
- Lip
- Q
Sensible Flux ($Q_H$), Latent Flux ($Q_E$)

POSTER 22: Xiangyu Ao, jianguo TAN, CSB Grimmond, et al. Challenges and results from conducting eddy covariance observations in areas of tall buildings
## UCM parameters localization

<table>
<thead>
<tr>
<th>Urban Parameters</th>
<th>default</th>
<th>Shanghai (local)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C/I</td>
<td>HDR</td>
</tr>
<tr>
<td>building height (ZR/ m)</td>
<td>10</td>
<td>7.5</td>
</tr>
<tr>
<td>STD (ZR) (m)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Roof width (m)</td>
<td>10</td>
<td>9.4</td>
</tr>
<tr>
<td>Road width (m)</td>
<td>10</td>
<td>9.4</td>
</tr>
<tr>
<td>AH (W m⁻²)</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>FRC_URB</td>
<td>0.95</td>
<td>0.9</td>
</tr>
<tr>
<td>ALBR/ALBB/ALBG</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Z0G</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>AHOPTION:</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3 urban types
C/I: Commercial/Industrial
HDR: High Density Residential
LDR: Low Density Residential
Model description

The Surface Urban Energy and Water Balance Scheme (SUEWS) Järvi et al. (2011)

Flow chart of the structure of LUMPS

Meteorological observations

Surface cover and morphometry (GIS)

\[
Q^* = Q_H + Q_E + \Delta Q_S, \quad (1)
\]

\[
\Delta Q_S = \sum_{i=1}^{n} (f_i \alpha_i) Q^* + \sum_{i=1}^{n} (f_i \alpha_{ai}) \left( \frac{\partial Q^*}{\partial t} \right) + \sum_{i=1}^{n} (f_i \alpha_{ai}). \quad (2)
\]

\[
Q_H = \frac{(1 - \alpha) + (\gamma/s)}{1 + (\gamma/s)} (Q^* - \Delta Q_S) - \beta \quad \text{and} \quad (3)
\]

\[
Q_E = \frac{\alpha}{1 + (\gamma/s)} (Q^* - \Delta Q_S) + \beta. \quad (4)
\]

α and β depend on surface properties, vary from city to city

Water balance: \( P + l_e + F = E + R + \Delta S \) [mm.h\(^{-1}\)]
Energy balance: \( Q^* + Q_F = Q_E + Q_H + \Delta Q_S \) [W.m\(^{-2}\)]
\( Q_E = L_v \, E \)

LUMPS (Grimmond and Oke, 2002; Loridan and Grimmond, 2010)
III. Urban impact-based forecast and Service

Wind risk assessment
Roughness

On Xujiahui Site, different methods (i.e., aerodynamic and urban morphological approach) used to estimated the roughness.
application of aerodynamic roughness to derive wind speed under neutral weather conditions is very useful for strong wind forecasts and wind disaster prevention.
Urban canopy winds

Research area

Wind tunnel + CFD

Wind distribution and profile
Bill board

Different type of bill board

Wind tunnel + CFD + force analysis
Vehicle

Different type of vehicle

Force analysis

WD, WS’s impact on driving speed
Different type of train

CFD+force analysis

WD, WS’s impact on the running speed
Wind risk assessment
To meet emerging science-and-user-driven needs and requirements, in coming years, Shanghai Meteorological Service will enhance SUIMON emphasizing on acquisition of information associated with physical processes in urban boundary layer and effect of underlying surface

- Meso-and micro-scale processes over urban surfaces (such as cloud microphysics, precipitation processes)
- Height (and structure) of the PBL and vertical profiles of wind, temperature, water vapor and atmospheric composition
- Field studies to validate satellite observations and modeling simulations of urban precipitation processes and to extend basic understanding of the processes involved
- Enhancing existing observing systems to focus on city-atmosphere interactions, especially to monitor and track land-cover/land-use changes, atmospheric composition, cloud microphysics, and precipitation processes
- Modeling systems that explicitly resolve multi-scale (e.g. urban canopy, street, building) processes, aerosols and cloud microphysics, complex land surfaces, to enable a more complete understanding of the feedbacks and interactions
Thank you for your attention!