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

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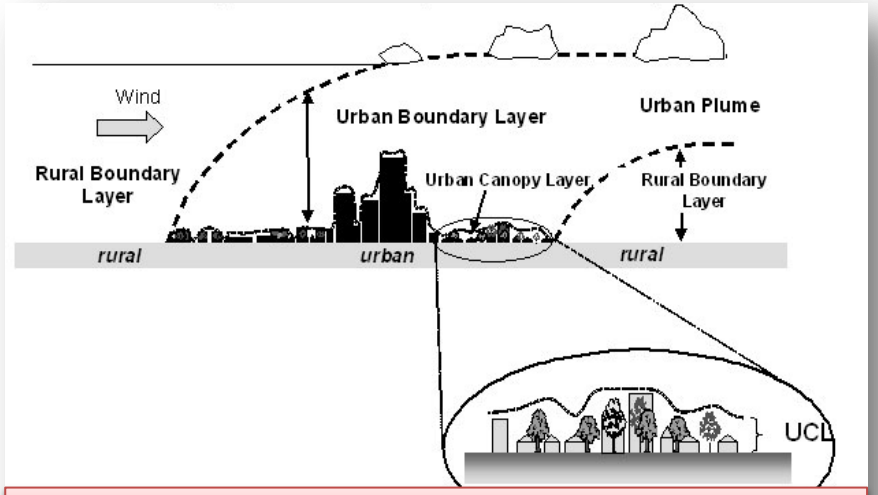
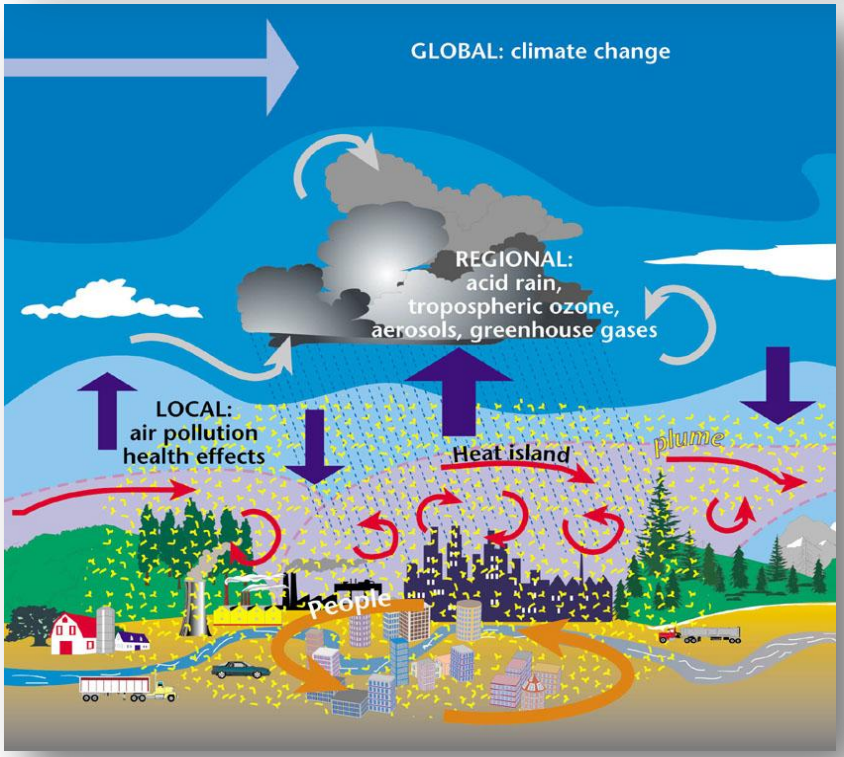
The goal of Urban Met-Observation is to provide the measurements for all the processes that influence urban weather/climate and environments with multi-scales in terms of time and space.



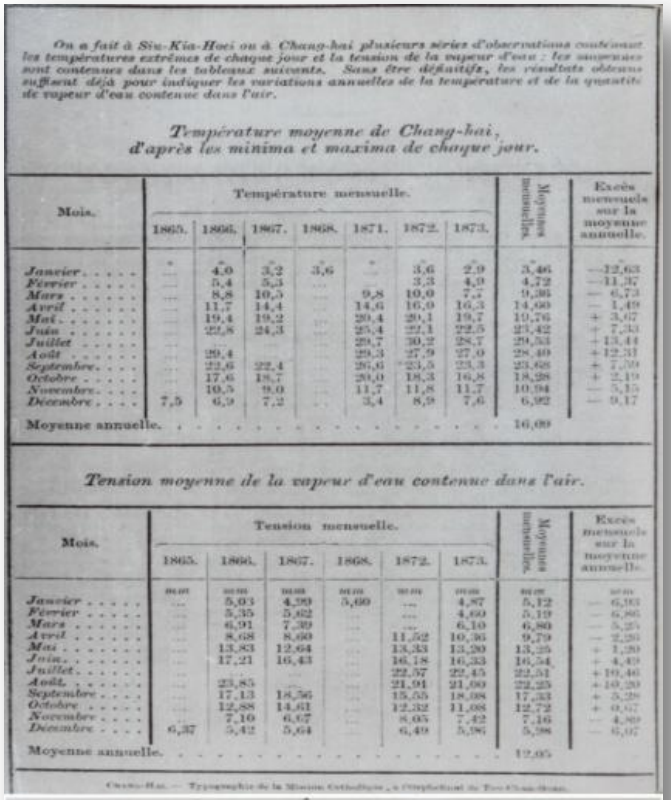
Component of Urban Atmosphere

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



On a fait à Siu-Kia-Hoei ou à Chang-hai plusieurs séries d'observations contenant les températures extrêmes de chaque jour et la tension de la vapeur d'eau ; les moyennes sont contenues dans les tableaux suivants. Sans être définitifs, les résultats obtenus suffisent déjà pour indiquer les variations annuelles de la température et de la quantité de vapeur d'eau contenue dans l'air.

Température moyenne de Chang-hai, d'après les minima et maxima de chaque jour.

Mois.	Température mensuelle. 1865.	1866.	1867.	1868.	1871.	1872.	1873.	Moyennes mensuelles.	Excès mensuels sur la moyenne annuelle.
	°	°	°	°	°	°	°	°	°
Janvier	...	4,0	3,2	3,6	...	3,6	2,9	3,46	—12,63
Février	...	5,4	5,5	...	...	3,3	4,9	4,72	—11,37
Mars	...	8,8	10,5	...	9,8	10,0	7,7	9,36	— 6,73
Avril	...	11,7	14,4	...	14,6	16,0	16,3	14,60	— 1,49
Mai	...	19,4	19,2	...	20,4	20,1	19,7	19,76	+ 3,67
Juin	...	22,8	24,3	...	25,4	22,1	22,5	23,42	+ 7,33
Juillet	...	...	...	...	29,7	30,2	28,7	29,53	+13,44
Août	...	29,4	...	...	29,3	27,9	27,0	28,40	+12,31
Septembre	...	22,6	22,4	...	26,6	23,5	23,3	23,68	+ 7,59
Octobre	...	17,6	18,7	...	20,0	18,3	16,8	18,28	+ 2,19
Novembre	...	10,5	9,0	...	11,7	11,8	11,7	10,94	— 5,15
Décembre	7,5	6,9	7,2	...	3,4	8,9	7,6	6,92	— 9,17
Moyenne annuelle.								16,09	

Tension moyenne de la vapeur d'eau contenue dans l'air.

Mois.	Tension mensuelle. 1865.	1866.	1867.	1868.	1872.	1873.	Moyennes mensuelles.	Excès mensuels sur la moyenne annuelle.
	mm	mm	mm	mm	mm	mm	mm	mm
Janvier	...	5,03	4,99	5,60	...	4,87	5,12	— 6,93
Février	...	5,35	5,62	...	...	4,60	5,19	— 6,86
Mars	...	6,91	7,39	...	...	6,10	6,80	— 5,25
Avril	...	8,68	8,60	...	11,52	10,36	9,79	— 2,26
Mai	...	13,83	12,64	...	13,33	13,20	13,25	+ 1,20
Juin	...	17,21	16,43	...	16,18	16,53	16,54	+ 4,49
Juillet	...	...	...	...	22,57	22,45	22,51	+10,46
Août	...	23,85	...	...	21,91	21,60	22,25	+10,20
Septembre	...	17,13	18,56	...	15,55	18,08	17,33	+ 5,28
Octobre	...	12,88	14,61	...	12,32	11,08	12,72	+ 0,67
Novembre	...	7,10	6,57	...	8,05	7,42	7,16	— 4,89
Décembre	6,37	5,42	5,64	...	6,49	5,96	5,98	— 6,07
Moyenne annuelle.							12,05	

Chang-Hai. — Typographie de la Mission Catholique, à l'Orphelinat de Tou-Se-Wei.

1865年董家渡天主教的气温、湿度观测记录

1872年，法国传教士在徐家汇小教堂附近开展气象观测

- 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

Wind profiler

Lightning positioning System

1 GPS-met network consisting of 14 reference stations

AWS (5 – 6 km)	256	1 min
Weather radar	2	6 min
Wind profiler	10	30 min
Met-towers	13	1 min
L-band radiosonde	1	6 h
Lightning positioning system	7	1 s
GPS/MET	31	30 min
Satellite receivers	9	30m/1h
Atmospheric component	10	1 min
Urban FLUX	1	30Hz
Mobile observation	5	

weather radar (WSR-88D)

Urban environment and micro-met observation

In-situ sites (10) for atmospheric chemistry measurements, monitoring air pollution level under different kind of emission impacts.

Characters of S U I M O N:

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.

Tan JG, Yang LM, Grimmond CSB, et al. Urban Integrated Meteorological Observations: Practice and Experience in Shanghai, China , BAMS, 2015,96(1):85-102

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:

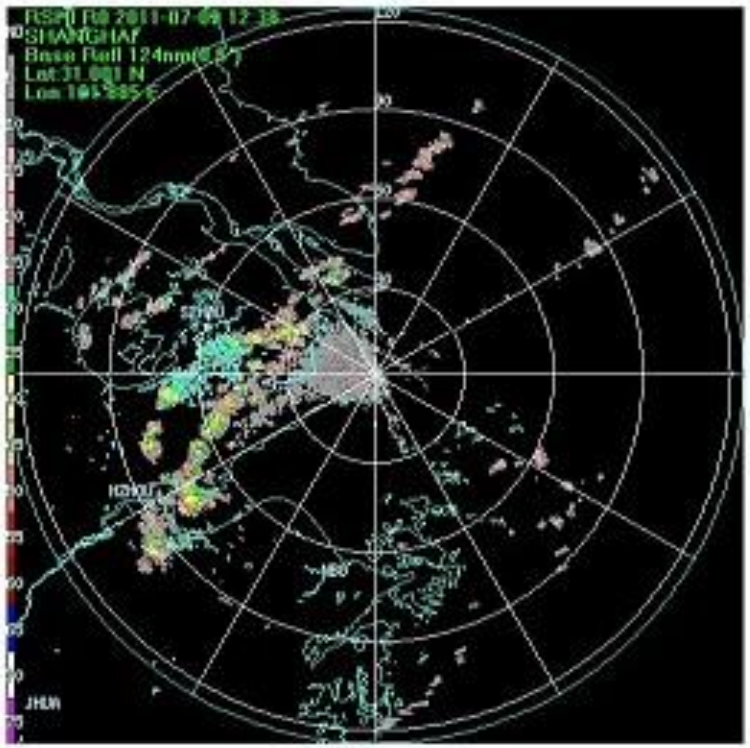
- *Urban Flux and Model localization*

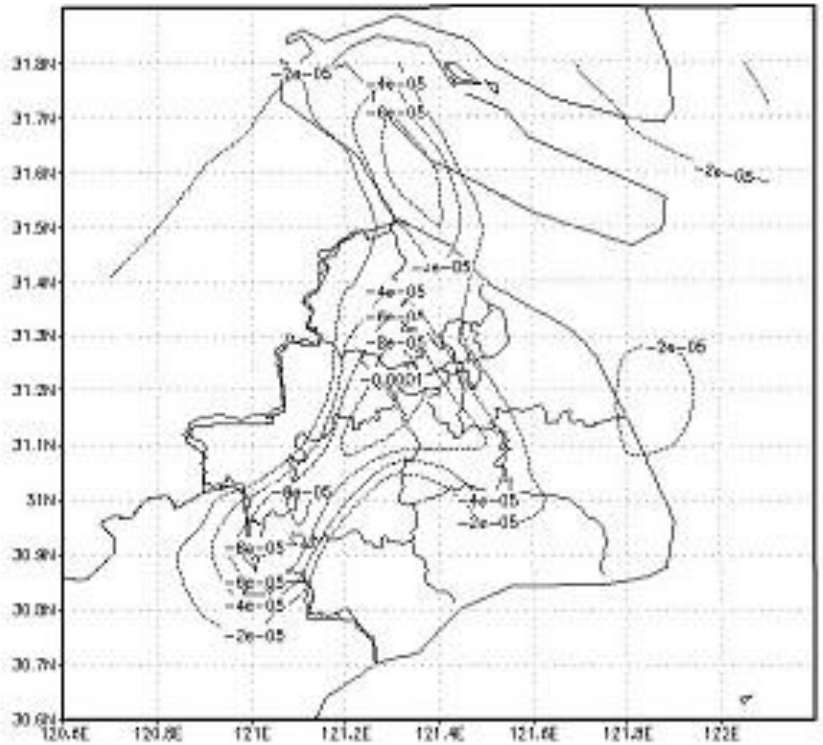
3. Urban impact-based forecast and Service:

- *Wind risk assessment*

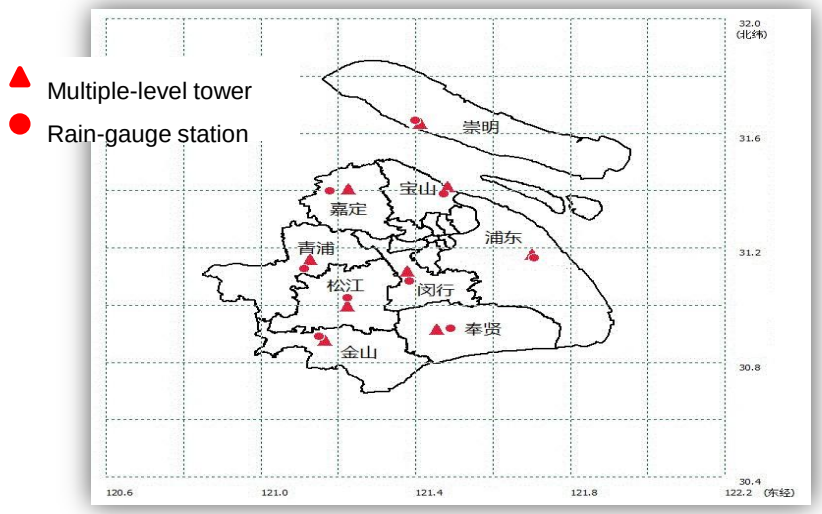
Urban Boundary Wind field

convergence and divergence at the UBL relates with convective weather

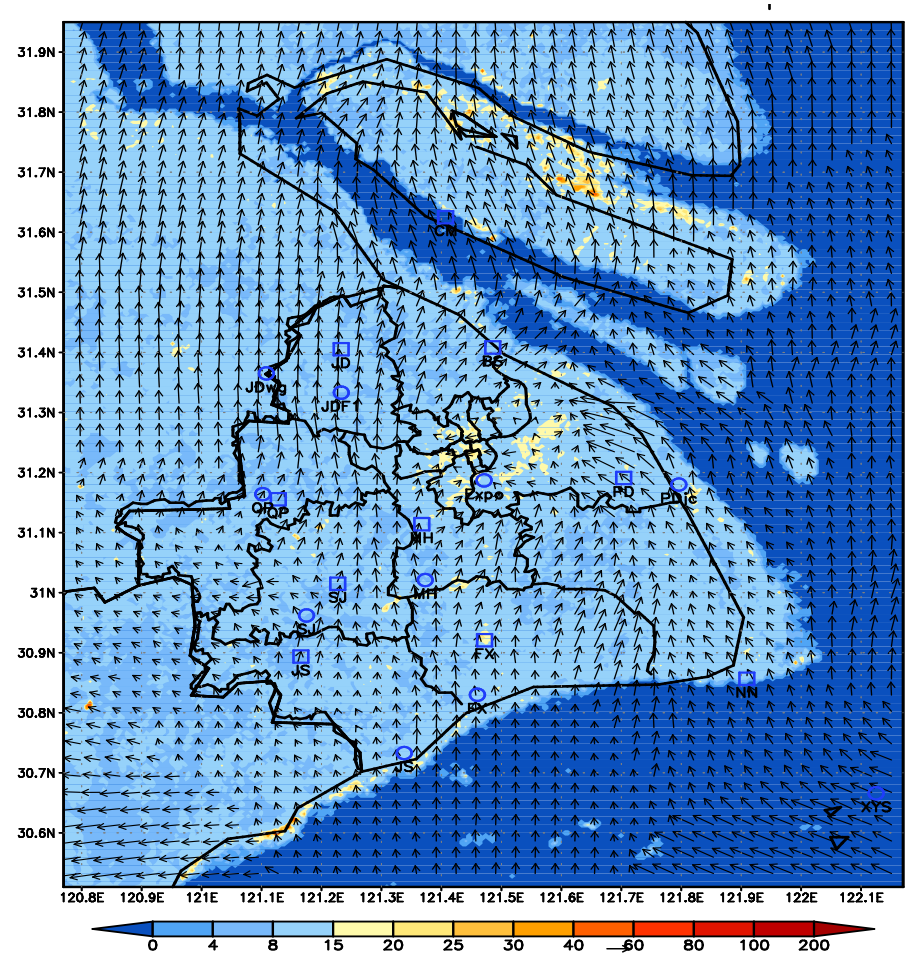




A mass-consistent model for boundary wind fields

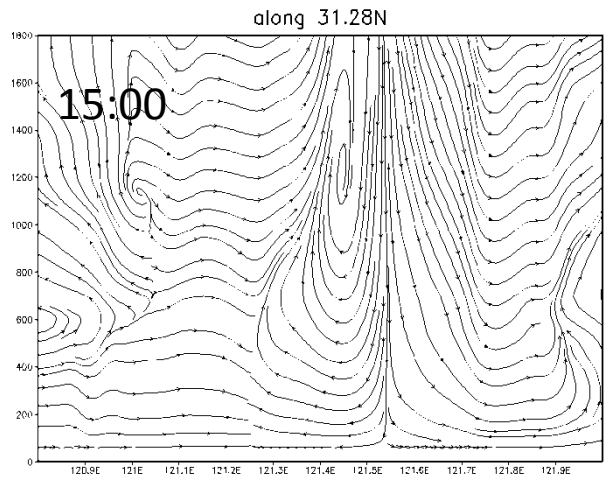


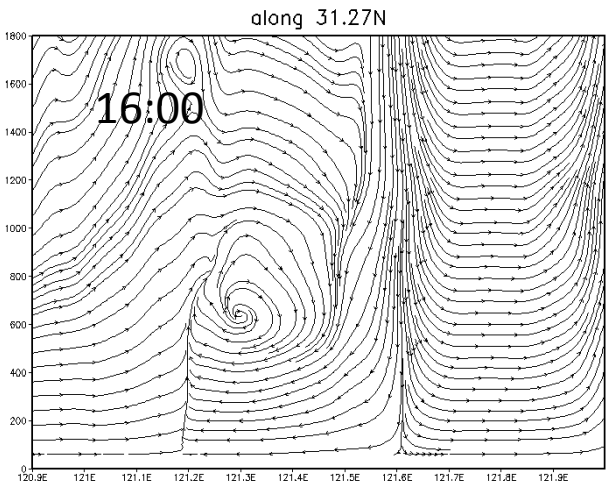
A mass-consistent model(MATHEW model) has been used for boundary wind fields based on AWS, Met-tower and Wind Profilers

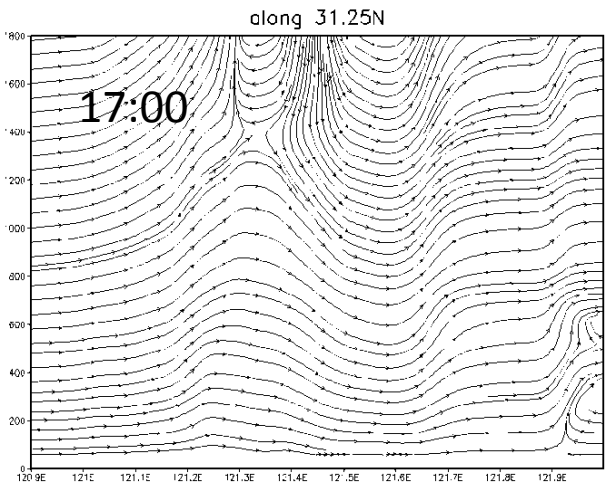


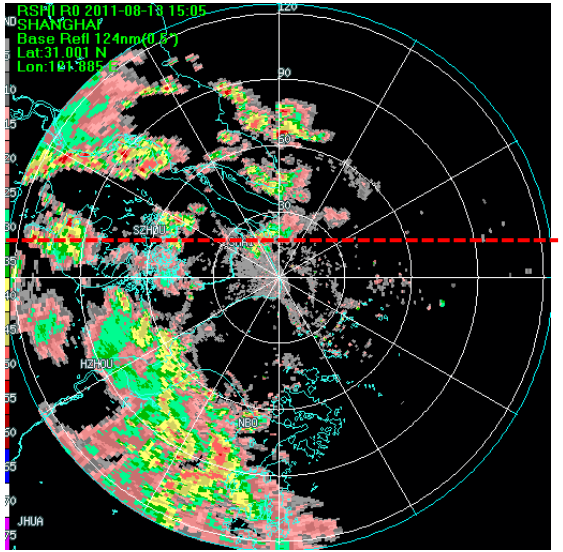
Case 1

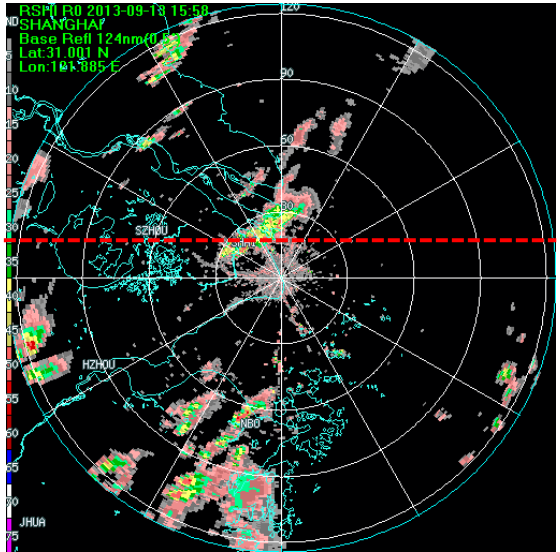
2011.8.13

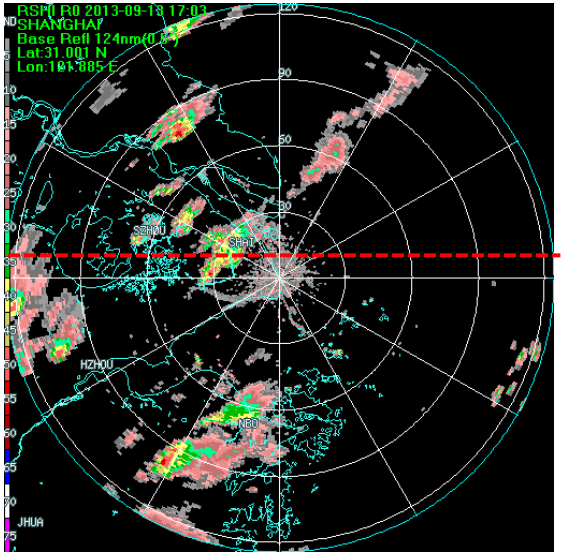






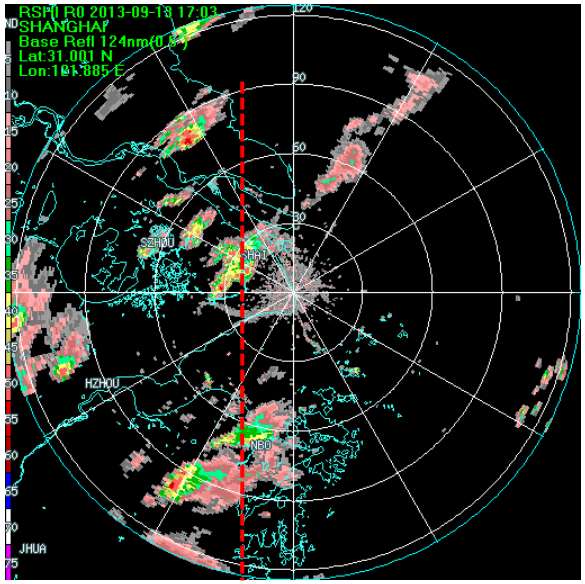




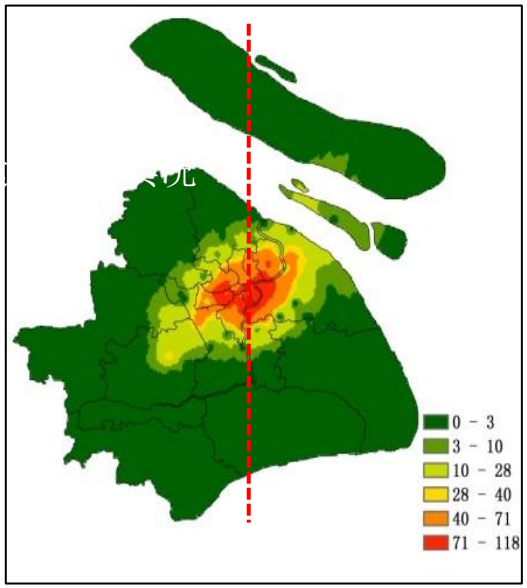


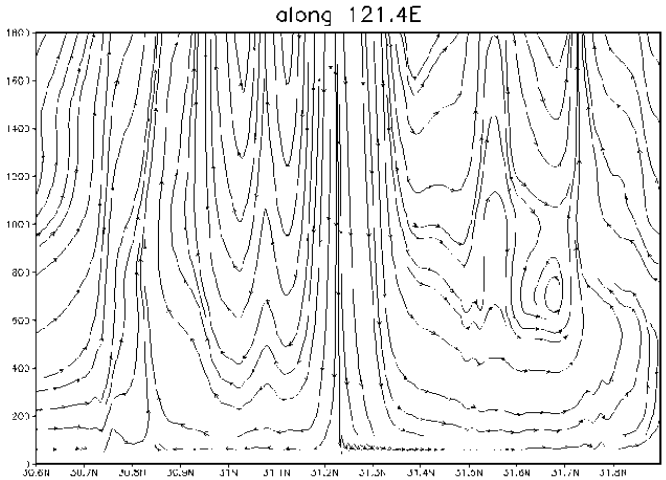
Case 2

2013.9.13

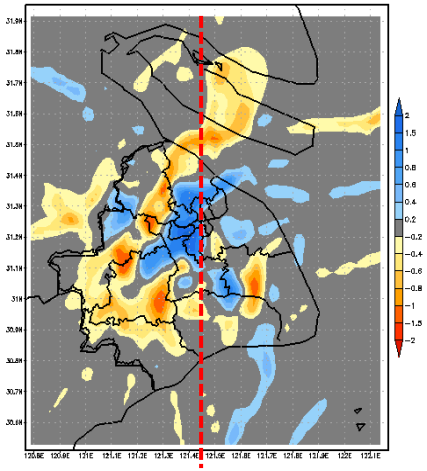


13:00~14:00 precipitation





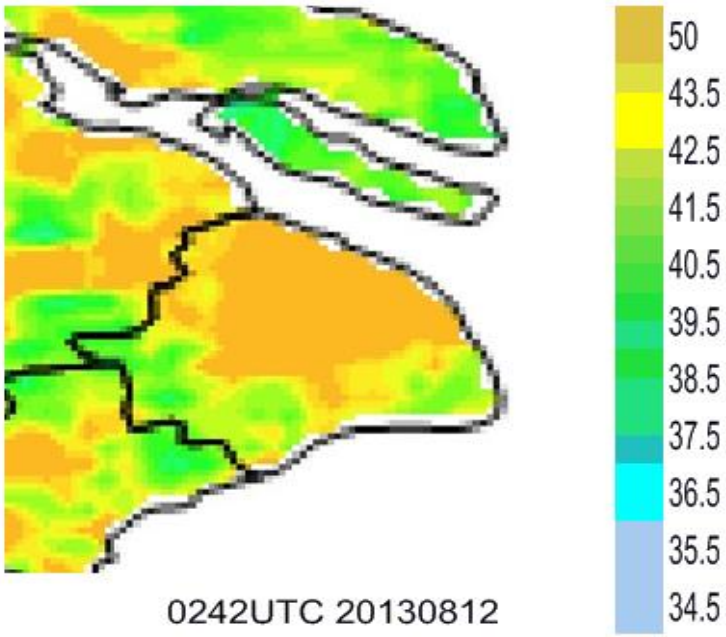
vertical section at **121.4E**

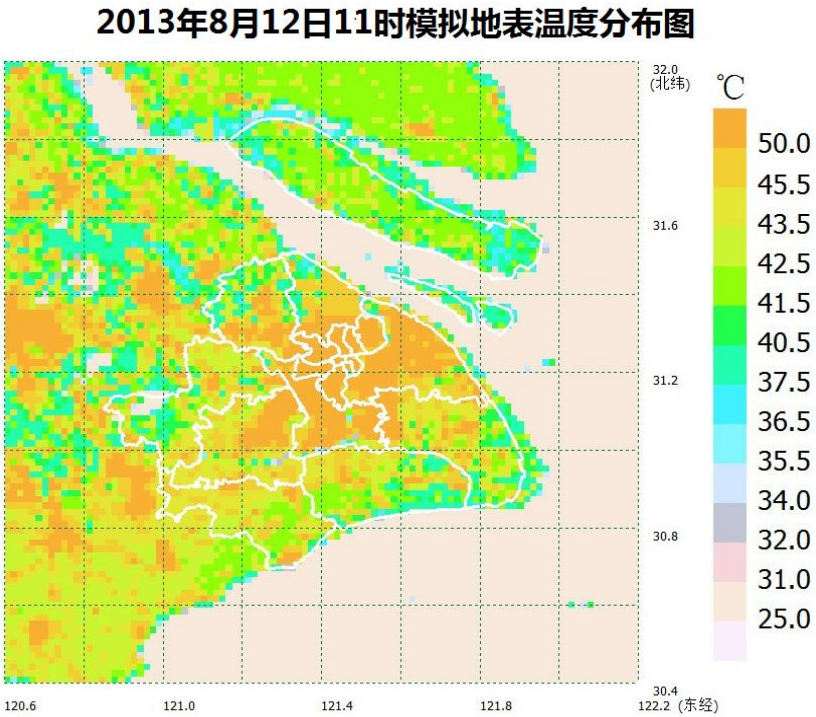


divergence at 1500m ($10^{-3}s$

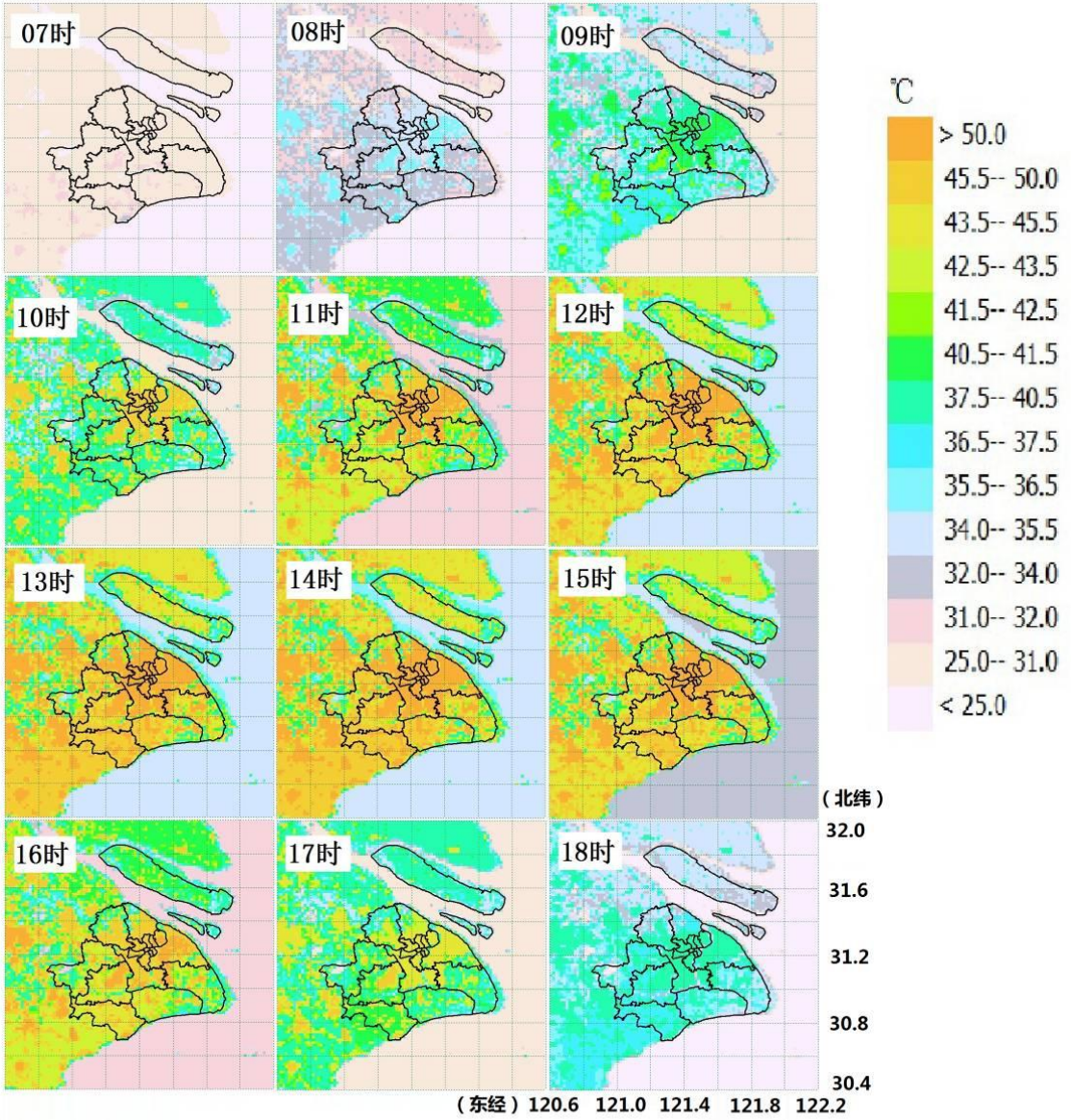
2、*Surface Temperature/ air Temperature downscaling*

A simple downscaling model based on OHM (Objective Hysteresis Model) and force-restore method is developed to simulate surface temperature and air temperature.



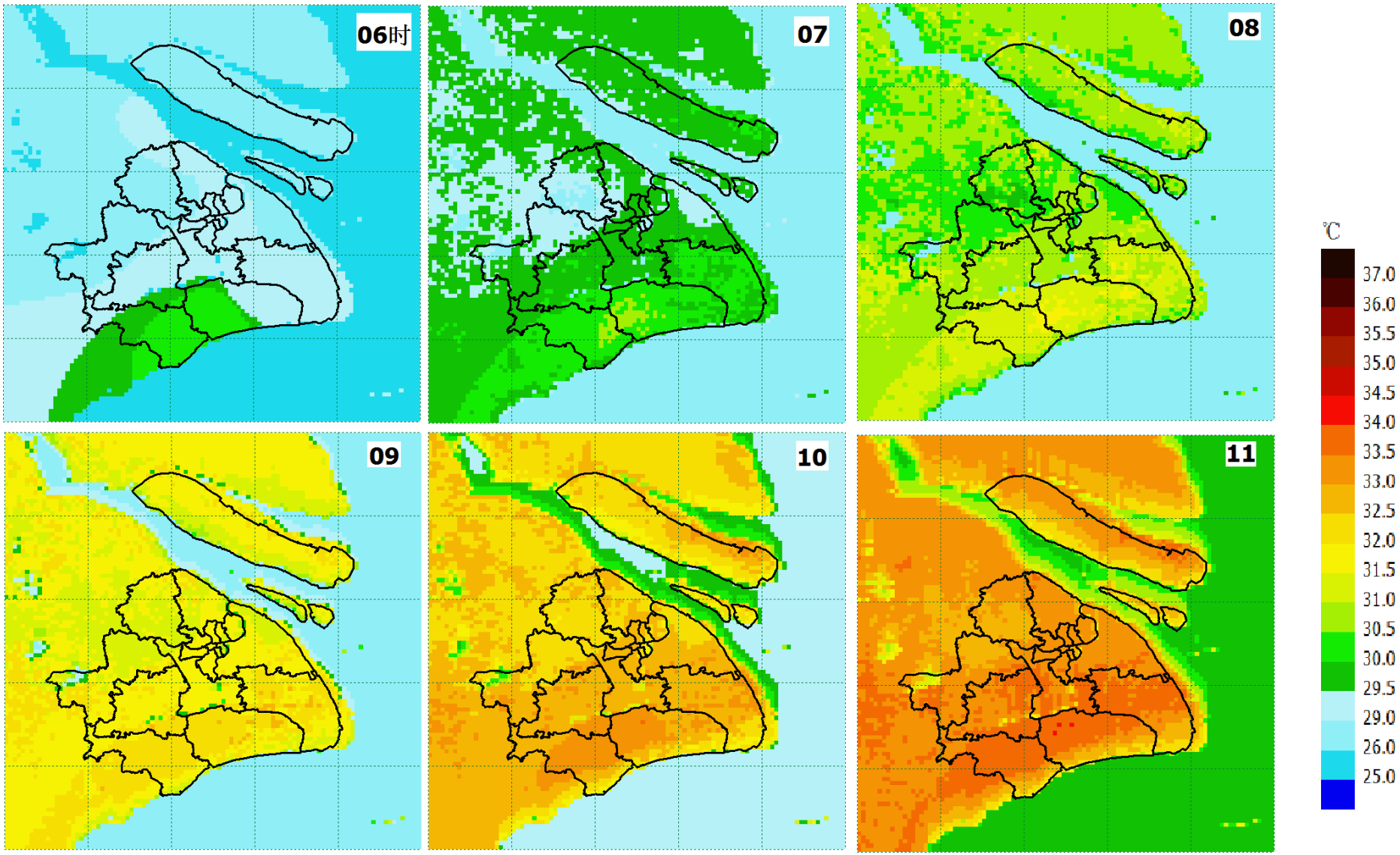


MODIS, Land surface temperature

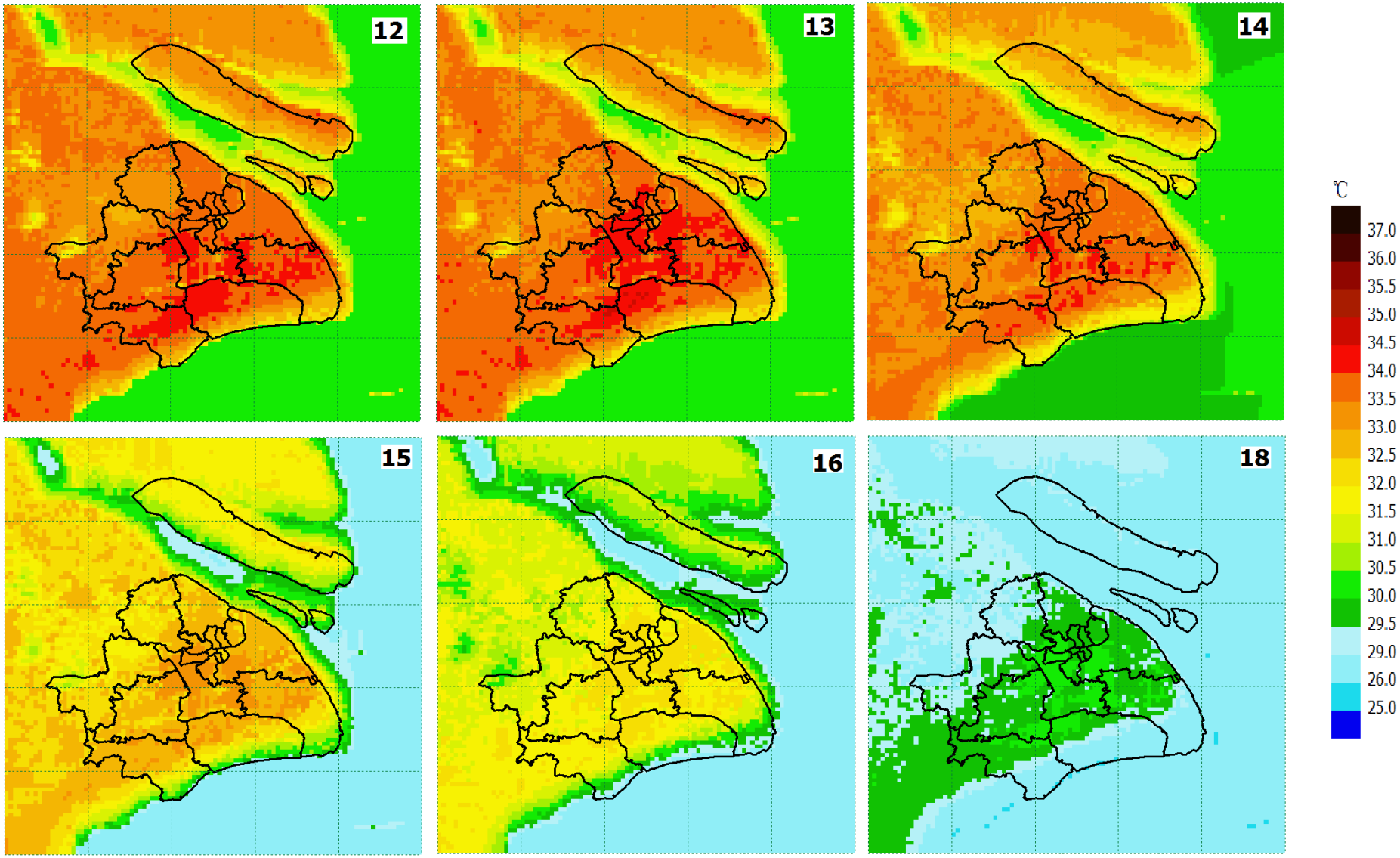


Simulated surface temperature(Aug. 12th,2013)

Simulated air temperature distribution (Aug.12th 2013)

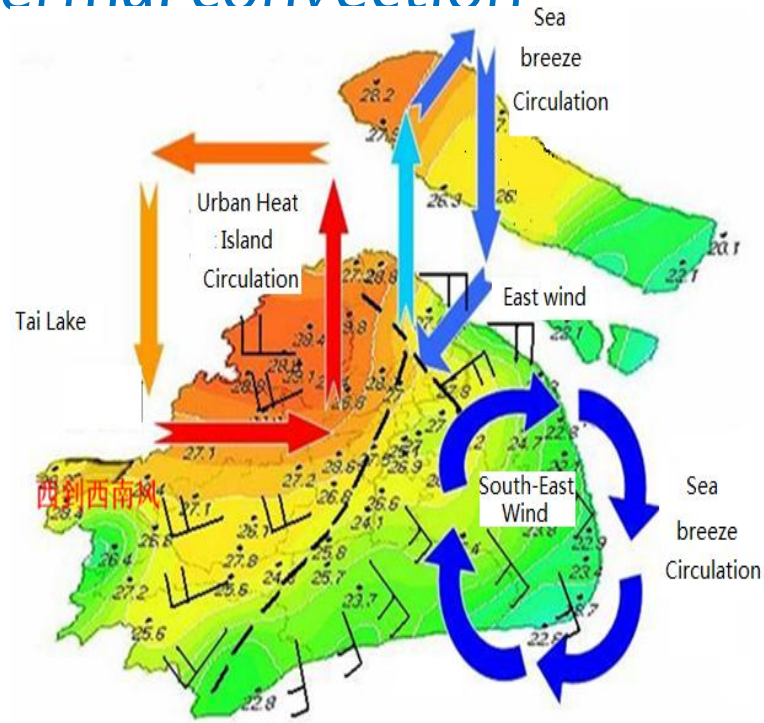


Simulated air temperature distribution (cont.) (Aug.12th 2013)

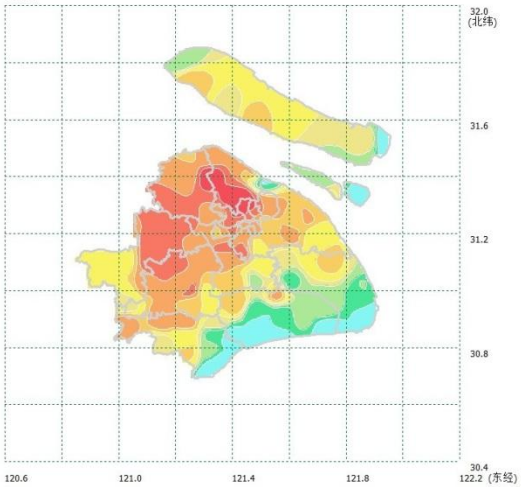


Urban heat island, Sea breeze and thermal convection

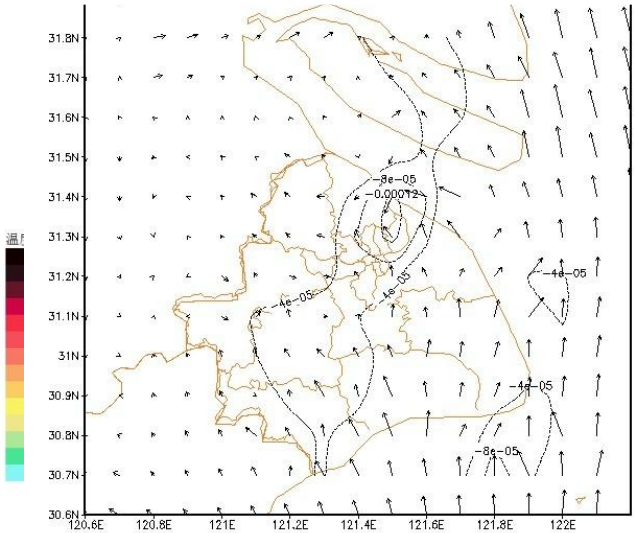
- Interaction between urban heat island and sea breeze circulations
- Determining the precipitation falling region



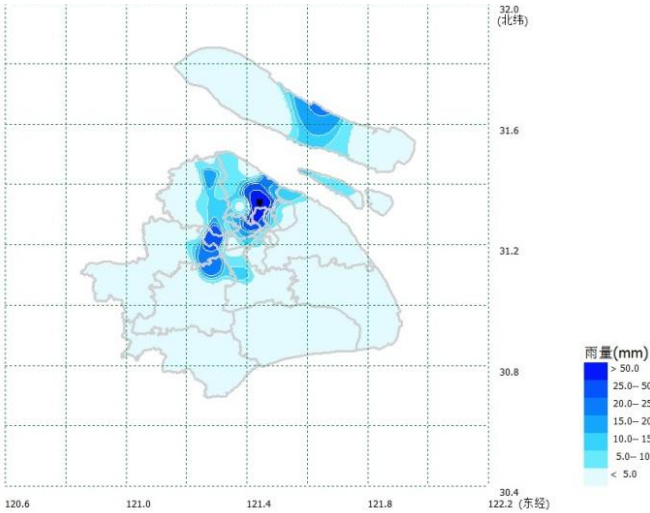
Temperature at 13:00 Aug. 15th, 2012



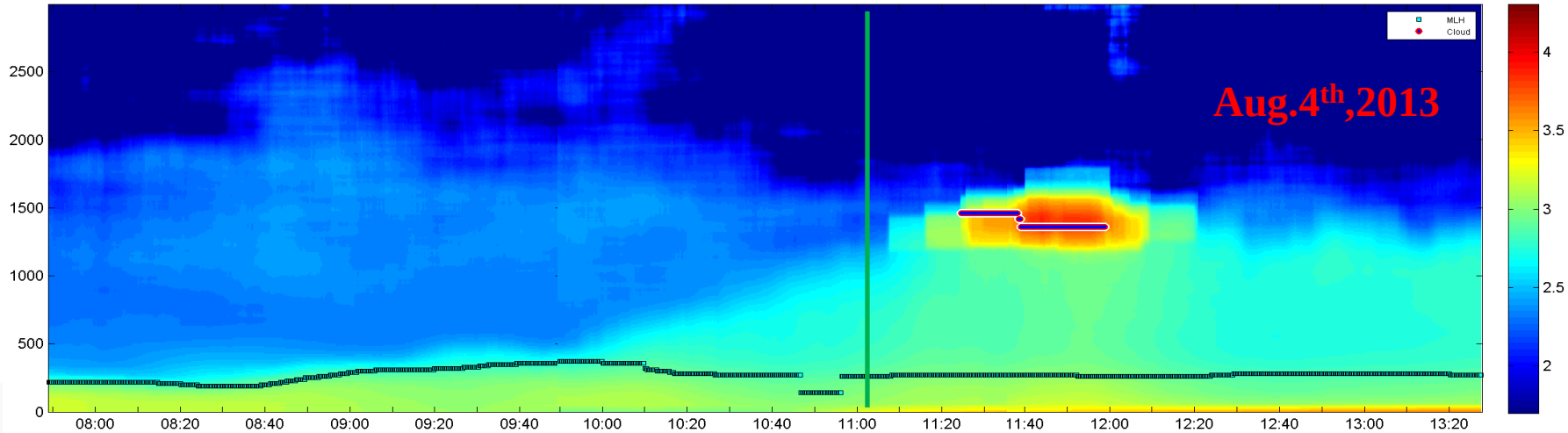
Wind field and convergence at 13:00 Aug. 15th ,2012

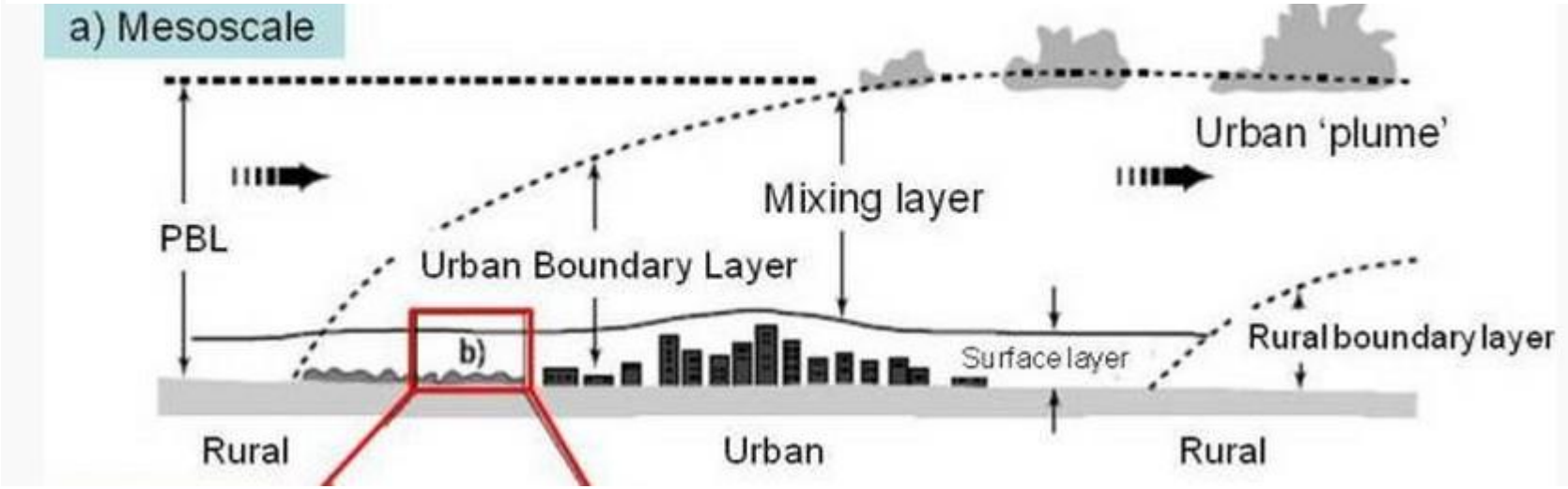


precipitation of 14:00-18:00 Aug. 15th ,2012



Boundary Height





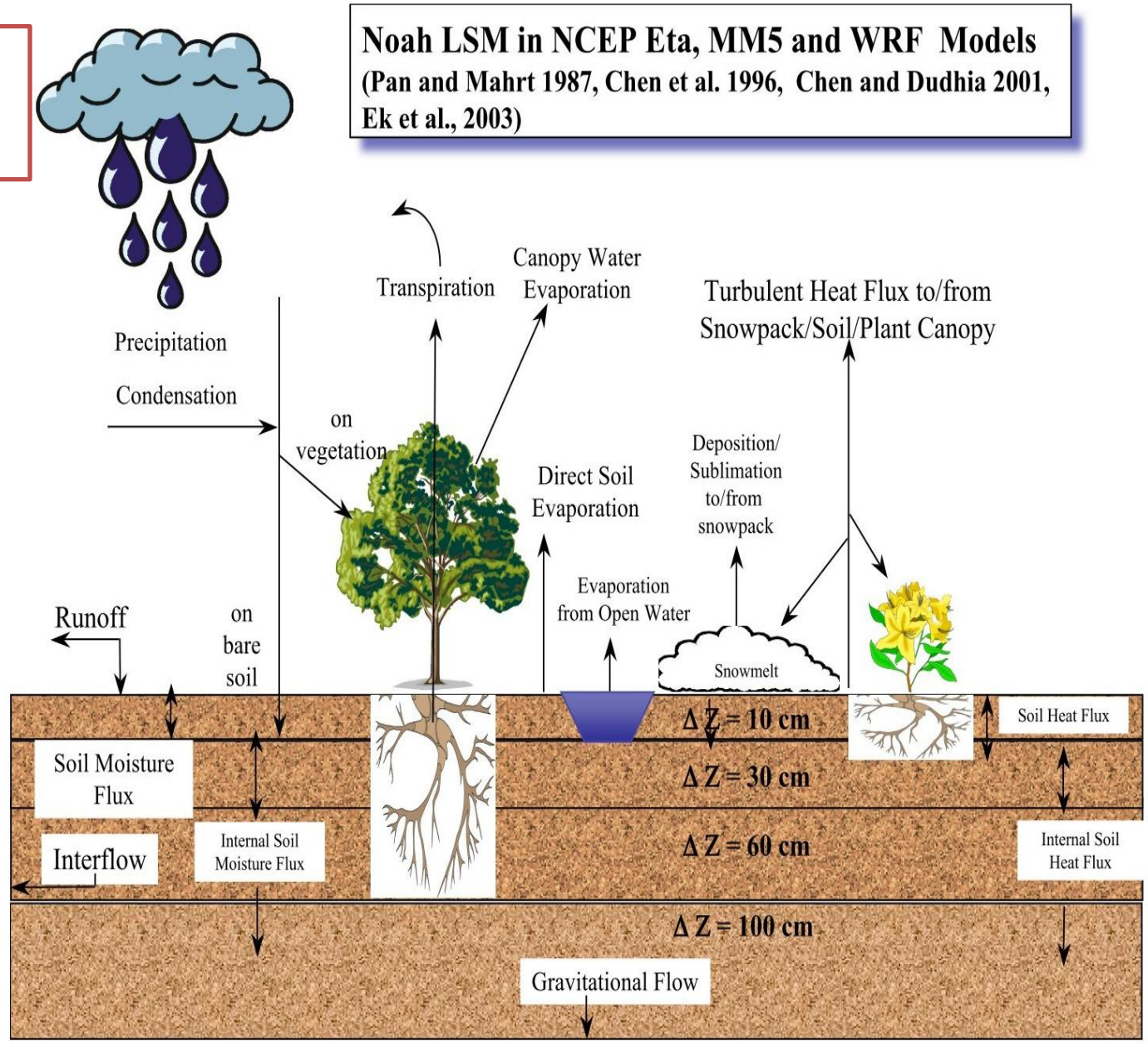
Comparison of different methods for boundary layer based on Ceilometer、Lidar and radio sounding.

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

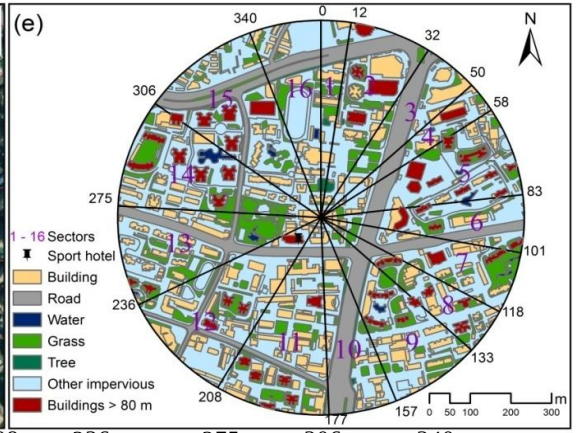
II. Model Urbanization

WRF/Noah/UCM

UCM can be integrated into WRF through LSM



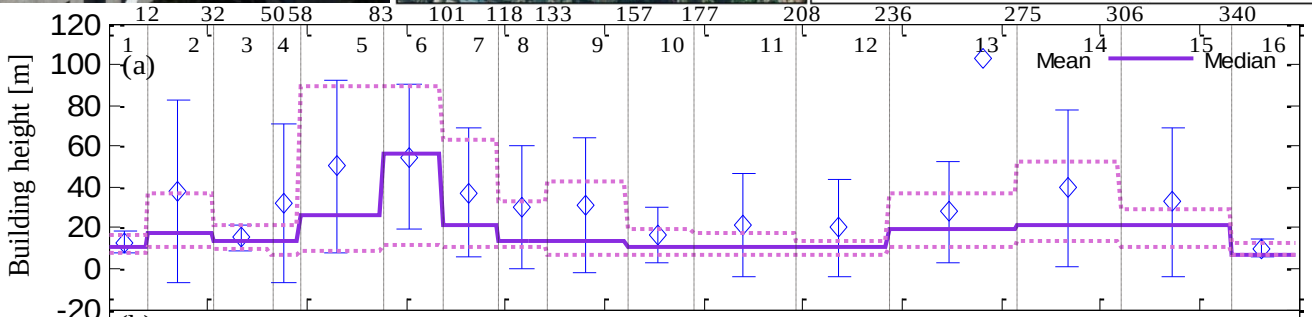
Surface parameters in Shanghai

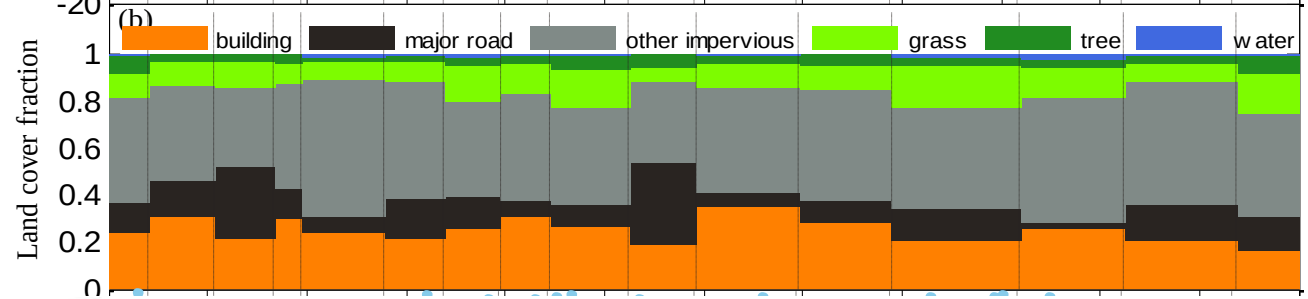


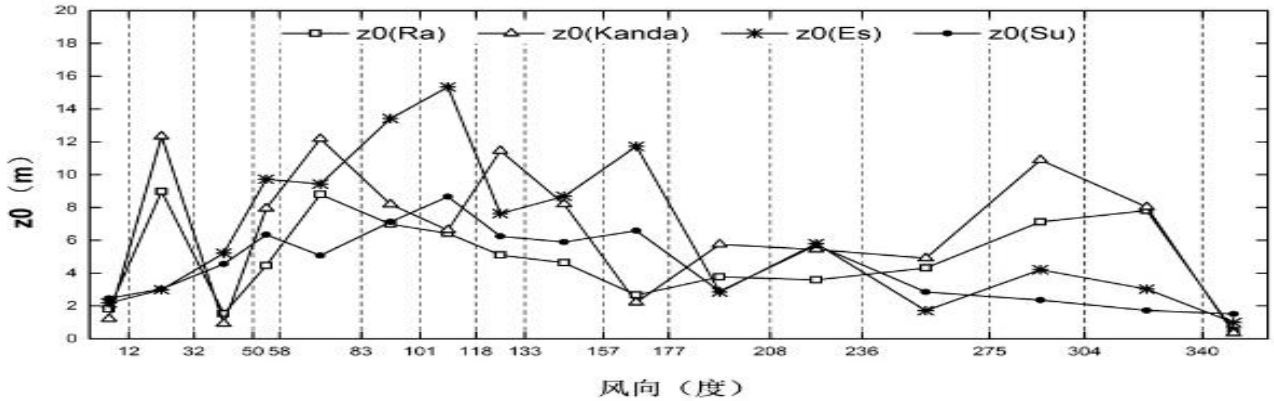
Building height(Z_R)

Land cover friction (fi);

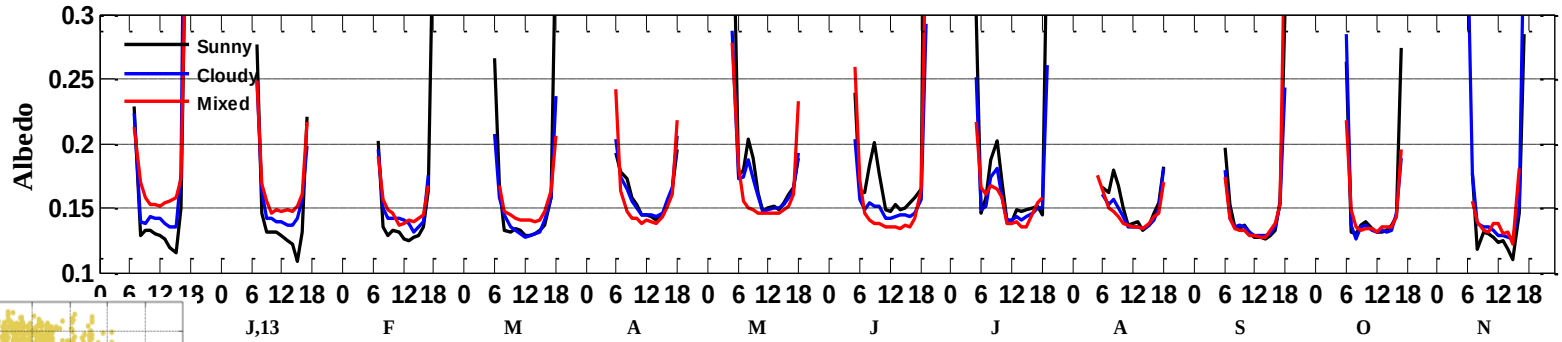
Roughness (z_0)

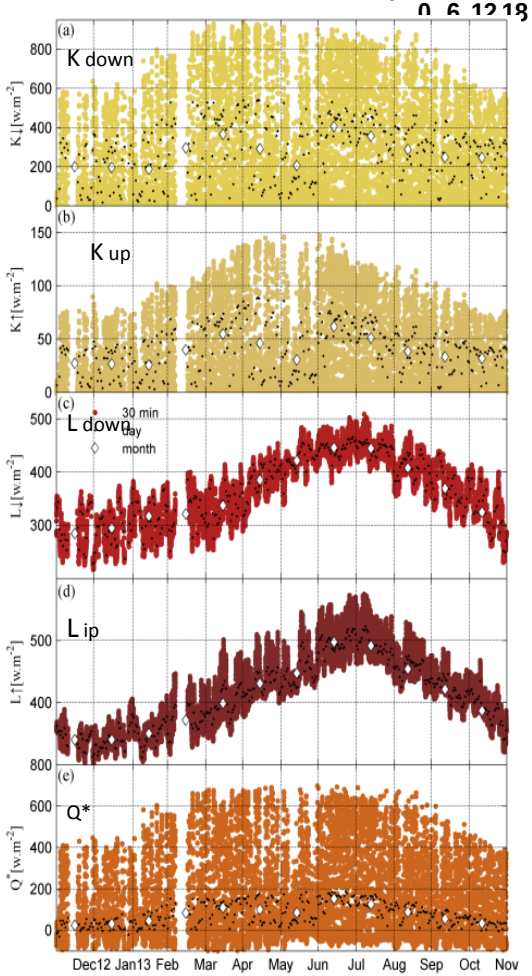


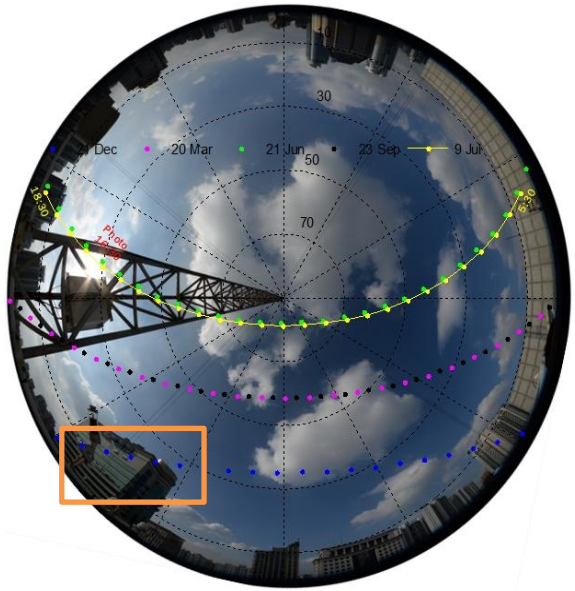


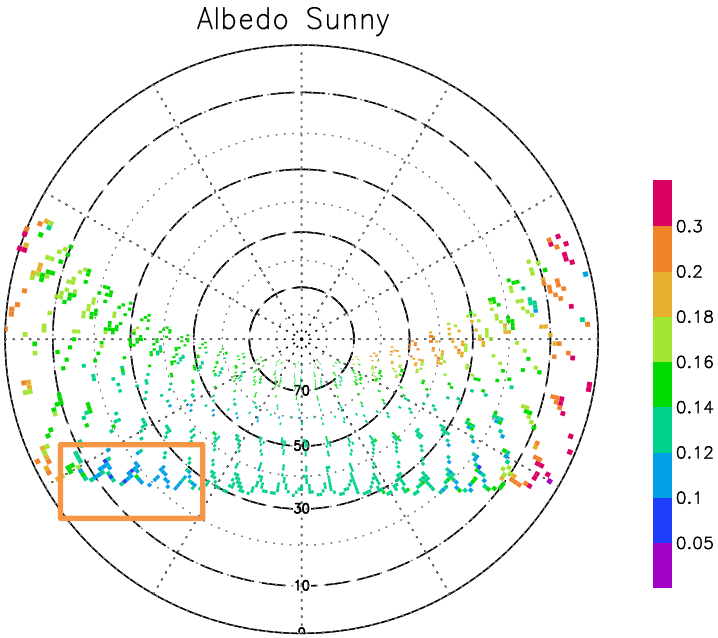


Albedo

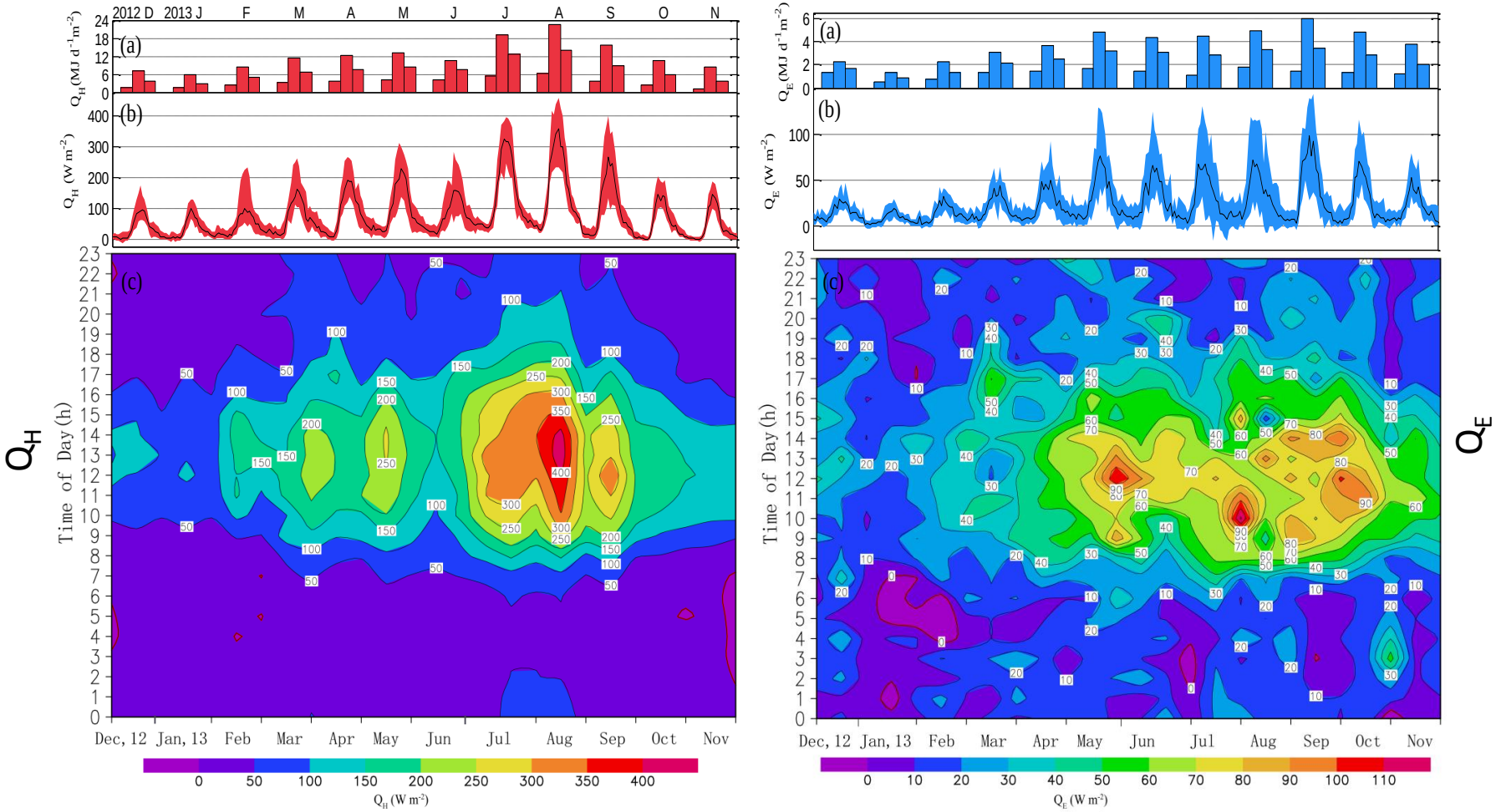

Albedo
Sunny
Cloudy
Mixed
0.3
0.25
0.2
0.15
0.1
J,13
F
M
A
M
J
J
A
S
O
N


(a)
K down
(b)
K up
(c)
L down
30 min
day
month
(d)
L up
(e)
Q*
Dec12 Jan13 Feb Mar Apr May Jun Jul Aug Sep Oct Nov


20 Mar
21 Jun
23 Sep
9 Jul
30
50
70


Albedo Sunny
70
50
30
10
0.3
0.2
0.18
0.16
0.14
0.12
0.1
0.05

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

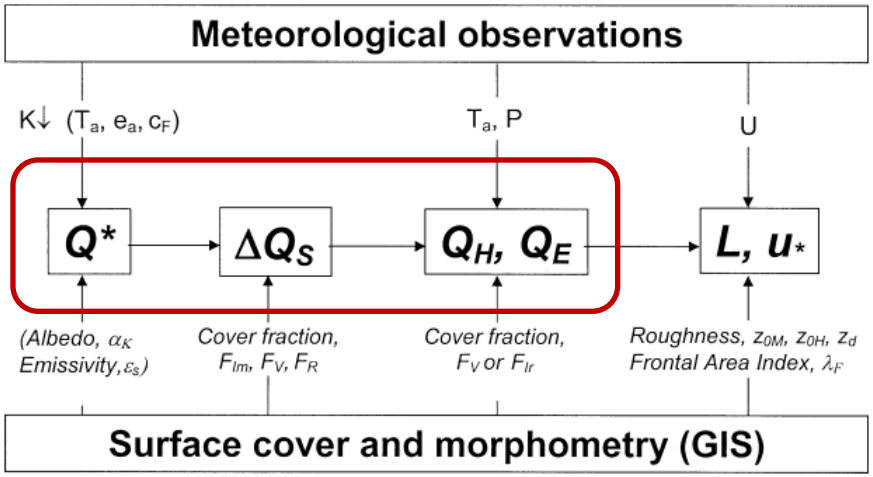
UCM parameters localization

Urban Parameters	default			Shanghai (local)		
	C/I	HDR	LDR	C/I	HDR	LDR
building height (ZR/ m)	10	7.5	5	/	35.9	/
STD (ZR) (m)	4	3	1	/	10	/
Roof width (m)	10	9.4	8.3	/	30	/
Road width (m)	10	9.4	8.3	/	20	/
AH (W m^{-2})	90	50	20	/	120	/
FRC_URB	0.95	0.9	0.5	/	0.95	/
ALBR/ALBB/ALBG	0.2	0.2	0.2	/	0.15	/
Z0G	0.01	0.01	0.01	/	6	/
AHOPTION:	0	0	0	/	1	/

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

Model description

Flow chart of the structure of LUMPS



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

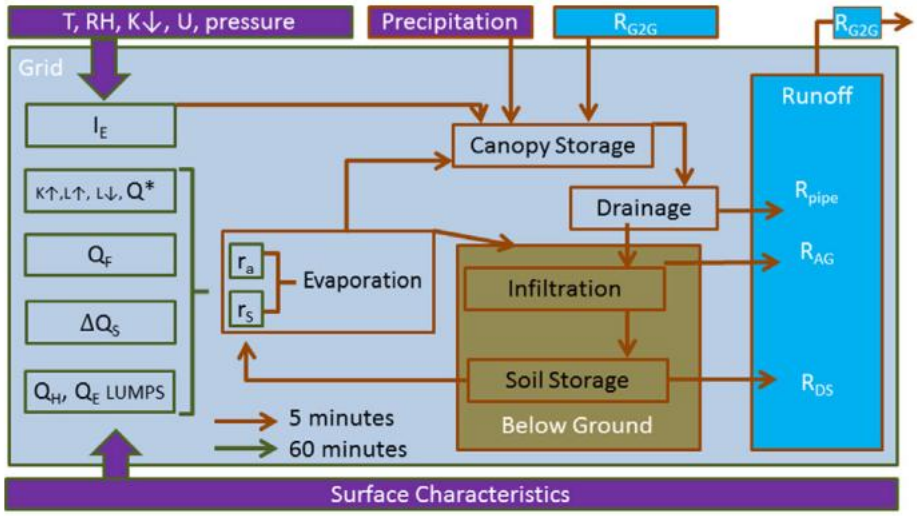
$$\Delta Q_S = \sum_{i=1}^{n} (f_i a_{1i}) Q^* + \sum_{i=1}^{n} (f_i a_{2i}) \left(\frac{\partial Q^*}{\partial t} \right) + \sum_{i=1}^{n} (f_i a_{3i}). \quad (2)$$

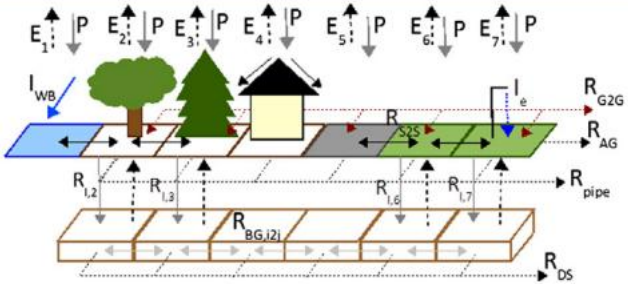
$$Q_H = \frac{(1-\alpha) + (\gamma/s)}{1 + (\gamma/s)} (Q^* - \Delta Q_S) - \beta \quad \text{and} \quad (3)$$

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

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

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

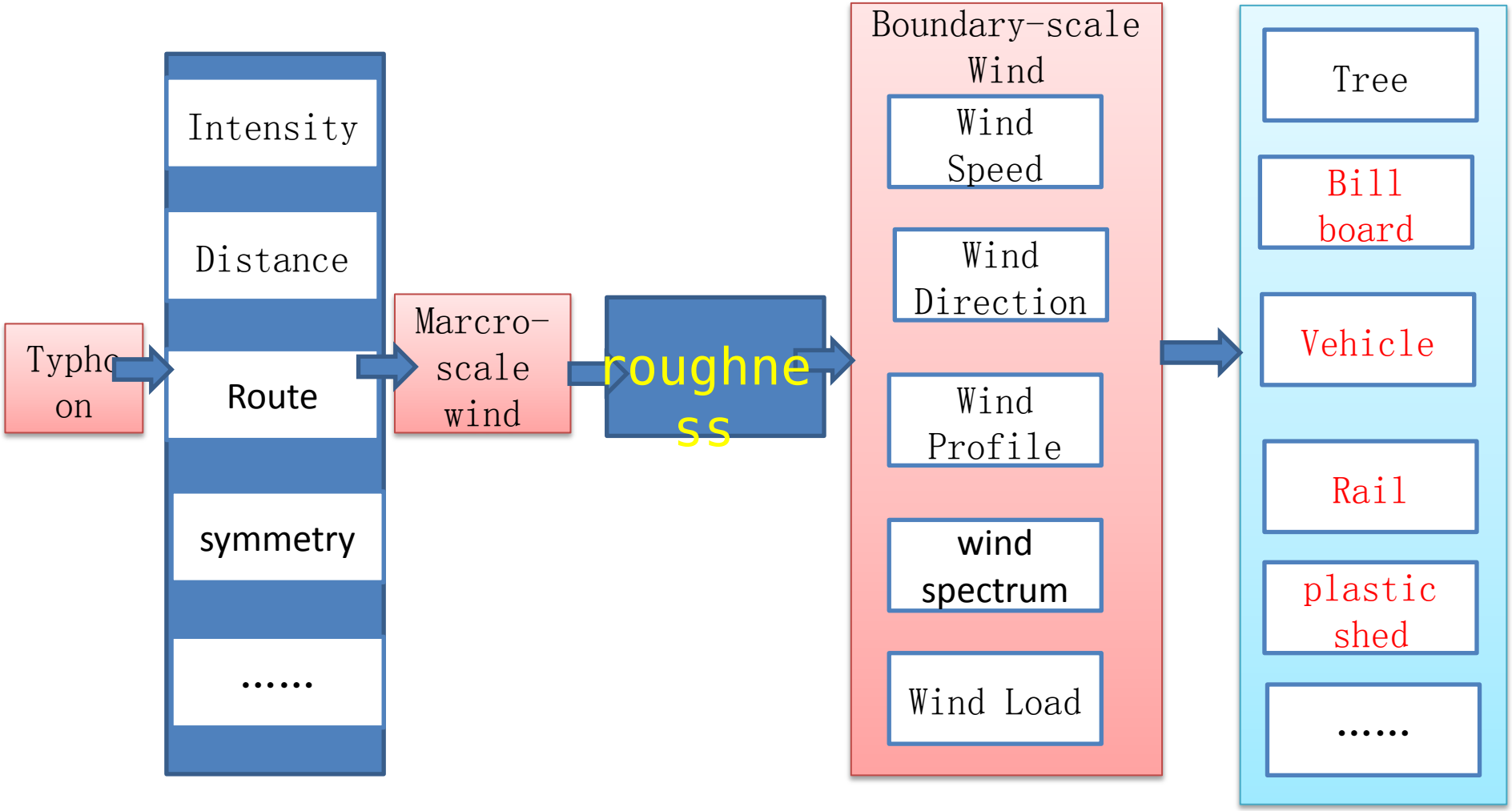




Water balance: P+Ie+F=E+R+ΔS [mm.h^{-1}]
Energy balance: $Q^*+Q_F=Q_E+Q_H+\Delta Q_S$ [W.m^{-2}]
QE=Lv E

LUMPS (Grimmond and Oke, 2002; Loridan and Grimmond, 2010)

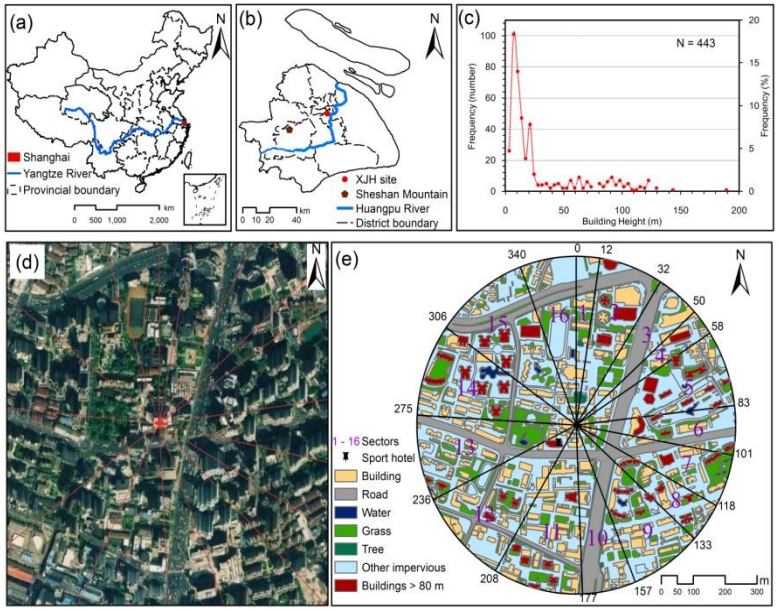
III. Urban impact-based forecast and Service

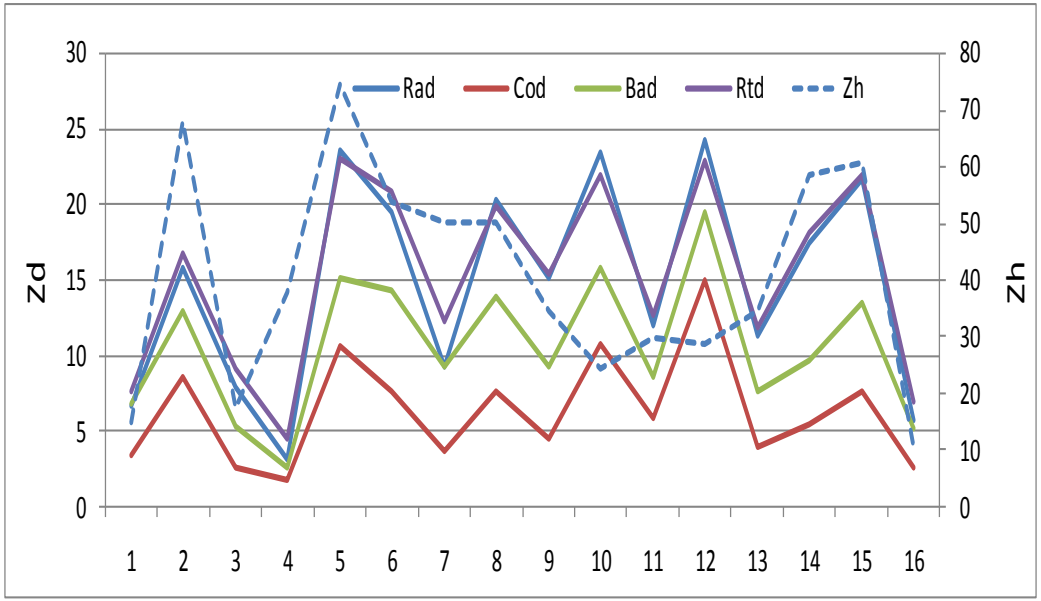


Wind risk assessment

Roughness

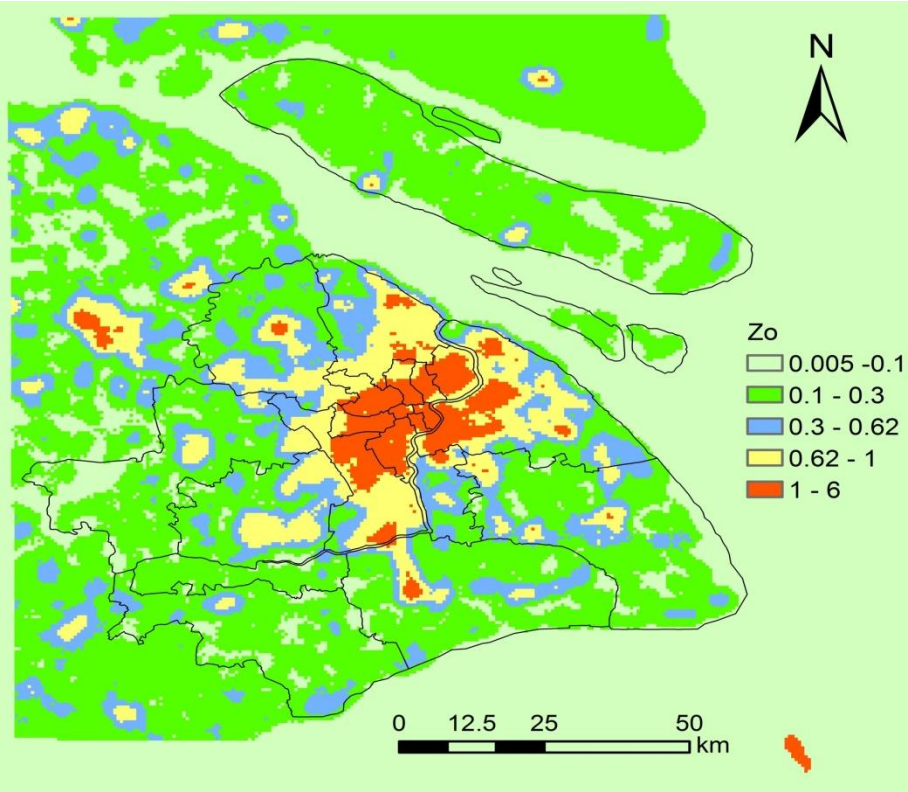
On Xujiahui Site, different methods(i.e. aerodynamic and urban morphological approach) used to estimated the roughness

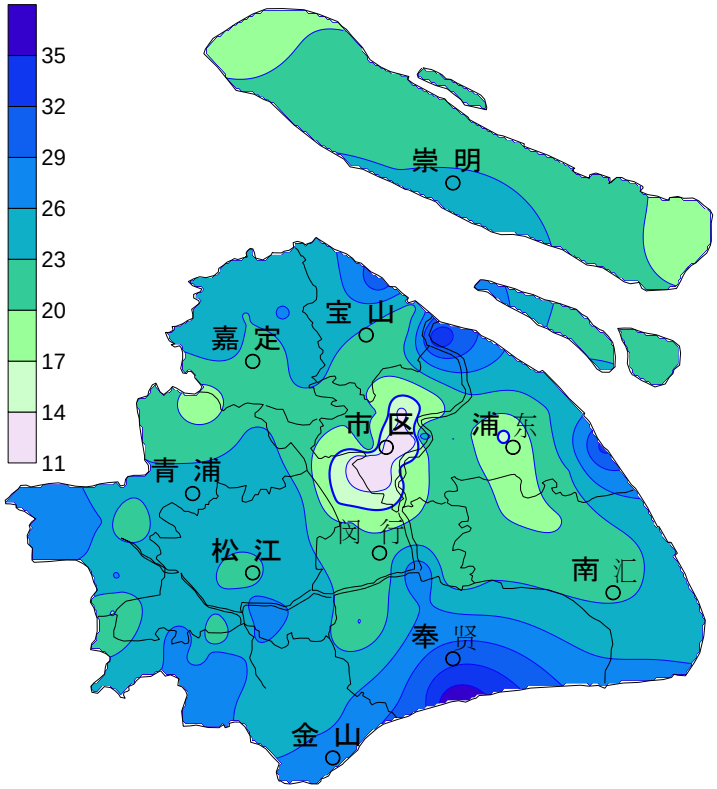




POSTER 22: Tang QY, Tan JG, Grimmond CSB, et al. Comparison on Different Methods to estimate Aerodynamic Parameters in Urban Areas.

Roughness and wind distribution

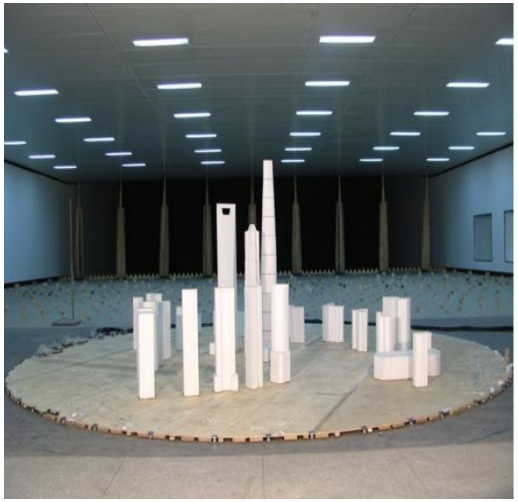


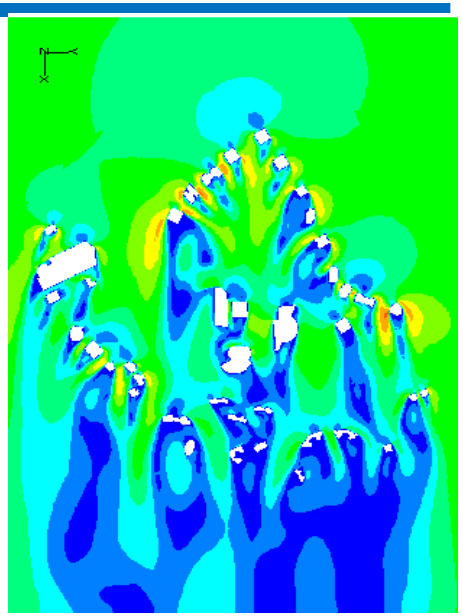


- application of aerodynamic roughness to derive wind speed under neutral weather conditions is very useful for strong wind forecasts and wind disaster prevention.

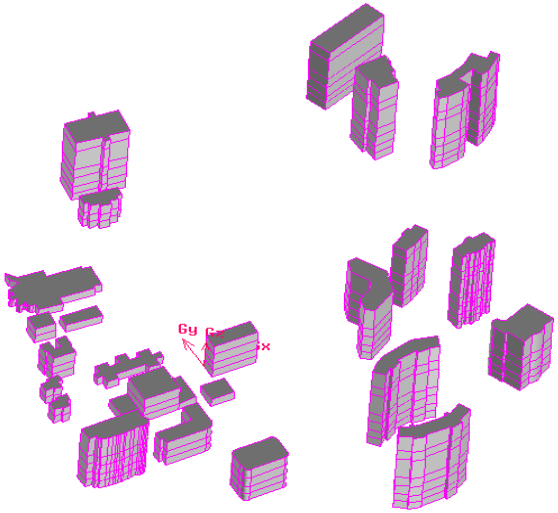
POSTER 22: Chang YY, Tan JG, Grimmond CSB, et al. Distribution of Aerodynamic Roughness Based on Land cover and DEM- A case study in Shanghai, China

Urban canopy winds

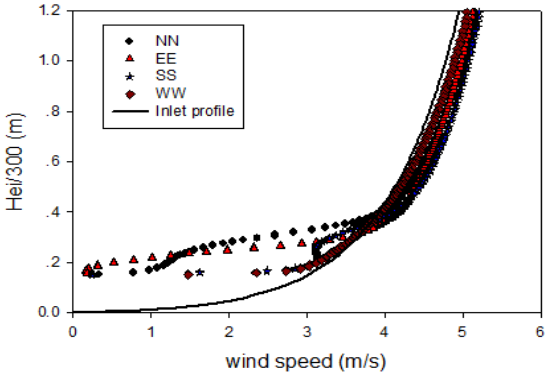




Research area

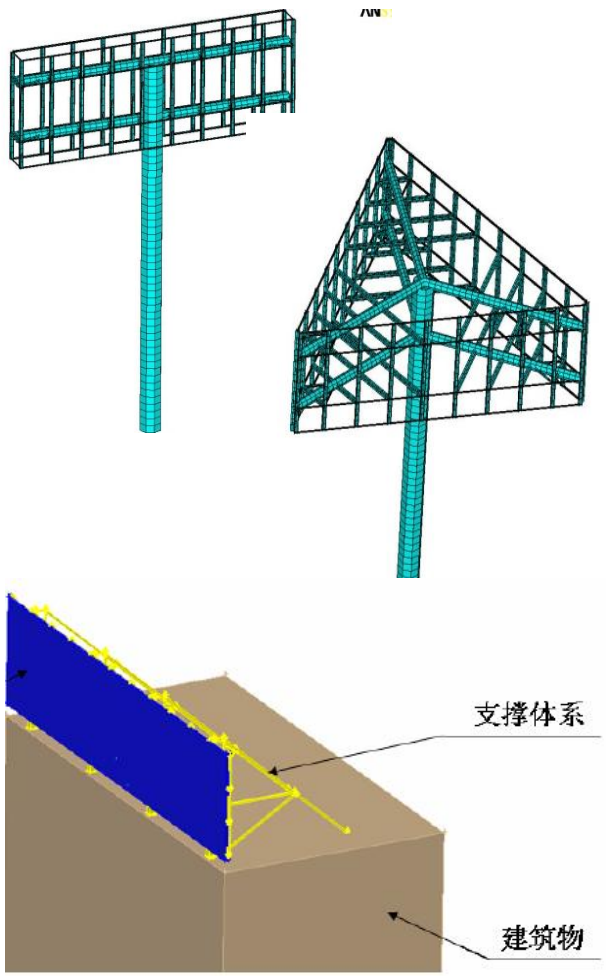


Wind tunnel +CFD

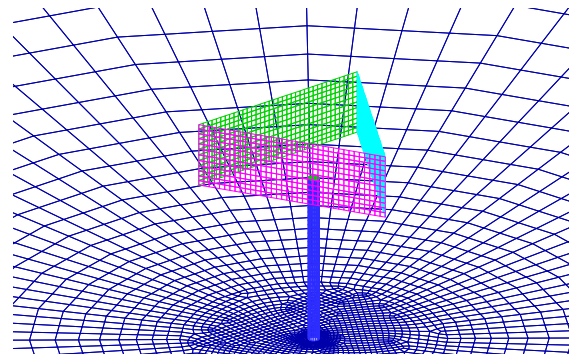


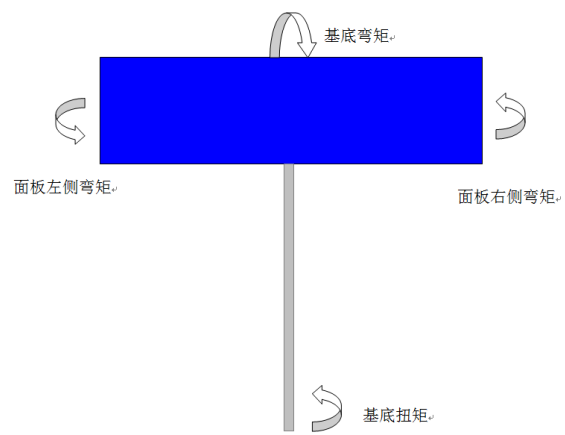
Wind distribution and profile

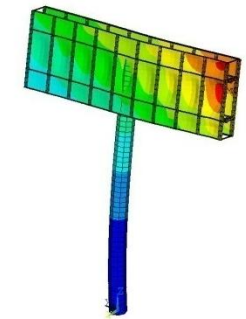
Bill board

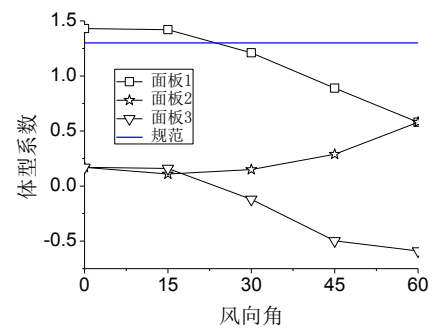


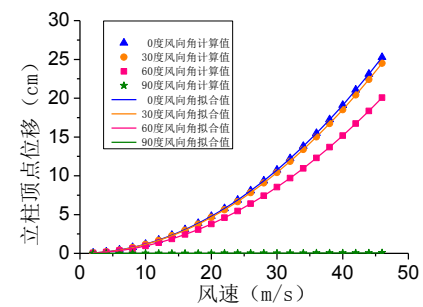
Different type of bill board





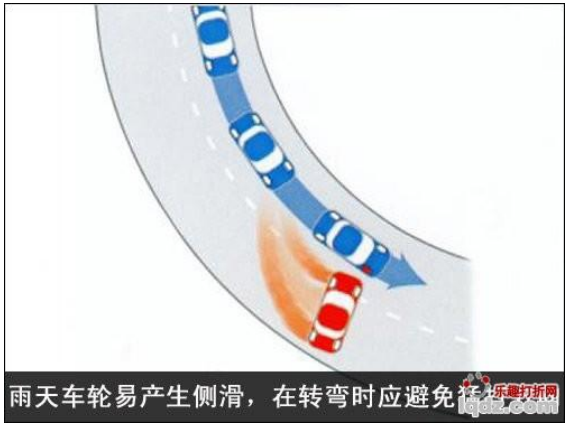


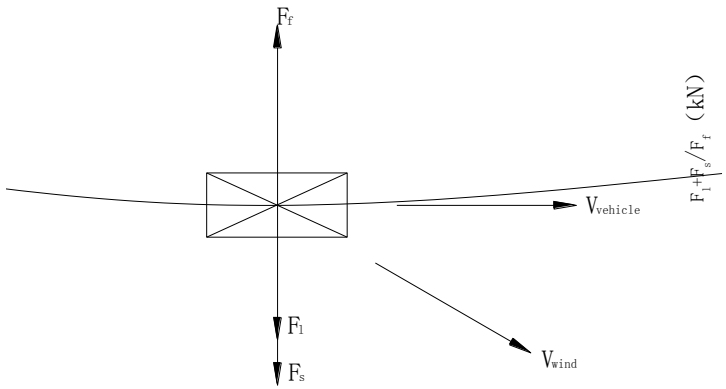


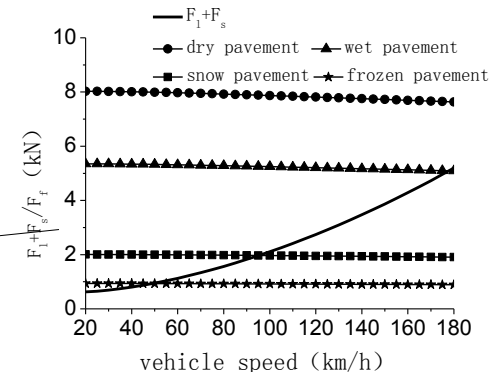


Wind tunal +CFD+force analysis

Vehicle







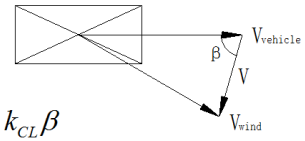
Different type of vehicle

$$F_l = mV_{vehicle}^2 / R$$

$$F_f = \mu_s (mg - F_L)$$

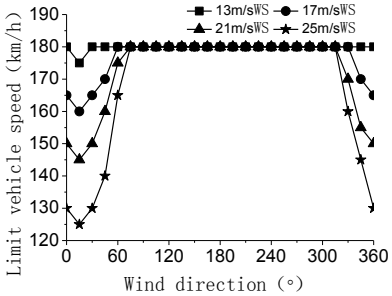
$$F_L = \frac{1}{2} C_L \rho V^2 A \qquad C_L = k_{CL}\beta$$

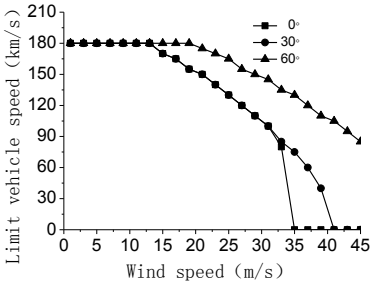
$$F_S = \frac{1}{2} C_S \rho V^2 A \qquad C_S = k_{CS}\beta$$



$$mV_{vehicle}^2 / R + \frac{1}{2} k_{CS}\beta\rho V^2 A \le \mu_s (mg - \frac{1}{2} k_{CL}\beta\rho V^2 A)$$

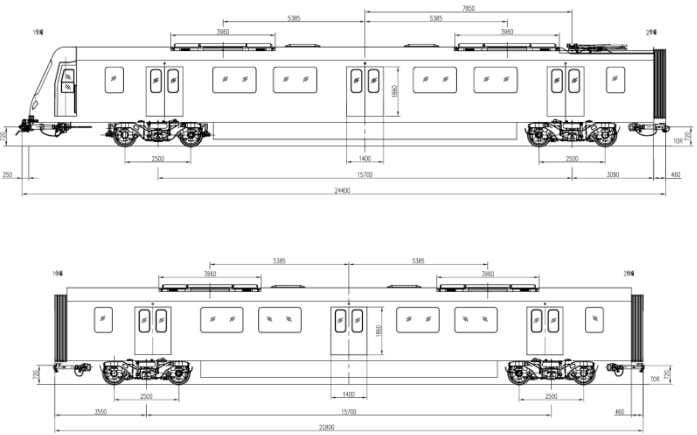
Force analysis



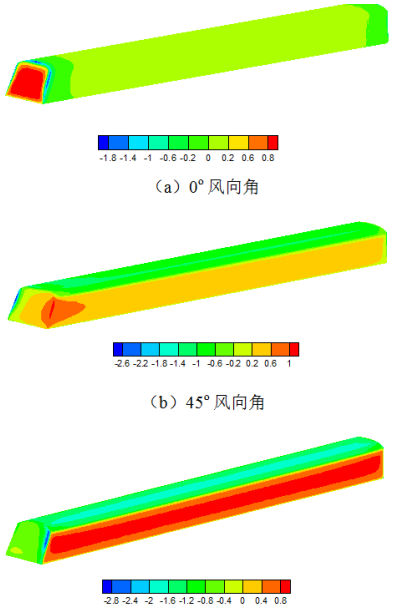


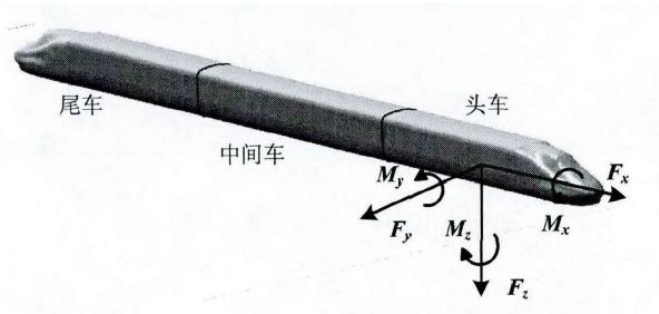
WD, WS's impact on driving speed

Rail

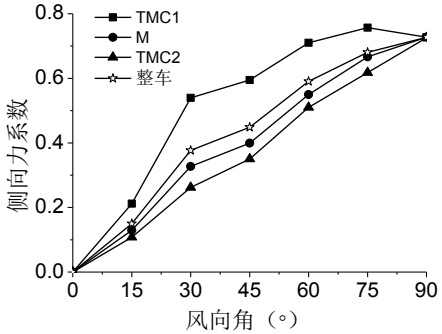


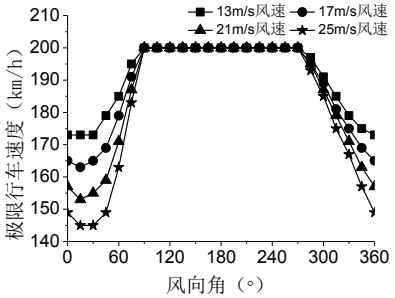
Different type of train

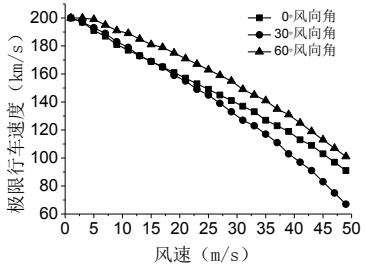




CFD+force analysis

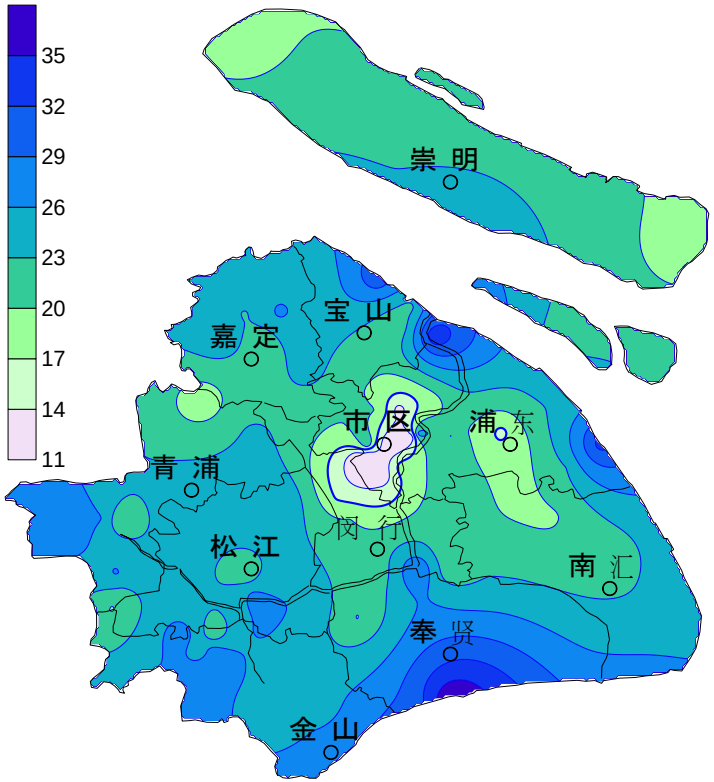


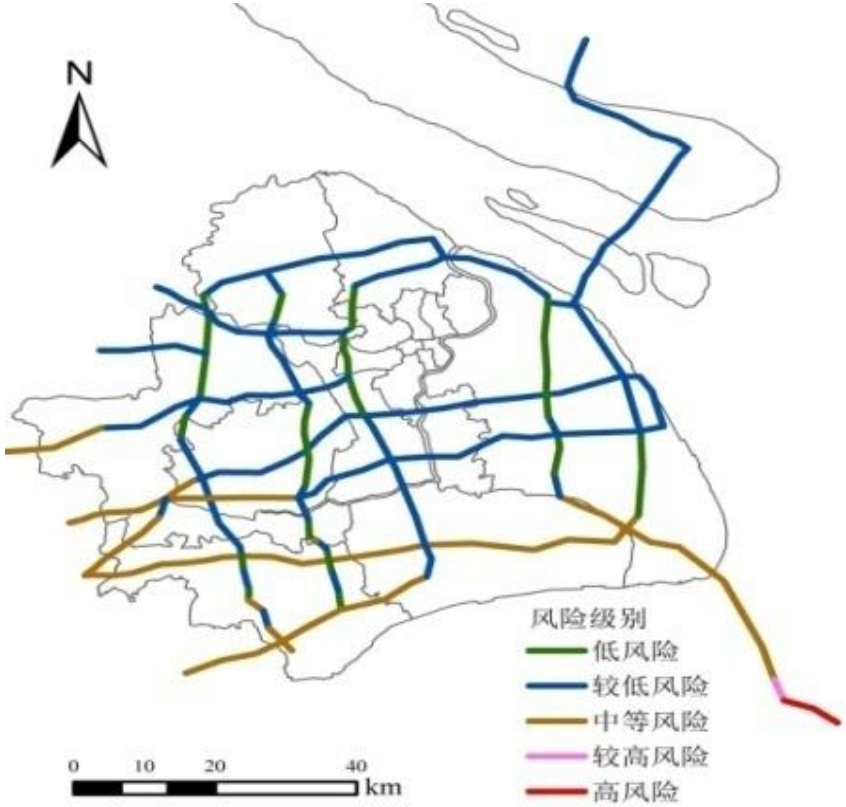




WD, WS's impact on the running speed

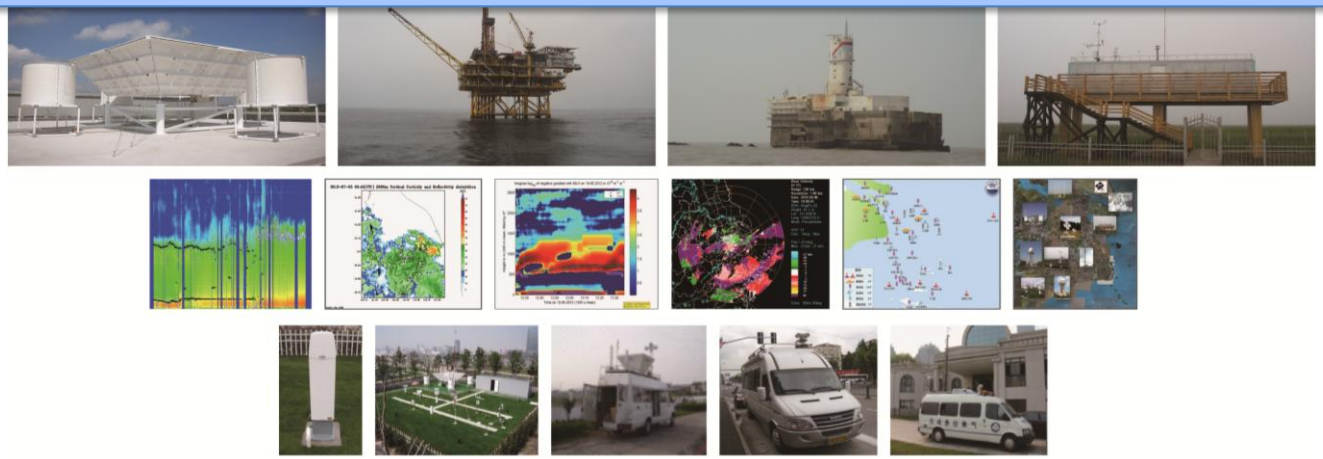
Wind risk assessment





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!