



Urban heat island circulation

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Thanks to the following colleagues and students

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PW Chan/TC Lee,
HKO

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CRF, GRF
Microsoft, Tsinghua

OUR TEAM

1. 王霄雪博士, 2015,
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2. 殷士, PhD, 2016,
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3. 汪凯, PhD, 2012-
4. 樊一帆, PhD, 2013-
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5. Wang Yi, PhD, 2013-
6. 彭磊, PhD, 2014-
7. Wang Qun, PhD, 2016-
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Past team members

杭建, PhD 2009, postdoc,
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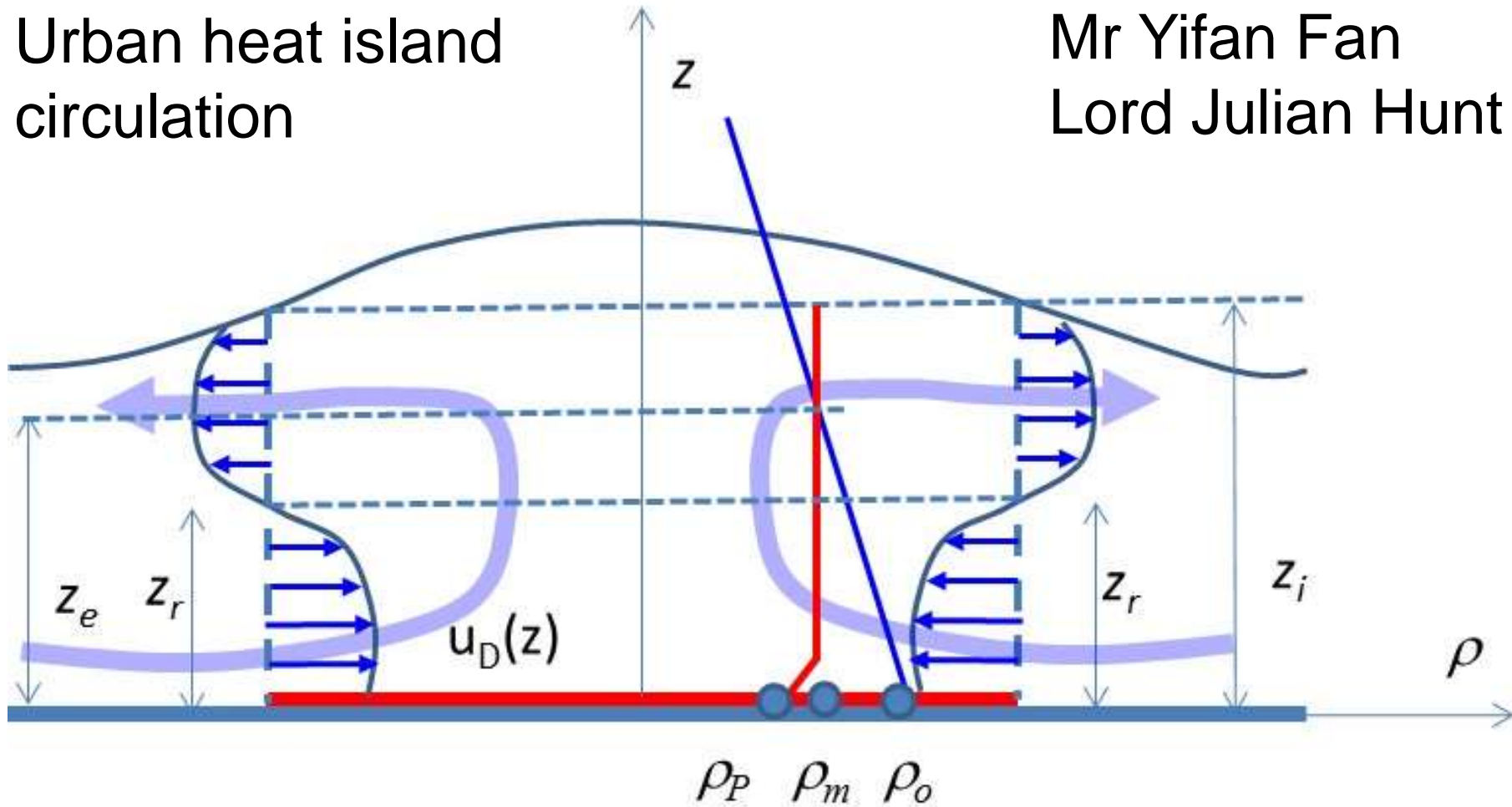
王尚, PhD, 2015

杨芯岩博士, 2013, postdoc,
2013-, UPF

Dr Jiang Lei, 2015-, post-doc₂

Urban heat island circulation

Mr Yifan Fan
Lord Julian Hunt



Heat island of diameter D (m)

小蜡烛群的奥秘 - A small demonstration using candle plumes (flames). Each building creates its own plume, like a candle plume.

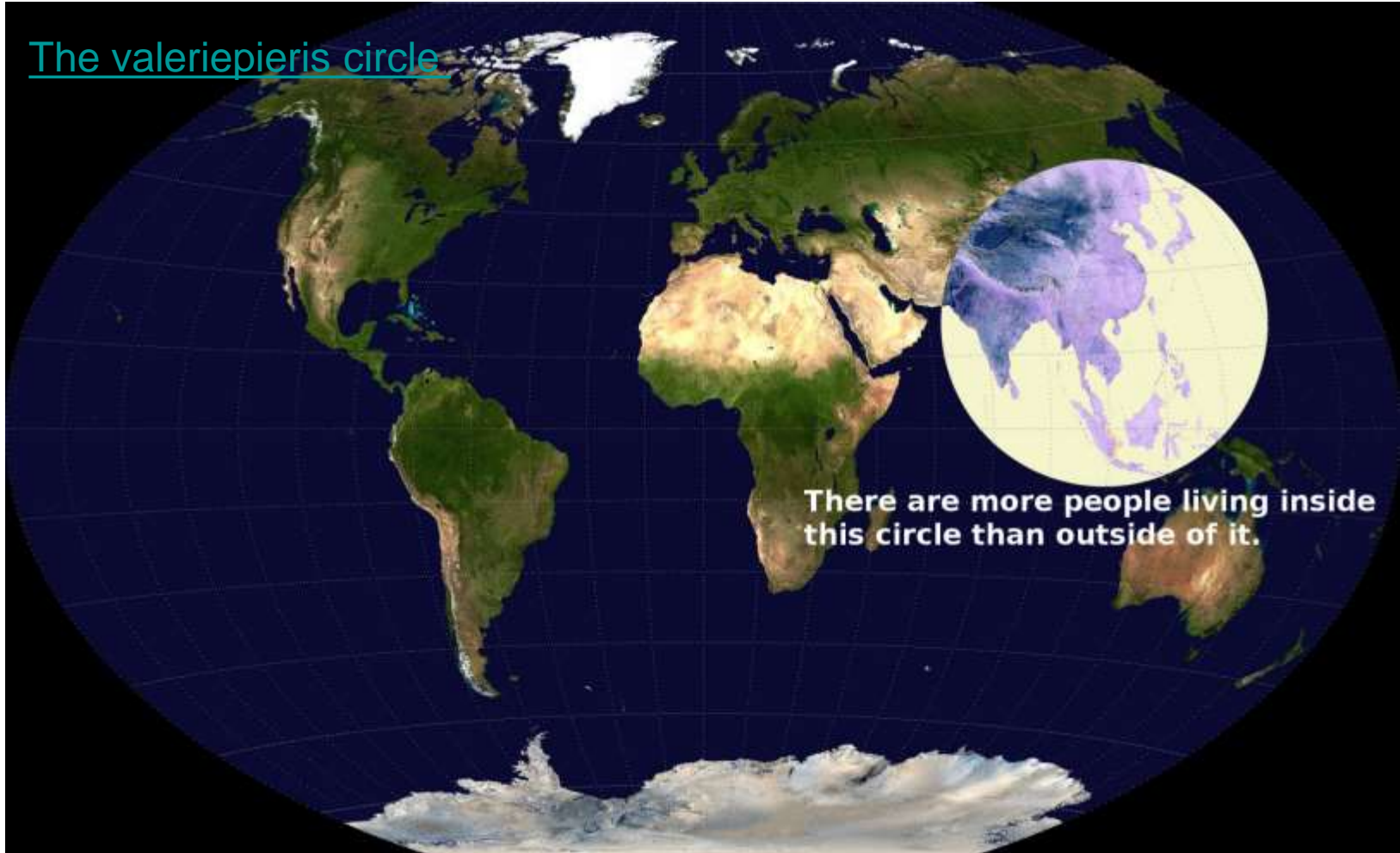


分离体现个性 When candles are far apart, each candle is an “individual”.



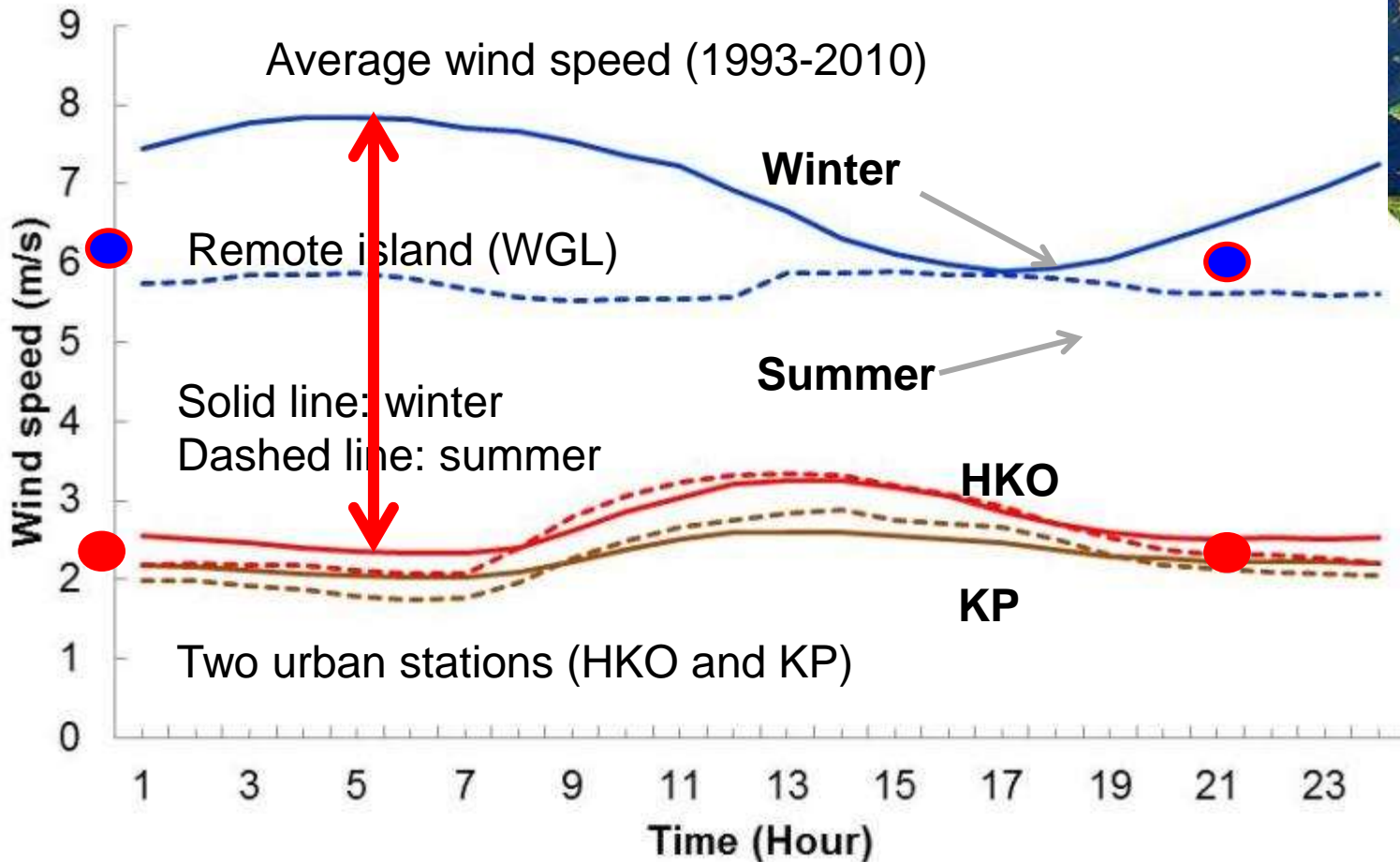
密集身不由己，力量大 When close, each is no longer an independent individual. A “large scale” converging phenomenon occurs.

Asian cities are denser, higher and larger?

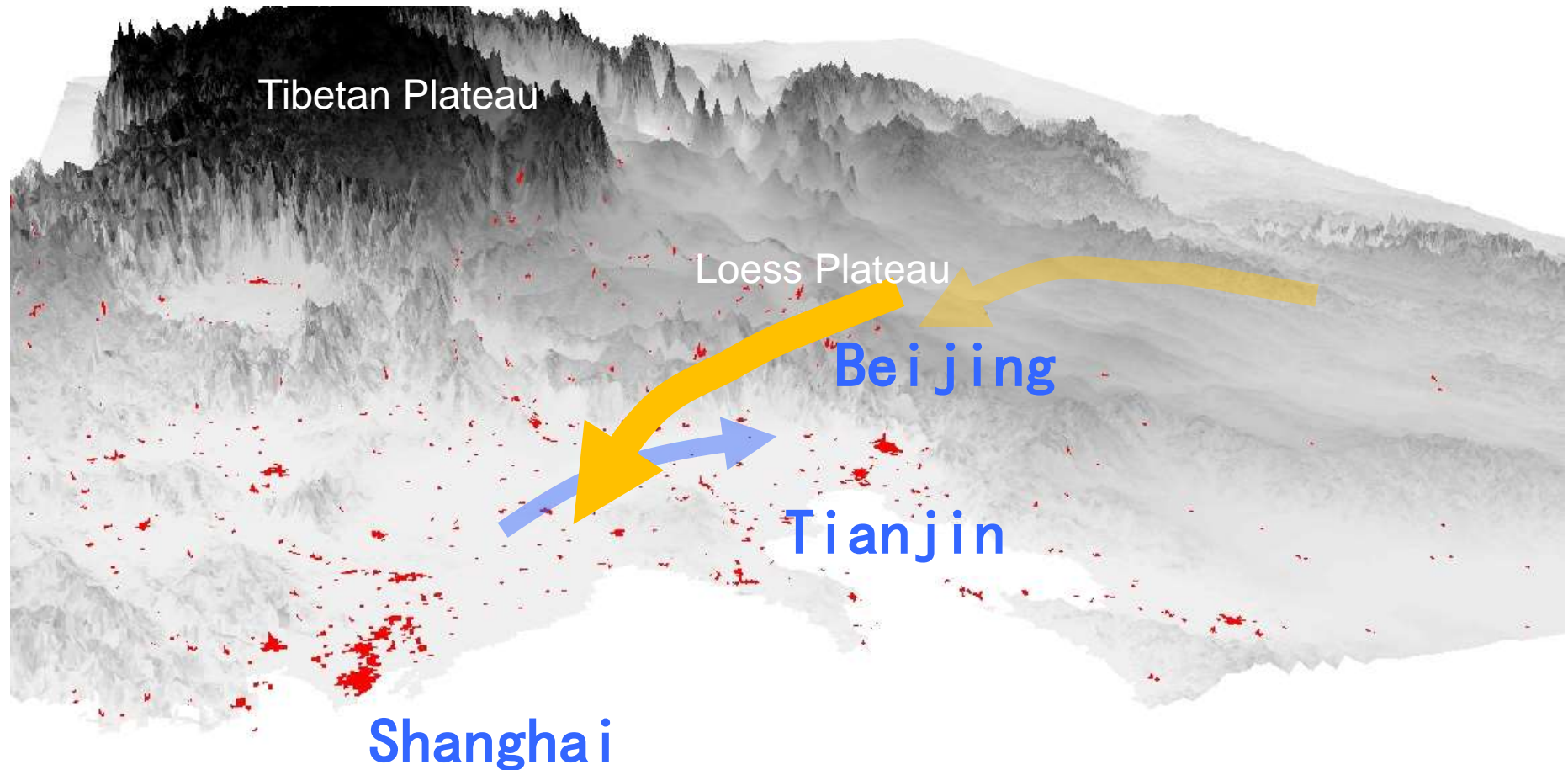


Why are there different trends in rural/urban daily cycle of wind speeds in winter? Different mechanism?

Stronger urban wind @ 11 am - 2 pm in rural areas. but weaker wind in urban areas during the same period.

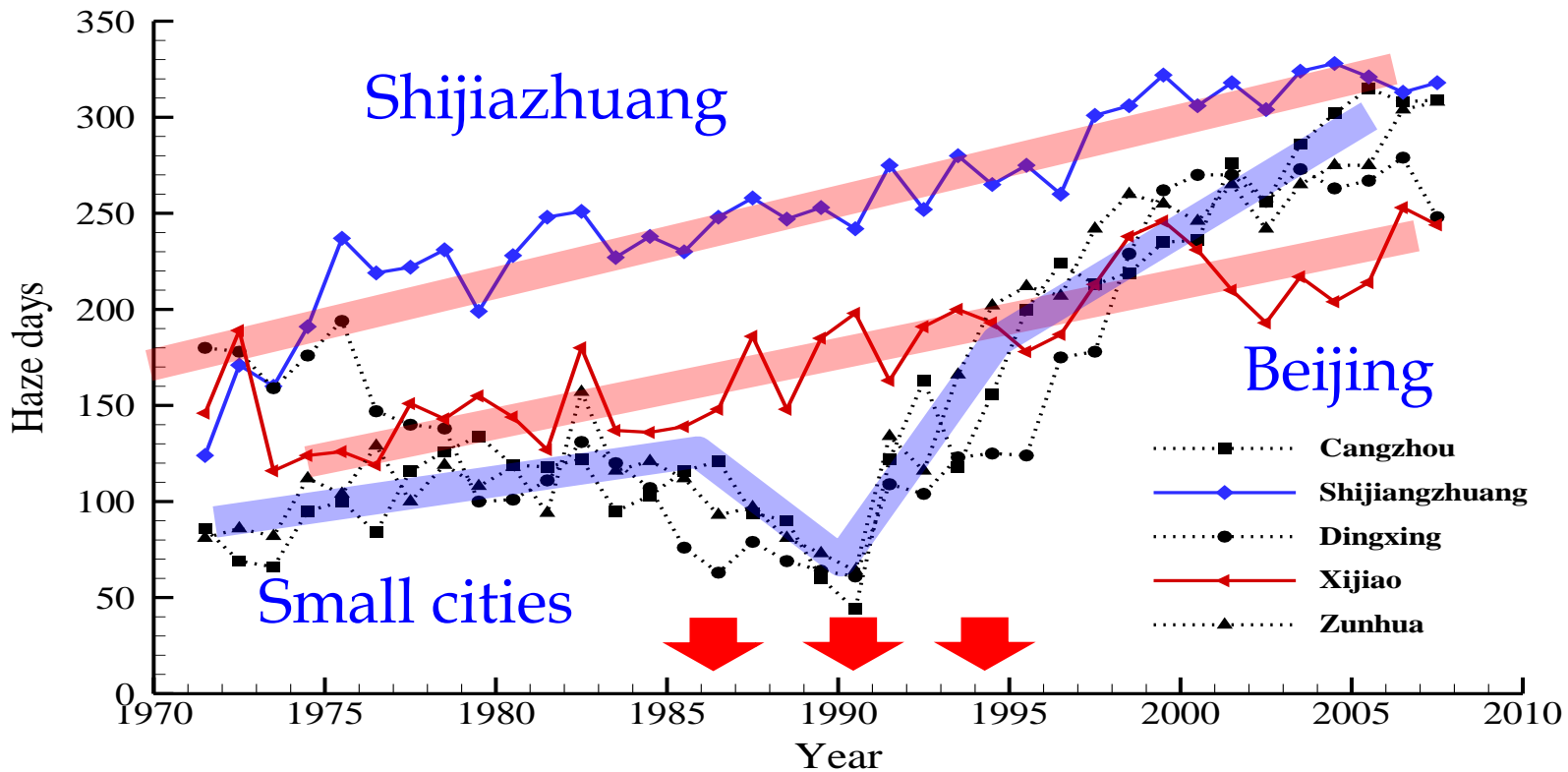


Jing Jin Ji 200k km², 100m population,
urban population will increase 50% by 2049.
Haze occurred when the winds are weak



Beijing, Tianjin and Hebei (JJJ) haze – 兩個現象

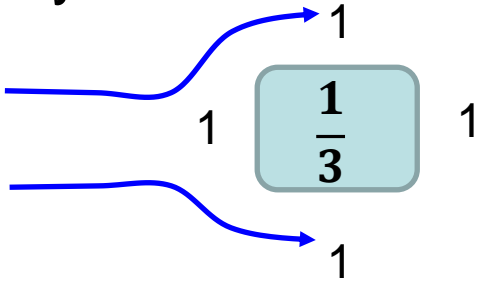
- **Small city phenomenon** - Small cities experienced less hazy days in the 90s while the whole JJJ region was developing.
- **Large city phenomenon** - SJZ separate from Beijing since late 70s.



王喜全, 孙明生, 杨婷, 王自发. 京津冀平原地区灰霾天气的年代变化. *气候与环境研究*. 2013;18(2):165-70.

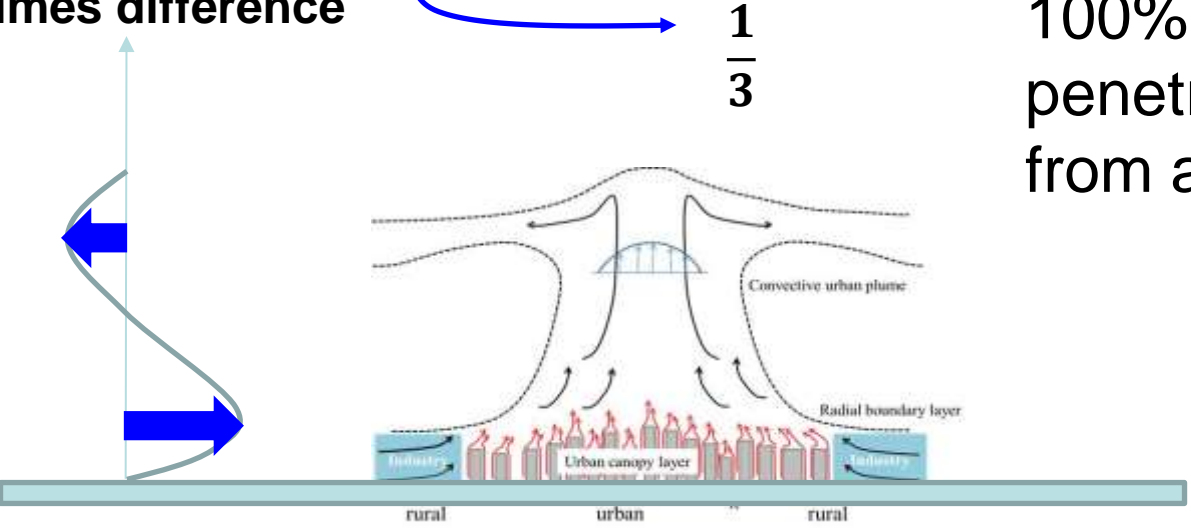
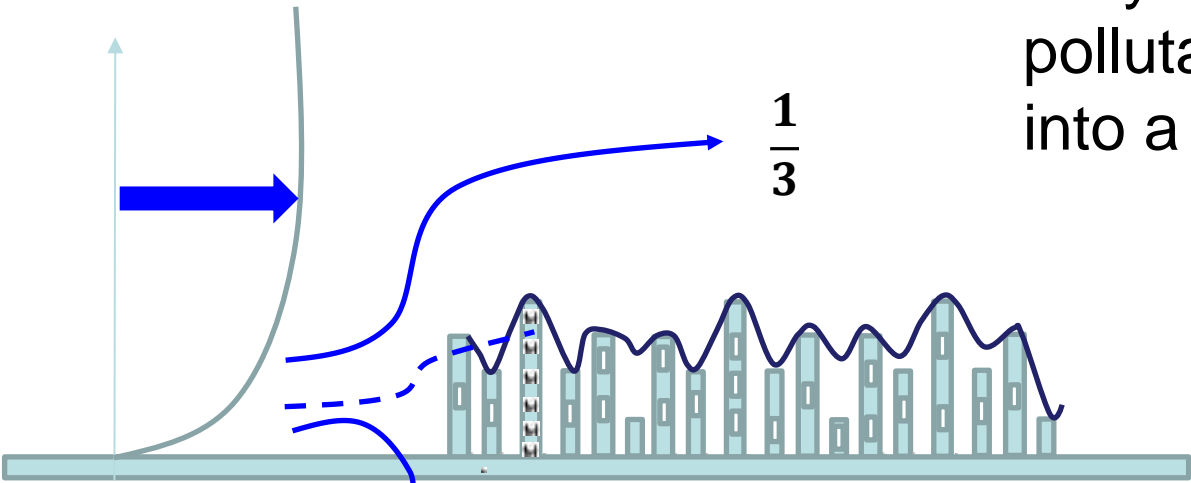
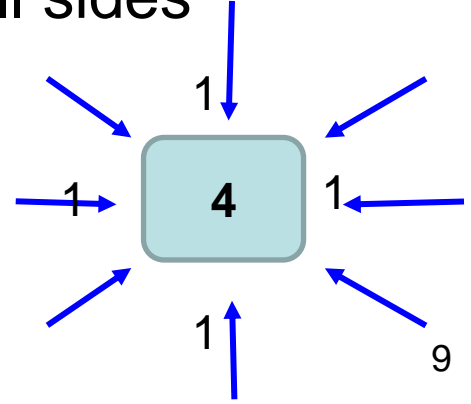
The Beijing haze mystery - haze concentration shoots 10 times higher over night - Where did pollutants come from?

Only 1/3 of the rural pollutants penetrates into a city



12 times difference

100% rural pollutants penetrates into a city from all sides

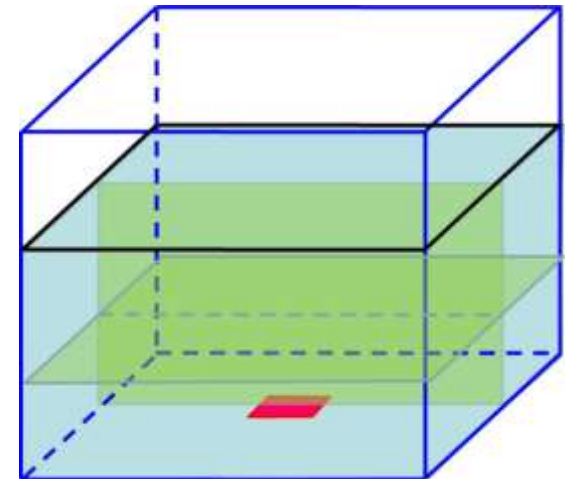


Wang X and Li Y (2016) Predicting urban heat island circulation using CFD. Building and Environment, 99:82-97.

(i)

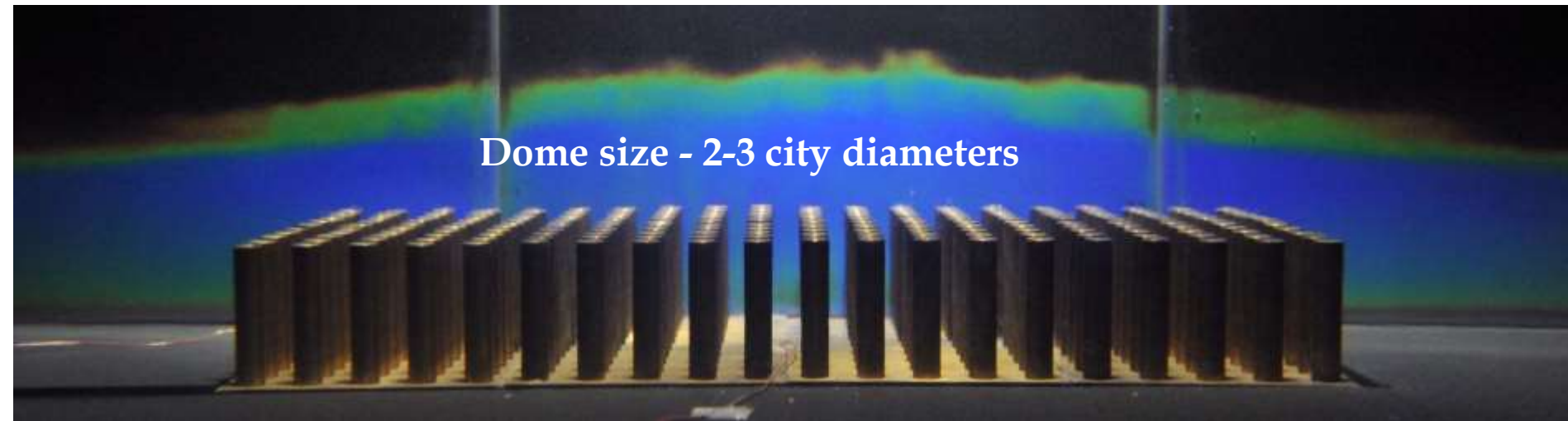
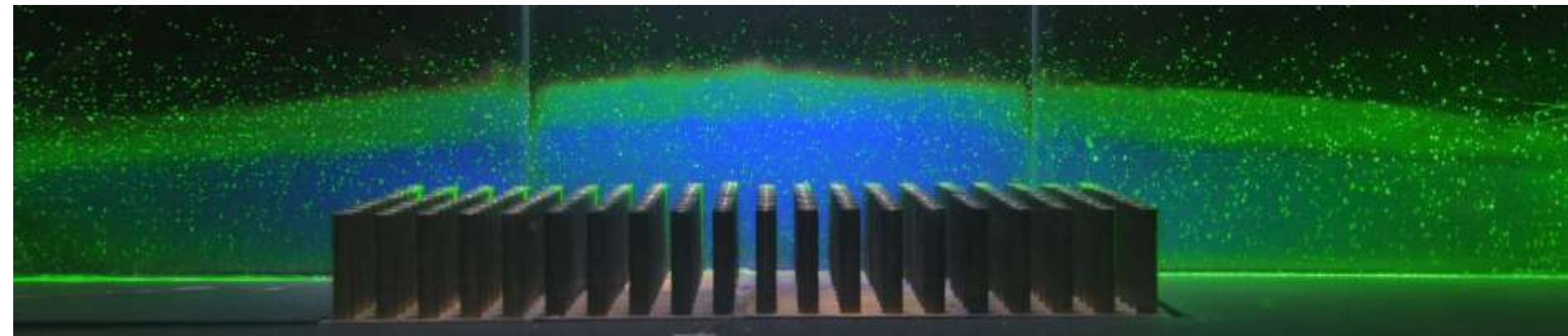


- (1) Transformers
- (2) Thermal couple data logger
- (3) Traverse device
- (4) Thermalchromic liquid crystal
- (5) Urban area
- (6) Bucket
- (7) Laser
- (8) High speed camera

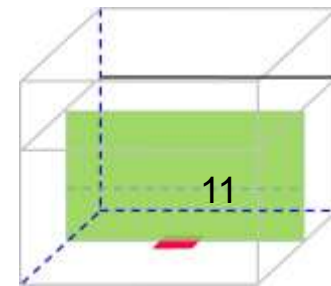
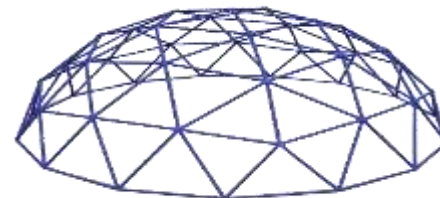


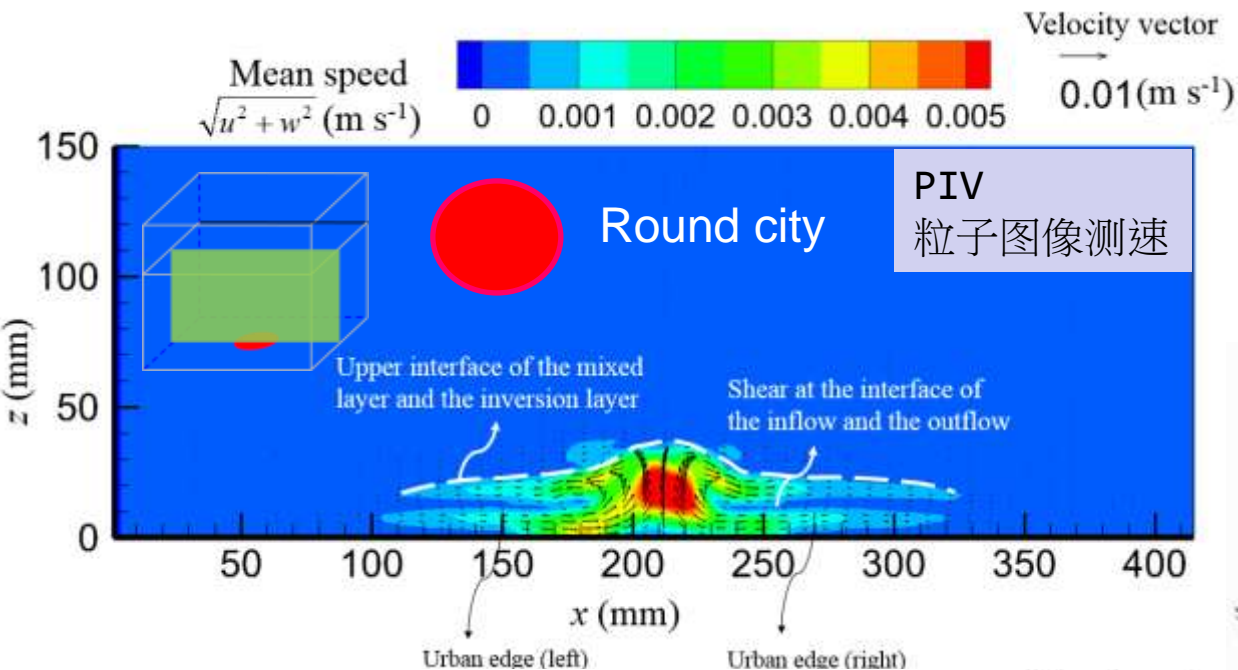
When the winds are relatively weak

With inversion, we have a dome 穹顶，穹隆，大锅盖

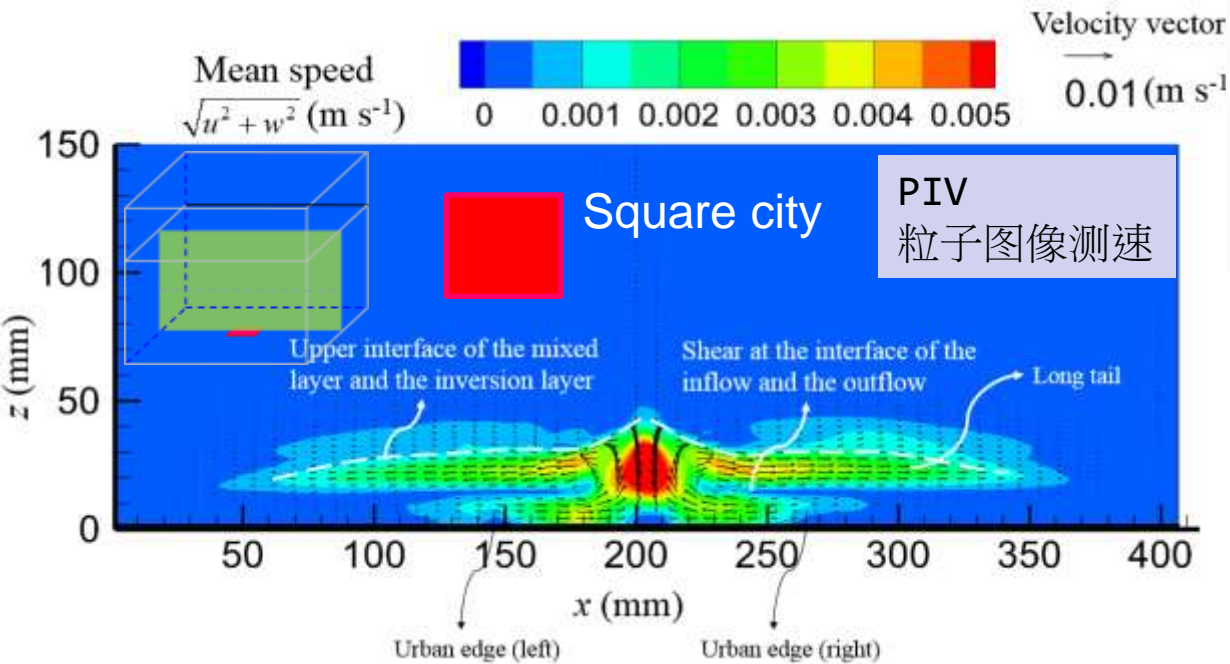
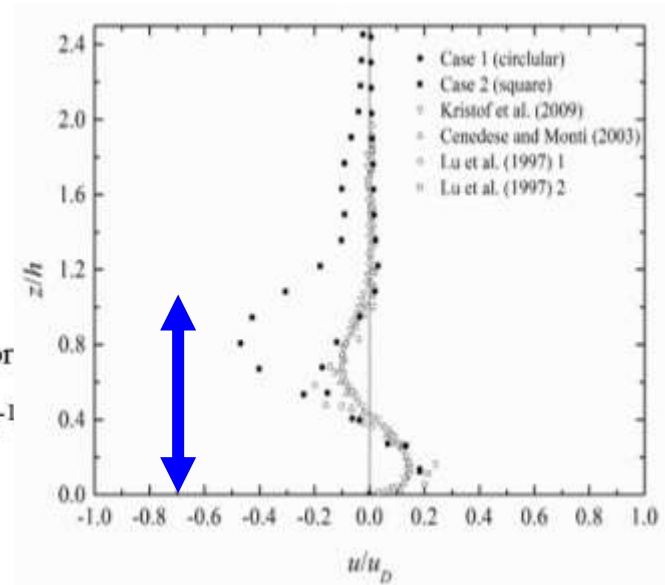


Fan Y, Li Y, Wang X and Catalano F (2016). Journal of Applied Meteorology and Climatology.





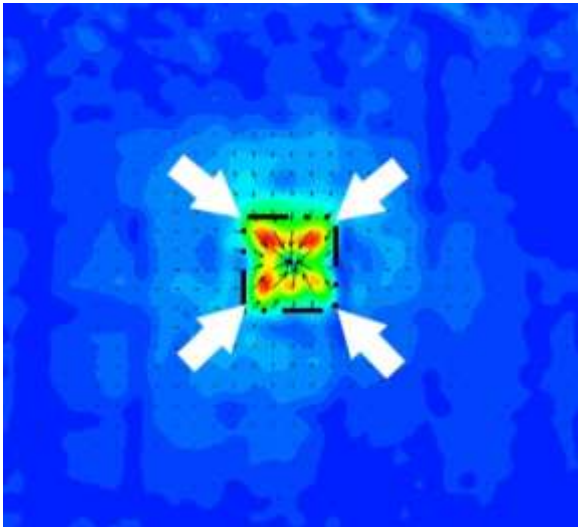
方形城市，出流比入流强的多，为什么？



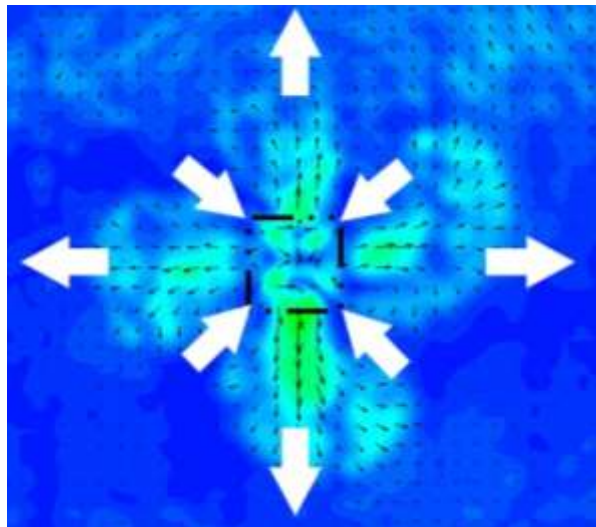
The square city asymmetry phenomenon

Square city 方形城市

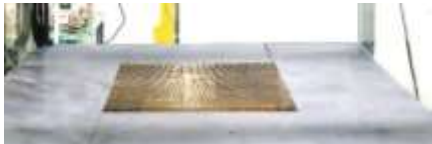
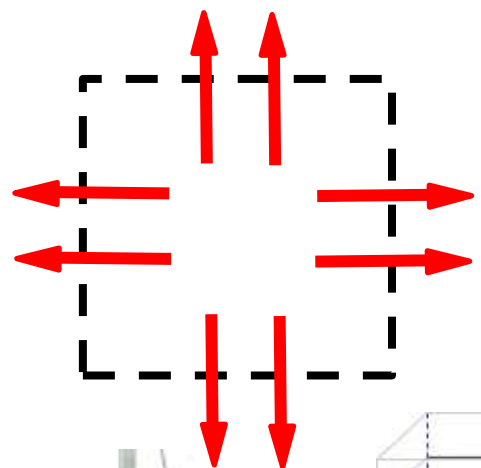
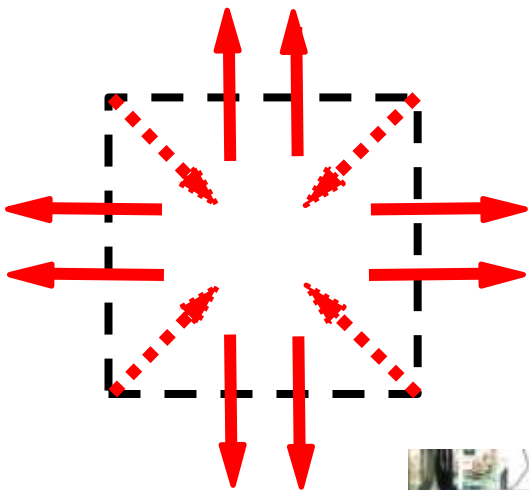
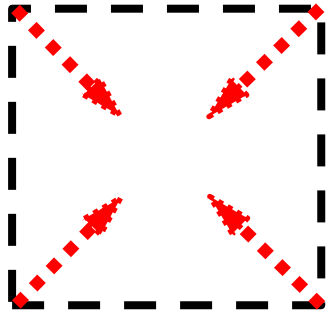
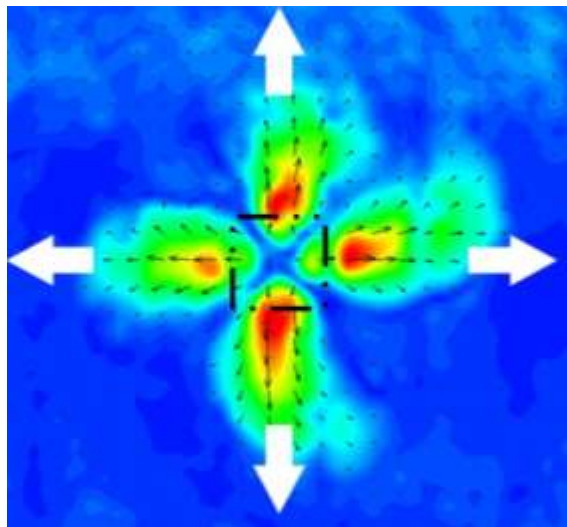
Lower (0.5cm)

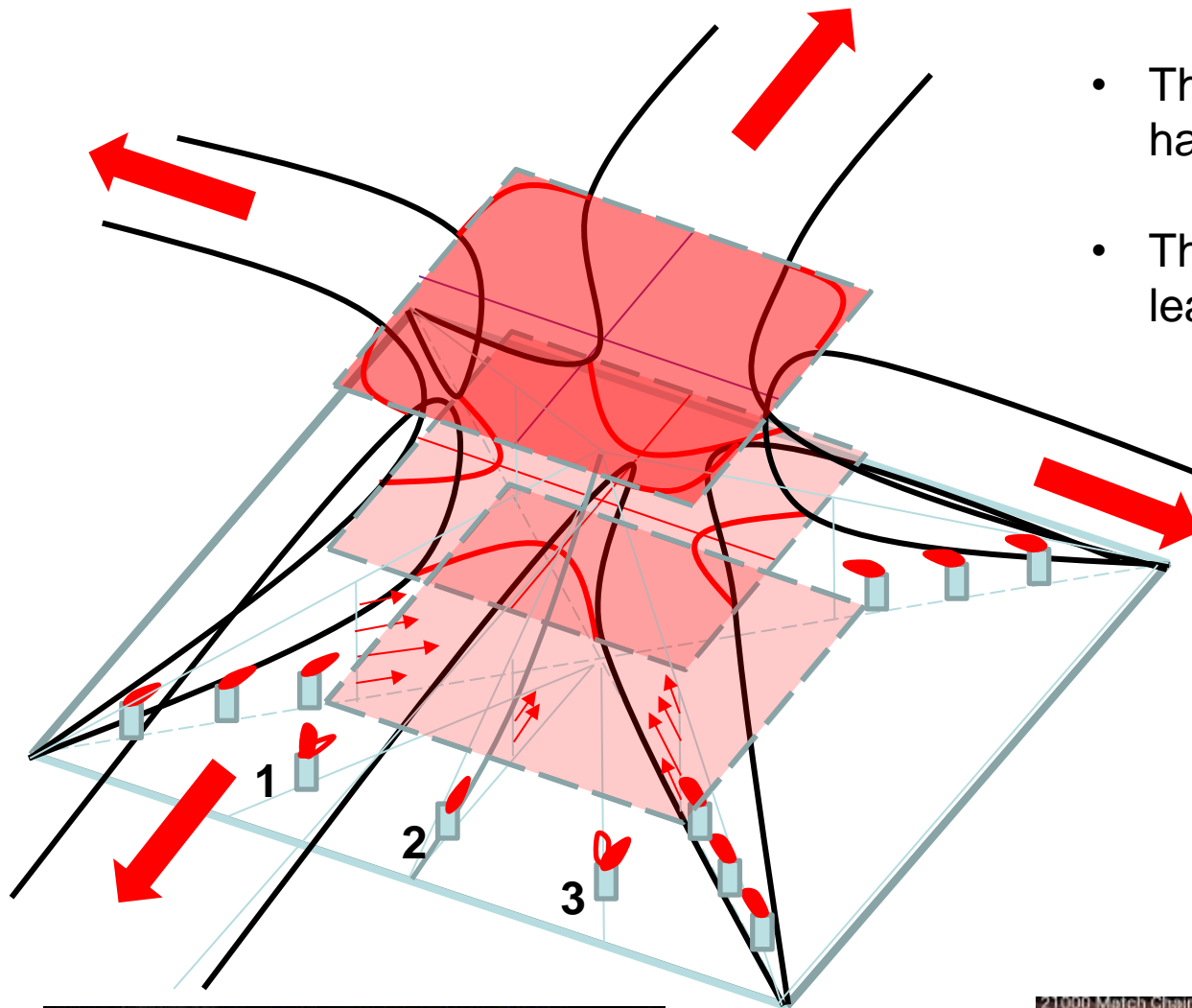


Middle (1.0cm)



Upper (1.5cm)





- The diagonal inflow direction has the strongest buoyancy.
- The sideward outflow has the least resistance.



Youtube videos



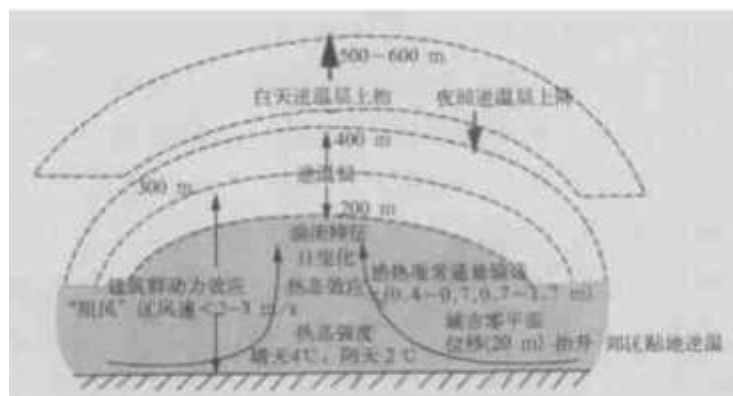
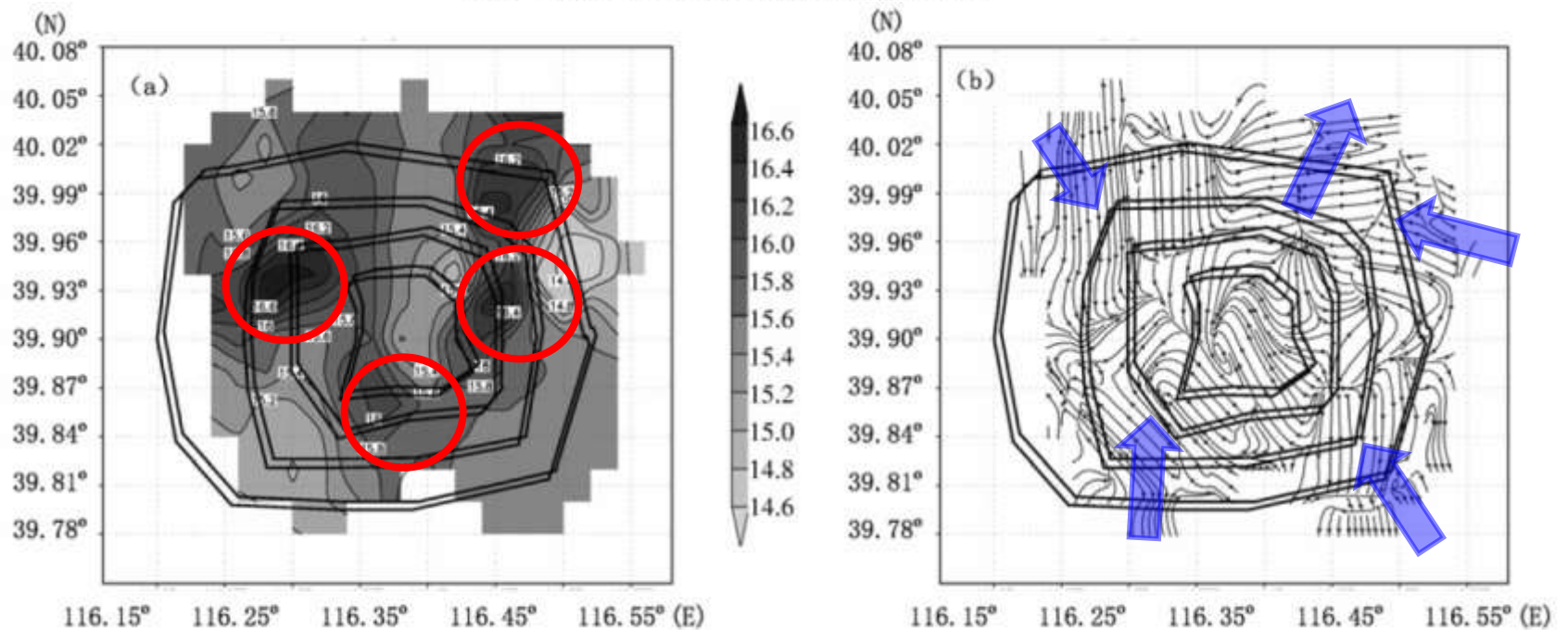
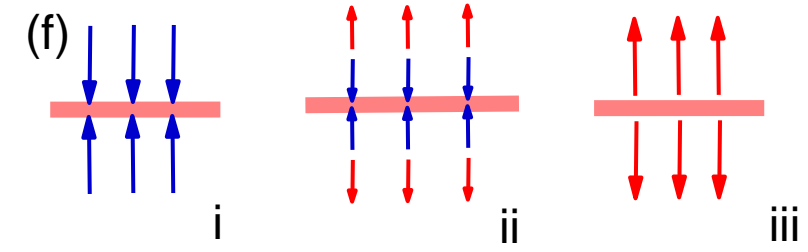
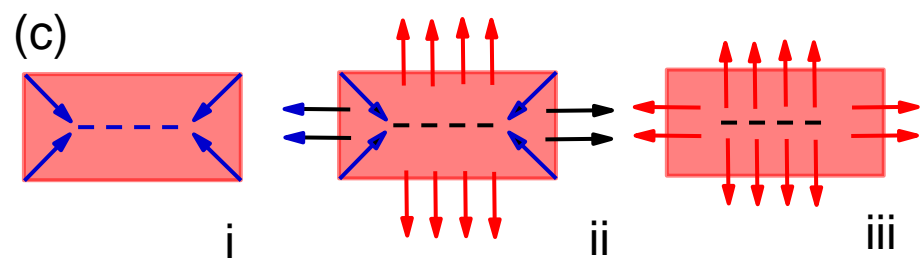
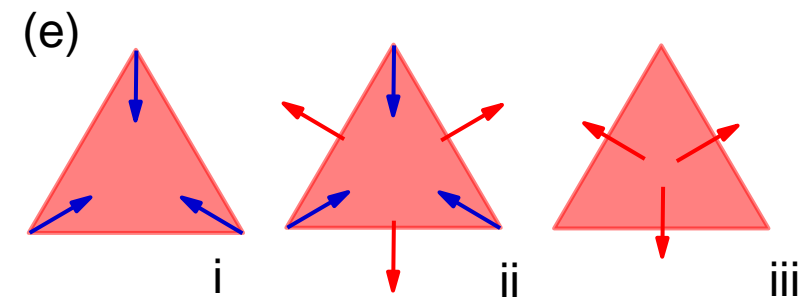
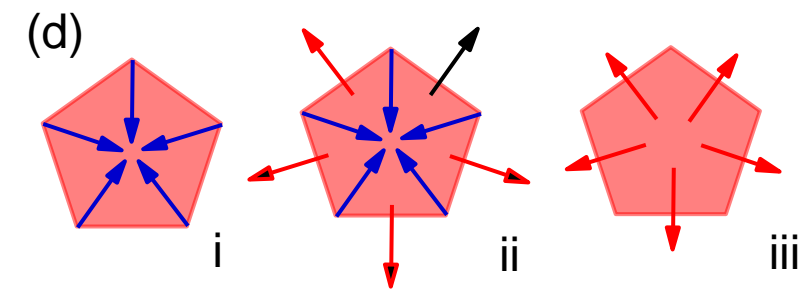
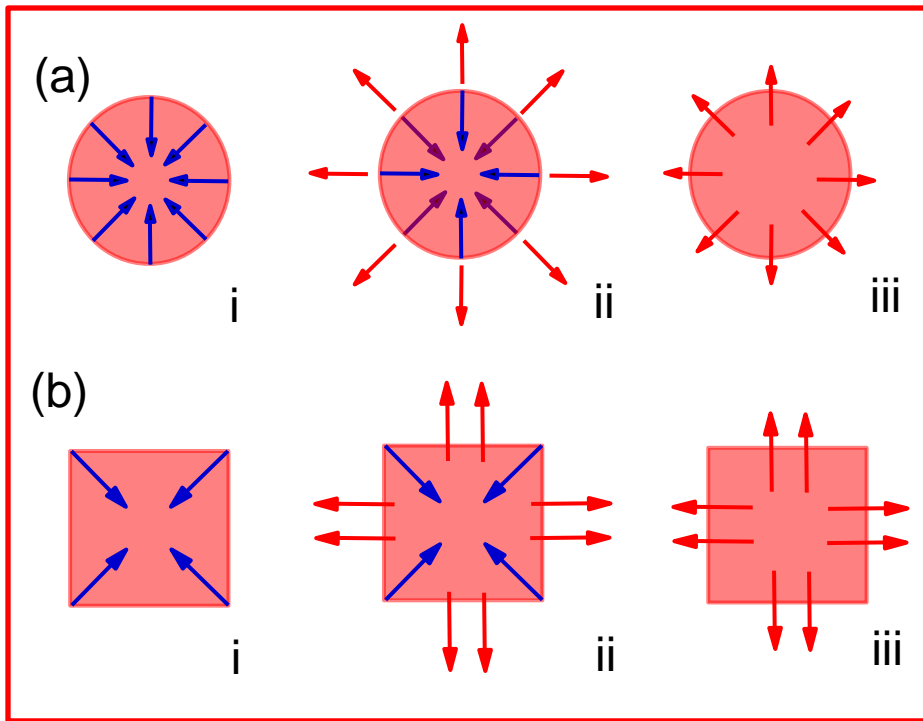


图2 城区“空气穹隆”动力结构综合示意

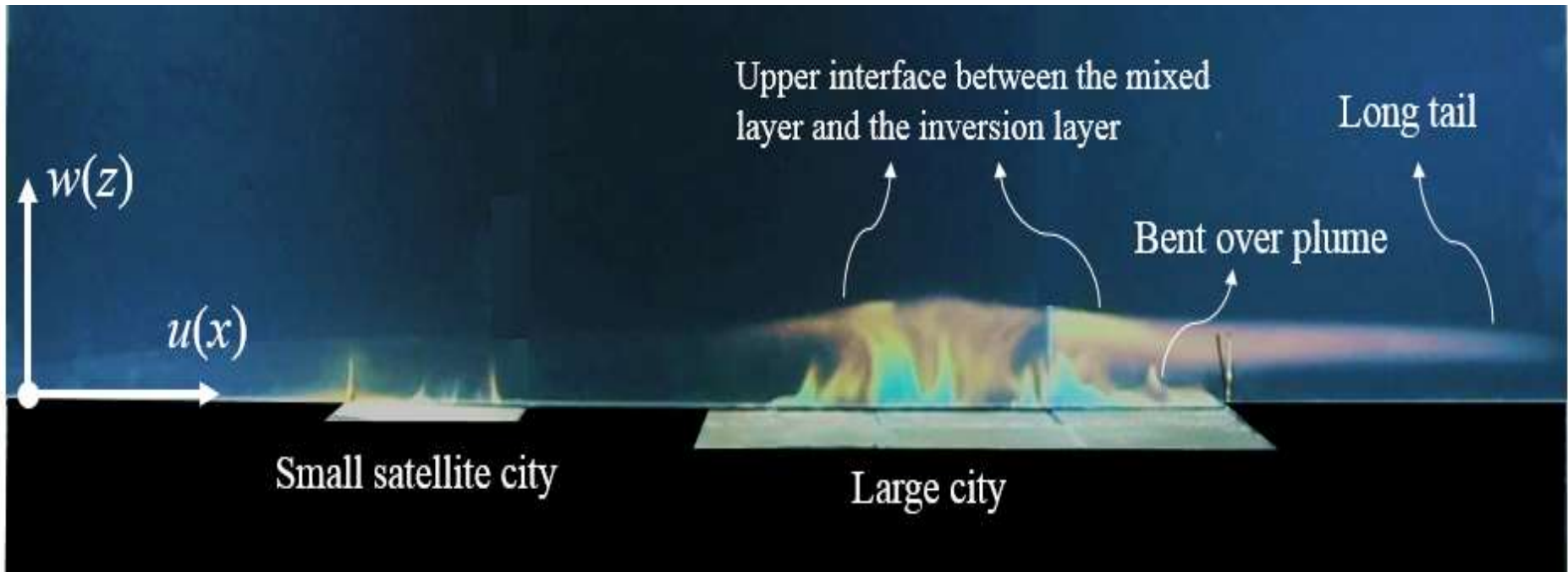
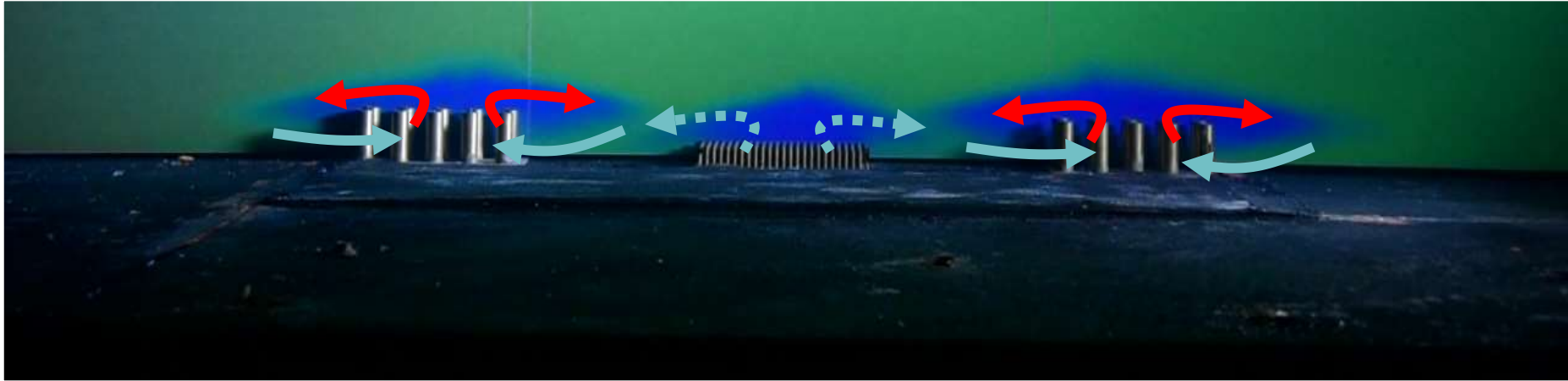


Monthly mean surface air temperature ($^{\circ}\text{C}$) and wind streamline of Oct 2003, Beijing.

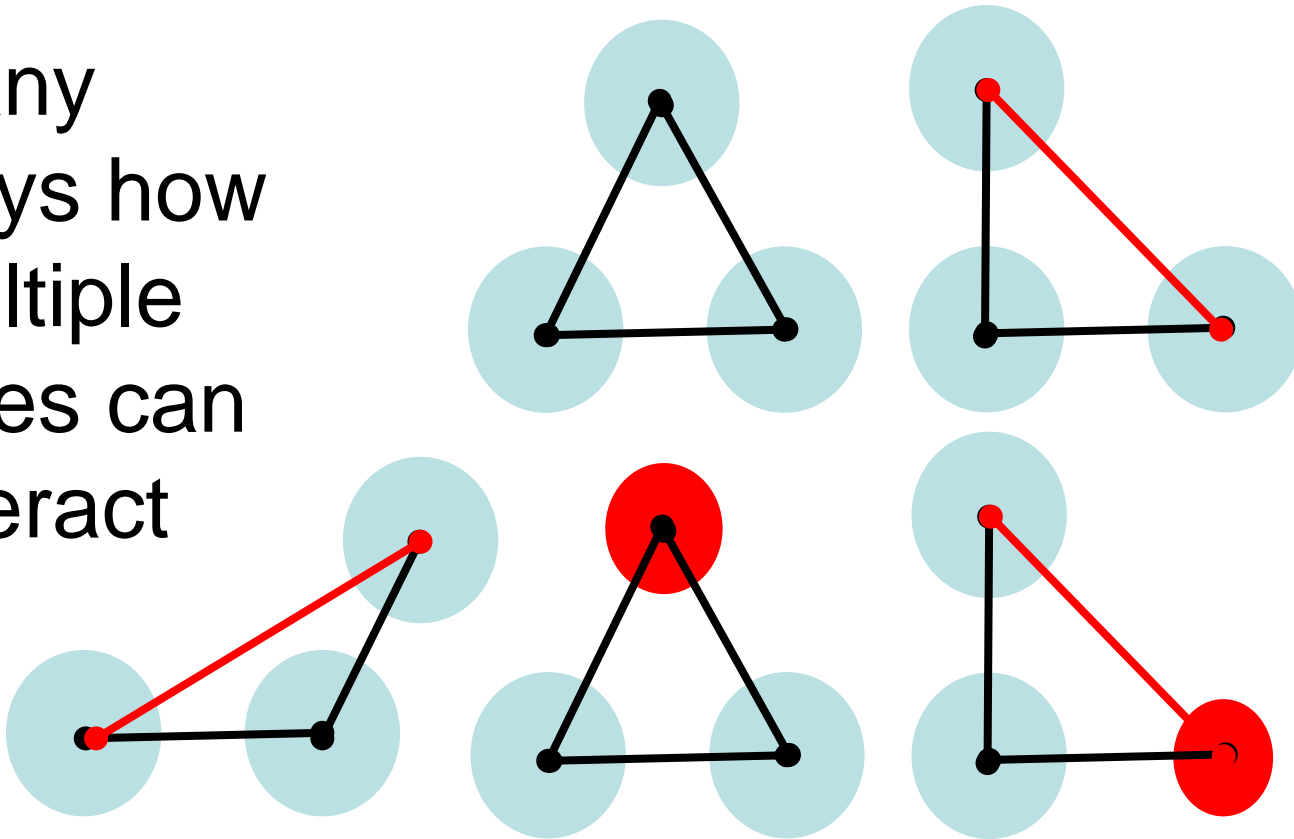
徐祥德, 丁国安, 卞林根, 谢立安. 气象学报.
2004 Oct; 62(5): 663-71.

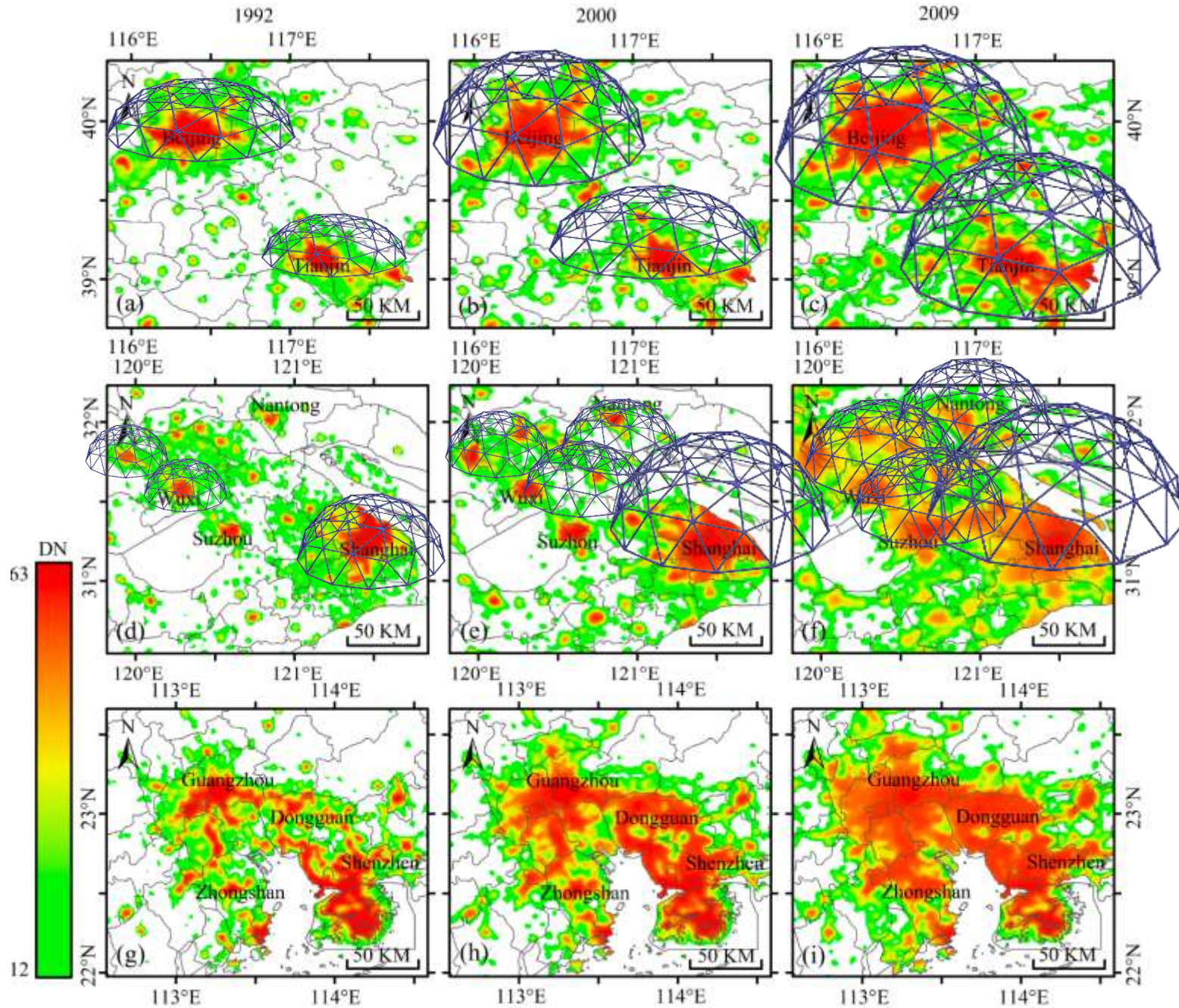


Two or three city domes – how far?



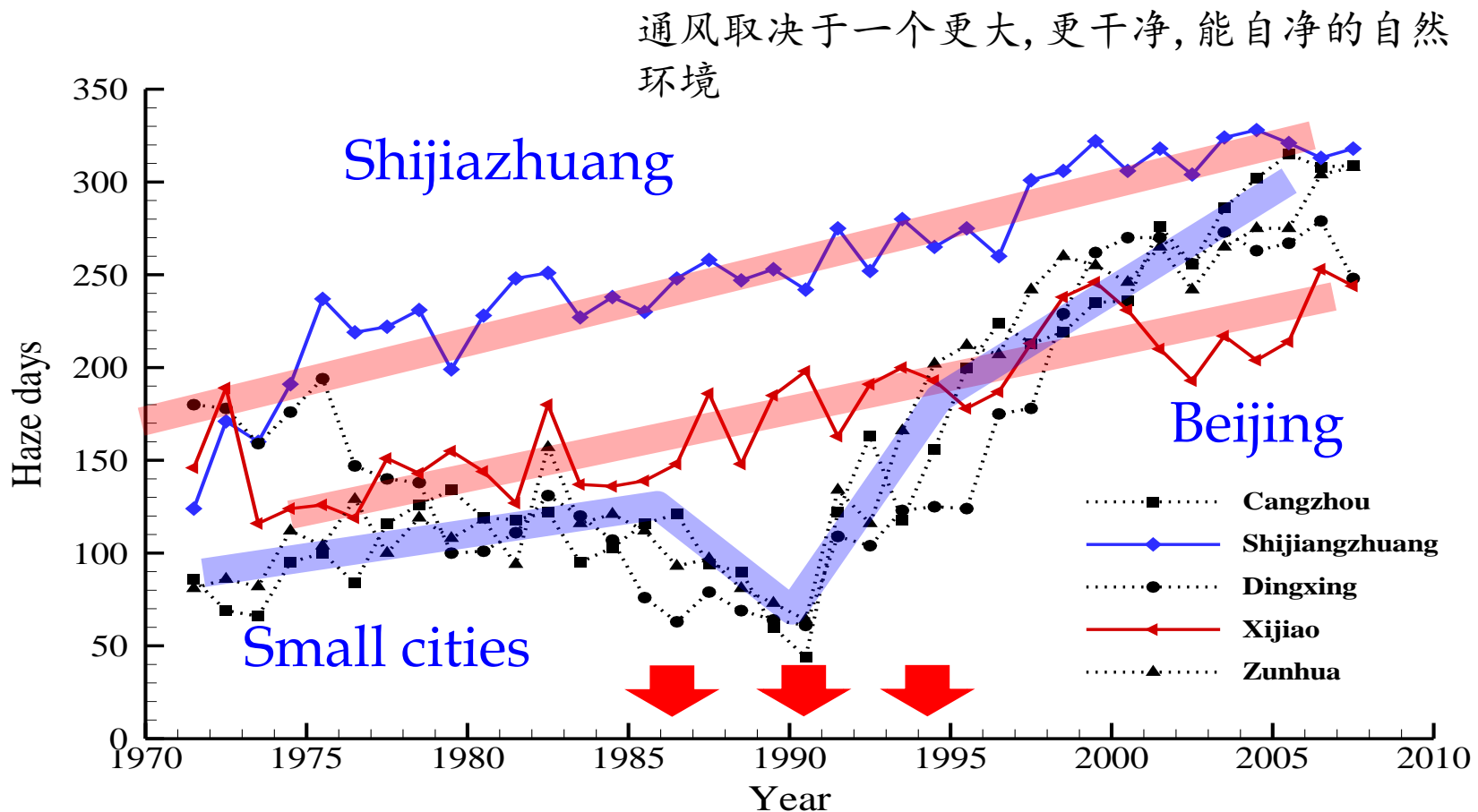
Many
ways how
multiple
cities can
interact





A dome cluster merging hypothesis -

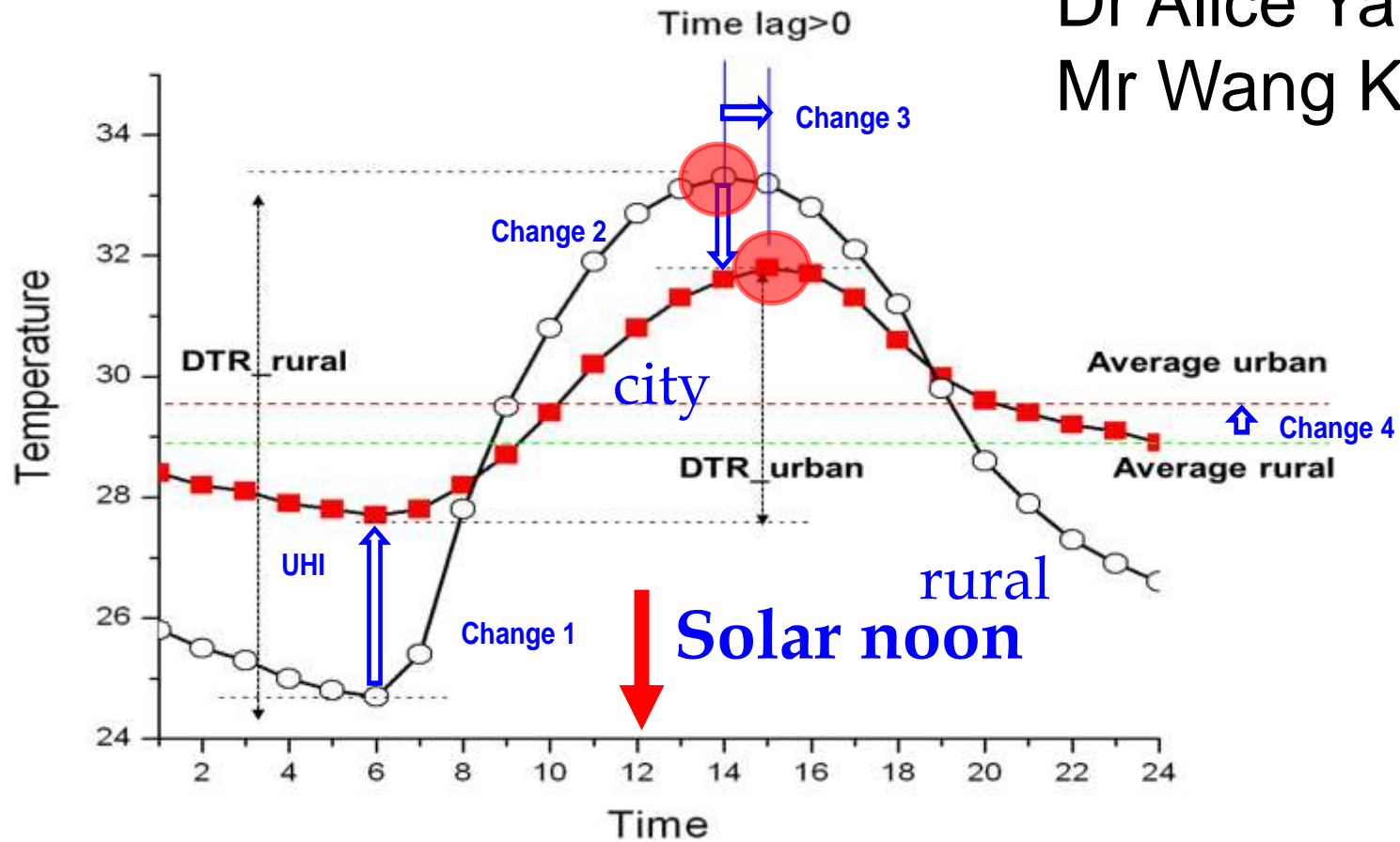
Urban domes expanded in 1986-1996 and merged to become regional.
However, each dome is still somehow independent



图源自: 王喜全, 孙明生, 杨婷, 王自发. 京津冀平原地区灰霾天气的年代变化. 气候与环境研究. 2013 Mar 27;18(2):165-70.

City warming – mean temperature increasing
Urban heat island – urban temp > rural temp

Dr Alice Yang
Mr Wang Kai



The west cities



The Asian cities



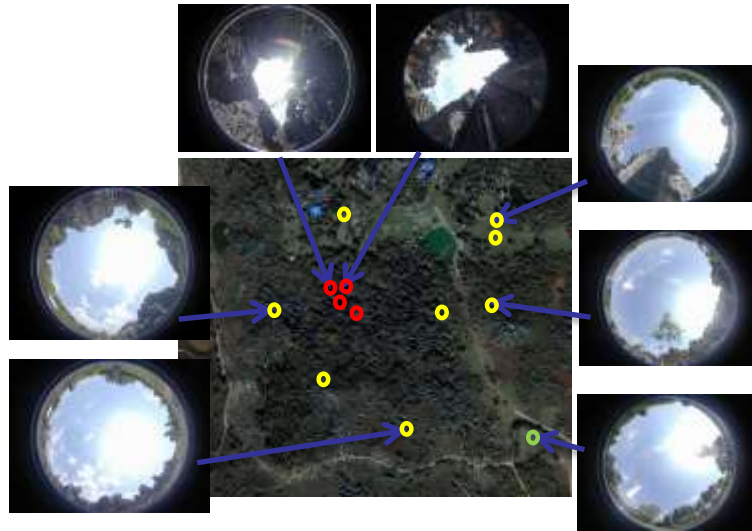
Small scale field model - **The Stone Forest**

- The heights of the karst stones range from 10 to 30m.
- The thermo-physical properties of the stones (limestone) are similar with the concrete of buildings.
- Minimum or zero air pollution and anthropogenic heat, which can **isolate the effects of man-made structures.**
- Different stone structures mimic different urban structures.

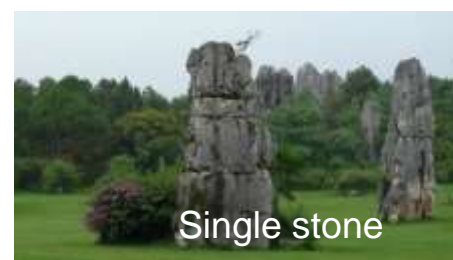


Measurements

- Air temperature at 2 m above ground (30 min interval, ibutton DS 1923 F5) at 13 locations. (July 2013-Mar 2016)
- Hourly surface temperature of the stones and vegetation using infrared camera (Flir SC600). (July 10-12th 2013; September 23-26th 2013; January 9-12th 2014)
- Two weather stations(Rainwise) outside/inside the Stone Forest (July 2013-Mar 2016)



	Sky View Factor
Compact	0.32±0.06
Sparse	0.75±0.10
Others	>0.9



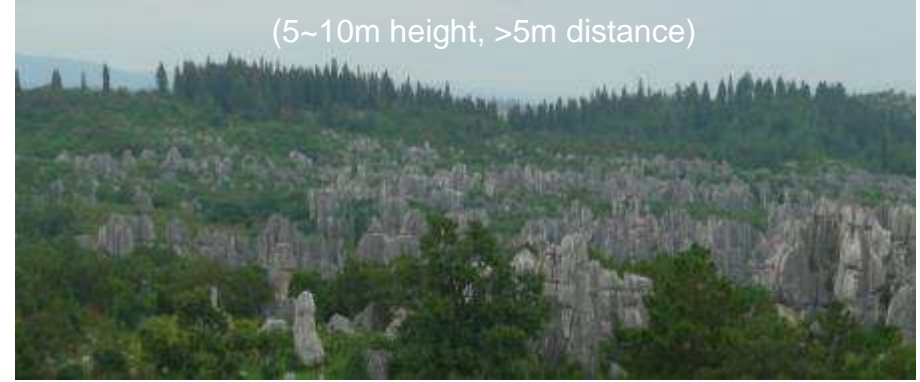
High-rise compact

(15~20m height, 1~2m distance)

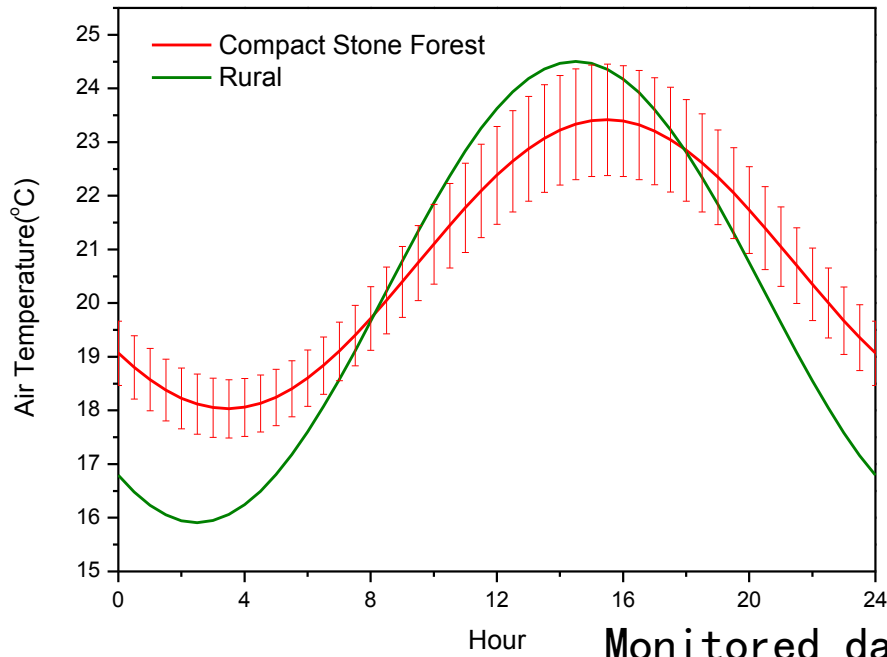


Low-rise sparse

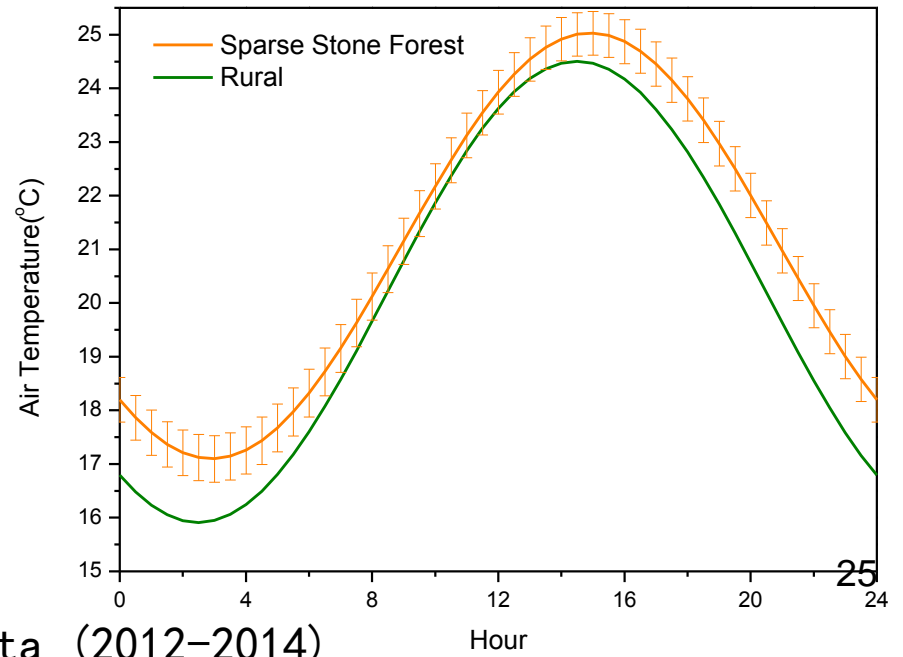
(5~10m height, >5m distance)



Similar to Hong Kong?



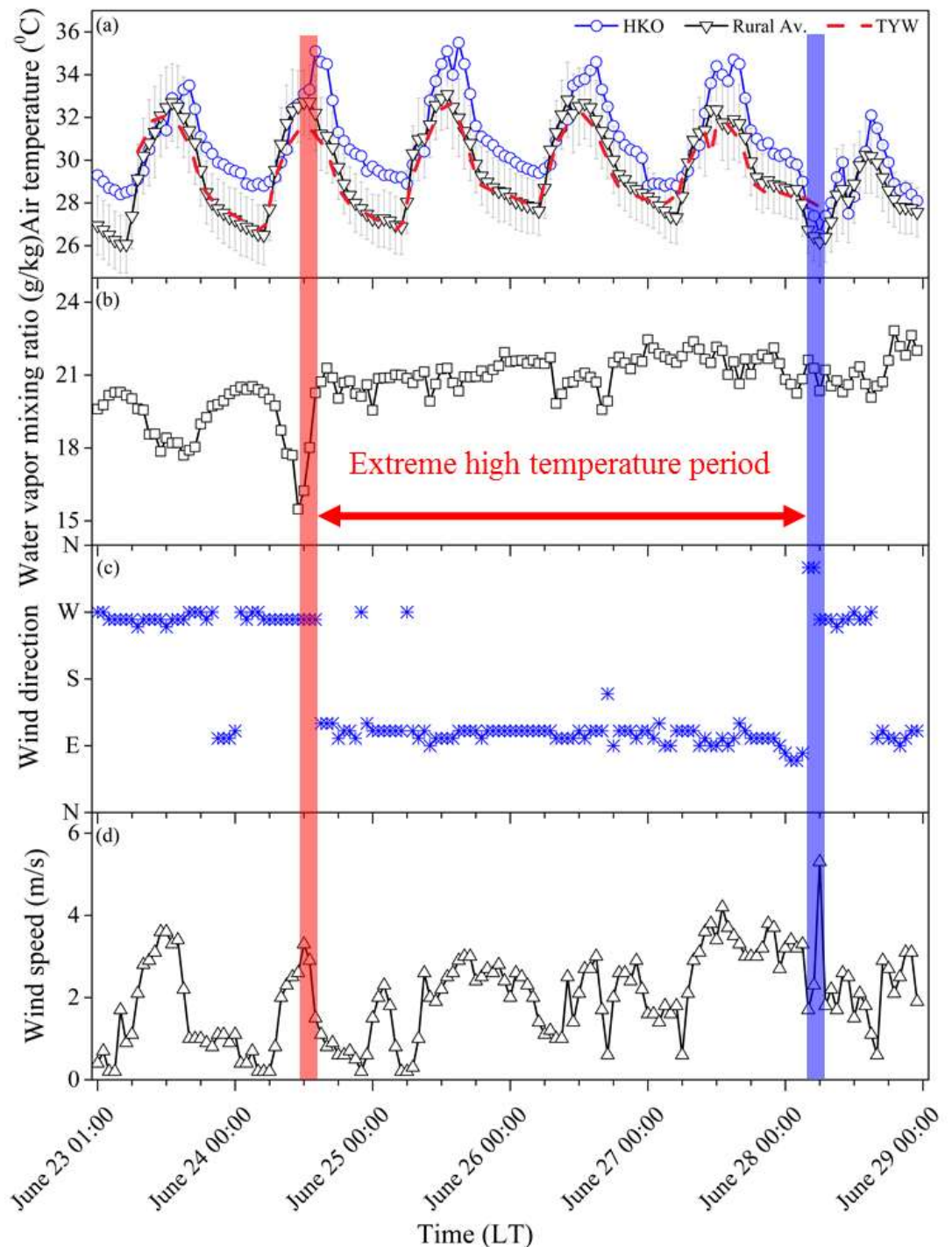
Similar to some sparse cities?



An extreme high temperature event in HK in 2016

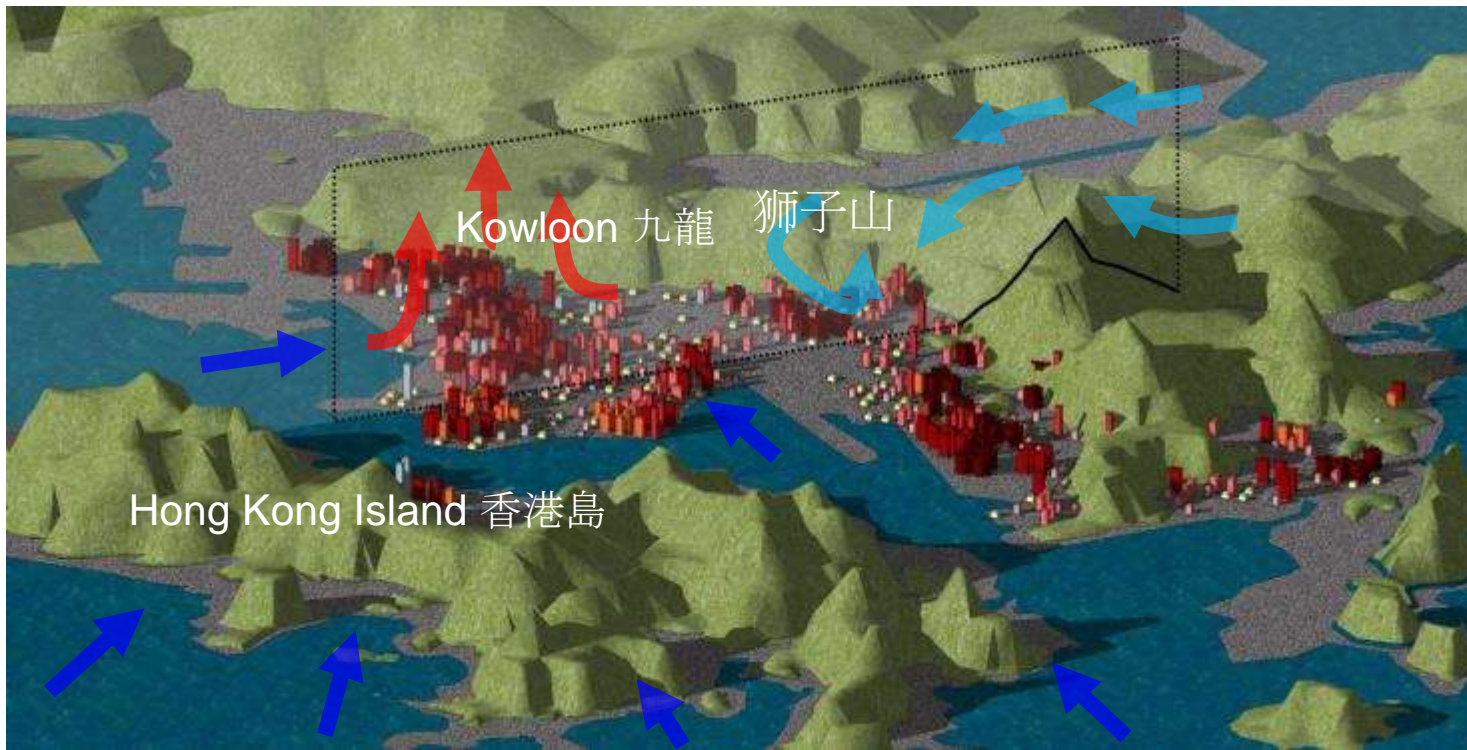
35.0 degrees from 24 to 27 June 2016, breaking the previous record of three consecutive days from 30 May to 1 June in 1963.

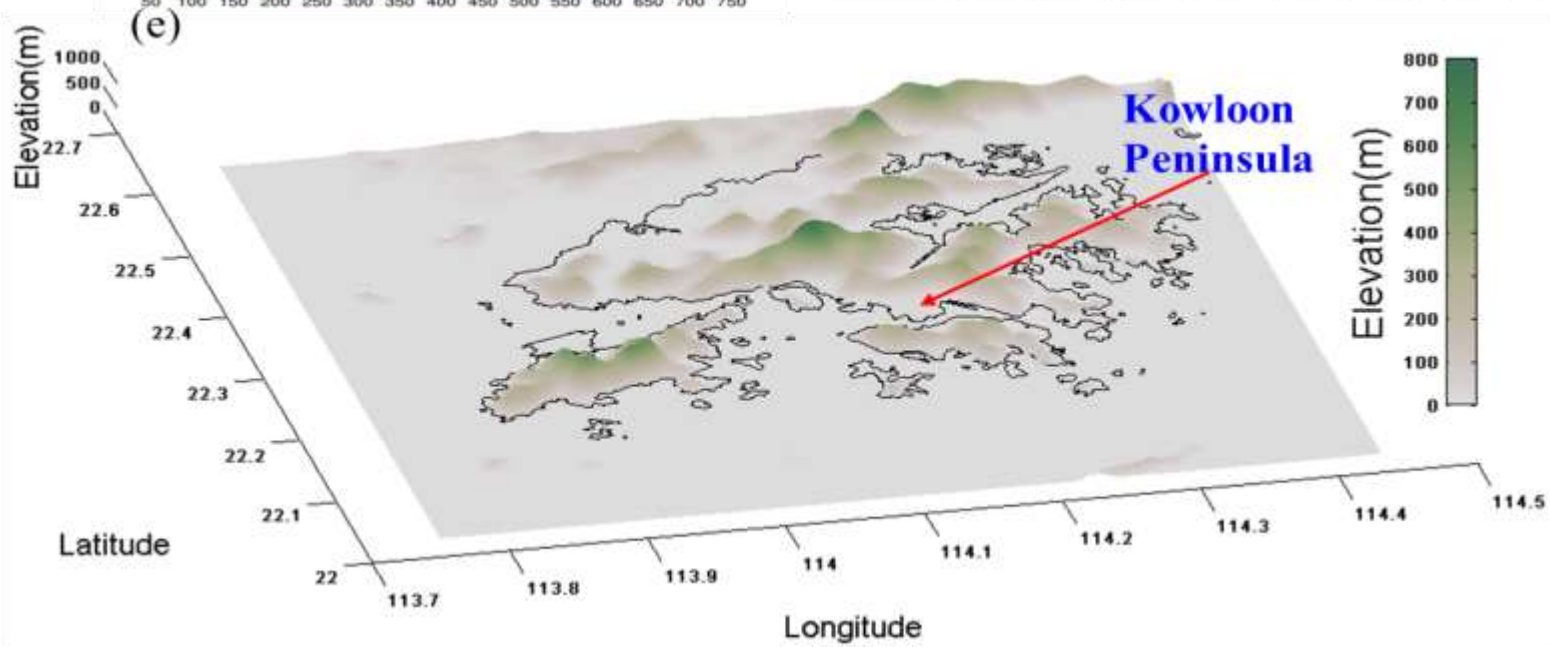
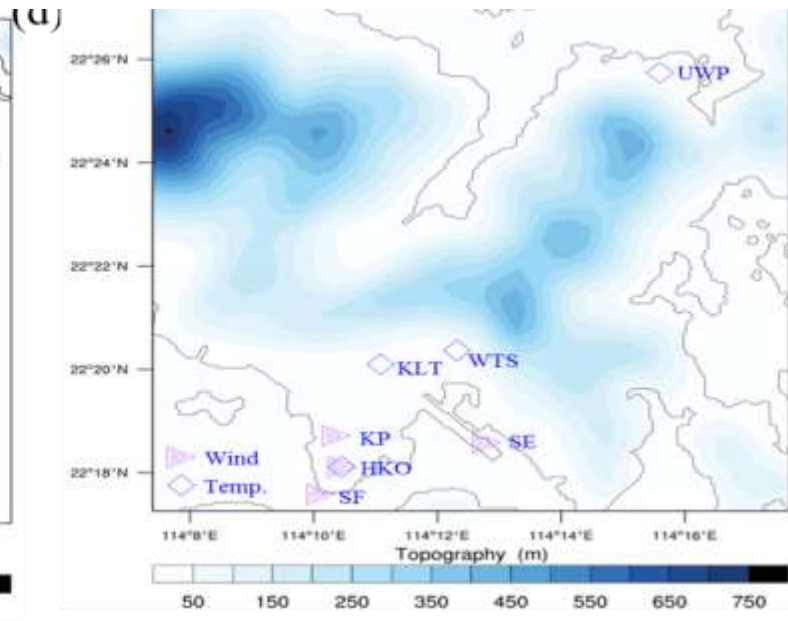
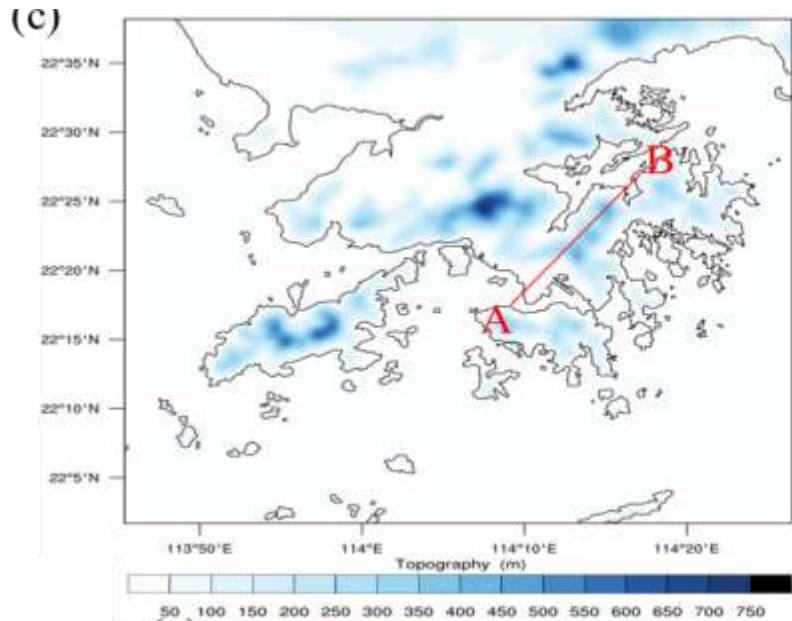
Wang Yi
PW Chan, HKO
TC Lee, HKO



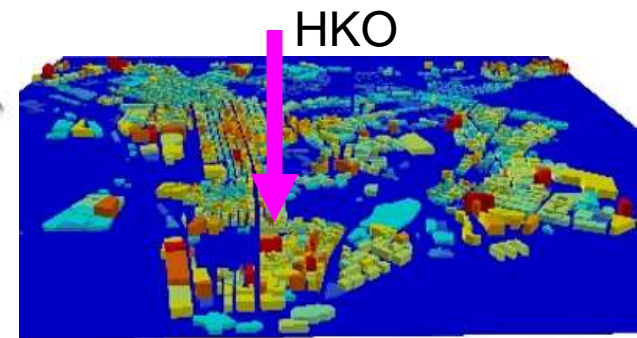
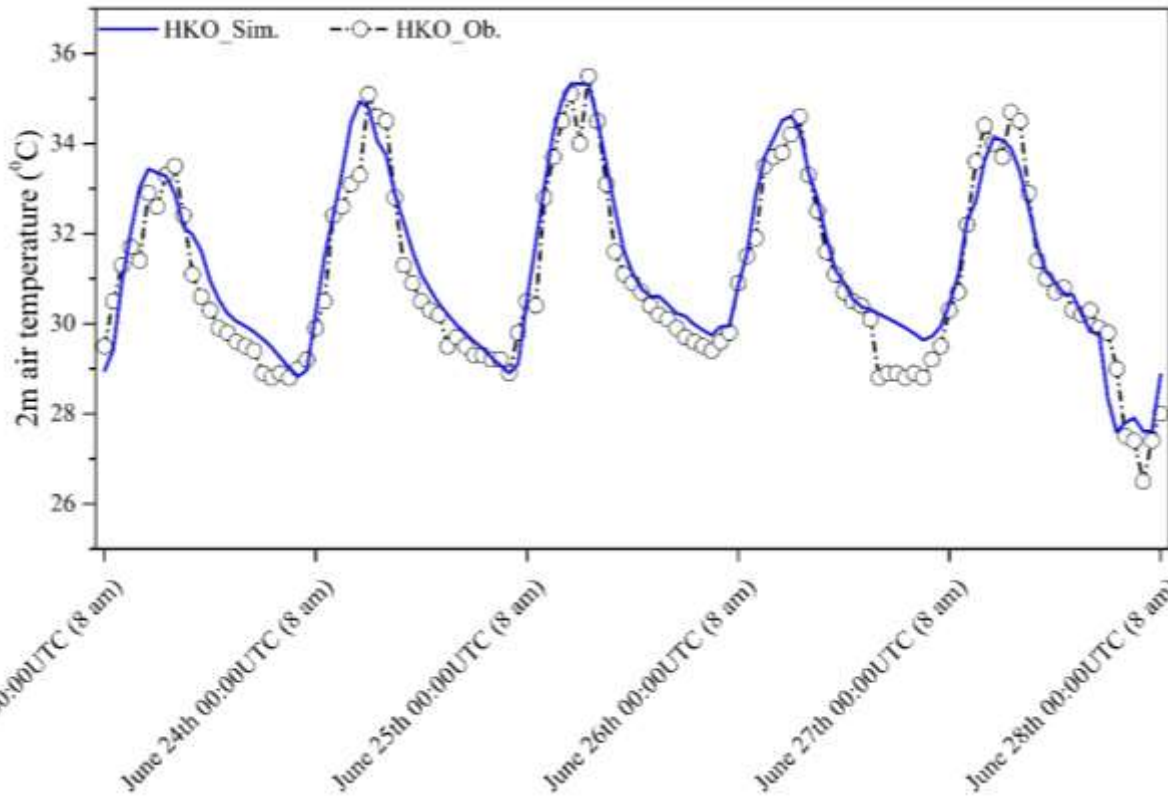
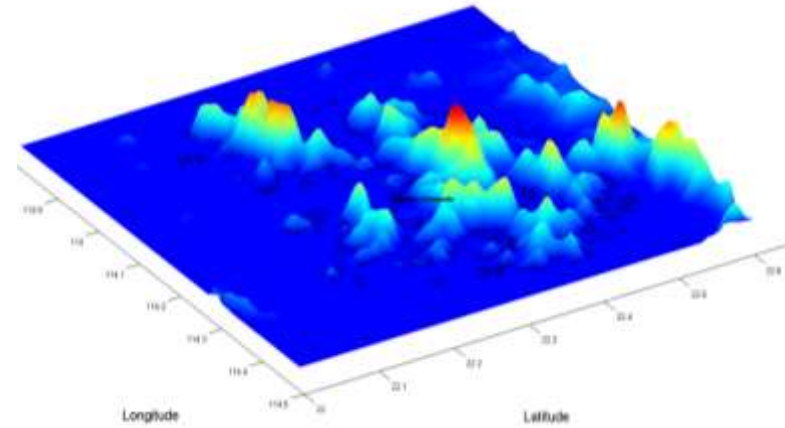


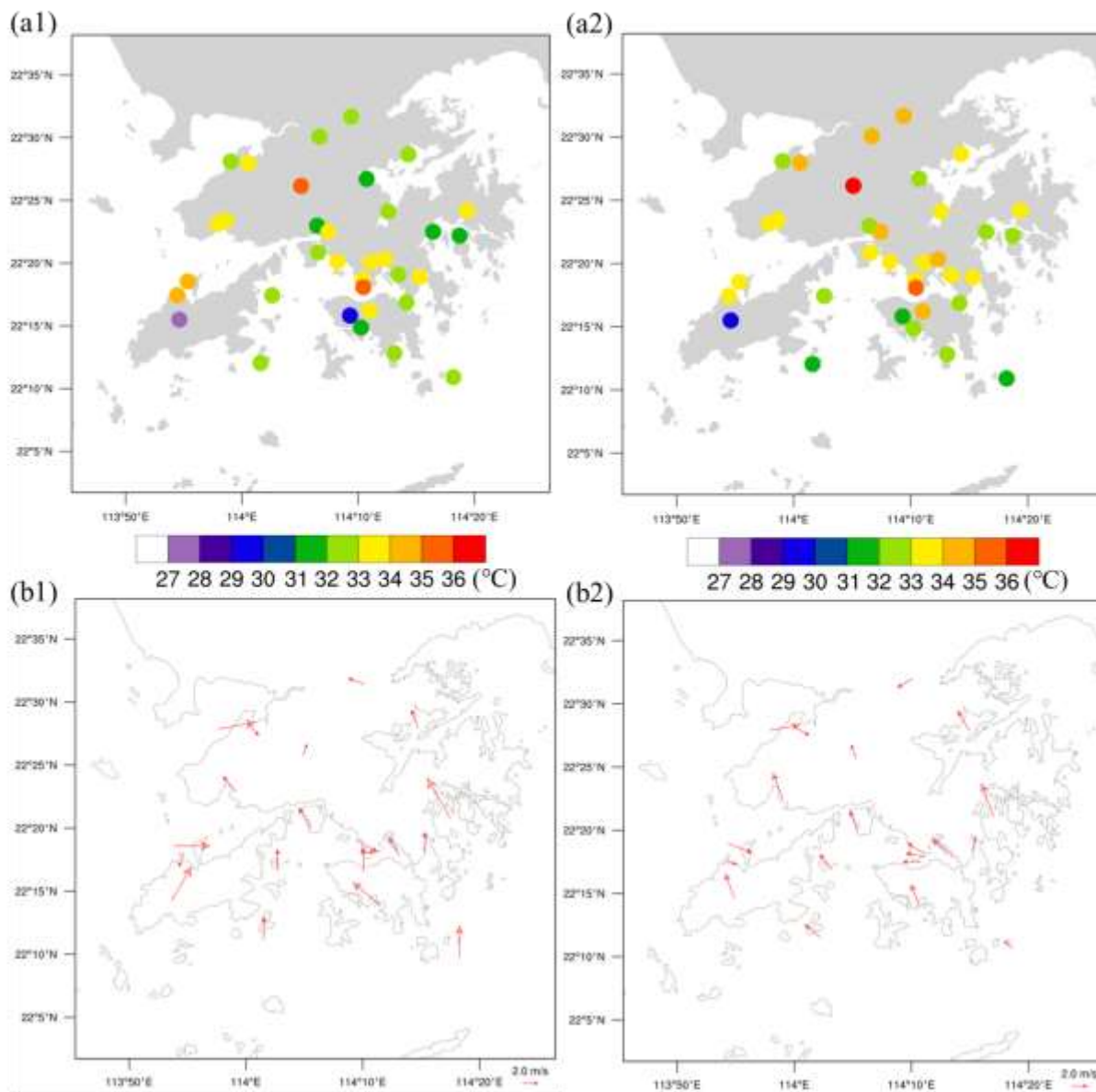
Elevated buildings, open high-rise, use sea breeze, lake breeze, river wind etc



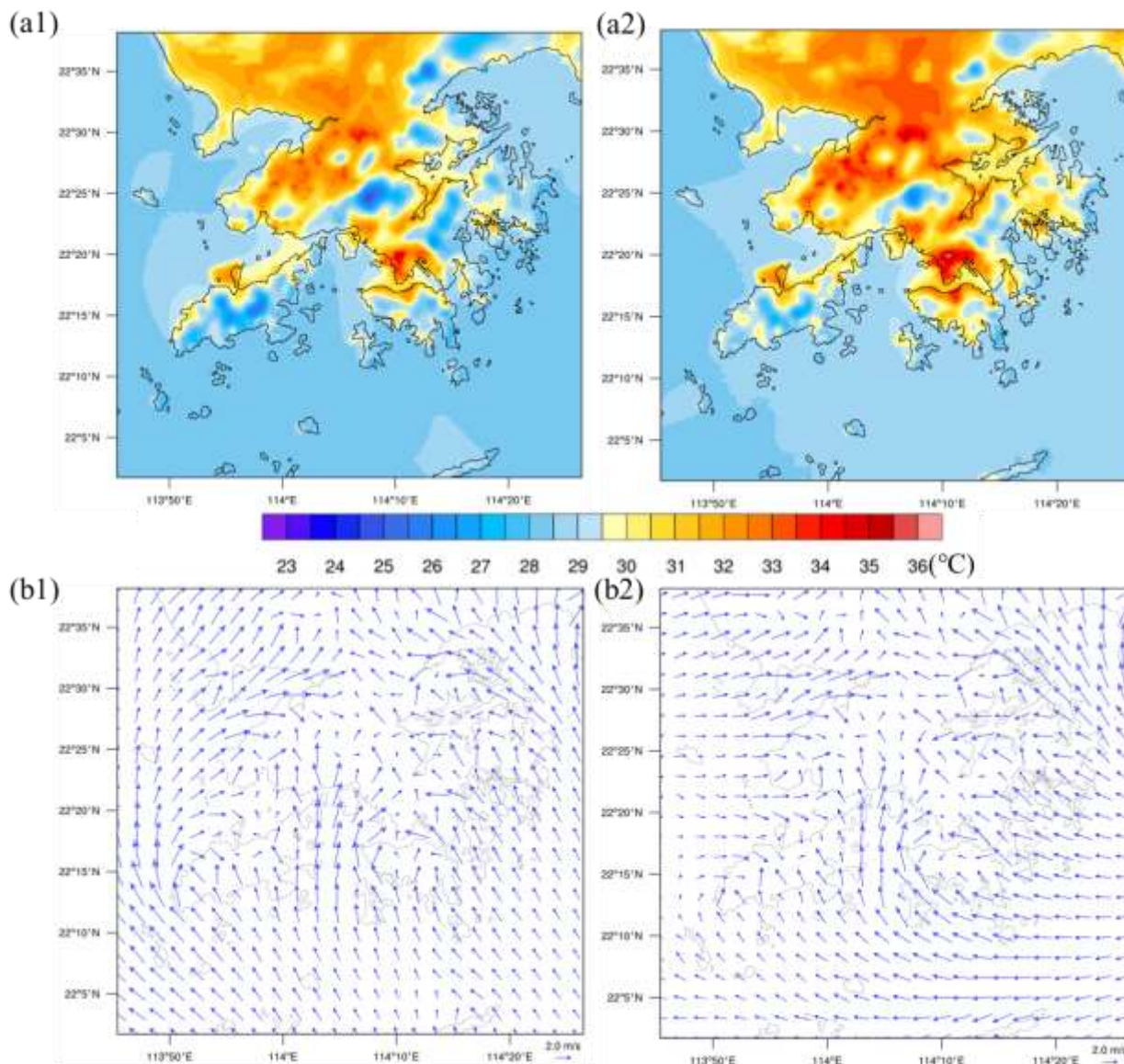


Using meso-scale Weather Research and Forecasting (WRF) modelling, and see what has happened?

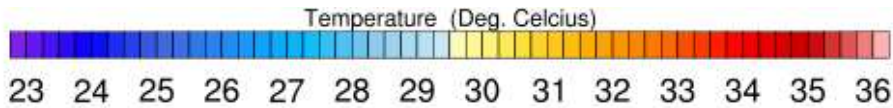




Observation results on 2m air temperature at (a1) 3:00 pm on 24 June, 2016 and (a2) 2:00 pm on 25 June, 2016; observation results of 10m wind fields at (b1) 3:00 pm on 24 June, 2016 and (b2) 2:00 pm on 25 June, 2016. All are in Local Time.



Simulation results on 2m air temperature at (a1) 3:00 pm on 24 June, 2016 and (a2) 2:00 pm on 25 June, 2016; observation results of 10m wind fields at (b1) 3:00 pm on 24 June, 2016 and (b2) 2:00 pm on 25 June, 2016. All are in Local Time.



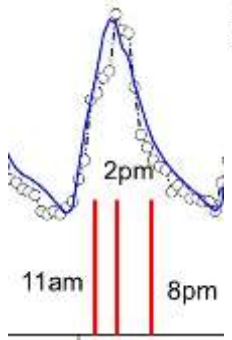
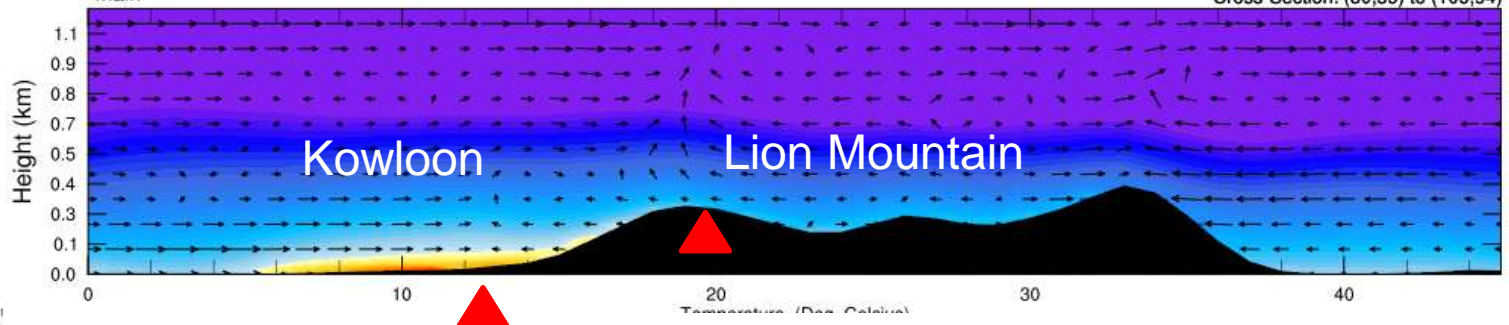
1.5 m/s
→



Temperature (Deg. Celcius)
x-wind component (m s⁻¹)
Main

2016-06-24_03:00:00UTC 11am

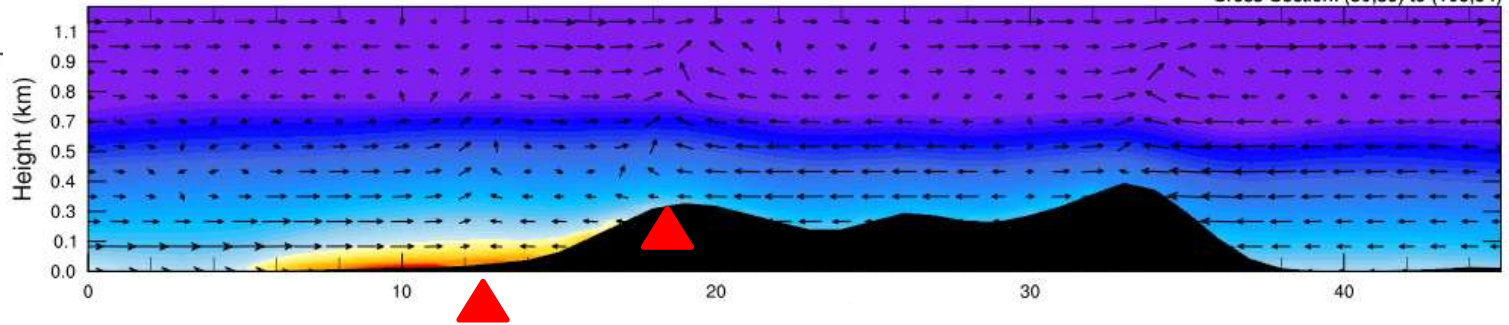
Cross-Section: (80,59) to (109,94)



Temperature (Deg. Celcius)
x-wind component (m s⁻¹)
Main

2016-06-24_04:00:00UTC 12pm

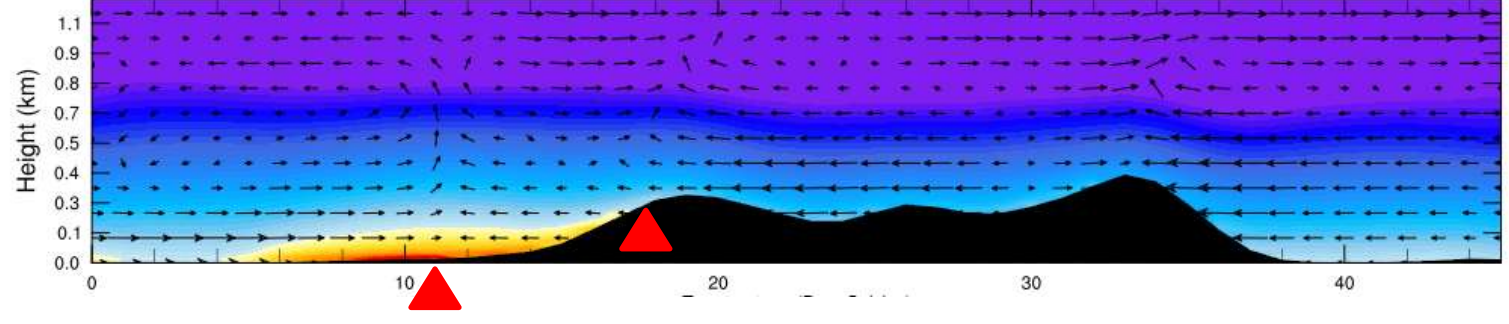
Cross-Section: (80,59) to (109,94)

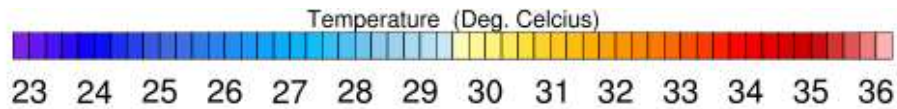


Temperature (Deg. Celcius)
x-wind component (m s⁻¹)
Main

2016-06-24_05:00:00UTC 1pm

Cross-Section: (80,59) to (109,94)





1.5 m/s
→

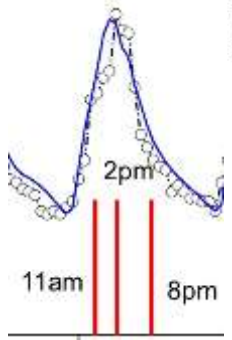
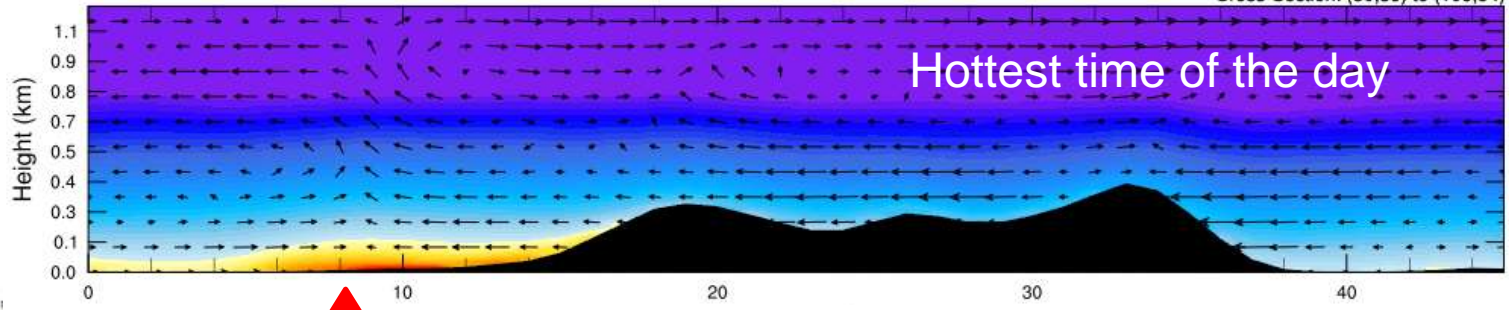


Temperature (Deg. Celcius)
x-wind component (m s-1)
Main

2016-06-24_06:00:00UTC

2pm

Cross-Section: (80,59) to (109,94)

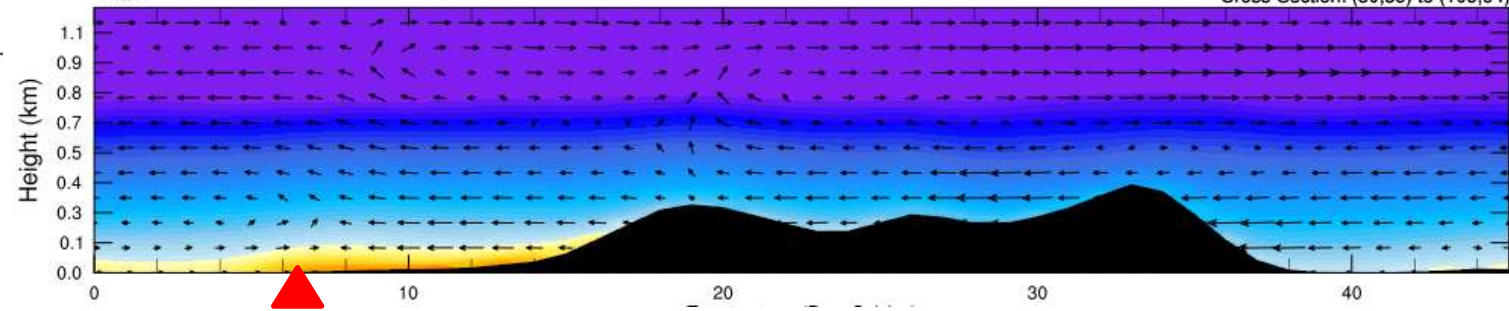


Temperature (Deg. Celcius)
x-wind component (m s-1)
Main

2016-06-24_07:00:00UTC

3pm

Cross-Section: (80,59) to (109,94)

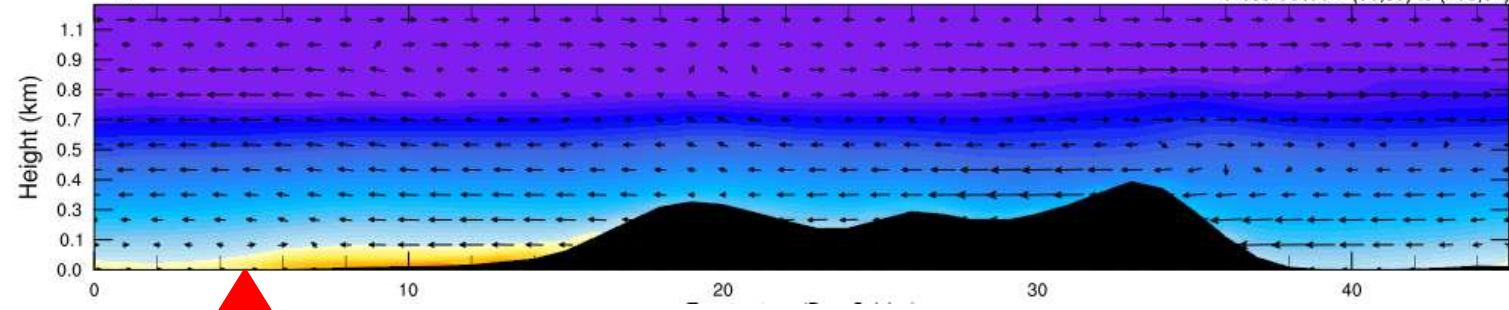


Temperature (Deg. Celcius)
x-wind component (m s-1)
Main

2016-06-24_08:00:00UTC

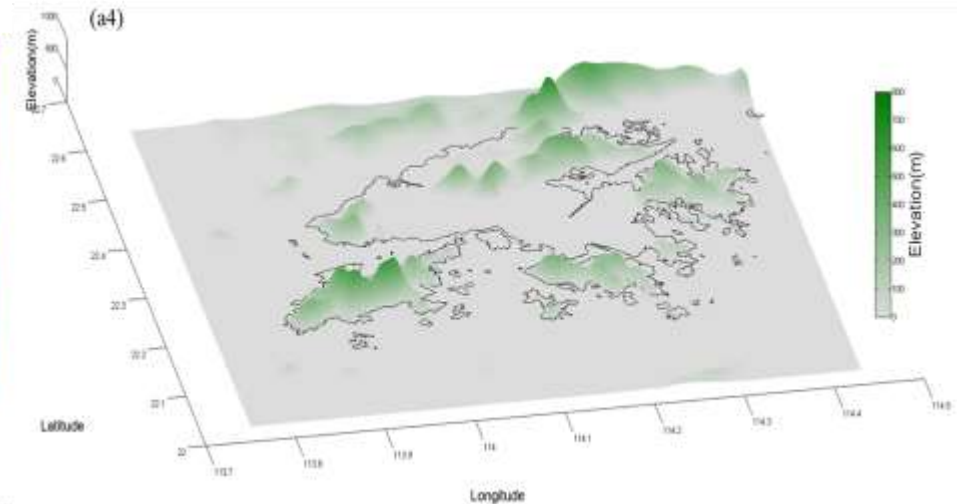
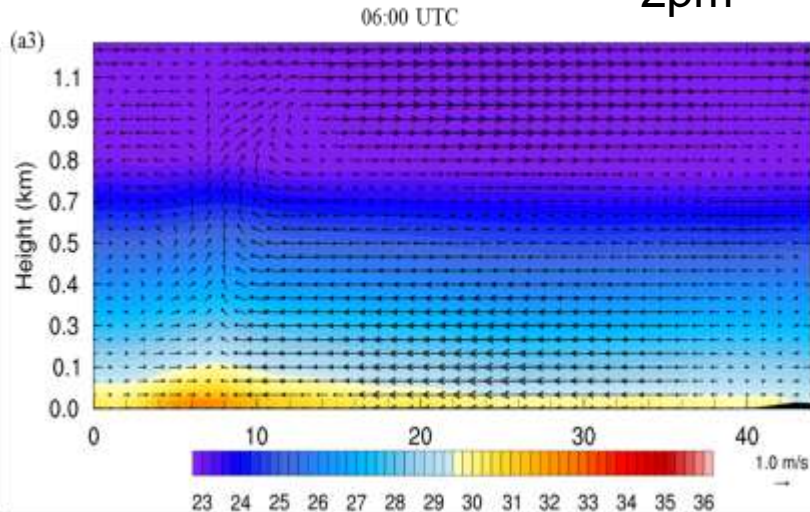
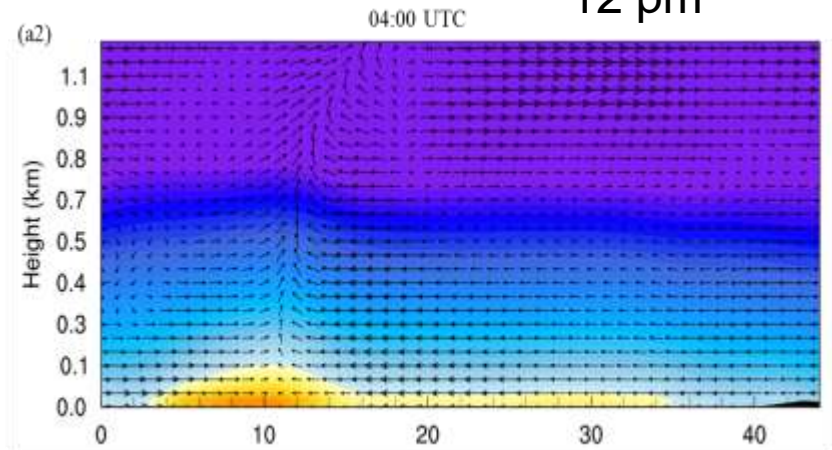
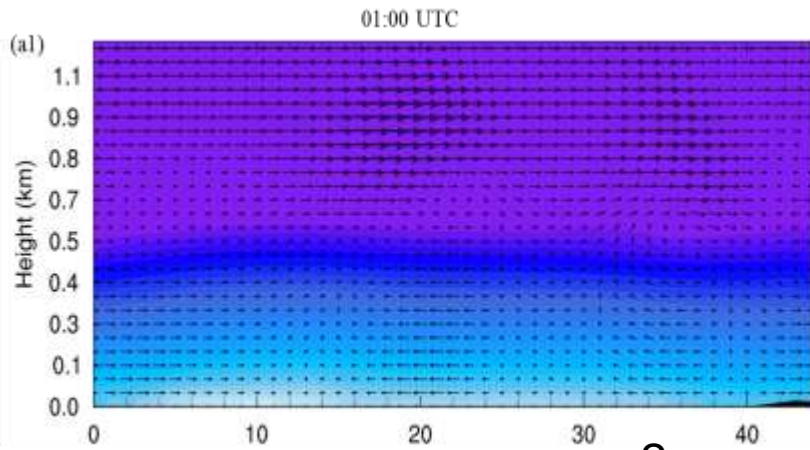
4pm

Cross-Section: (80,59) to (109,94)



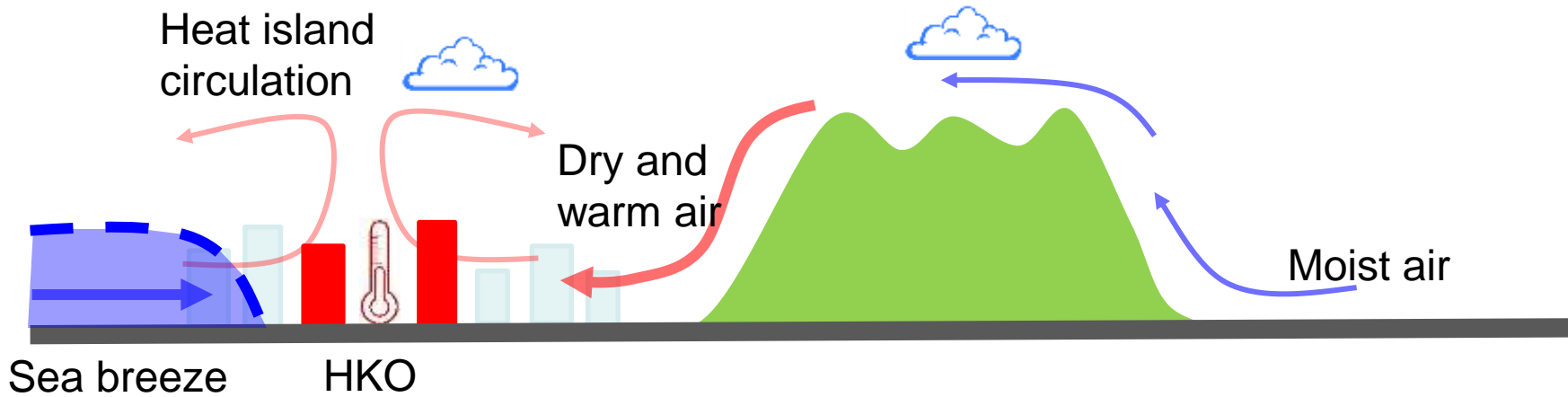
Local time: 9 am

12 pm



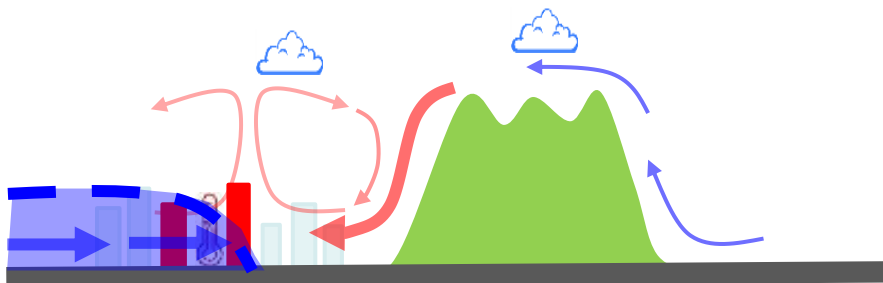
The vertical cross section (the same as transect A-B shown in Figure 1c) of simulated wind vectors (m/s), temperature (shaded) ($^{\circ}\text{C}$) from ground level up to 1.2 km at 01:00 UTC (a1), 04:00 UTC (a2), and 06:00 UTC (a3) on **24 June, 2016** for No_Moun Case; (a4) topography of No_Moun in the innermost domain. 34

Interacting of the foehn wind and sea breeze

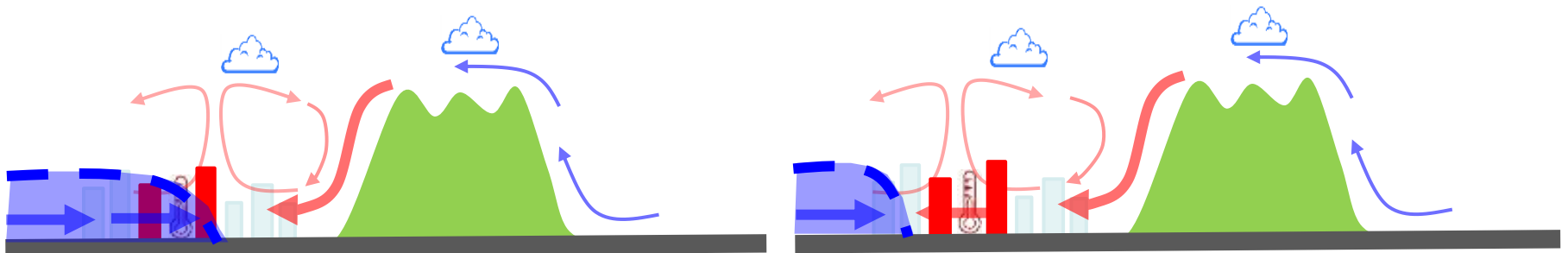


Under weak wind conditions, possible interaction of sea breeze and UCHIC assisted foehn wind

Cool Kowloon Situation



Hot Kowloon Situation

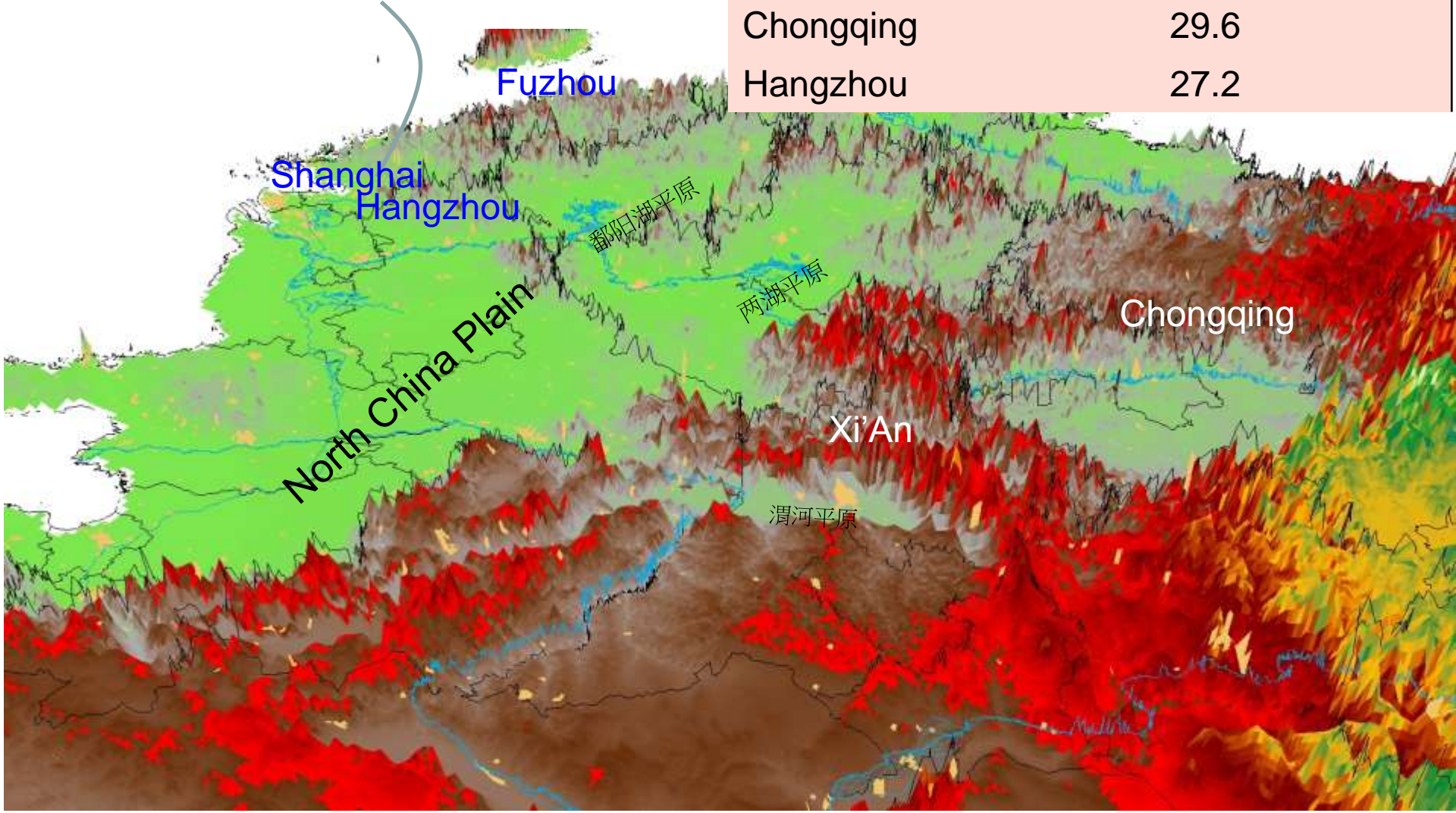


City thermal heights similar to our surrounding mountains. Each city climate should be designed accordingly.

Hottest cities in China 1 1981-2010

City	no of days for max temp $\geq 35^{\circ}\text{C}$
Fuzhou	32.6
Chongqing	29.6
Hangzhou	27.2

Extreme heat 41.6°C
9 Aug 2013



Thank you