Department of GEOGRAPHY | THE UNIVERSITY OF HONG KONG

SDG13: Microclimate Sensor Development & GEOG Field Work Study

4 JUL 2025

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Urban Heat Island and Land-Atmosphere Interface

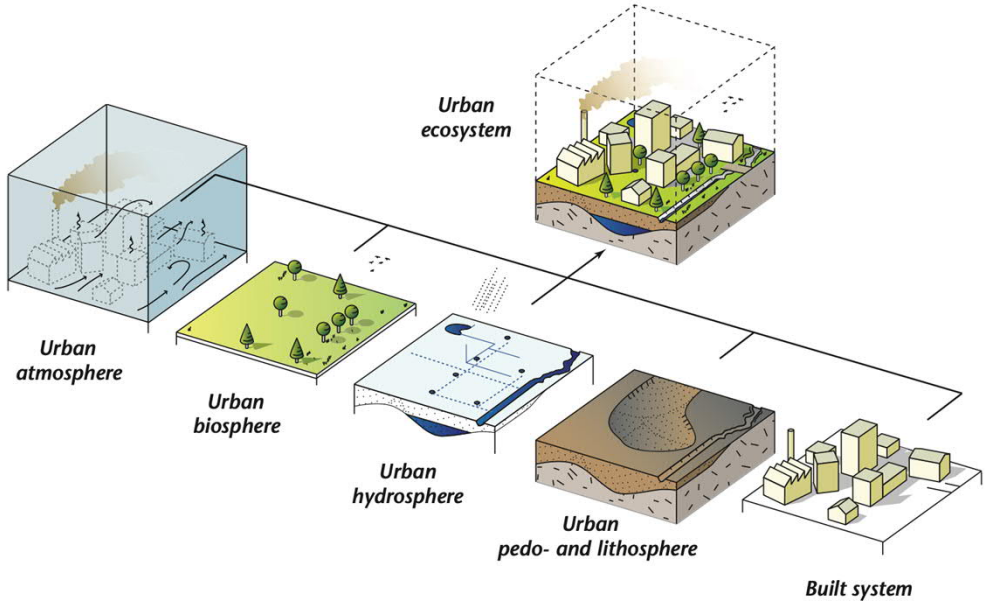
城市熱島 與 陸地-大氣界面

1 Urban Heat Island and Land-Atmosphere Interface

Urban ecosystems

is the science of the relationships among living organisms, their communities and their abiotic environment in cities (Sukopp, 1998)

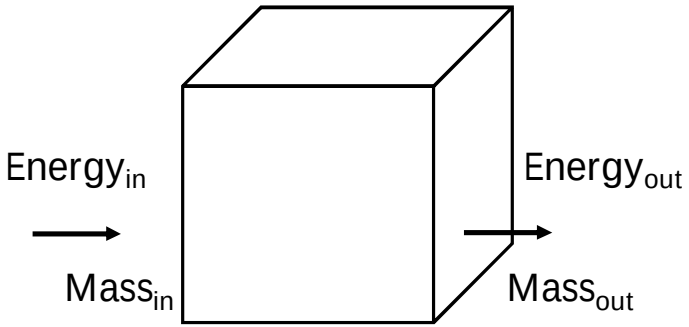
→ Vegetation
→ Animals
→ People

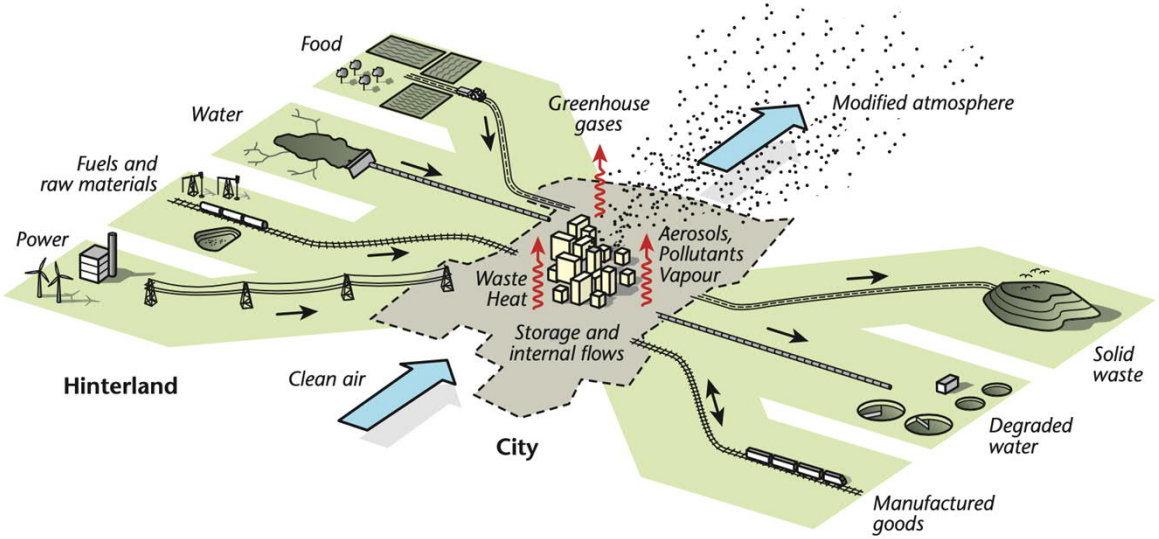


Ecosystems are created and reshaped in the process of urban development and urban transformation

1 Urban Heat Island and Land-Atmosphere Interface

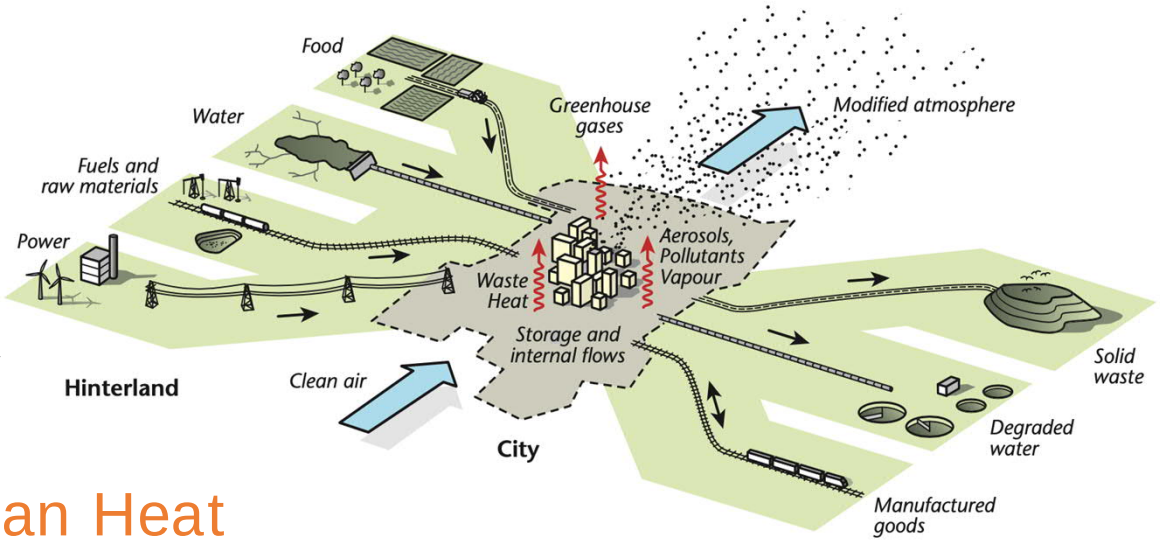
- The city is considered “an integrated open system of living things interacting
  with their physical environment” (Douglas, 1983)
- Urban metabolism describes the flow and transformation of materials and energy in a





1 Urban Heat Island and Land-Atmosphere Interface

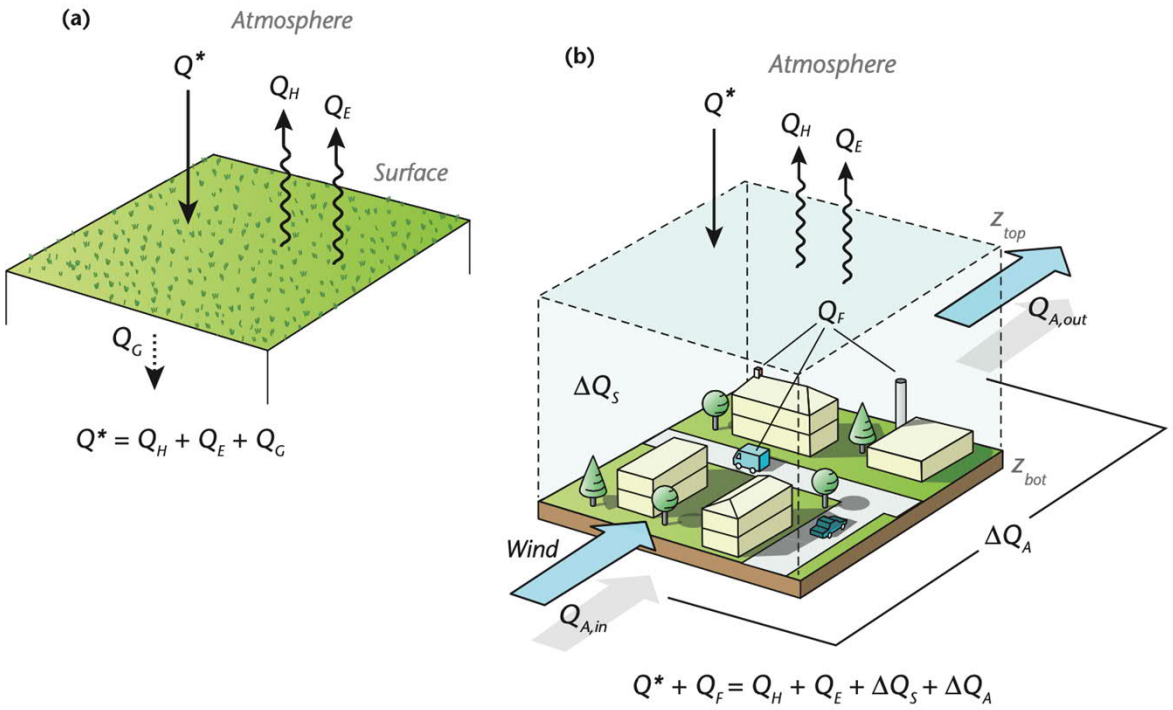
The sum of the inputs does not necessarily equal that of the outputs over a period of inventory. However, since the principle of conservation (Mass and Energy) must apply, inequality between input and output signals will change net storage by the system.



Net storage of (heat) energy in the system

= Accumulation of Urban Heat

1 Urban Heat Island and Land-Atmosphere Interface



The Surface Energy Balance Equation

Q^* Net all-wave radiation

Q_G Ground heat flux density (sensible heat)

Q_H Turbulent heat flux (sensible heat)

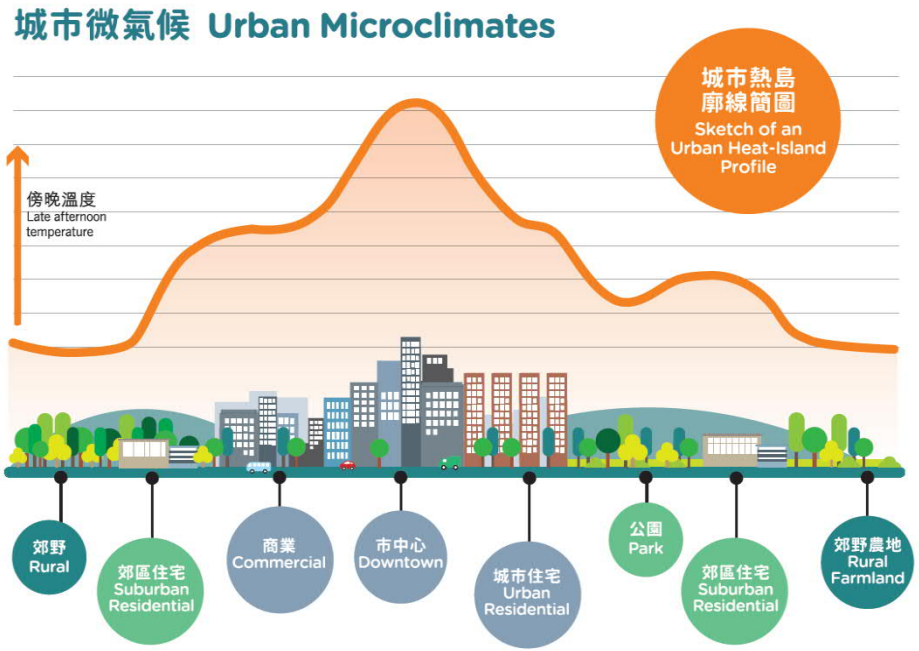
Q_E Turbulent heat flux (latent heat)

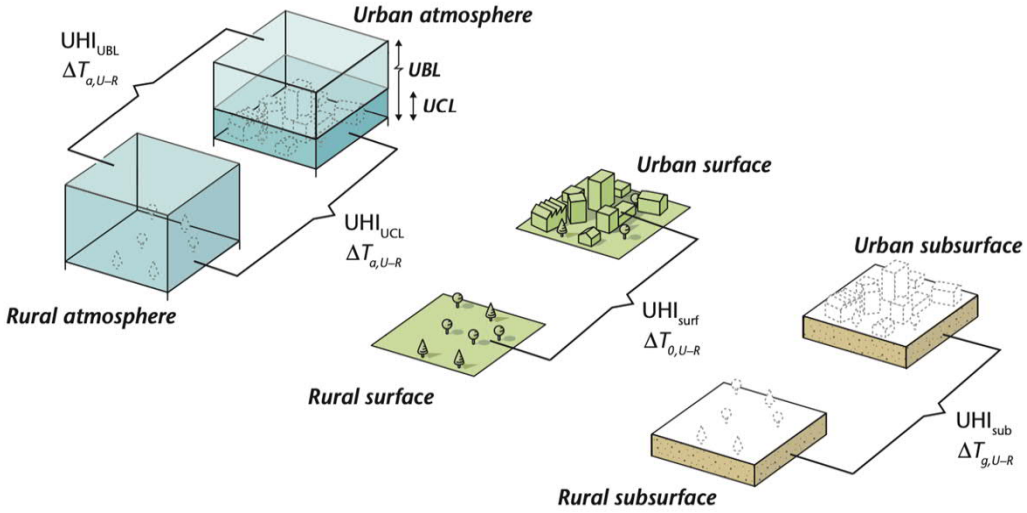
Q_F Anthropogenic heat flux
(Human living, work and travel)

ΔQ_S Net heat storage by urban fabric
(Materials, trees, ground and air)

ΔQ_A Net heat energy added by advection

1 Urban Heat Island and Land-Atmosphere Interface

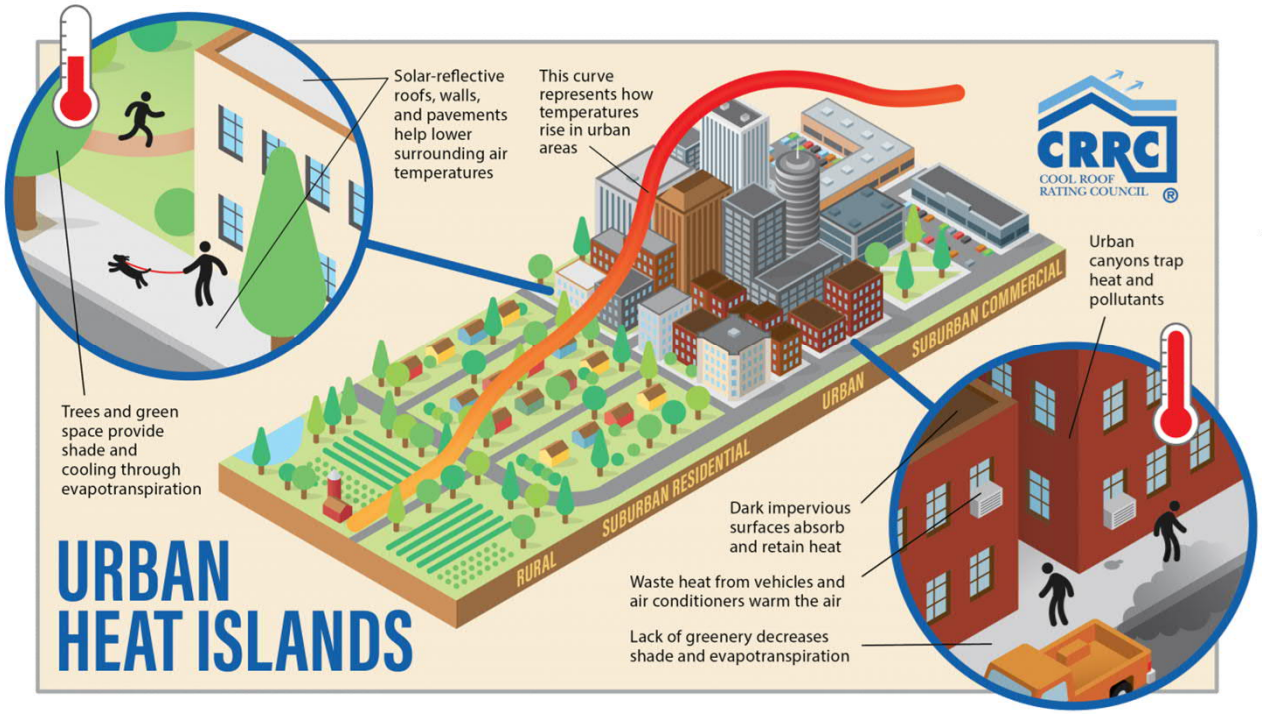




Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat.

1 Urban Heat Island and Land-Atmosphere Interface

Effects of Weather and Surface State



1. Paved and impermeable surfaces
2. Thermal mass (Buildings)
3. Lack of vegetation
4. Waste heat
   (From transportation, air-con, etc.)
5. Climate change impacts

Wind Speed

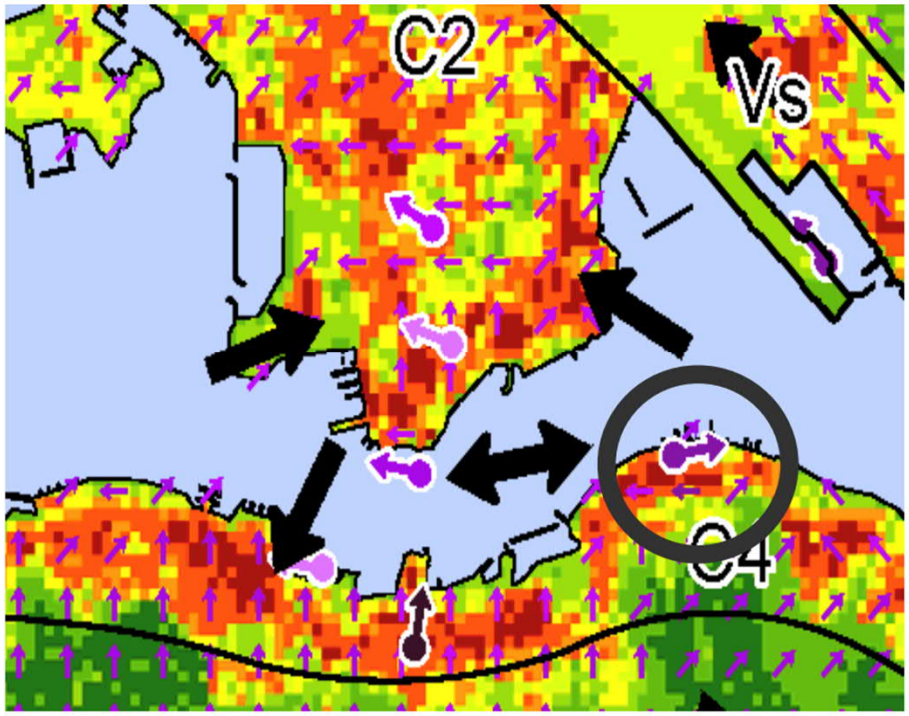
Cloud

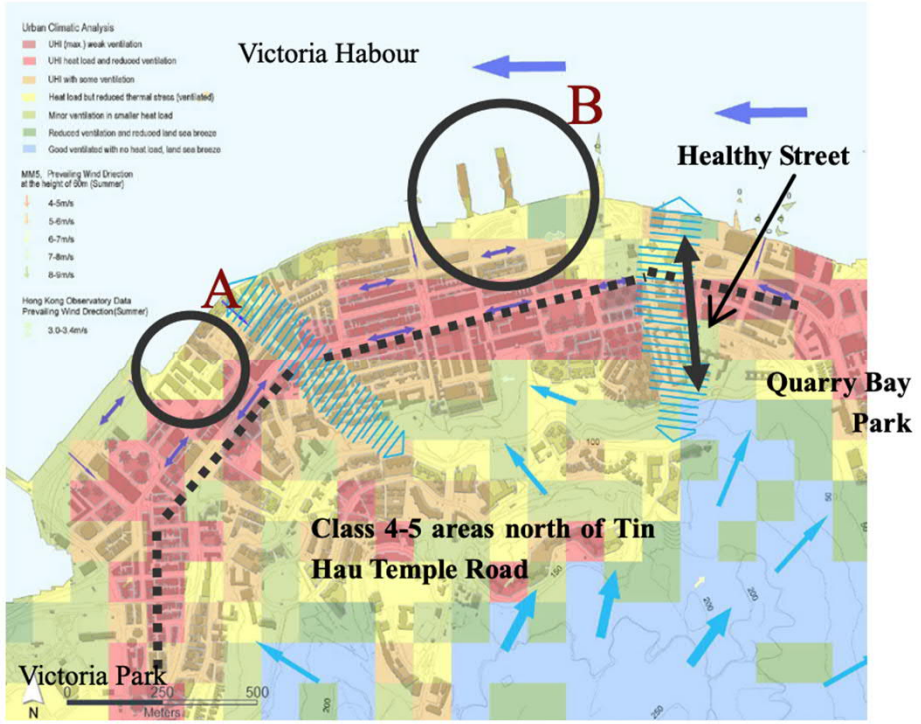
Soil Surface

Impact of Weather Effects

1 Urban Heat Island and Land-Atmosphere Interface

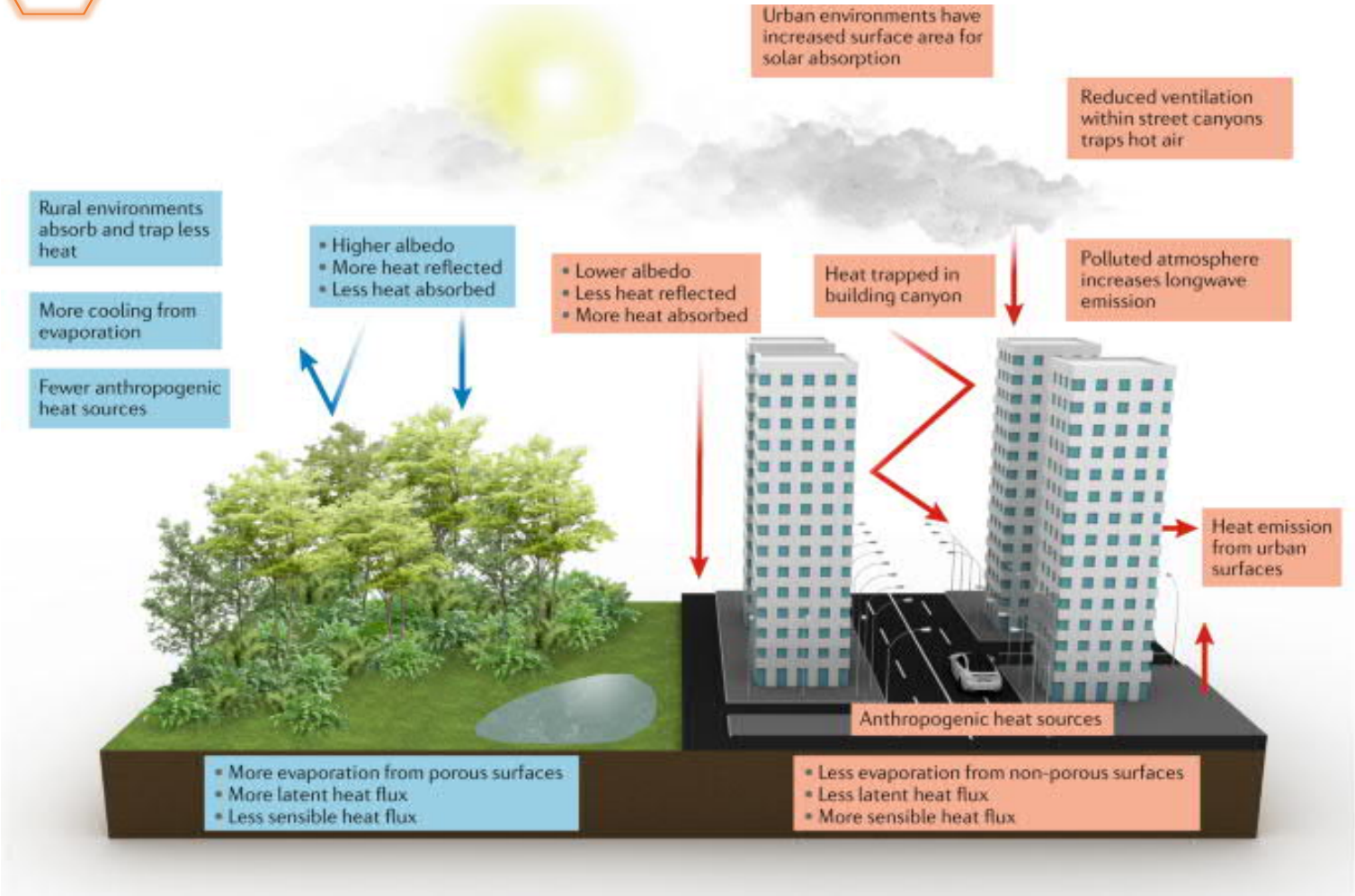
Urban Heat Heterogeneity in Hong Kong





Ng E., Ren C., Katzschner L. (2012) Urban Climatic Mapping in Hong Kong. Journal of Heat island Institute International Vol.7-2

1 Urban Heat Island and Land-Atmosphere Interface



Methodologies in Urban Climate Assessment

城市氣候評估方法

2 Methodologies in Urban Climate Assessment

(a) Field Observations

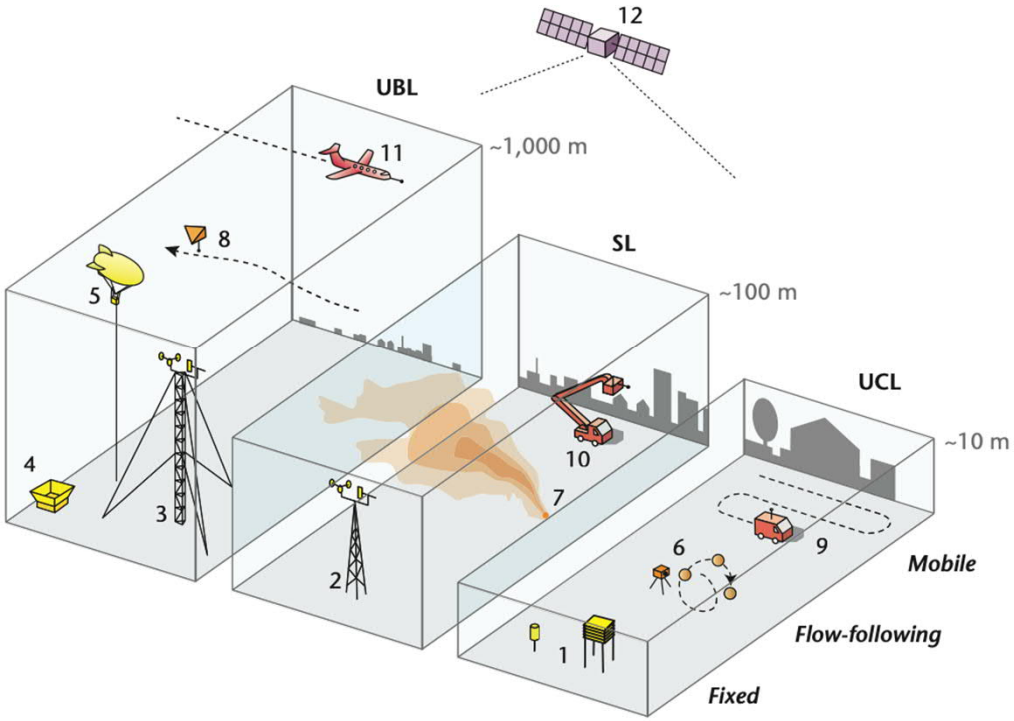
Two main types of observations are deployed.

(1) Instrumented station situated to provide long-term but routine urban meteorological information (e.g. hourly readings of air temperature, pressure, wind and pollutants)

(2) Field campaign established to evaluate some aspect of the urban climate, often to answer specific questions. These campaigns have a shorter life but their particular *foci* may require instruments that are uncommon, or are placed in dense configurations, or record at unusually high frequency.

2 Methodologies in Urban Climate Assessment

(a) Field Observations



(1) Stevenson Screen
(2) Meteorological tower at least 1.5zH high
(3) Tall tower
(4) Ground-based remote-sensing platforms
(5) Tethered balloon with instruments that are winched up and down
(6) Flow-following include small-scale balloons tracked by cameras
(7) A tracer release experiment
(8) Tetroon balloon
(9) Mobile / traversing approaches (along back)
(10) Mobile crane platforms
(11) Helicopters, airplanes or drones
(12) Satellite remote-sensing

2 Methodologies in Urban Climate Assessment

(a) Field Observations

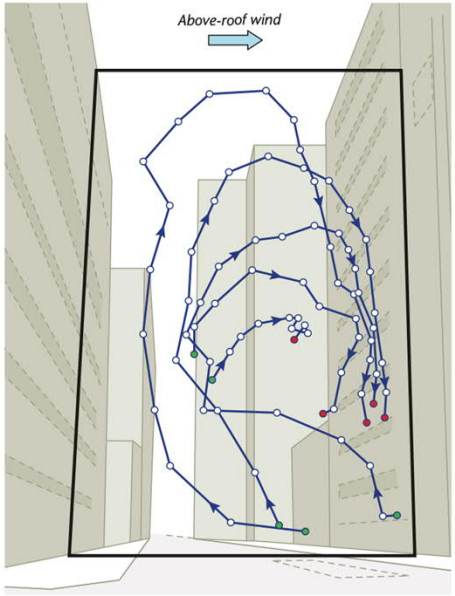


Figure 3.14 Circulation within a street canyon in Chicago, United States. The above canyon wind is perpendicular to the axis of the street and drives a vortex across the canyon cross-section. The flow pattern is revealed by the motion of neutrally buoyant balloons, whose positions were photographed at regular intervals (Source: DePaul and Sheih, 1986; © Elsevier, used with permission).

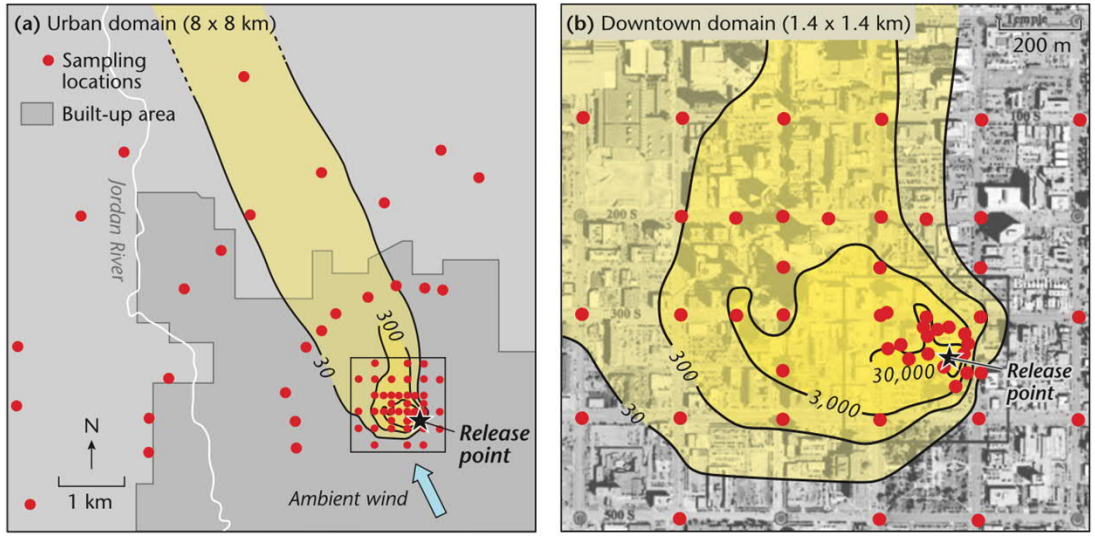
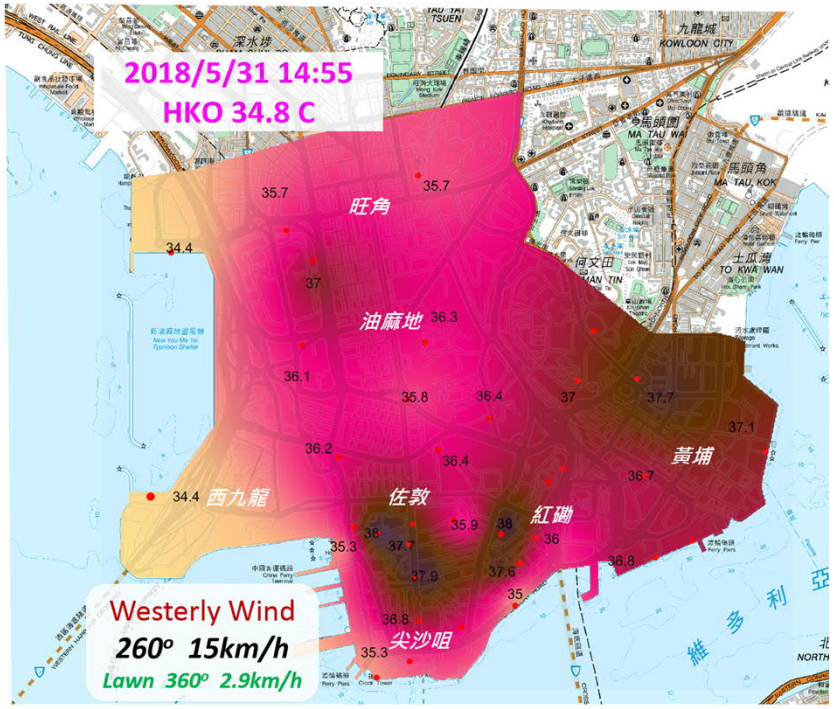
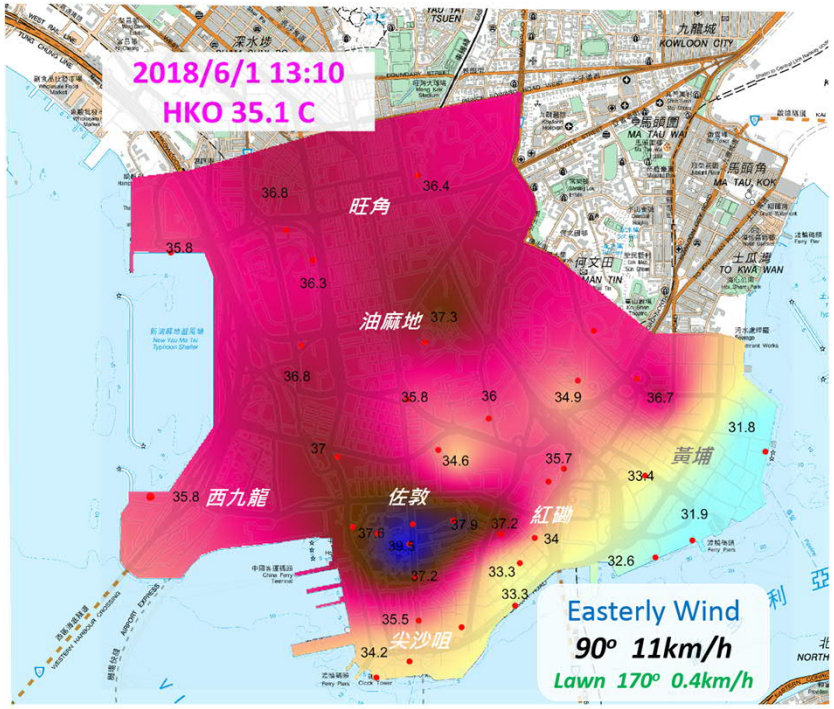


Figure 3.15 Isopleths of half-hourly average sulfur hexafluoride (SF_6) concentration in parts per trillion at the end of a one hour tracer release, conducted during a field observation campaign in Salt Lake City, United States. Results are from 0100 MST 26 Oct 2000 and show: **(a)** a portion of the urban domain and the associated arcs of sampling locations, **(b)** the downtown domain (Modified after: Allwine et al., 2002; © American Meteorological Society; used with permission).

2 Methodologies in Urban Climate Assessment

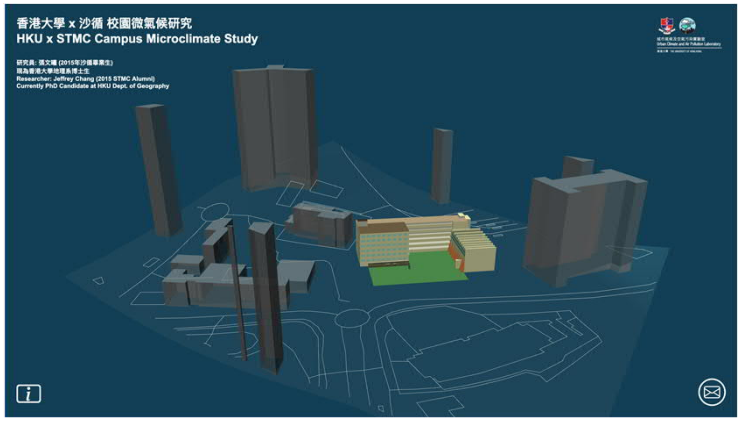
(a) Field Observations (Example)

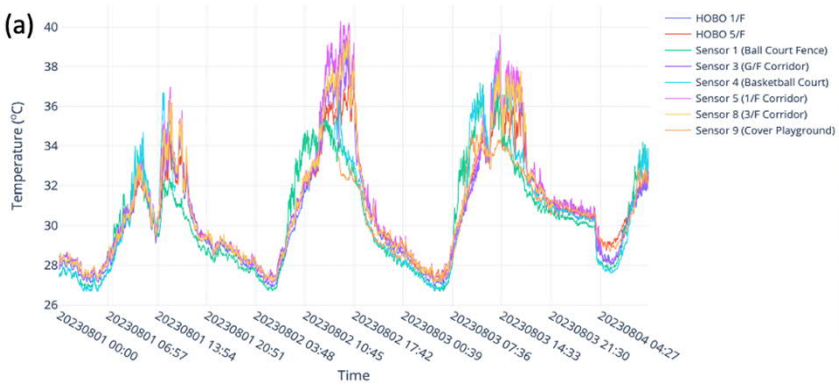




2 Methodologies in Urban Climate Assessment

(a) Field Observations (Example)

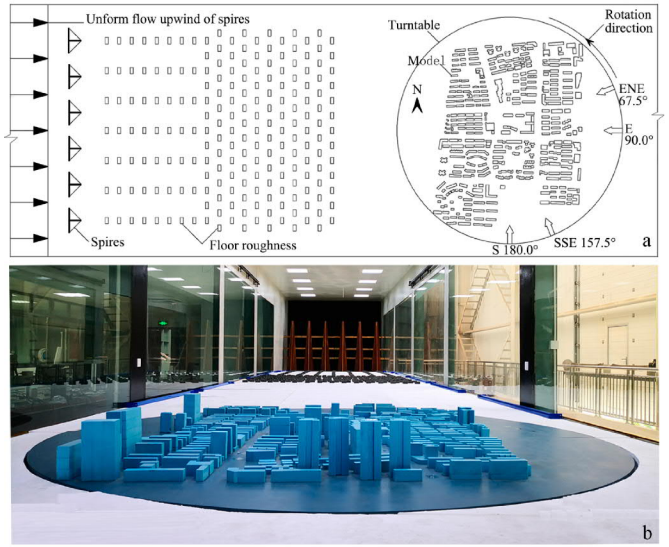


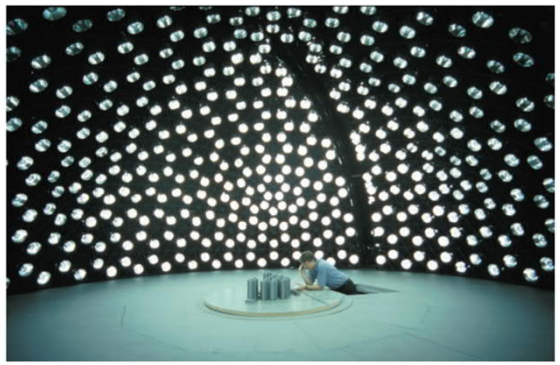


2 Methodologies in Urban Climate Assessment

(b) Physical Modelling

A physical model, also called a hardware or scale model, is a simplified surrogate of a real-world system. Models are constructed at full or reduced scale and its climatic effects result from exposure to selected conditions, sometimes described as forcings.



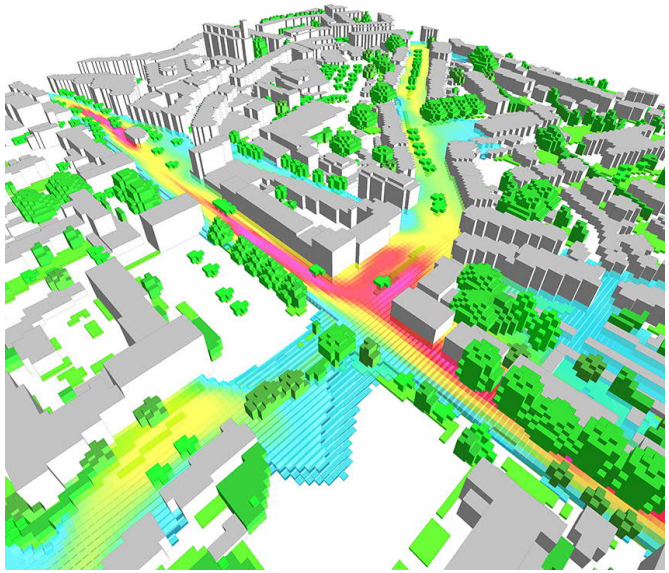


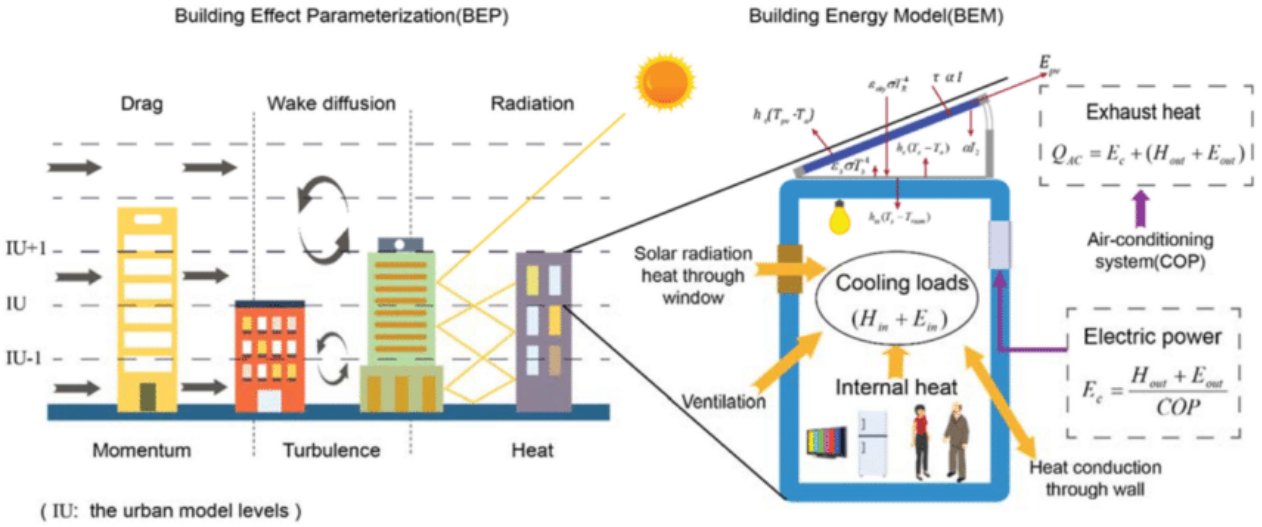
- Laboratory simulation
(i.e. Wind Tunnel, Sun machine, Scaled model)

2 Methodologies in Urban Climate Assessment

(c) Numerical Modelling

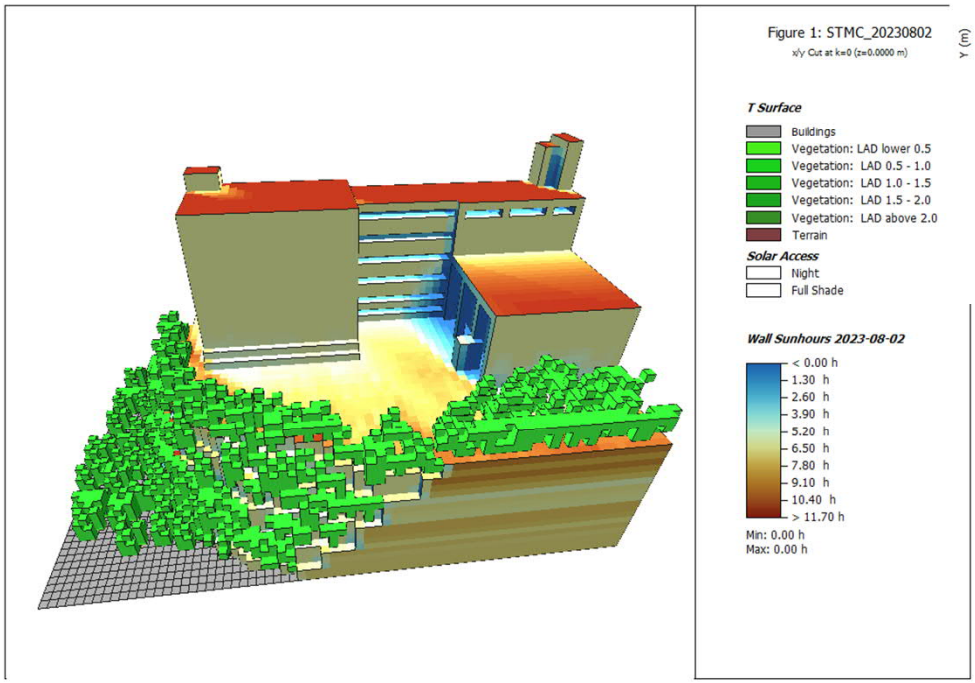
Numerical models simulate real-world phenomena using a set of equations that link properties (e.g. air temperature) to processes (e.g. sensible heat flux





2 Methodologies in Urban Climate Assessment

(c) Numerical Modelling (Example CFD Model: ENVI-Met



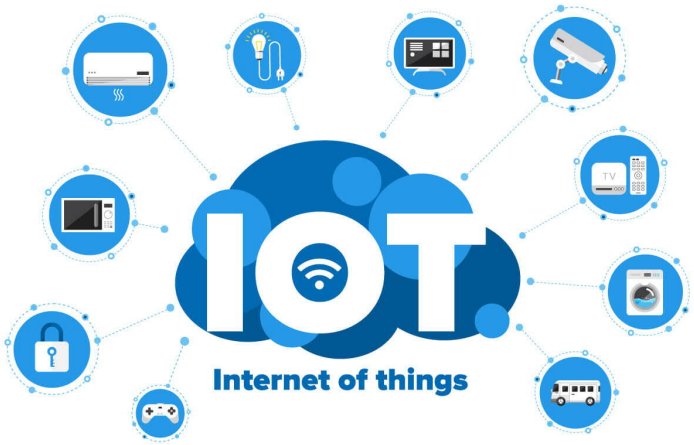
IoT Sensor Applications

物聯網感測器應用

3 IoT Sensor Applications

What is Internet of Things (IoT) ?

The Internet of Things (IoT) describes the network of physical objects THINGS

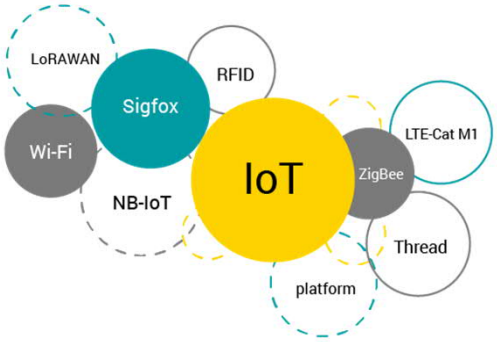


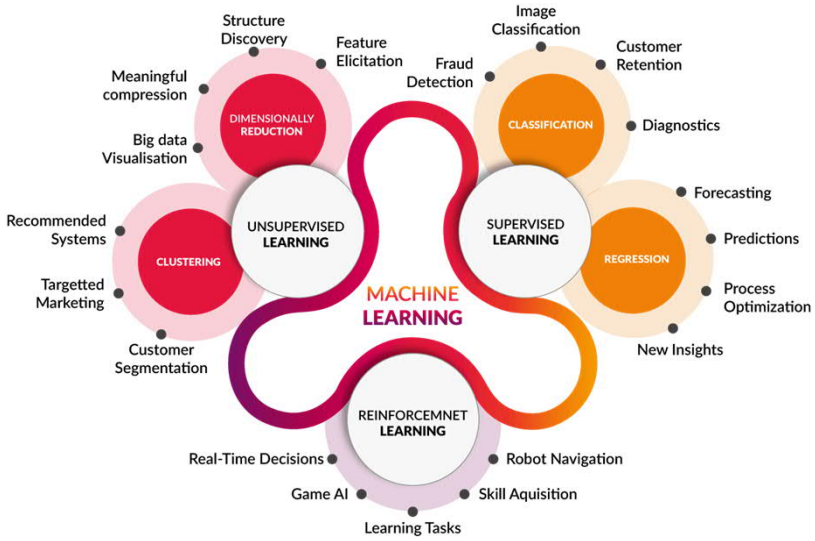
that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.

3 IoT Sensor Applications

What technologies have made IoT possible?

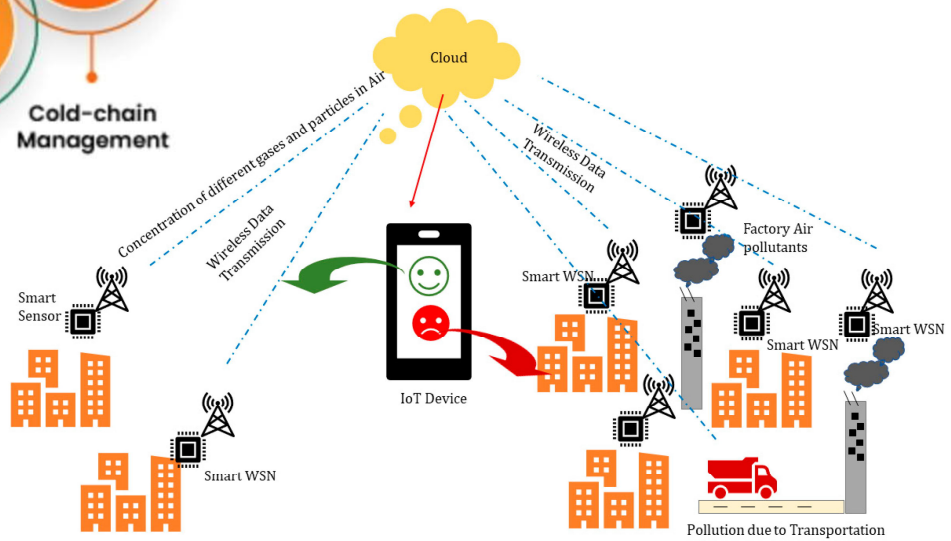
- Access to low-cost, low-power sensor technology
- Connectivity
- Cloud computer platforms
- Machine learning and analytics
- Conversational artificial intelligence (AI)





3 IoT Sensor Applications

IoT Applications in Environmental Sustainability



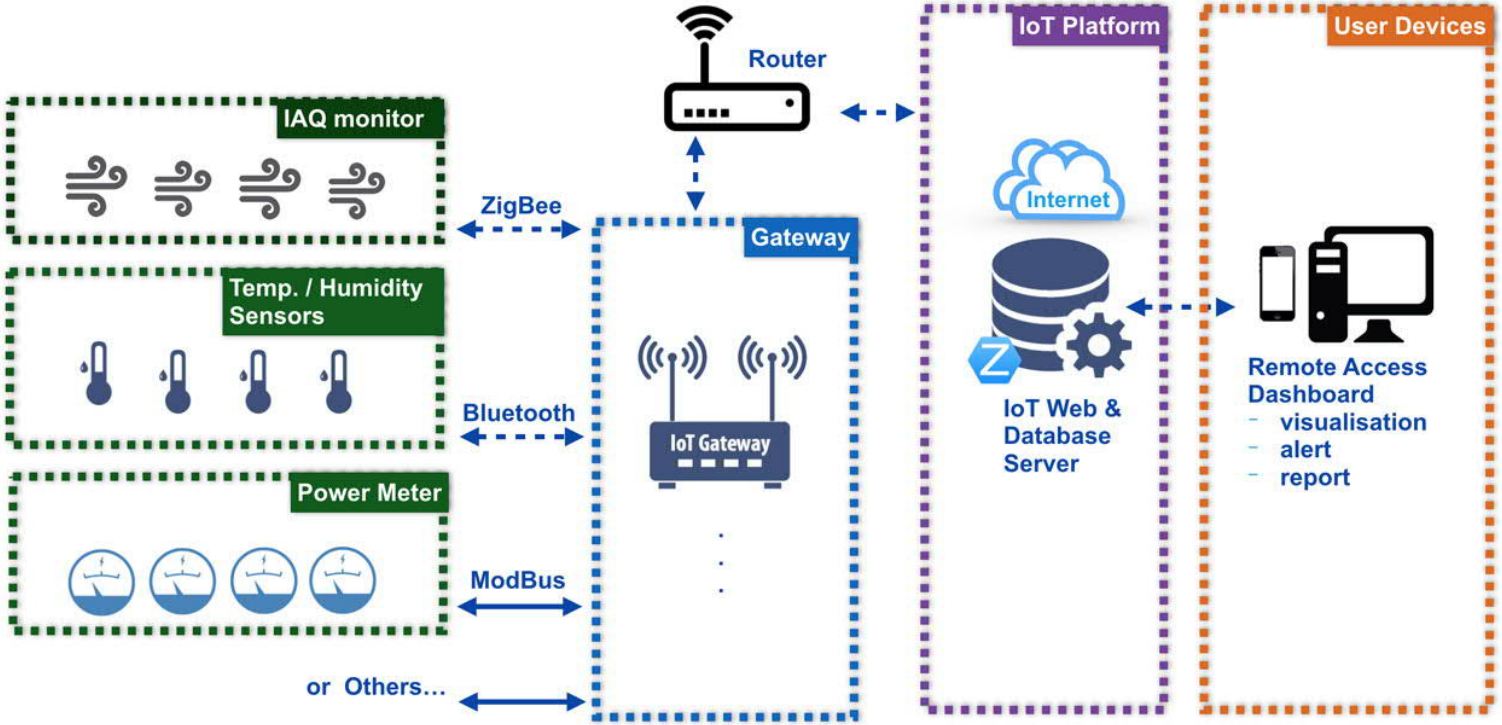
3 IoT Sensor Applications

IoT Applications in Environmental Sustainability

	Local Area Network Short Range Communication	Low Power Wide Area (LPWAN) Internet of Things	Cellular Network Traditional M2M
	40%	**45%**	**15%**
☺	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
☹	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.0 · ZigBee · Wi Fi	LoRa	GSM · 3G+ / H+ · 4G

3 IoT Sensor Applications

IoT Applications in Environmental Sustainability



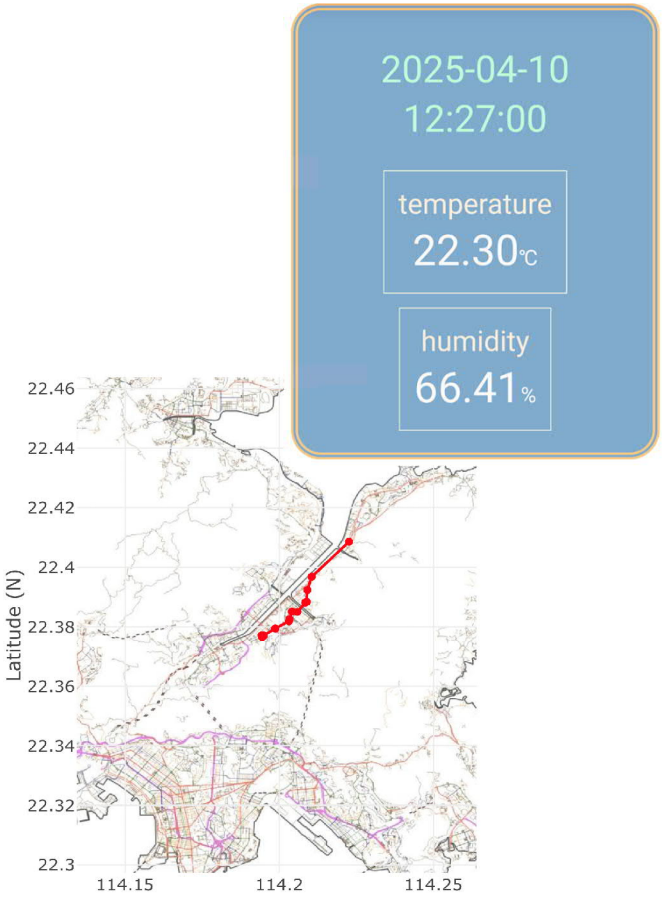
3 IoT Sensor Applications

科學為民 – 天文台微氣候監測站 https://www.youtube.com/watch?v=N8KhhqzWo1E

DIY Portable Microclimate Sensor

DIY便攜式微氣候感測器

4 DIY Portable Microclimate Sensor



Instruction Manual

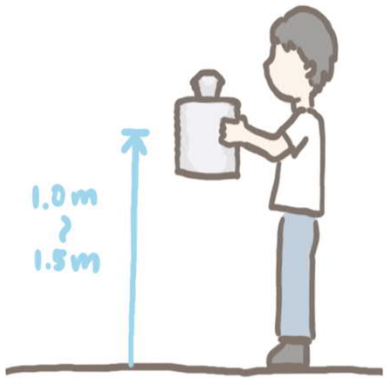
FIELDWORK TECHNIQUES

實地考察技巧

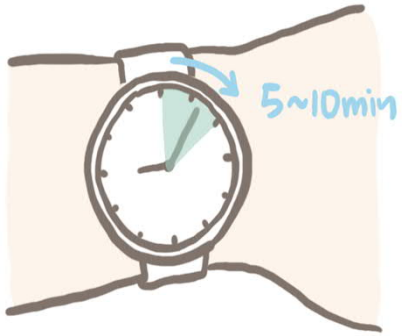
FIELDWORK TECHNIQUES

Field Sampling for Urban Climate

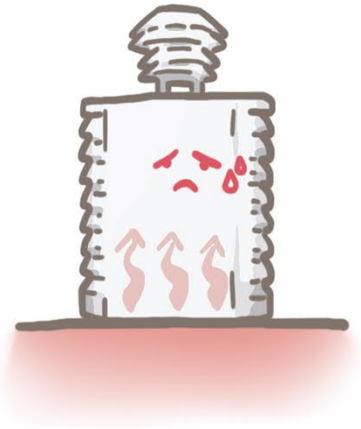
Guide for temperature and air sampling



1. 從地面約1.0–1.5 米高進行測量
Measurement at ~1.0– 1.5 meter from ground surface.



2. 每個點測量大約 5 – 10 分鐘
Take measurement for 5 – 10 mins for each location



3. 避免將感測器放置在混凝土或導熱表面上
Avoid placing the sensors on the concrete / heat conducting surfaces

.

4. 選擇通風良好的測量地點
Select a measurement site with good ventilation

.

Thank you ~

Acknowledgement
& Special Thanks

合辦機構 香港大學 THE UNIVERSITY OF HONG KONG 香港童軍總會 Scout Association of Hong Kong 支持單位 香港天文台 Hong Kong Observatory 香港資優教育學苑 The Hong Kong Academy for Gifted Education

Team of Professor Nicky Lam

城市氣候與空氣污染實驗室
Urban Climate and Air Pollution Laboratory
香港大學 THE UNIVERSITY OF HONG KONG