Local Climate Zones

Origins, development, and application to urban heat islands

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## Definition

<table>
<thead>
<tr>
<th></th>
<th><strong>Standard meaning</strong> from dictionary</th>
<th><strong>Contextual meaning</strong> for landscape classification</th>
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</thead>
<tbody>
<tr>
<td><strong>Local</strong></td>
<td>“Characteristic of, or associated with, a particular area”</td>
<td>Horizontal scales of $10^2$ to $10^4$ meters</td>
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<tr>
<td><strong>Climate</strong></td>
<td>“Long-term weather conditions of an area”</td>
<td>Screen-height air temperature</td>
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<tr>
<td><strong>Zone</strong></td>
<td>“An area characterized by some distinctive feature or quality”</td>
<td>An area of distinctive surface morphology, land cover, and air temperature</td>
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</table>

### Operational meaning for urban heat islands

| **Local Climate Zones** | $\Delta T_{LCZ} = UHI$ magnitude |
Communicating local climate zones

Datasheets

**LCZ Compact Highrise**

**Definition**

**Form:** Dense and irregular mix of tall buildings to 10s of stories. Buildings close-set, free-standing. Sky view from street level significantly reduced. Streets paved. Buildings of steel, concrete, and glass construction. Little or no pervious ground. High space heating/cooling demand. Heavy traffic flow.

**Function:** Commercial (office buildings, highrise hotels); residential (apartment towers). **Location:** City core ("downtown," central business district). Periphery (highrise subcentre, highrise sprawl). **Correspondence:** UCLZ1 (Oke, 2004); Dc1 and Dc8 (EIllefsen, 1990/1).

**Illustration**

High angle

Eye level

**Properties**

- **Sky view factor:** 0.2 – 0.4
- **Canyon aspect ratio:** > 2
- **Mean building height:** > 15 m
- **Terrain roughness class:** 8
- **Building surface fraction:** 40 – 60 %
- **Impervious surface fraction:** 40 – 60 %
- **Pervious surface fraction:** < 10 %
- **Surface thermal admittance:** 1,100 – 1,300 J m⁻² K⁻¹
- **Surface albedo:** 0.10 – 0.20
- **Anthropogenic heat flux:** 50 – 300 W m⁻²

**LCZ Low Plant Cover**

**Definition**

**Form:** Featureless landscape of pervious ground cover, predominantly low plants. Few or no trees, buildings, roads, or other roughness objects. Trees, if any, are widely set. Plant canopy < 1 metre above ground. Full sky view from ground level. Little or no impervious ground. Space heating/cooling demand nil. **Function:** Natural grassland (savannah, steppe). Agriculture (pasture and arable farmland). Urban recreation (grassy parks, green spaces). **Location:** City or country. **Correspondence:** UCZ7 (Oke, 2004).

**Illustration**

High angle

Eye level

**Properties**

- **Sky view factor:** > 0.9
- **Tree aspect ratio:** < 0.1
- **Mean plant height:** < 1 m
- **Terrain roughness class:** 3 – 4
- **Building surface fraction:** < 10 %
- **Impervious surface fraction:** < 10 %
- **Pervious surface fraction:** > 90 %
- **Surface thermal admittance:** 800 – 1,000 J m⁻² K⁻¹
- **Surface albedo:** 0.15 – 0.25
- **Anthropogenic heat flux:** 0 W m⁻²
Constructing the LCZ Framework

How do we form a comparative, climate-based view of urban and rural field sites?

Challenges:

• Landscape interpretation varies with culture, region, and language…

• Sites are diverse in exposure, land cover, building materials, human activities…

• “Urban” and “rural” are deeply rooted in UHI methodology; lack meaningful definition…

• No comprehensive site classification system; UTZ (Ellefsen 1990-91) and UCZ (Oke 2004) are good but no rural zones…

Find common physical traits in all sites, then group traits into distinctive classes…
Constructing the LCZ Framework

1. Height of roughness features

**Buildings**
- **highrise**: > 25 m
- **midrise**: 10-20 m
- **lowrise**: < 8 m
- **no rise**: 0 m

**Vegetation**
- **trees**: > 3 m
- **bush**: 1-2 m
- **grasses**: < 1 m
- **soil**: 0 m
Constructing the LCZ Framework

2. Packing of roughness features

Buildings

- compact: H/W > 1
- open: H/W < 1
- sparse: H/W < 0.25

Vegetation

- compact: H/W > 1
- open: H/W < 1
- sparse: H/W < 0.25
Constructing the LCZ Framework

3. Surface cover around roughness features

- Impervious: concrete/rock
- Pervious: low plants, soils

4. Thermal admittance of materials

- Heavy: concrete, stone
- Lightweight: sheet metal, wood
Local Climate Zones

Standard Set

- Compact highrise
- Compact lowrise
- Open-set highrise
- Open-set lowrise
- Compact midrise
- Extensive lowrise
- Open-set midrise
- Lightweight lowrise
- High-energy industrial
- Sparsely built
- Close-set trees
- Open-set trees
- Bush/scrub
- Bare rock/concrete
- Low plant cover
- Bare sand/soil
Summary

- UHI datasets from Uppsala (1948, 1976), Nagano (2000-06), and Vancouver (1992-2010).
- Observations support the hierarchical structure of the LCZ system.
- Each LCZ class has a unique thermal climate.
- Temperature patterns are sensitive to surface relief, surface wetness, tree geometry, and weather.

Evening temperatures in Vancouver 2010

- March 3
- March 5
- March 8
- Average

Departure from group mean (K)

Summary
S. Krayenhoff
University of British Columbia

- Highly simplified approach (treed zones excluded).
- Urban-surface (TEB) and plant-soil (CAPS) schemes coupled with atmospheric boundary layer model.
- Simulated DTR varies with building height, packing, land cover, and surface wetness.
- Dry/natural zones more thermally responsive than wet/built-up zones.

See Krayenhoff et al., 2009. Preprints, 8th Symposium on the Urban Environment.
Application of local climate zones

- Quantifying UHI magnitude in Vancouver, CANADA
- Mapping urban terrain in Novi Sad, SERBIA
- Assessing social inequalities in Santiago, CHILE
- Classifying weather stations in HONG KONG

Sites of LCZ testing / application
Quantifying UHI magnitude: VANCOUVER

3 March 2010 19:30 hr

**Investigators**

- I. Stewart and T. Oke
  University of British Columbia

**Purpose**

- To define and quantify UHI magnitude through inter-zone temperature differences ($\Delta T_{LCZ}$).

**Results**

- UHI magnitude ($\Delta T_{LCZ}$) varies with differences in morphology and land cover between LCZ pairs.
  - $\Delta T_{LCZ} > 7$ K for zones with large morphological differences; $< 2$ K for zones with small differences.
Purpose

• To classify HKO weather stations into LCZs, and identify representative sites for UHI measurement.

Results

• Three of seventeen stations are representative of local scale.
• New standardized documentation system for station metadata.
• Challenges with LCZ system in Hong Kong.

Investigators

• C. Siu and M. Hart
• University of Hong Kong

Mapping urban terrain: SERBIA

Investigators
- J. Unger et al.
  University of Szeged / Novi Sad

Purpose
- To map urban terrain and air temperature in Novi Sad using LCZs, and recommend strategic configuration for an urban climate network.

Results
- Seven LCZs identified in Novi Sad urban area.
- Spatial correlation between LCZs and modeled air temperatures.
- Ten-station network recommended for UHI monitoring in Novi Sad.

Unger J. et al. Article submitted to Advances in Meteorology.
Assessing social inequalities: CHILE

**Purpose**

- To map LCZs in Santiago and assess the socio-economic status of district populations.

**Results**

- LCZ morphology reflects thermal and social inequalities in Santiago.
  - *High-density districts*: high temperatures, low-income populations.
  - *Low-density districts*: low temperatures, affluent populations.

**Investigators**

- H. Romero *et al.*
  Universidad de Chile

What does the local climate zone system offer?

- The first comprehensive, climate-based classification of landscapes for heat island investigators.

- A user-friendly classification that transfers easily to any city, region, or culture.

- A standardized definition of UHI magnitude through climatologically defined urban and rural zones ($\Delta T_{\text{LCZ}}$).

- An educational and analytical tool for students, researchers, and practitioners of urban climatology.