URBAN CLIMATOLOGY

Part 1. Motivation to study urban climates, objectives, historical overview

Department of Geography
Petr Dobrovolný

Outline

1. Motivation to study urban climates, historical overview
2. Main factors controlling urban climate (UC), UC scales, layers, energy balance
3. The climate of Brno as an example (data, methods, main outcomes)
4. Urban heat Island (UHI), UHI types, atmospheric UHI, UHI intensity
5. Urban Remote Sensing, surface UHI
6. Precipitation in urban areas
7. Spatio-temporal variability of other meteorological elements in urban areas
8. Local climate zones
9. Urban Climate Modelling
10. Urban adaptation to climate change

Paper to read

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Urban climatology: History, status and prospects

Gerald Mills

School of Geography, Planning & Environmental Policy, UCD, Dublin, Ireland

https://is.muni.cz/auth/el/sci/podzim2022/ZX601/um/67875456/01_Mills_2014.pdf

1.1 Objective

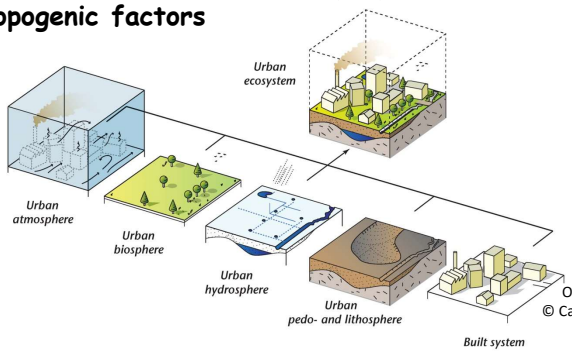
Climate in urban areas differ from that of rural areas due to process of urbanization.

Manhattan-Mannahatta: on right is a reconstruction of Manhattan Island circa 1609 (called "Mannahatta"), as compared to today, based on historical landscape ecology and map data.

- First phase of urbanization (initiated by the industrial revolution)
- Second phase (uncontrolled development in less-developed countries)
- As for climate, urbanization means …
- Problem of **sustainability**

1.1 Objective

- Most meteorological elements and climatological characteristics have **specific features of their spatial and temporal variability** in urbanized areas
- However, typical spatiotemporal variability of urban climate in individual cities is formed as a **superposition of natural and anthropogenic factors**



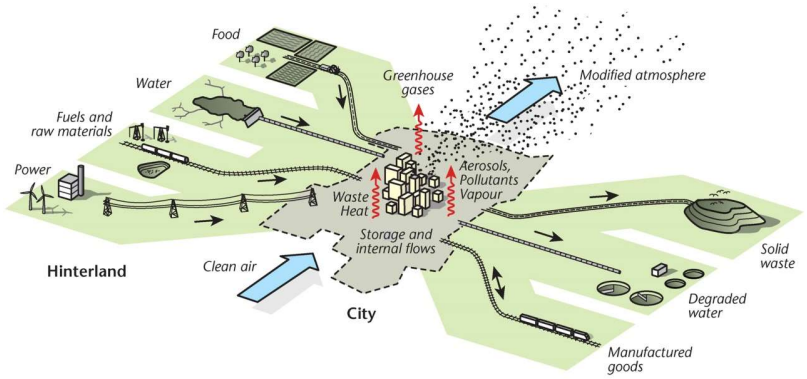
Oke *et al.*, 2017, *Urban Climates*

The biophysical components of an urban ecosystem. They include all aspects of the pre-urban natural environment subsequently modified by the introduction of built infrastructure

Urban climate = natural climate variability + urban forced climate variability

1.1 Objective

- Specific features of urban climate may strongly **affect** economic **activities**, infrastructure functioning, quality of life, etc.



Oke *et al.*, 2017, *Urban Climates*

The representation of the inputs to, and outputs from, an urban ecosystem (concept of **urban metabolism**).

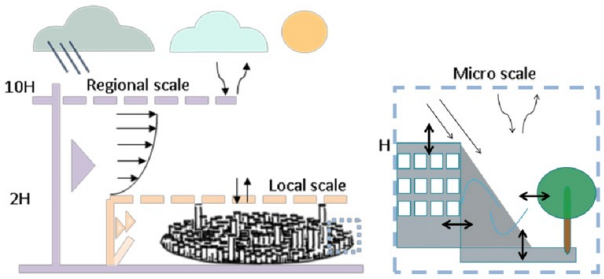
1.1 Objective

Urban climatology objective is to study:

a) How cites impact climate

b) How climate impacts cities and their dwellers

Built-up areas create specific category of **local climate** – urban climate

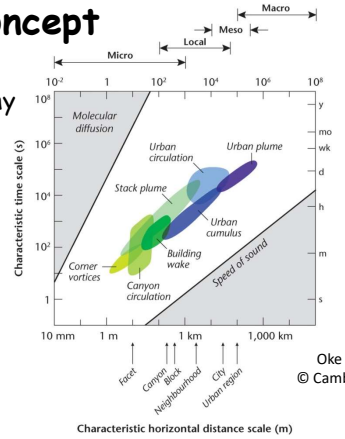


Bourikas, 2016

The peculiarities of the urban climate can be studied at the level of the **mesoclimate**, **local climate** or **microclimate** categories

1.2 Urban Climate concept

Climate categories: The hierarchy of climate scales from global to regional to meso-scale to local to micro-scale



Oke *et al.*, 2017, *Urban Climates*

For local climate it is typical that the processes in the **lower layers of the atmosphere** are significantly shaped by the radiation, thermal, aerodynamic, and moisture properties of **active surfaces**.

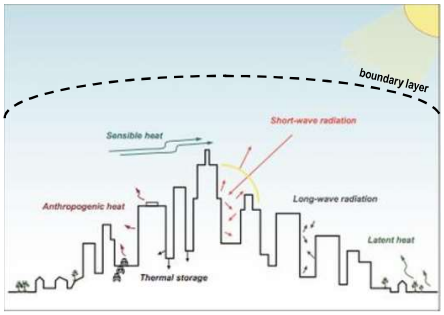
1.2 Urban Climate concept

Active surface – transition between the atmosphere and the lithosphere or hydrosphere (surface of soil, water, vegetation, roads, roofs of houses, etc.), on which radiation energy is **reflected** and/or **transformed** into other types of energy (primarily heat).

In cities, active surfaces create complicated hierarchy:

Scale

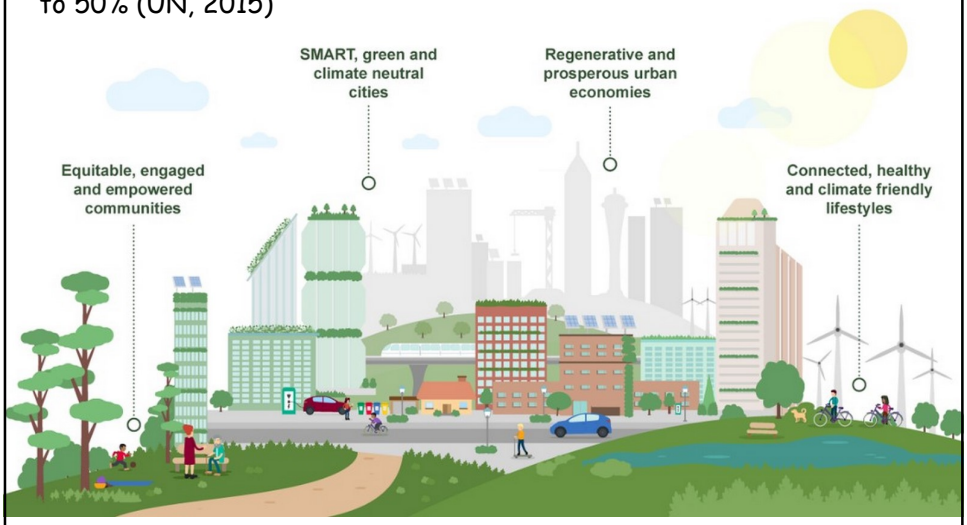
Urban region
City (bulit up area)
Neighbourhood (LCZ)
Block
Canyon
Element
Facet



Active surface influences atmospheric processes in the **boundary layer** of the atmosphere through its physical and chemical properties (relief height, orientation, albedo, thermal conductivity, humidity, soil composition and structure, vegetation, …).

1.3 Motivation

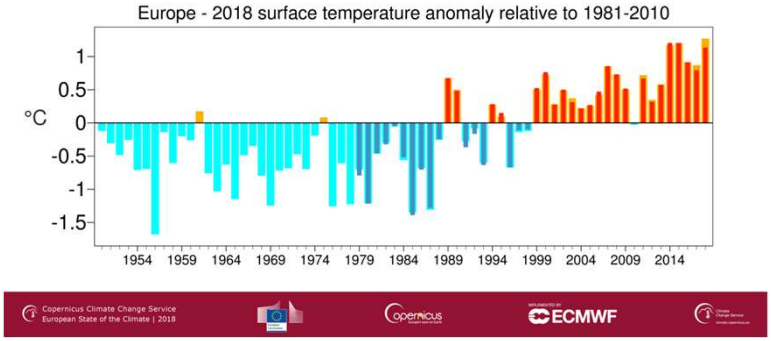
Over the last 200 years, the global population has increased sevenfold and the fraction of the people living in urban areas increased from 3% to 50% (UN, 2015)



Urban sustainability © https://www2.helsinki.fi

1.3 Motivation

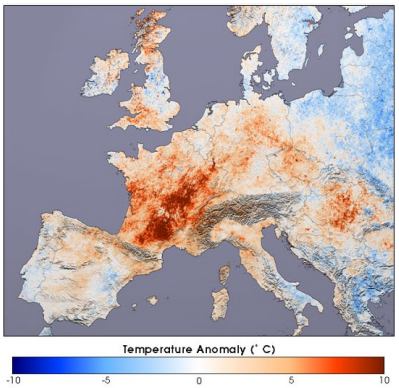
Importance of urban climate studies increase in recent decades due to **global climate change**



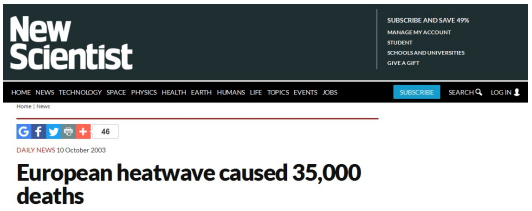
European surface air temperature anomaly for annual averages from 1950 to 2018, relative to the annual average for the period 1981-2010. Data source: ERA5 (dark blue and red, starting 1979) and E-OBS (light blue and yellow). Credit: Copernicus Climate Change Service (C3S)/ECMWF/KNMI.

1.3 Motivation

It is very probable that the **frequency and intensity of hydrometeorological extremes** will be higher in the near future

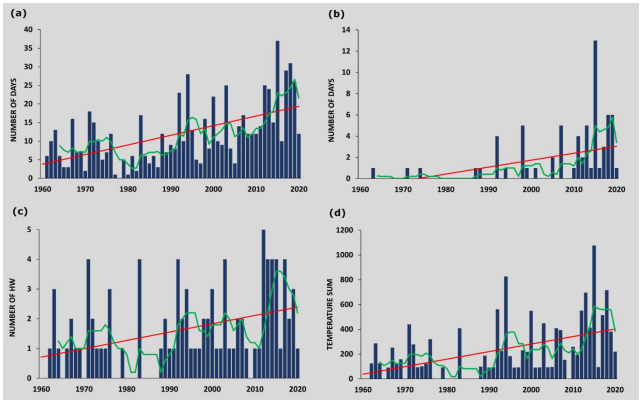


Heat wave in the western Europe: temperature differences between July 2003 and July 2001



http://earthobservatory.nasa.gov/NaturalHazards

1.3 Motivation



Annual number of tropical days (a), tropical nights (b), number (c) and intensity (d) of heat waves in Brno, airport station in the 1961–2020 period

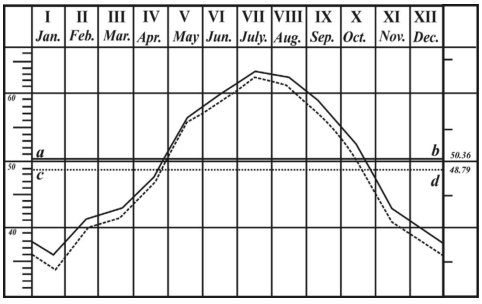
- **Higher heat load and higher extremity of weather and climate** may negatively influence living conditions in urban areas with the direct impact to quality of life and health of population
- Better knowledge of causes and mechanisms that form urban climate are necessary for the **mitigation** of negative impacts and for the realization of **adaptation** strategies

1.4 History

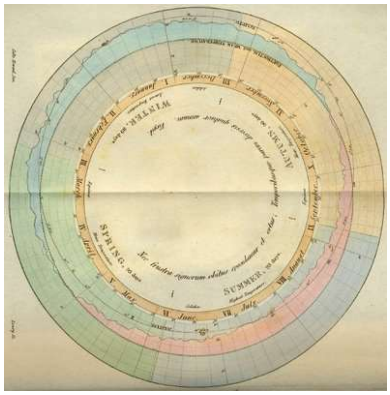
- Antiquity, middle ages
- Bad quality of air in the cities, air pollution

- Luke Howard (1772–1864)

The Climate of London (1833)



A comparison between the air temperature observations by Luke Howard (solid) against those made by the Royal Society within London (broken). Source: Howard (1833).



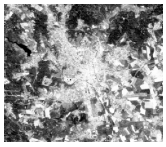
1.4 History

20th century

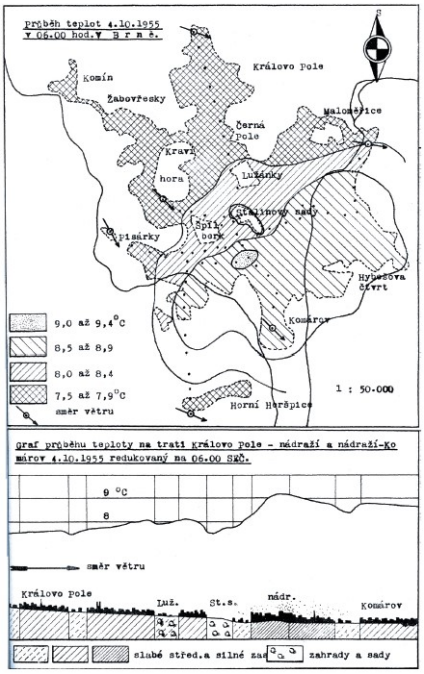
- Special purpose measurements

- Mobile measurements

- Urban remote sensing



E. Quitt (1957) The climate of Brno



1.4 History

- **21th century**
- concept of Local Climate Zones
- urban climate modelling (WRF, MUKLIMO_3D, ENVIMET)
- realisation of adaptation and mitigation measures

- *www.urban-climate.org/*

Urban Climate Change Research Network

- *http://uccrn.org/*

1.4 Future prospects

- 'Reducing solitudes' in urban climatology
- Improving scientific knowledge (the urban effect on precipitation)
- To overcome the paucity of information on the rapidly growing cities of the less prosperous regions
- Rapid advances in sensor technologies, problem of appropriate measurement devices and methods
- More realistic descriptions of land cover; better characterization of the city structure: material properties, geometry, and functions (traffic)
- Development of models (physical, numerical)
- Concept urban – rural is regionally different and mostly pays for mid-latitudes; rural mostly does not mean natural but managed natural

1.5 Definitions

Oke (2006) described the evolution of urban climatology using **eight modes of investigation or practice**:

- Conceptualisation
- Theorisation

- Field observation
- Modelling
- Model evaluation

- Application in urban design and planning
- Impact assessment (post-implementation)
- Policy development and modification.

1.5 Definitions

Urban climatology is concerned with the study of the climate effect of urban areas and the application of the knowledge acquired to the better planning and design of cities.

Descriptive climatology

Despite the accumulation of evidence (e.g. on the urban air temperature effect), much of it was specific to particular places and used distinct methods that made generalisations difficult.

$$\Delta T_{U-R(\max)} = 2.96 \log P - 6.41$$

Physical climatology

Adopts a quantitative and systematic approach to research. Its the most common expression was formulation of the surface energy balance in cities.

$$Q^* = Q_H + Q_E + Q_G$$

The research focus was shifted from **describing effects** (responses) to seeking their cause (**processes**).

1.6 Final remarks and questions

1. Why it is important to study urban climates?
2. What are the main objectives of urban climatology
3. What do you know about history of urban meteorology and climatology?
4. Characterize urban climate within the scale of climate categories
5. What is the difference between "descriptive" and "physical" urban climatology?
6. What are the main topics of urban climatology in the near future?