URBAN CLIMATOLOGY

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

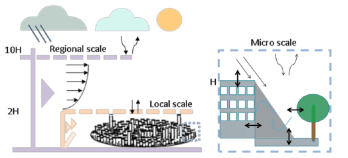
Department of Geography
Petr Dobrovolný

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

1.1 Objective

- Built-up areas create specific category of **local climate** – urban climate
- Climate in urban areas differ from that of rural areas due to process of **urbanization**



Bourikas, 2016

- **Urban climatology** objective is to study:
  a) How cites impact climate
  b) How climate impacts cities and their dwellers

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

1.1 Objective

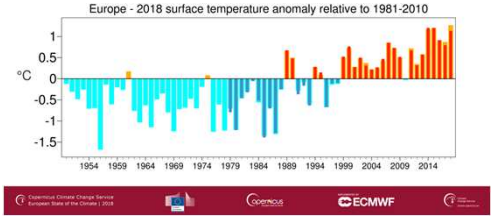
- Specific features of urban climate may strongly **affect** economic **activities**, infrastructure functioning, quality of life, etc.

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

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

1.2 Motivation

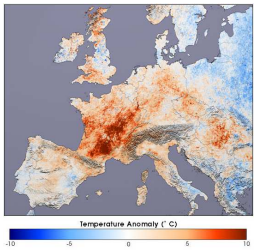
- Over the last 200 years, the global population has increased sevenfold and the fraction of the people living in urban areas increased from 3% to 50% (UN, 2015)
- Importance of urban climate studies increase in recent decades due to **global climate change**



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.

1.2 Motivation

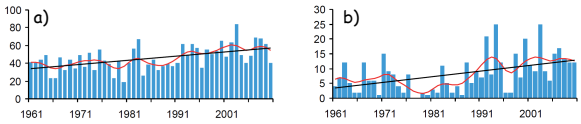
- It is very probable that the **frequency and intensity of hydrometeorological extremes** will be higher in the near future



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

http://earthobservatory.nasa.gov/NaturalHazards

1.2 Motivation



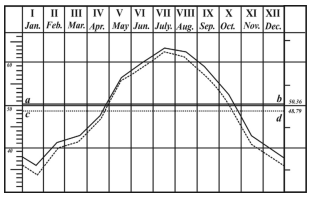
Annual number of summer days (a) and tropical days (b) in Brno, airport station in the 1961–2010 period completed with the low-pass Gaussian filter (10 years) and with the estimate of the linear trend

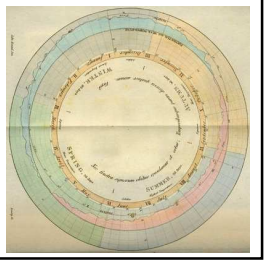
- **Higher heat load and higher extremity of weather and climate** may negatively influence living conditions in urban areas with the direct impact to quality of life and health of population
- Better knowledge of causes and mechanisms that form urban climate are necessary for the **mitigation** of negative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

1.3 History

- Antiquity, middle ages
- bad quality of air in the cities, air pollution
- Luke Howard (1772–1864)

The Climate of London (1833)

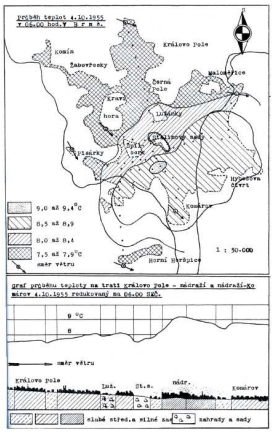




A comparison between the air temperature observations by Luke Howard (solid) against those made by the Royal Society within London (broken). Source: Howard (1833).

1.3 History

- 20th century
- Special purpose measurements
- Mobile measurements
- Urban remote sensing



- dr. Quitt (1957) The climate of Brno,
  - mobile measurements

1.3 History

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

- *www.urban-climate.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

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.

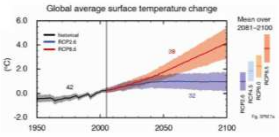
$$Q^* = Q_H + Q_E + Q_G$$

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

1.3 Final remarks and questions

1. Is it an actual problem to study urban climates?
2. What do you know about history of urban meteorology and climatology?
3. What is the difference between "descriptive" and "physical" urban climatology?
4. May there be positive aspects of the climate change?
5. What are the main topics of urban climatology in the near future?

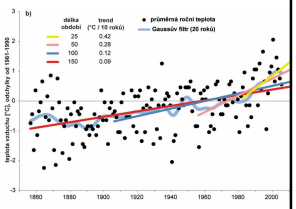
1.1 Motivation



Global climate change: increase of the mean global near-surface air temperature in the 2016-2035 period comparted to the 1986-2005 period will reach with high probability 0.3°C ~ 0.7°C

For the period 2081-2100 it will be about 0.3°C ~ 1.7°C (RCP2.6), 2.6°C ~ 4.8°C (RCP8.5)

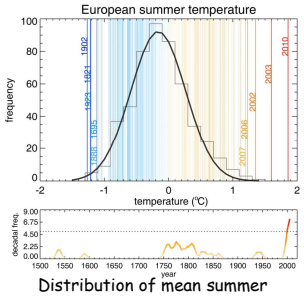
(IPCC 2013)



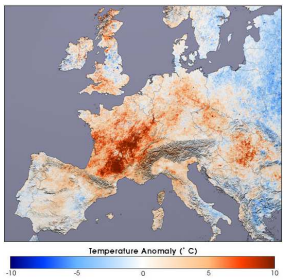
Mean annual air temperature on the territory of CR in the 1856–2005 period (Brázdil et al. 2012) completed with estimates of the linear trend for the last 150, 100, 50 and 25 years

1.1 Motivation

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



Distribution of mean summer temperatures in Europe in the 1500-2010 period



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

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1.2 Definitions

Problem of appropriate measurement devices and methods

Development of models (physical, numerical)

quasi-experiments that could be replicated.

More realistic descriptions of land cover

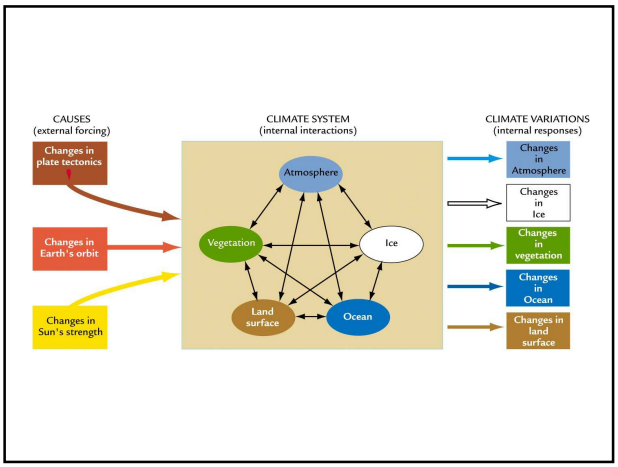
Better characterisation of the city structure: material properties, geometry (SVF), and functions (traffic)

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

The hierarchy of climate scales (categories) from global to regional to meso-scale to local to micro-scale

Concept urban – rural – regionally different, pays for midd latitudes

Rural mostly does not mean natural but managed natural


CAUSES
(external forcing)
Changes in plate tectonics
Changes in Earth's orbit
Changes in Sun's strength
CLIMATE SYSTEM
(internal interactions)
Atmosphere
Vegetation
Ice
Land surface
Ocean
CLIMATE VARIATIONS
(internal responses)
Changes in Atmosphere
Changes in Ice
Changes in vegetation
Changes in Ocean
Changes in land surface