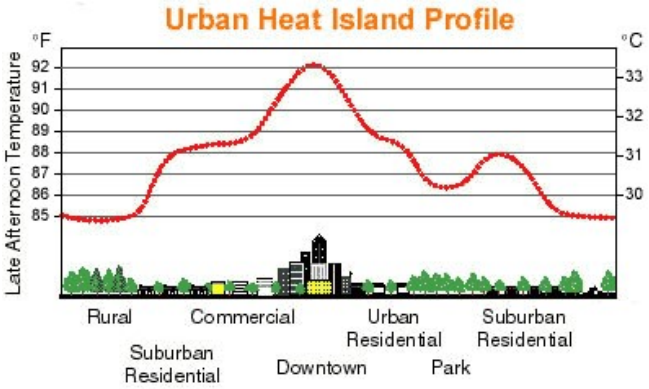
URBAN CLIMATOLOGY

4. Urban heat Island, UHI types, atmospheric UHI, UHI intensity

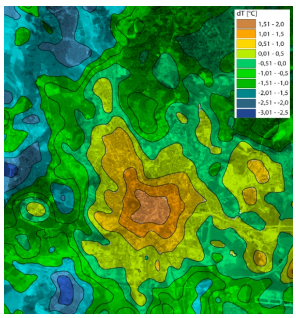
Paper to read

https://is.muni.cz/auth/el/sci/podzim2022/ZX601/um/67875456/04_UHI_BasicsCompendium.pdf

4.1 Urban Heat Island concept

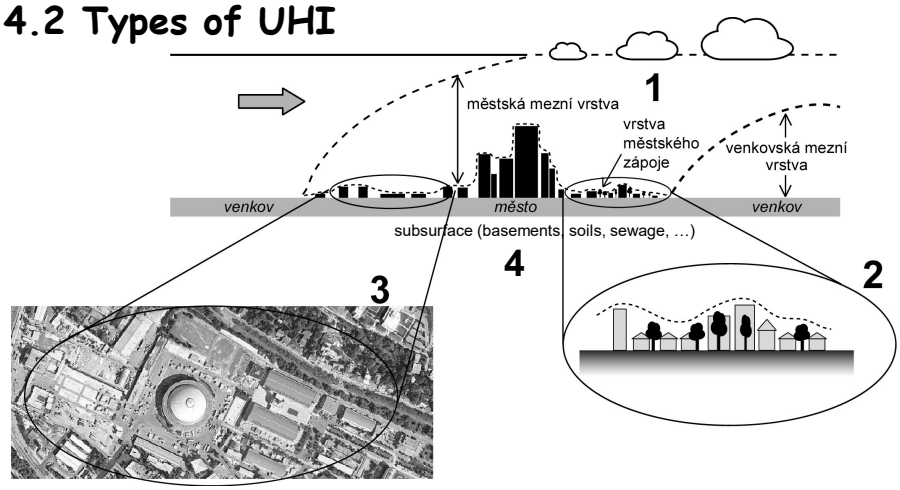


http://weather.msfc.nasa.gov/urban/urban_heat_island.html)



Simplified model – role of natural and anthropogenic factors?

4.2 Types of UHI

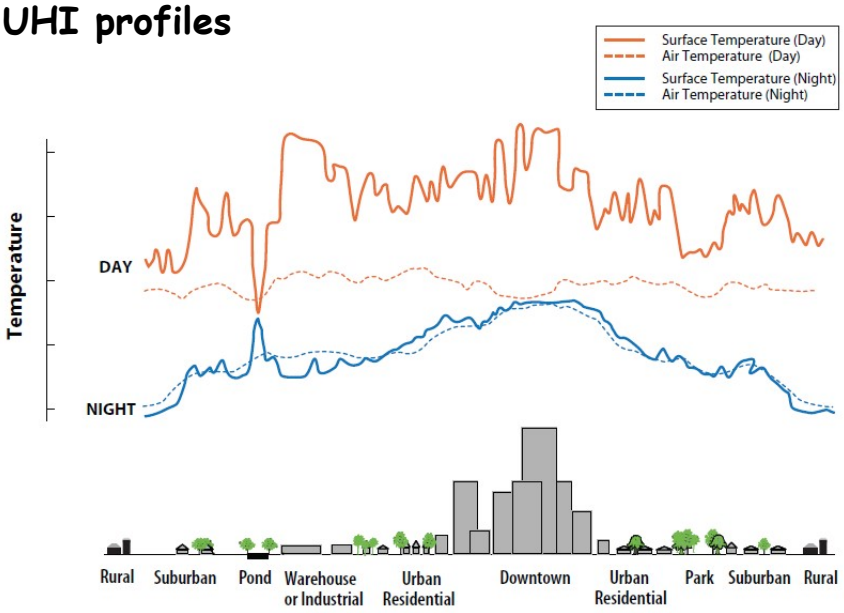


1. Atmospheric Boundary layer Urban Heat Island
2. Atmospheric Canopy Layer Urban Heat Island
3. Surface Urban Heat Island
4. Subsurface Urban Heat Island

What variables are measured?

(Oke et al., 2017)

UHI profiles



Reducing Urban Heat Islands: Compendium of Strategies and (Voogt 2000)

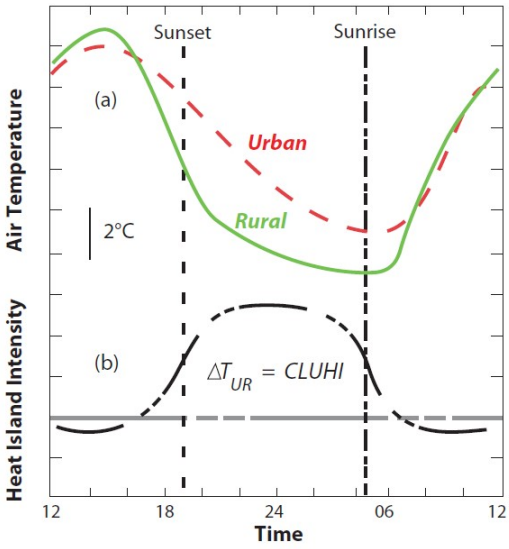
UHI types characteristic

Table 1: Basic Characteristics of Surface and Atmospheric Urban Heat Islands (UHIs)[4]

Feature	Surface UHI	Atmospheric UHI
Temporal Development	• Present at all times of the day and night • Most intense during the day and in the summer	• May be small or non-existent during the day • Most intense at night or predawn and in the winter
Peak Intensity (Most intense UHI conditions)	• More spatial and temporal variation: ▪ Day: 18 to 27°F (10 to 15°C) ▪ Night: 9 to 18°F (5 to 10°C)	• Less variation: ▪ Day: -1.8 to 5.4°F (-1 to 3°C) ▪ Night: 12.6 to 21.6°F (7 to 12°C)
Typical Identification Method	• Indirect measurement: ▪ Remote sensing	• Direct measurement: ▪ Fixed weather stations ▪ Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph

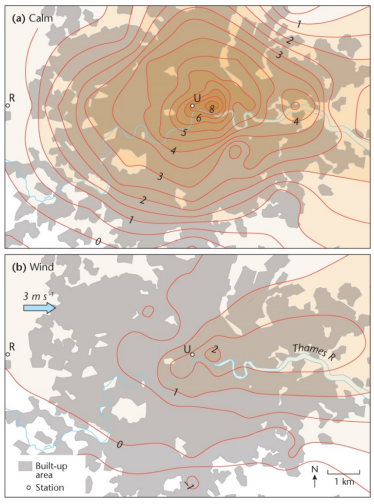
Reducing Urban Heat Islands: Compendium of Strategies and (Voogt 2000)

UHI intensity (ΔT_{u-r})



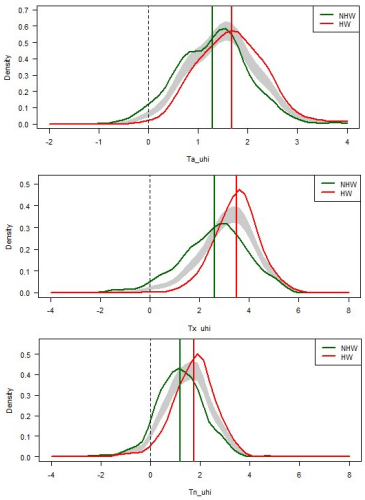
Conceptual Drawing of the Diurnal Evolution of the Urban Heat Island during Calm and Clear Conditions (modified from Oke, 1982)

UHI intensity and weather types



Nocturnal UHI intensity in London durinf the radiation-driven (a) and advection-driven (b) weather

Oke *et al.*, 2017, *Urban Climates*
© Cambridge University Press 2017



UHI intensity for heat wave days (HW) and non-HW days (NHW) during the summer months (JJA season) of the 2011–2020 period at Brno BISK station. Vertical lines are mean UHIIs, and their differences express the heat magnitude (HM).

UHI intensity (ΔT_{u-r})

The size of the city forms the intensity of UHI in general

The size of the city can be characterized via number of inhabitants

There is a relation between maximum UHI intensity (*UHImax*) and number of dwellers(*P*) (van Hove et al. 2011):

$$UHImax = 2{,}93 \log P - 11{,}95$$

For Brno (P = 380 ths.) UHImax = 4,4 °C

How we can estimate UHI intensity depending on available data?

4.3 Measuring the UHI effect

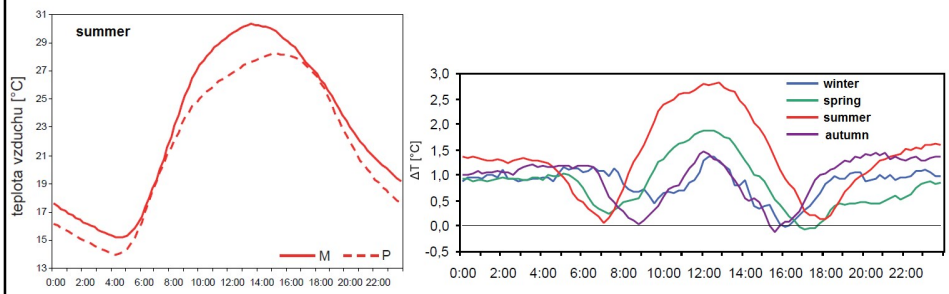
- „Point" measurements – standard meteorological stations
- „Point" measurements – special-purpose automatic stations
- Mobile measurements
- Urban remote sensing
- Urban climate and UHI intensity modelling

All types of measurements also involve three different components that are hardly to quantify (Lowry 1977):

1. the „backgound" climate
2. the effects of local climate (topoclimate)
3. the effect of local urbanization

Where are the spatial limits of the urban effect?

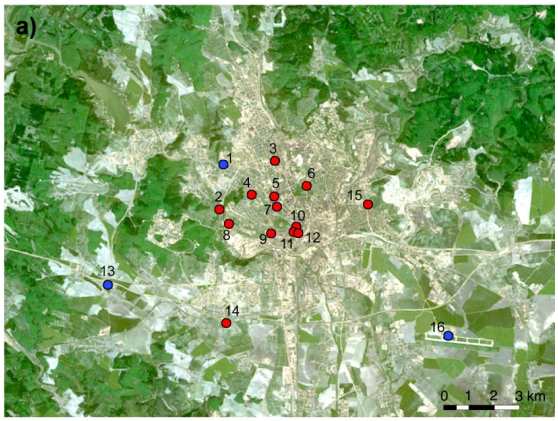
UHI Intensity in Brno



Mean daily variations of summer air temperature at urban (M) and rural (P) stations during clear and calm days in Brno region (left) and daily variation of urban heat island intensity (ΔT); UHI intensity is expressed as a difference between mean air temperature at urban and rural stations (right)

AUHI – „point" measurements

a)



b)

stanice	NV	NDVI	DENS
MEND	210	0,29	20
BOTA	242	0,18	27
FILO	232	0,21	39
UKZU	218	0,34	14
GEON	226	0,31	17
KRAV	297	0,35	16
VERO	222	0,02	46
BISK	245	0,11	41
KAPU	221	0,05	43
VETE	237	0,26	25
ZIDE	215	0,31	19
ZABO	236	0,40	20
JUND	257	0,55	7
TROU	277	0,36	9
LISK	238	0,52	1
TURA	241	0,24	5

Spatial distribution of meteorological stations in Brno area (a) and their characteristics: Elevation (NV), density of buildings (DENS), and amount of vegetation (NDVI) (b)

AUHI – from „point" measurements to maps

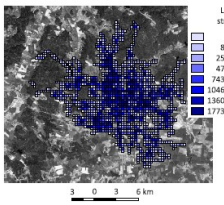


Figure 2 Total length of streets (further TLoS) calculated for a regular grid (300 x 300 m) in the study area.

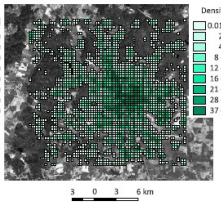


Figure 3 Density of buildings (%) (further DENS) calculated for a regular grid (300 x 300 m) in the study area.

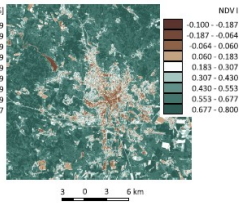
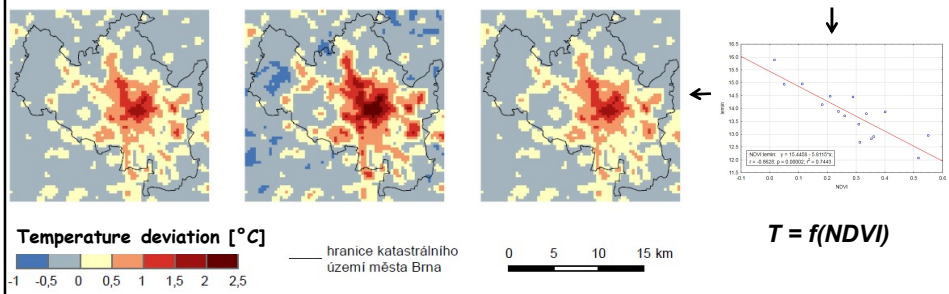


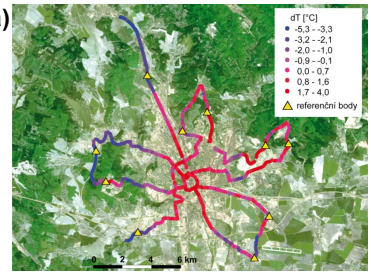
Figure 4 Normalized Difference Vegetation Index (further NDVI) as an indicator of vegetation amount and vigor in Brno area.



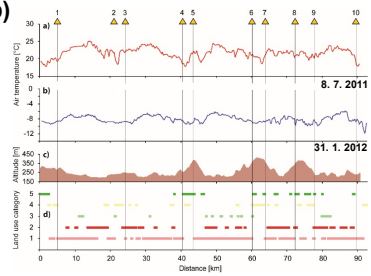
Spatial distribution of mean daily air temperature (Tavg), temperature minimum (Tmin) and intensity of UHI (ΔT) in Brno area during clear and calm days in summer; air temperatures are expressed as deviations from mean temperature of the study area (c)

AUHI – mobile measurements

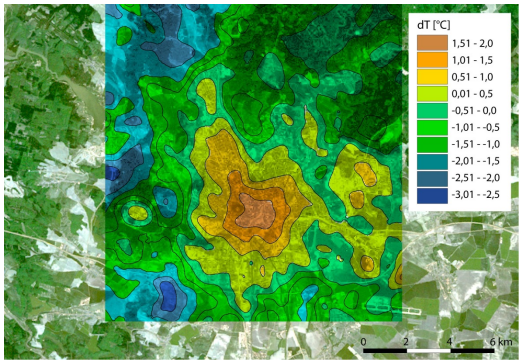
a)



b)

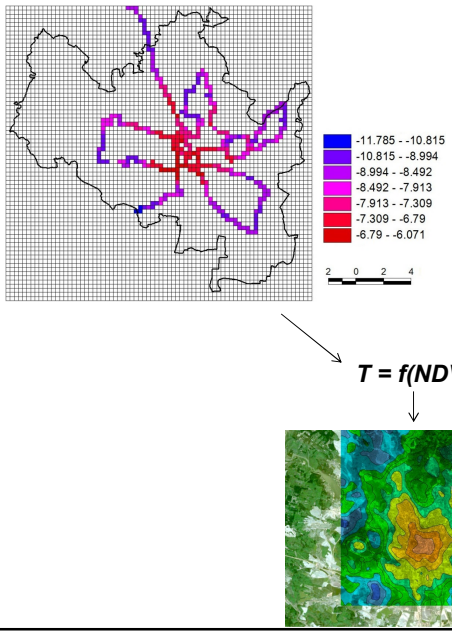


c)

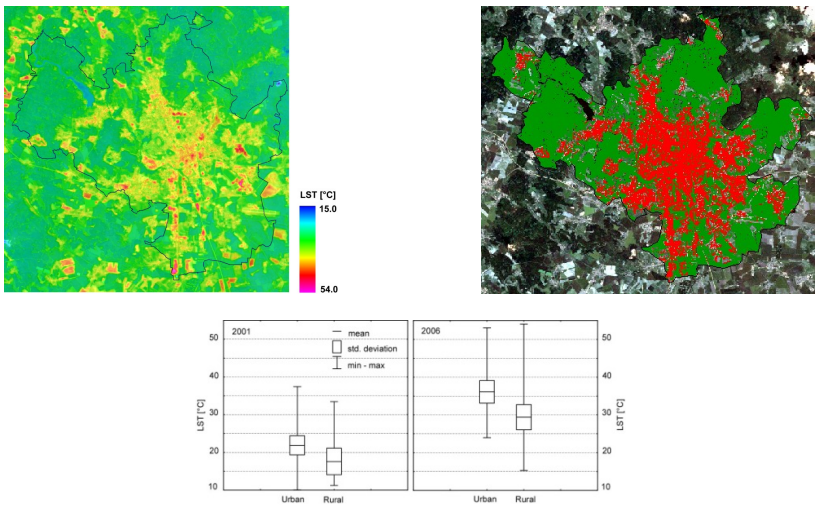


Design of measuring routes (**a**), air temperature profile along measurement routes (**b**) and typical spatial distribution of air temperature in central part of Brno in early night hours; air temperature is expressed as deviation (dT) from mean value of the study area and is typical for clear and calm weather during summer (**c**)

AUHI – from mobile measurements to maps



SUHI – remote sensing

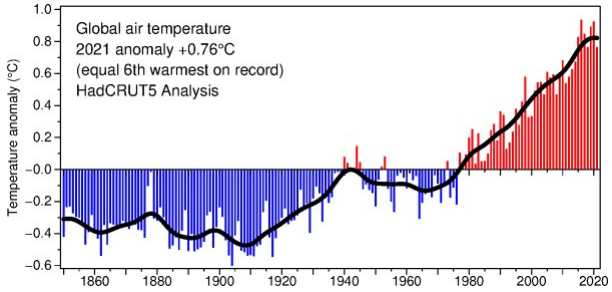


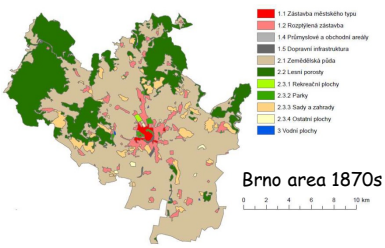
(a) Spatial variability of LST values within the Brno region; LST derived from Landsat thermal imagery acquired on 15 June 2006. (b) Intensity of surface UHI in Brno region defined as the difference between urban (M) and rural areas (P); LSTs

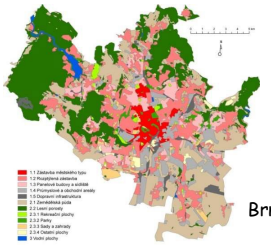
UHI consequences

- UHI impacts may be direct and indirect, negative effects prevail in general
- Diurnal Temperature Range is smaller in cities
- Higher air pollution reduce nighttime cooling, both factors increase a discomfort for city dwellers
- Increased temperatures during summer in cities amplify energy demand for air conditioning.
- Higher surface temperatures can heat storm water runoff with negative effect of various water ecosystems (thermal pollution)
- Impacts to plants through changes in phenology may be ambiguous (beginning and end of individual phases of the growing cycle

4.4 UHI and recent global warming





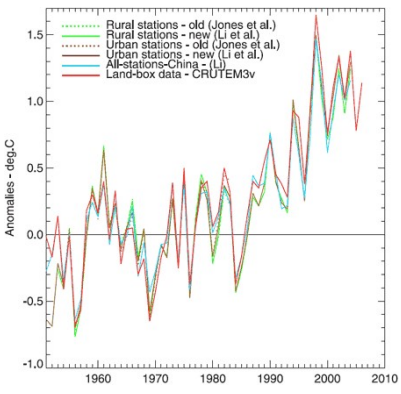


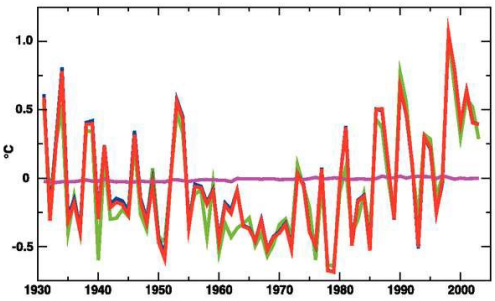
Brno area 2010s

A paper by McKitrick & Michaels (2004) concludes that half of the global warming trend from 1980 to 2002 is caused by Urban Heat Island.

UHI and recent global warming

Urban and rural regions show the same warming trend.

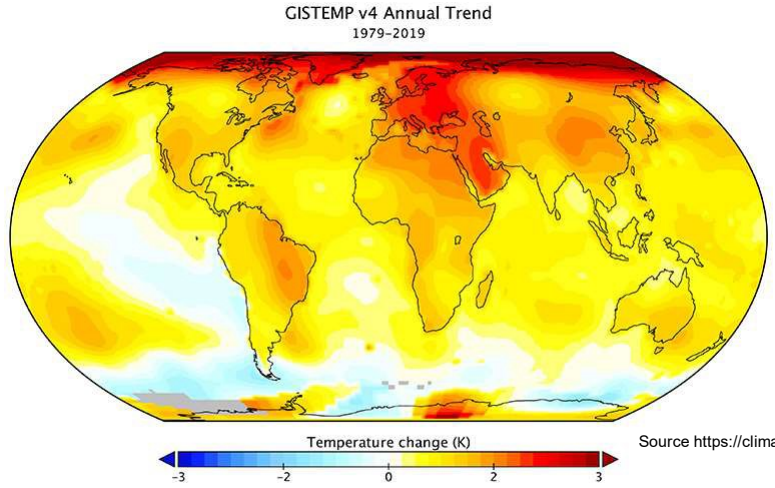




Anomaly (°C) time series relative to the 1961 to 1990 mean of the full US Historical Climatology Network (USHCN) data (red), the USHCN data without the 16% of the stations with populations of over 30,000 within 6 km in the year 2000 (blue), and the 16% of the stations with populations over 30,000 (green). The full USHCN set minus the set without the urban stations is shown in magenta. Source IPCC 2007

Parker (2004, 2006) noted that warming trends in night minimum temperatures over the 1950-2000 period were not enhanced on calm nights, which would be the time most likely to be affected by urban warming.

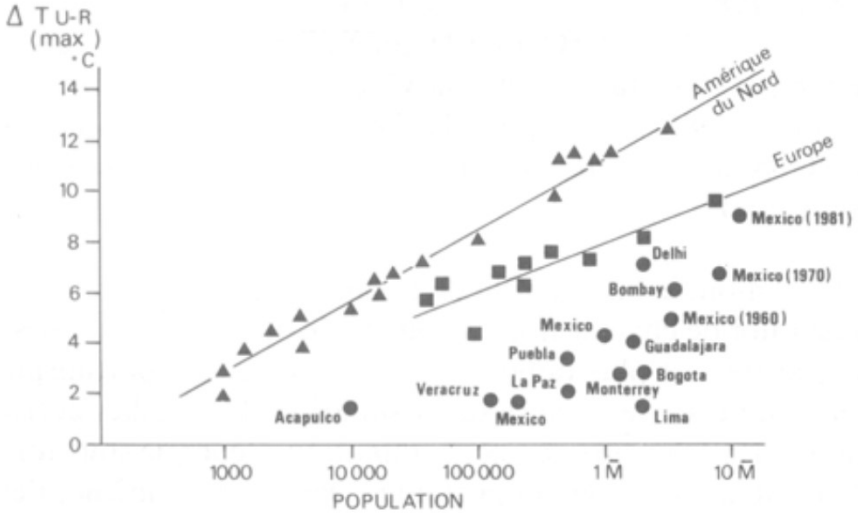
UHI and recent global warming



Source https://climate.nasa.gov

Due to the polar amplification The greatest difference in temperatures for the long term averages where across Russia, Alaska, far north Canada and Greenland and not where major urbanization has occurred.

4.5 Final remarks and questions



Relationship of the maximum heat island intensity with urban population in European, North American and tropical cities (Escourrou, 1991) are different. What is the reason?

4.5 Final remarks and questions

- How do Urban Heat Islands form?
- How we can estimate UHI intensity depending on available data?
- What are the main problems related to UHI?
- What is a relation between heat waves and UHI?
- Can be there any benefits of UHI?
- Is there any relation to recent global climate change?

(Strategies to Reduce Urban Heat Islands will be discussed in the final lecture)