Městské klima Olomouce: Místní klimatické zóny a jejich regionalizace

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Podzimní cyklus přednášek ČHMÚ Ostrava (8. 12. 2014)

OBSAH PŘEDNÁŠKY

1. Studium městského klimatu Olomouce a okolí

2. Klasifikace místních klimatických zón (LCZ): ÚVOD

3. Klasifikace místních klimatických zón v Olomouci a okolí

4. Teplotní rozdíly mezi místními klimatickými zónami v Olomouci

Multilevel data sources

historical data

MESSO

mobile measurement

surface thermal monitoring

satellite thermal images

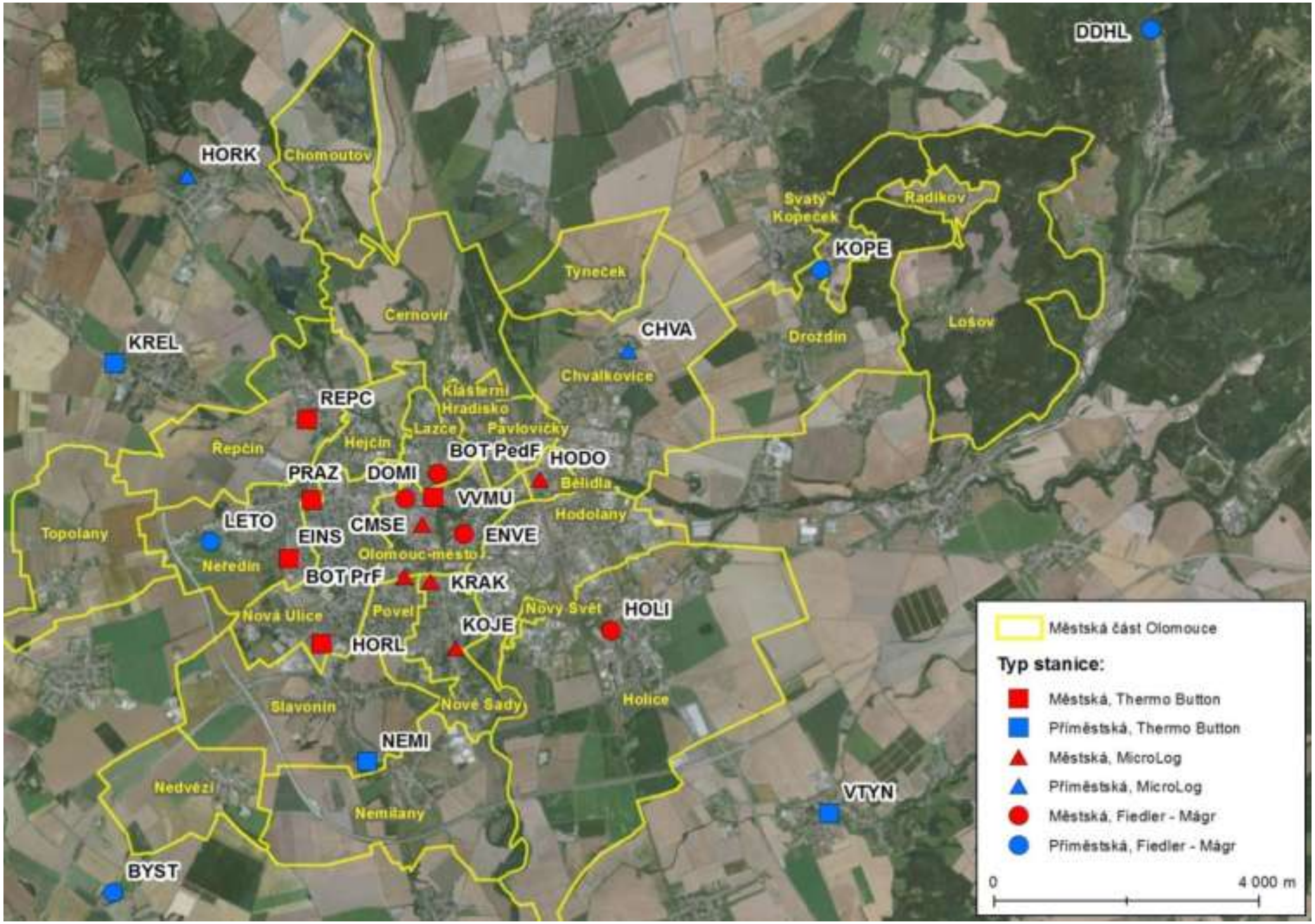
Level 1: Historical data

OLOMOUC – Klášterní Hradisko

Precipitation: since 1876

Air temperature: 1876-1961

Level 2: Metropolitan Station System Olomouc (MESSO)



METROPOLITAN STATION SYSTEM OLOMOUC (MESSO)

Setting of MESSO:
- 2009

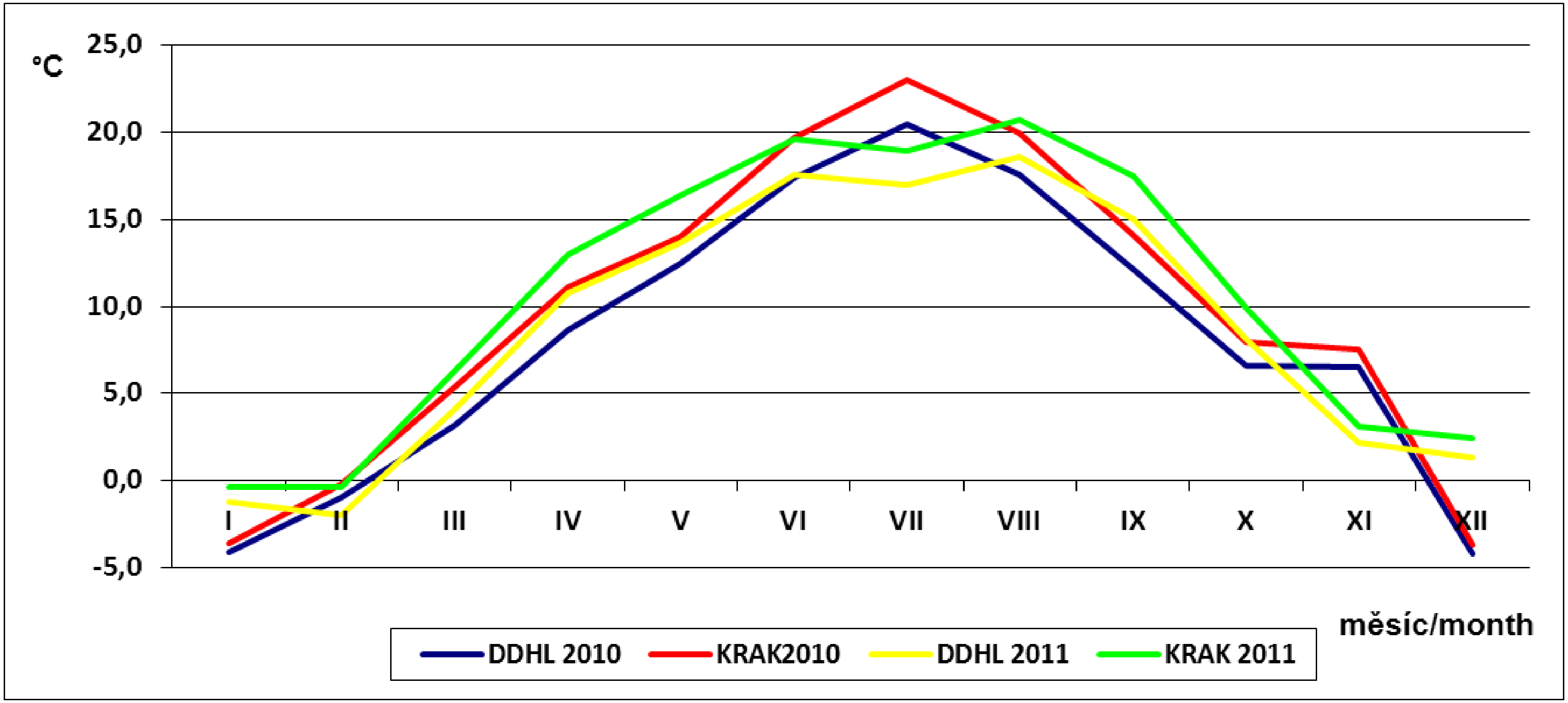
Observation program:
- Air temperature: 1,5 m, (0,5 m)
- Air humidity: 1,5 m, (0,5 m)
- Soil temperature: 0,2 m, (0,05 m, 0,5 m)
- Soil moisture
- Precipitation
- Global radiation
- Albedo
- Wind speed
- Wind velocity

Time interval of recording:
- 10´ - CET

Urban stations: 15

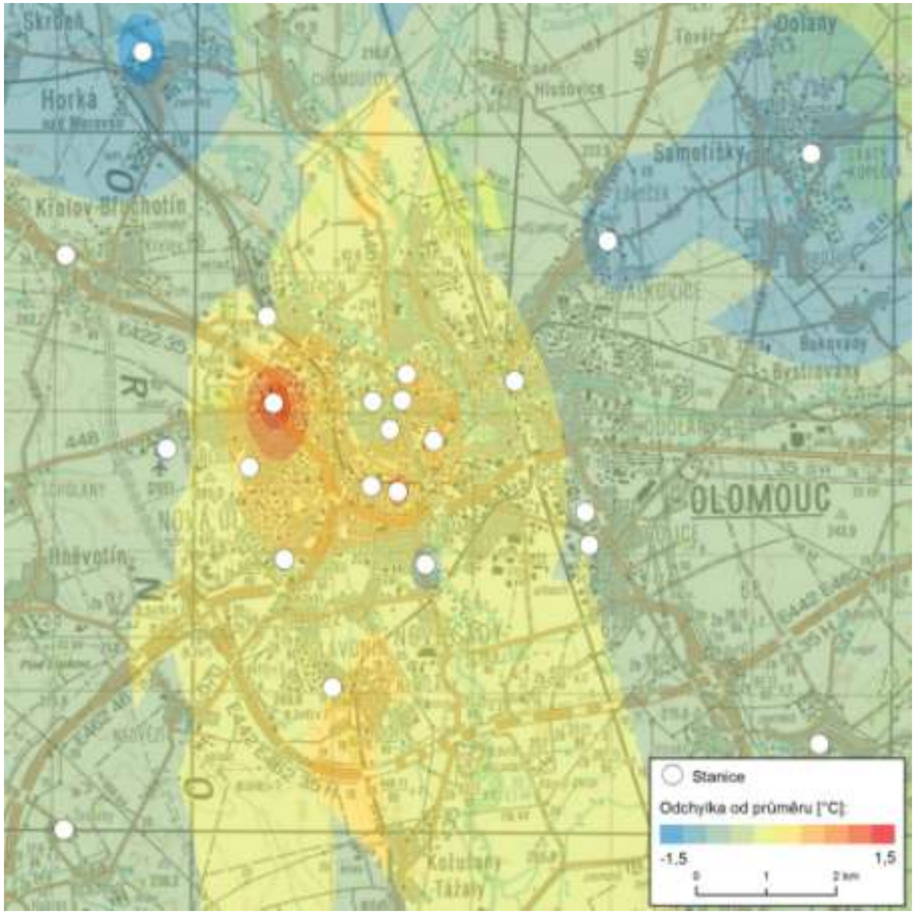
Suburban stations: 9

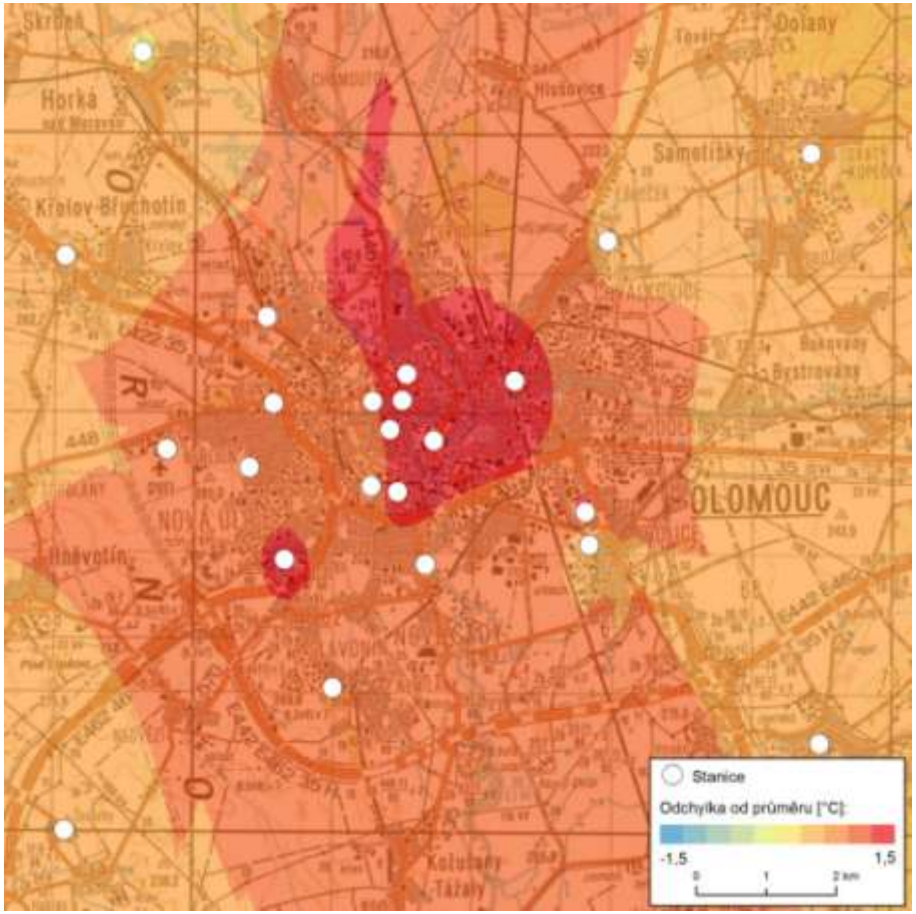
Temperature field in Olomouc based on the MESSO measurements in 2010–2011



- **Annual variation of air temperature at the warmest (KRAK) and coldest (DDHL) MESSO station in 2010 and 2011**

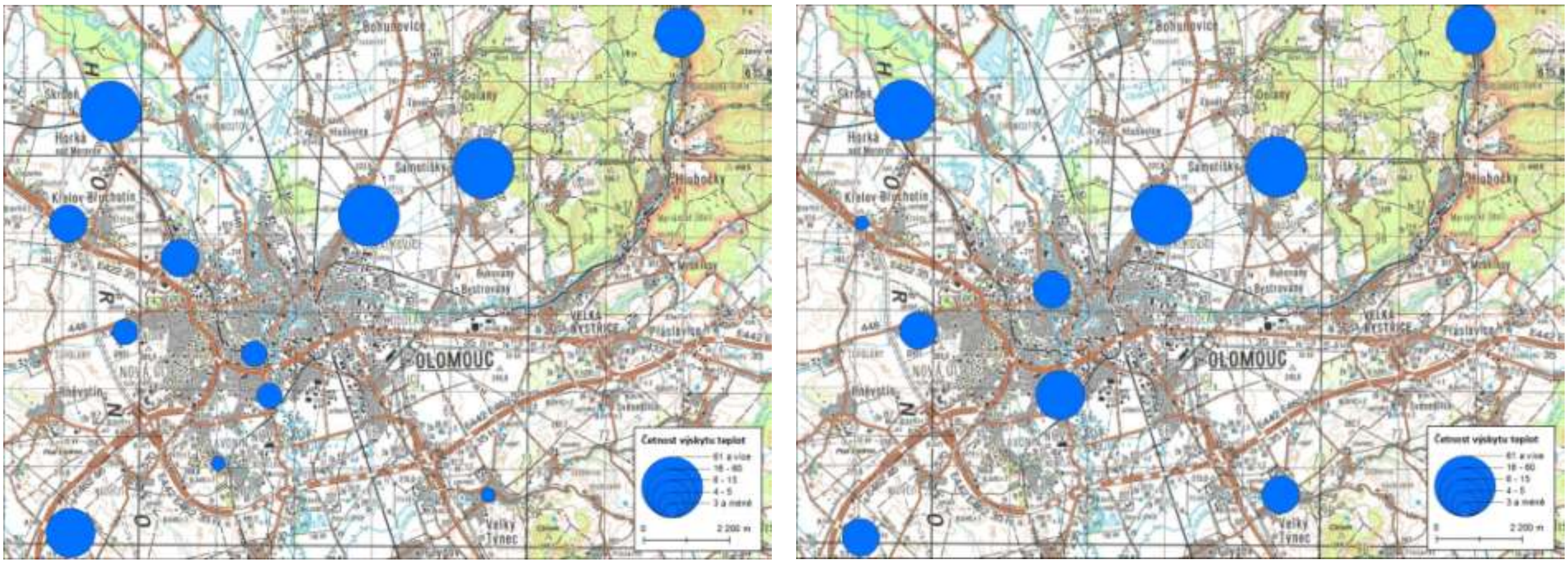
Temperature field in Olomouc based on the MESSO measurements in 2010–2011





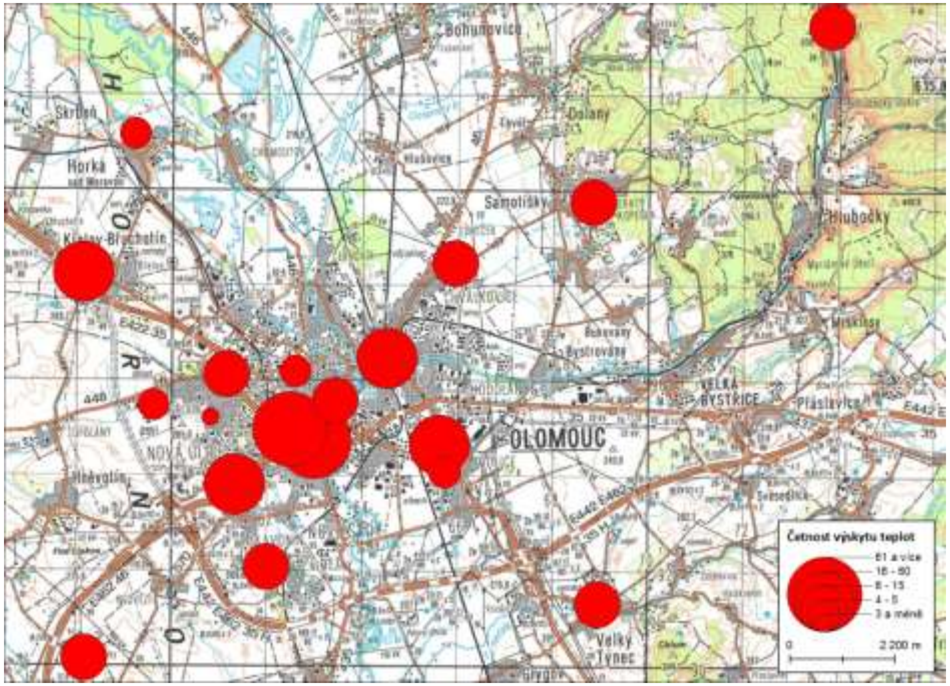
- **Average annual air temperature in urban and suburban landscape of Olomouc 2010 (left) and 2011 (right)**

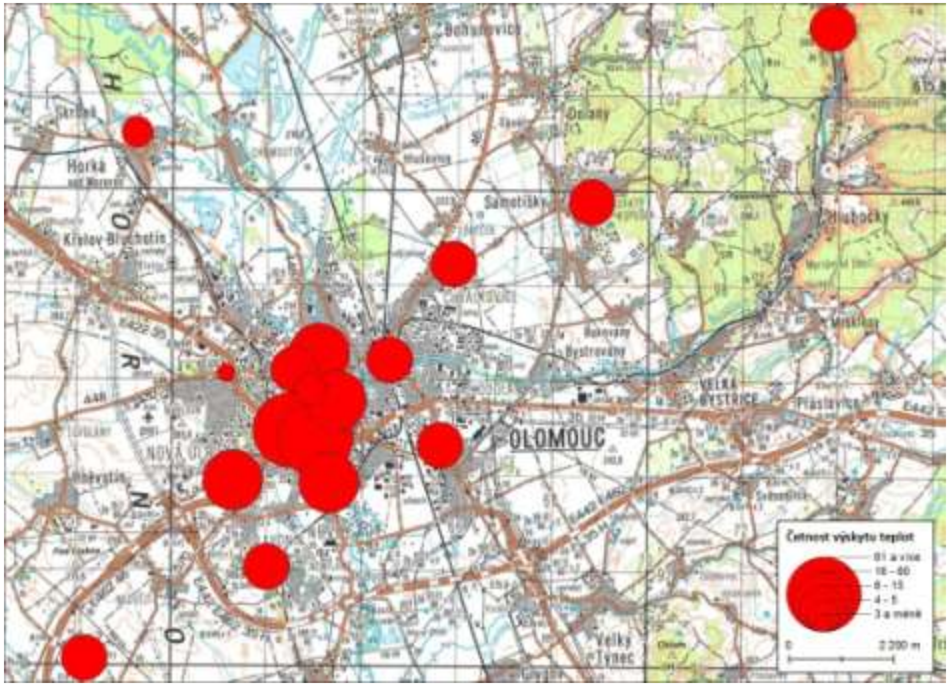
Temperature field in Olomouc based on the MESSO measurements in 2010–2011



- **Frequency od daily minimum air temperature occurrence at MESSO station 2010 (left) and 2011 (right)**

Temperature field in Olomouc based on the MESSO measurements in 2010–2011



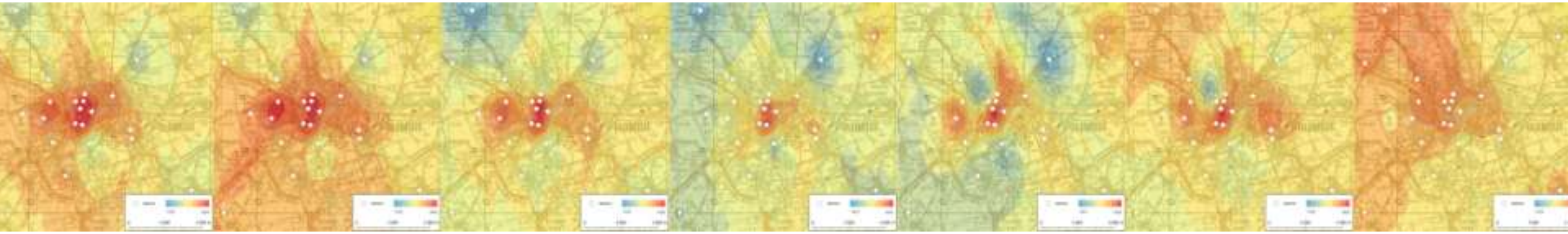


- **Frequency od daily maximum air temperature occurrence at MESSO station2010 (left) and 2011 (right)**

Analysis UHI (urban heat island) and UCI (urban cold island)

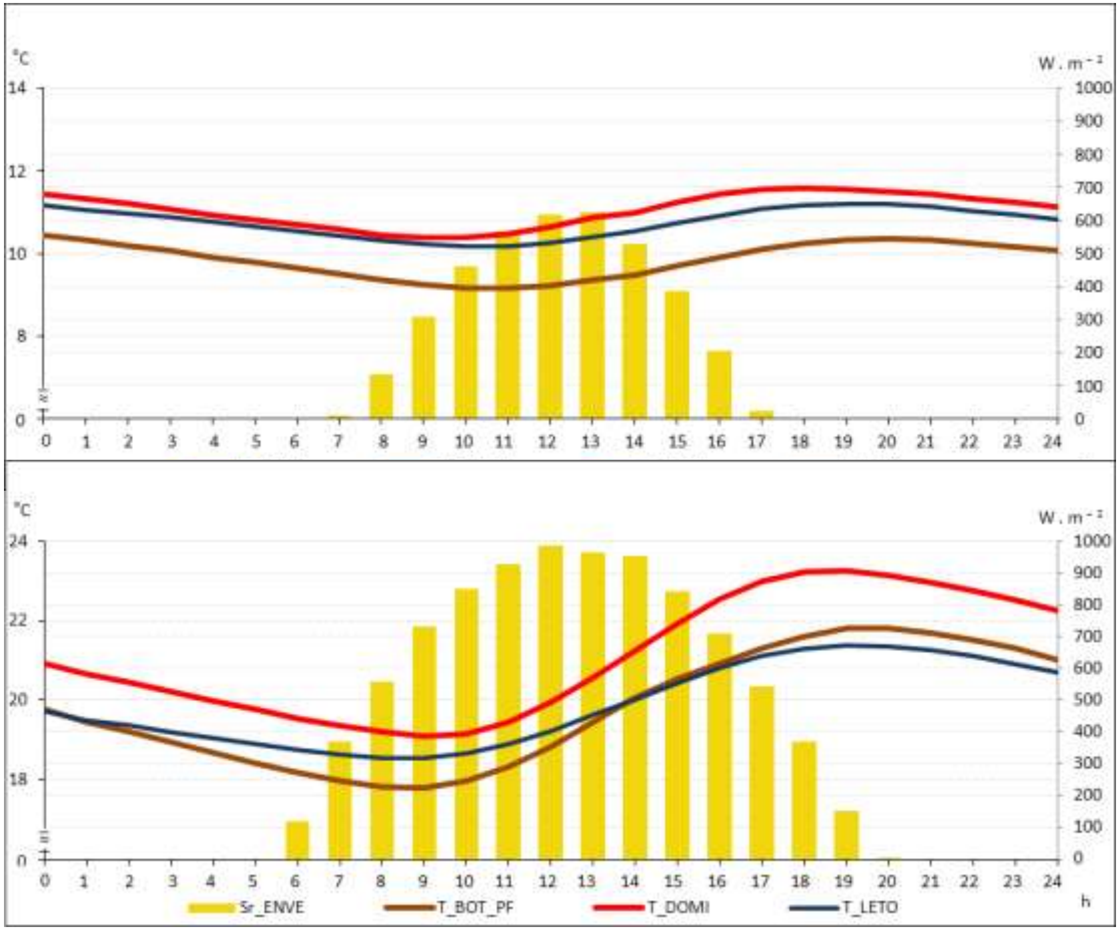
- **UHI/UCI in Olomouc:**
- analysis of air temperature differences in MESSO stations in 7 hourly moments (18:00–24:00),
- selected days with radiation weather regime.
- **Maximum difference:**
  - **9.1 °C**, October 1st 2011 at 19:00 between stations LETO (20.1 °C) and HORK (11.0 °C) - paradoxically suburban stations
- **The second highest difference:**
  - **8.7 °C**, October 1st 2011, between stations KOPE and CHVA (or HORK)
- **UHI/UCI is reality in the middle–sized city such as Olomouc.**

1. Evaluation of UHI/UCI in selected days



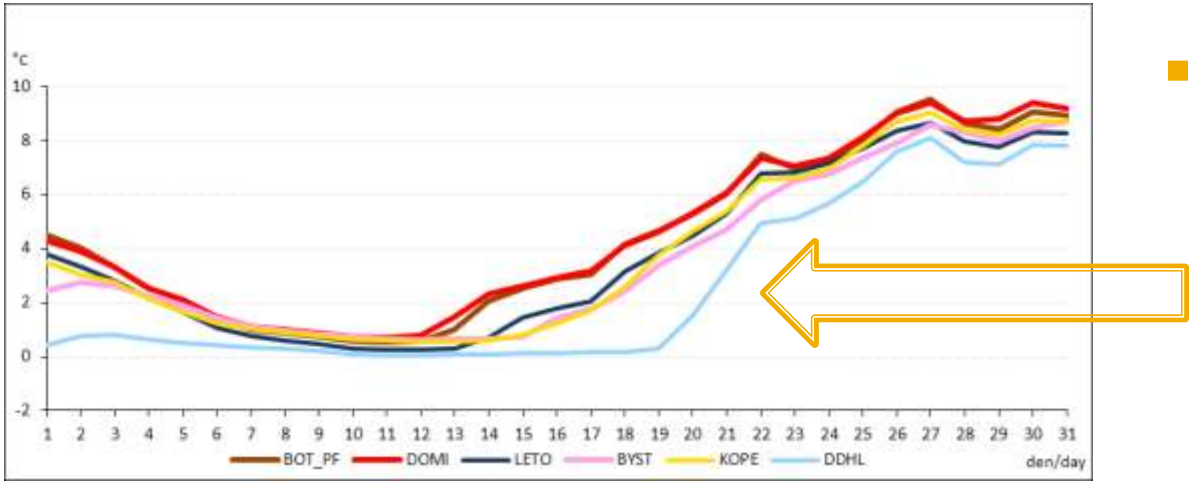
- **UHI and UCI evaluation on December 30, 2010 (every hour from 18:00 to 24:00)**

Soil temperature and weather regime

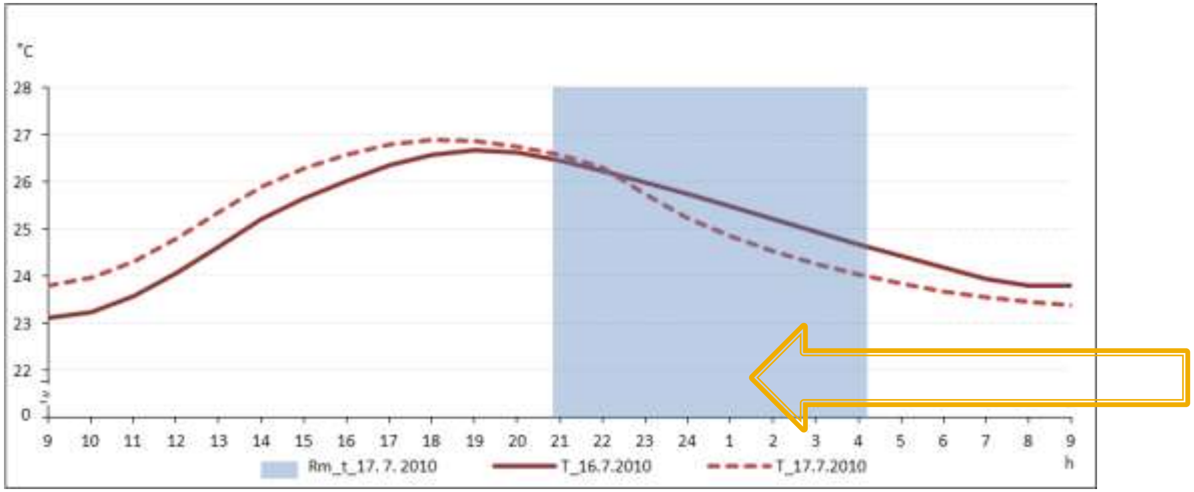


- **Soil temperature and global radiation - radiative weather Autumn (above), Summer weather (down)**

Soil temperature and weather regime

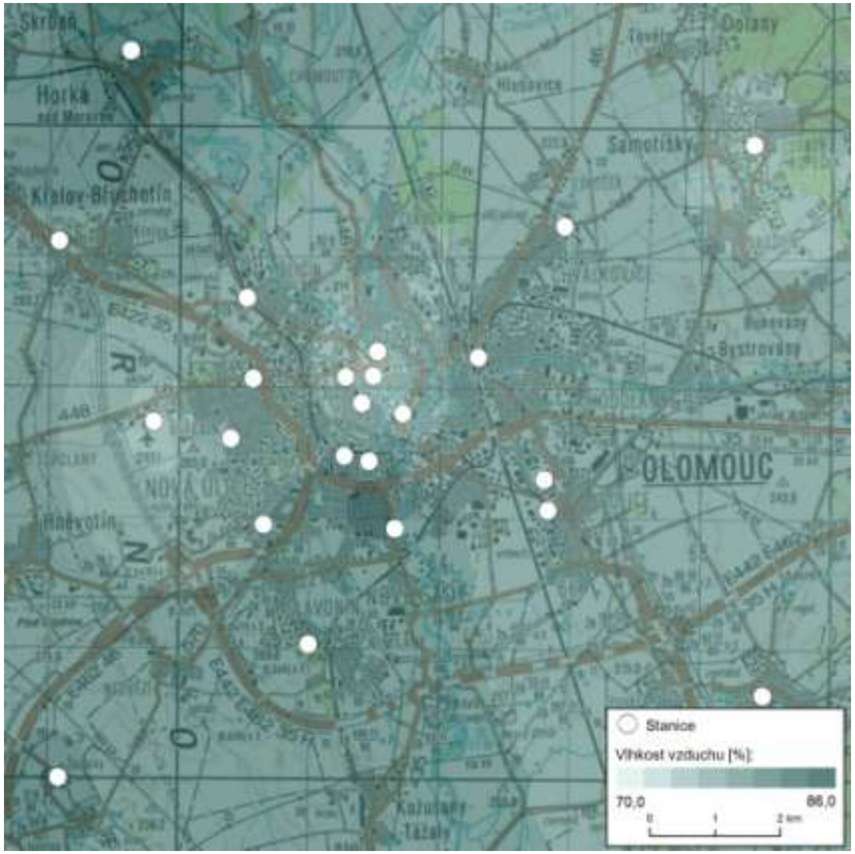


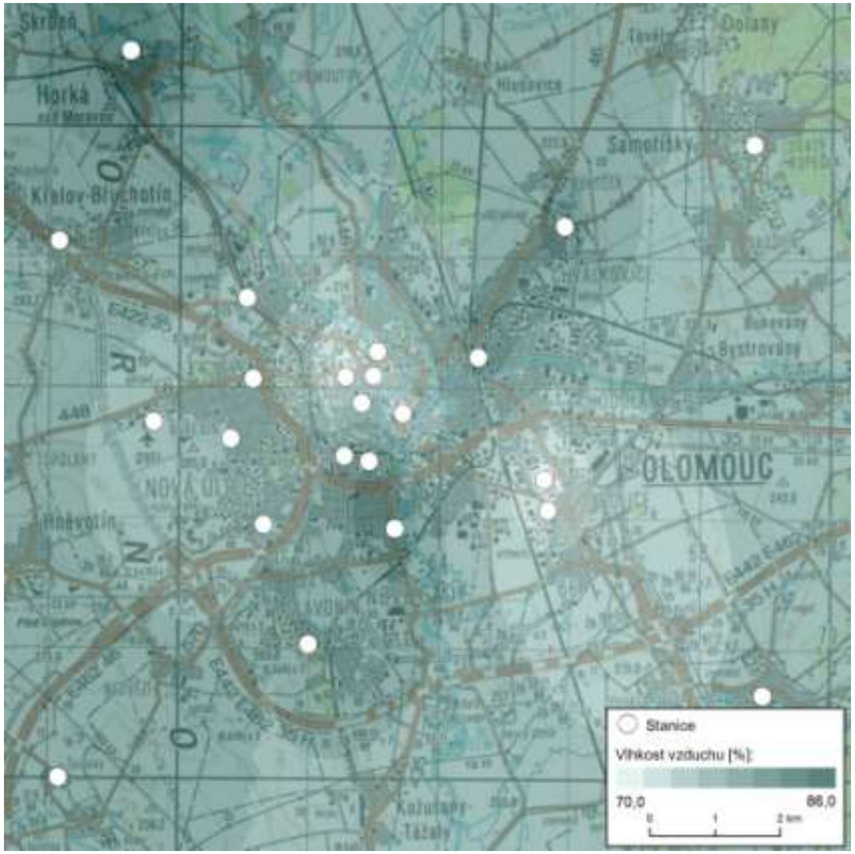
- **Daily soil temperature regime and snow cover**



- **Effect of precipitation on soil temperature**

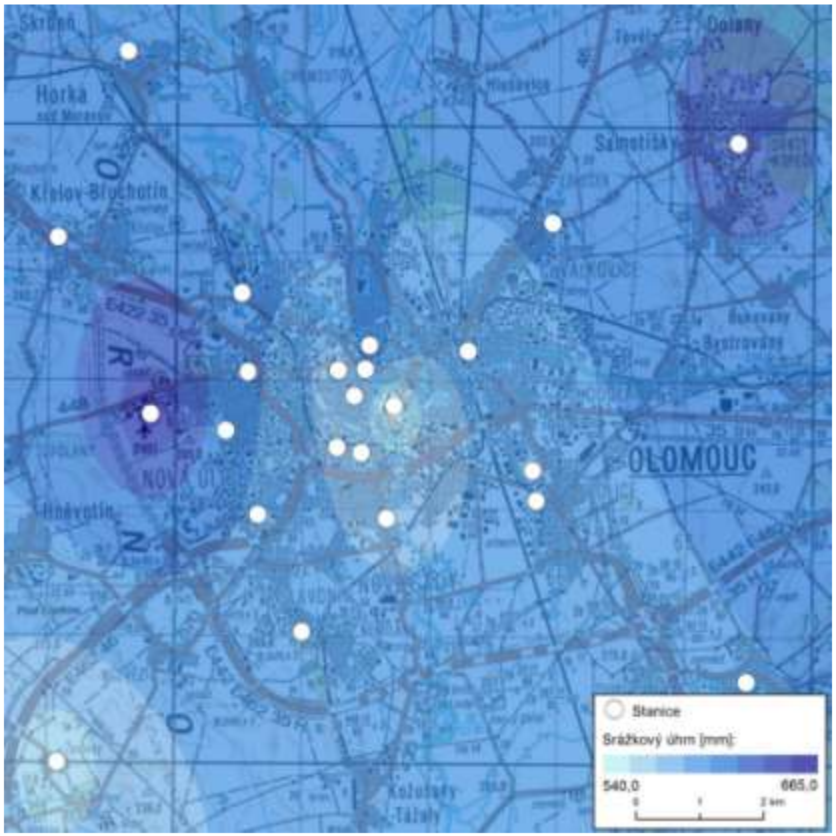
Air humidity

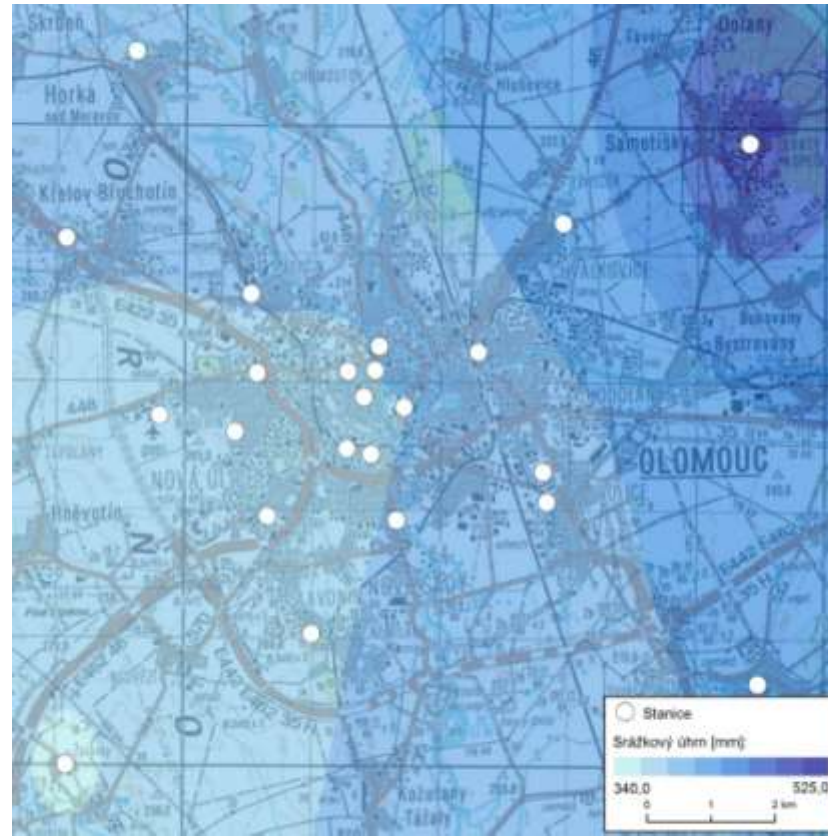




- **Spatial variability of air humidity field at urban and suburban landscape of Olomouc in 2010 and 2011**

Precipitation – summer half-year





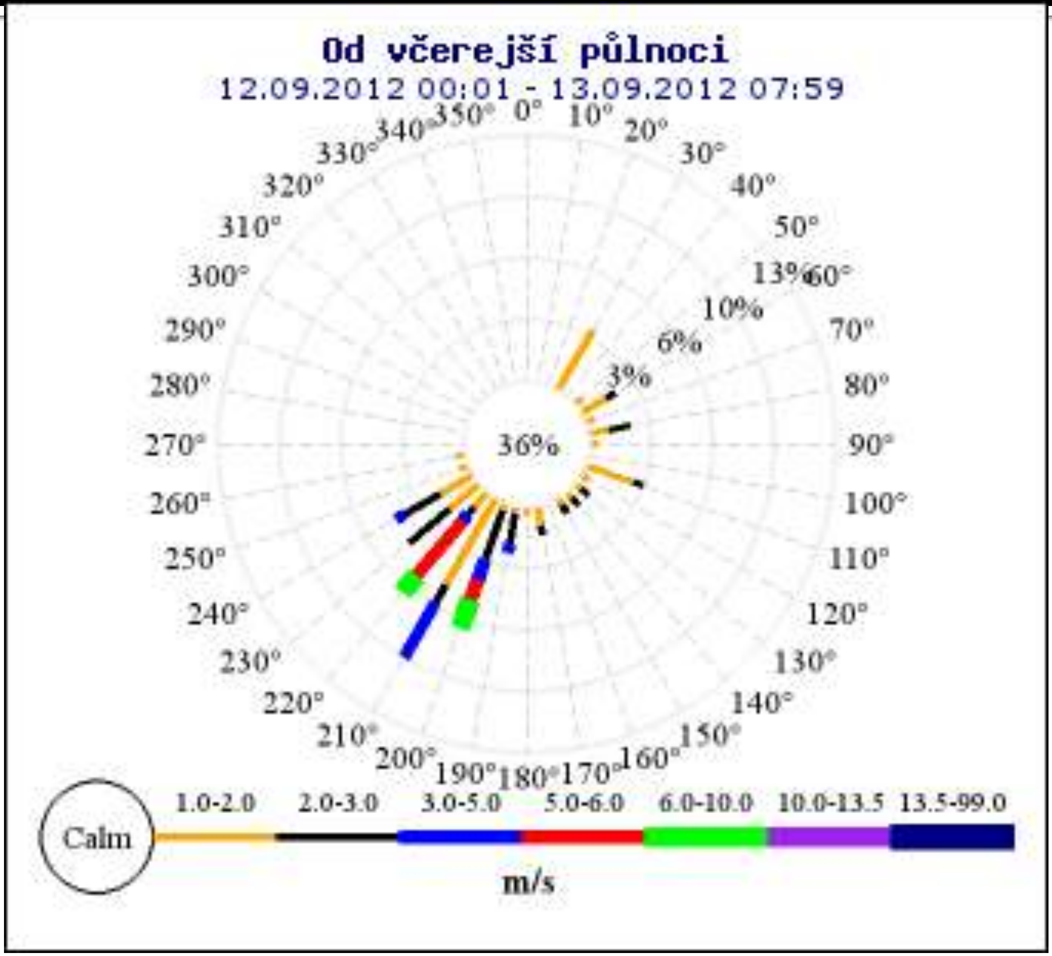
- **Spatial variability of atmospheric precipitation in summer half-year at MESSO stations 2010 and 2011**

Precipitation – summer half-year

Station	BOT_PeF	BYST	DDHL	DOMI	ENVE	JUTA	KOPE	LETO
One–day precipitations totals	55,2	46,7	32,9	46,0	48,3	27,1	59,2	107,8
Two–days precipitations totals	63,0	56,3	50,6	65,2	54,1	32,9	69,2	119,6
Three–days precipitations totals	63,4	61,5	52,2	65,6	54,6	33,6	69,2	120,2

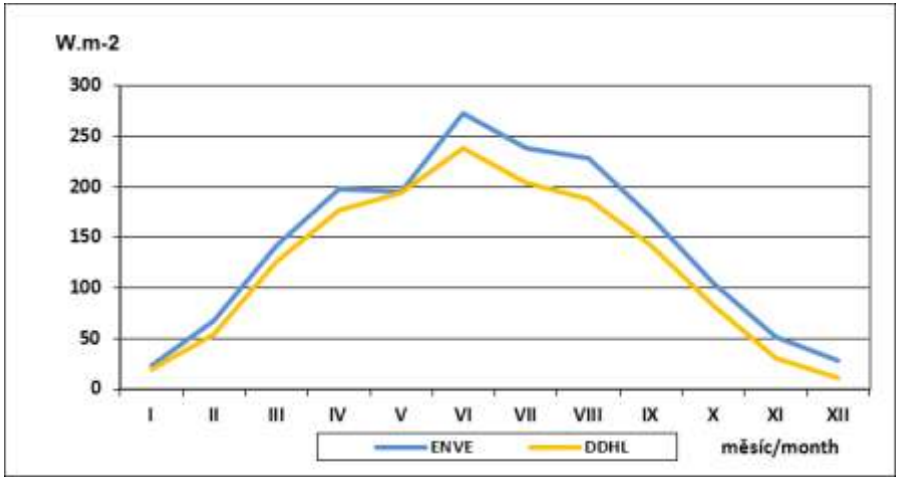
- **Average annual maxima of one–day, two–day and three–day precipitation totals (mm) at MESSO stations in 2010**

Wind velocity and direction

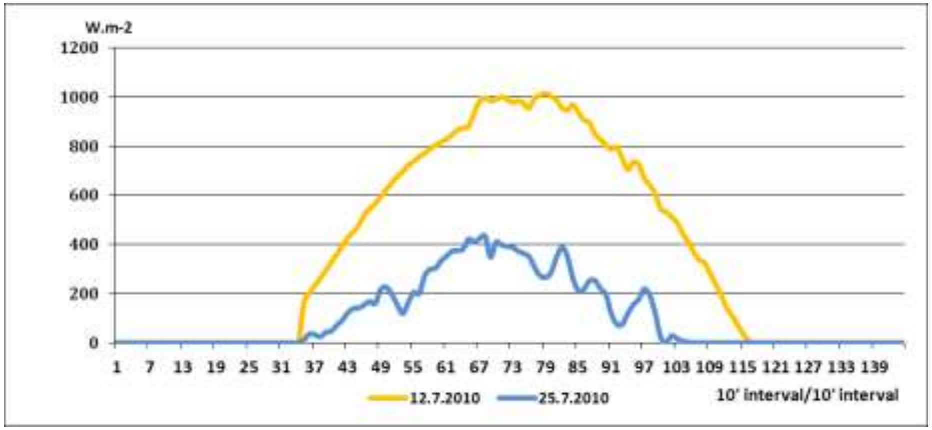


- **Max. speed: August 14, 2010, 19,7 m.s^{-1} (70,92 km.hour^{-1})**

Global solar radiation

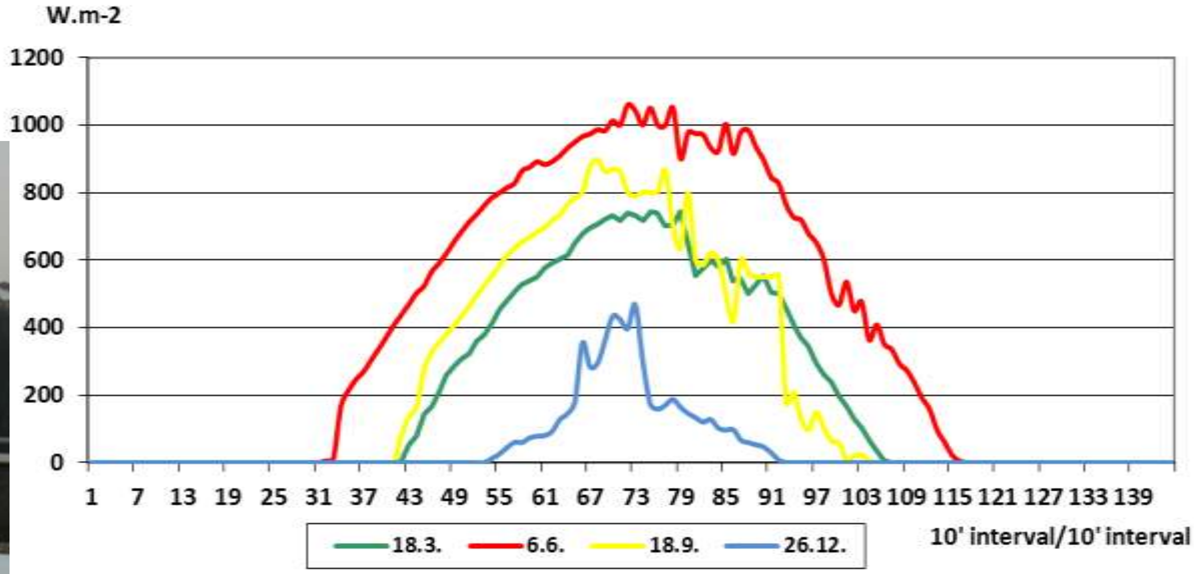


- Annual variation of global radiation at station ENVE and DDHL



- Example of global radiation variability at station ENVE during clear sky and overcast day

Global solar radiation



- **The example of daily solar global radiation course at station ENVE in selected days of first months of climatic seasons of year (March, Juny, September, December)**

Selected hazardous atmospheric phenomena

- **local radiative air temperature inversion**
- **hot waves**
- **cold waves**
- **extraordinary precipitation totals**

Profile KOPE-DOMI
KOPE – 362 m a. s. l.
DOMI – 220 m a. s. l.

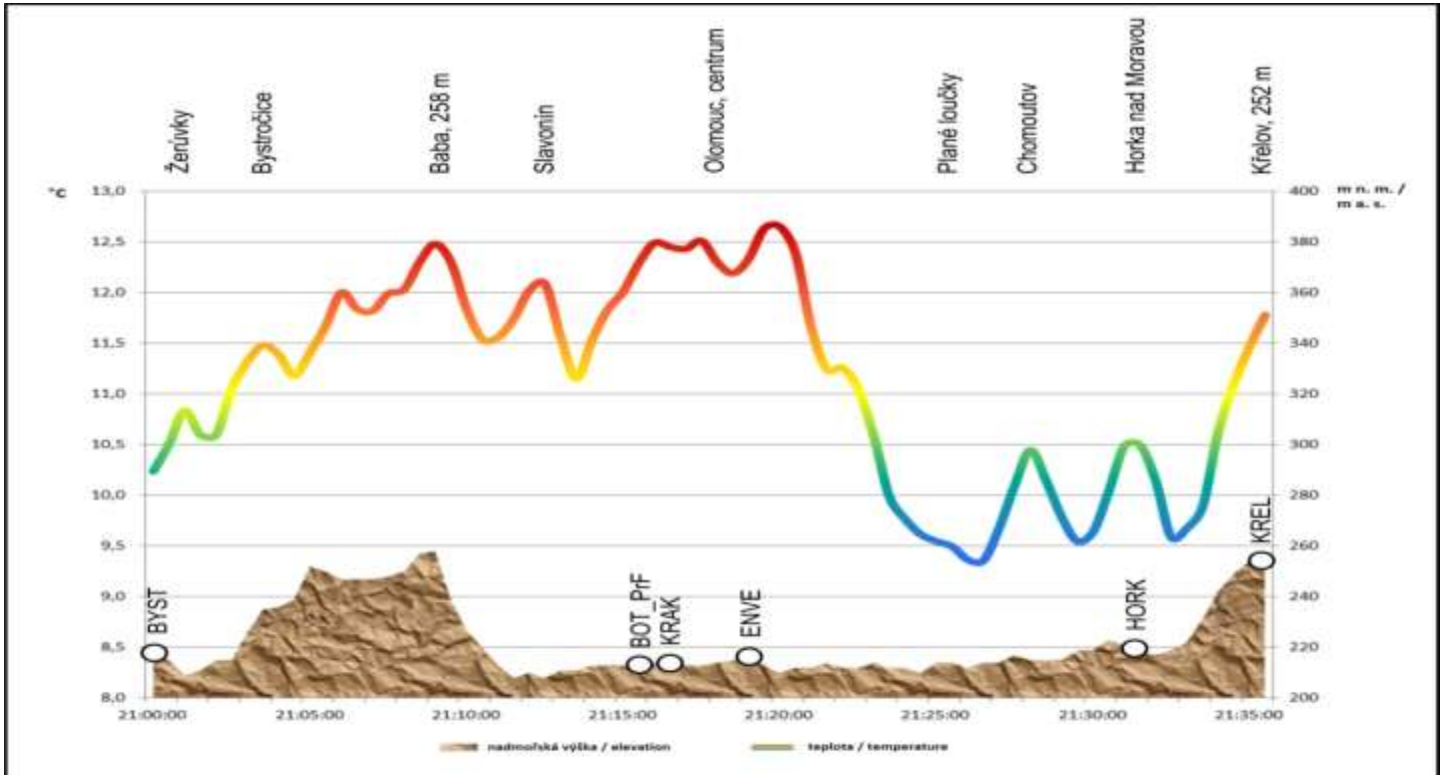
Average intensity 2011: 2,4 °C
Maximum intensity 10‘: 9,6 °C
24.12.2010, 03:00 AM

Profile LETO-DOMI
LETO – 265 m a. s. l.
DOMI – 220 m a. s. l.

Average intensity 2011: 1,7 °C
Maximum intensity 10‘: 6,5 °C
13.11.2011, 18:10 PM

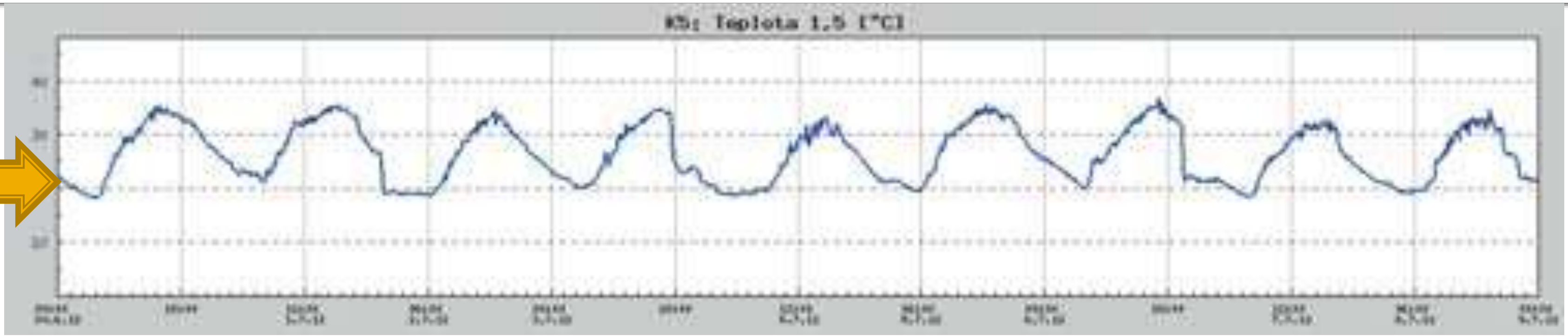
Profile KREL-HORK
KREL – 250 m a. s. l.
HORK – 220 m a. s. l.

Average intensity 2011: 2,2 °C
Maximum intensity 30‘‘: 10,7 °C
15.2.2010, 14:30 PM



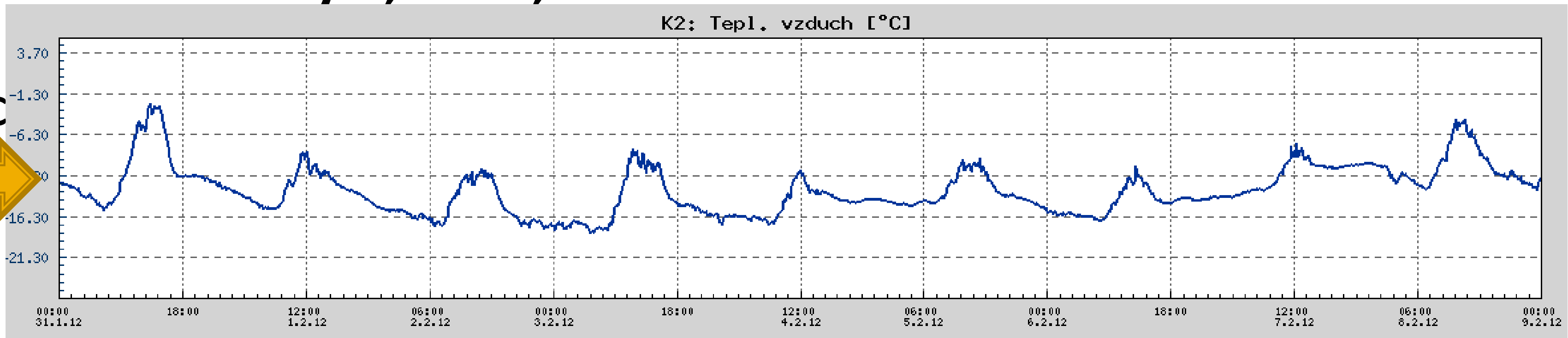
Hot waves   Cold waves

30,0 °C



- **<u>Criterion:</u> 5 days sequence Td,max. ≥30,0 °C**
- **June 30 - July 8, 2012, ENVE station**

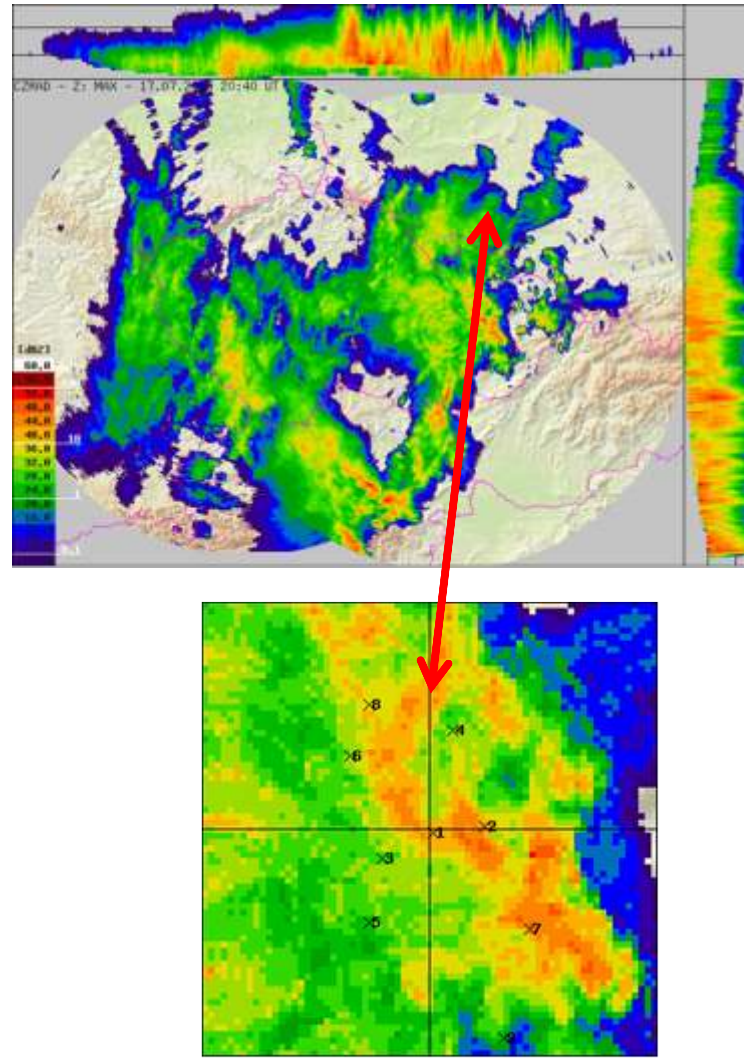
-10,0 °C

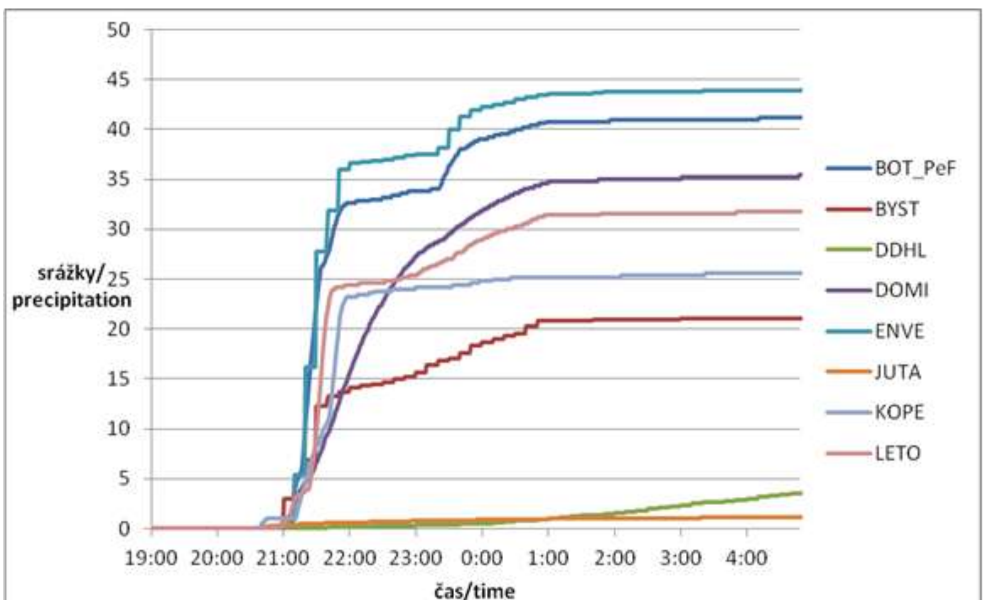


- **<u>Criterion:</u> 5 days sequence Td,max ≤ -10,0 °C**
- **Januar 31 - Februar 8, 2012, KOPE station**

Extraordinary precipitation

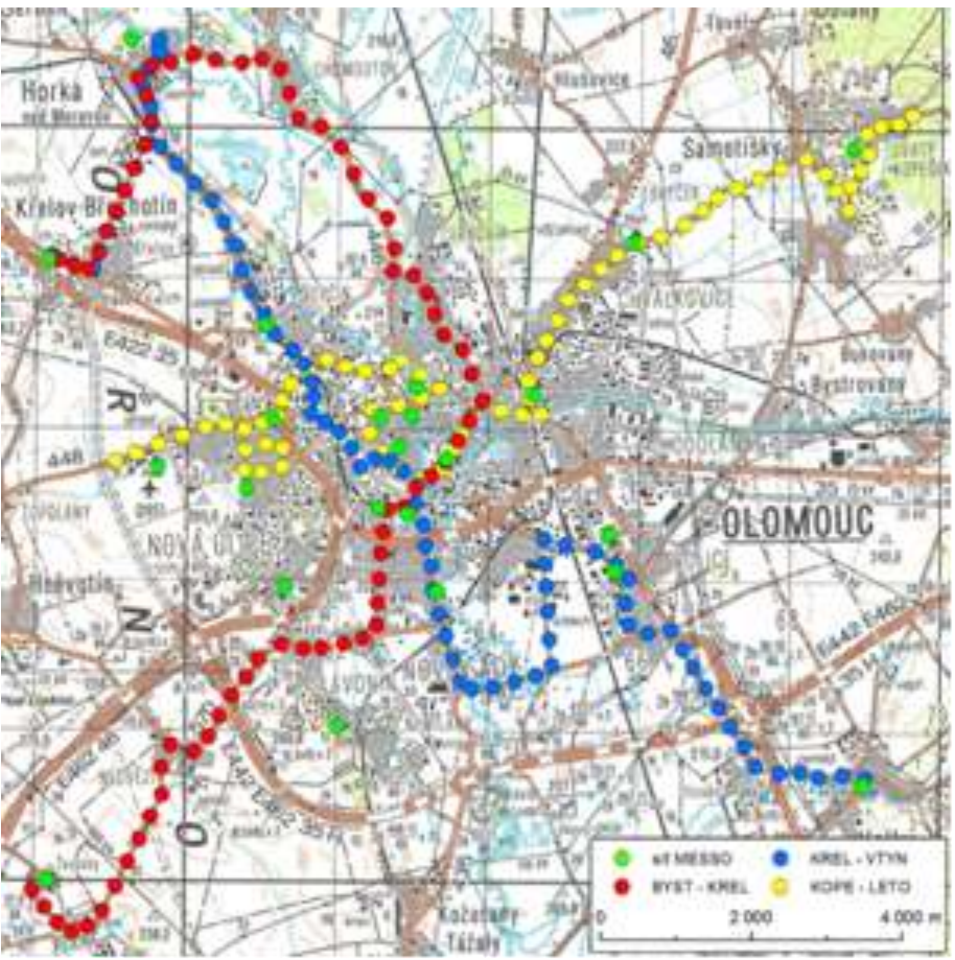
- **Thunderstorm event on 17th July 2010 at MESSO**
- **expressed by cumulative sum total**
- **Daily sum total interval: 8,5 mm (DDHL) – 44,4 mm (ENVE)**

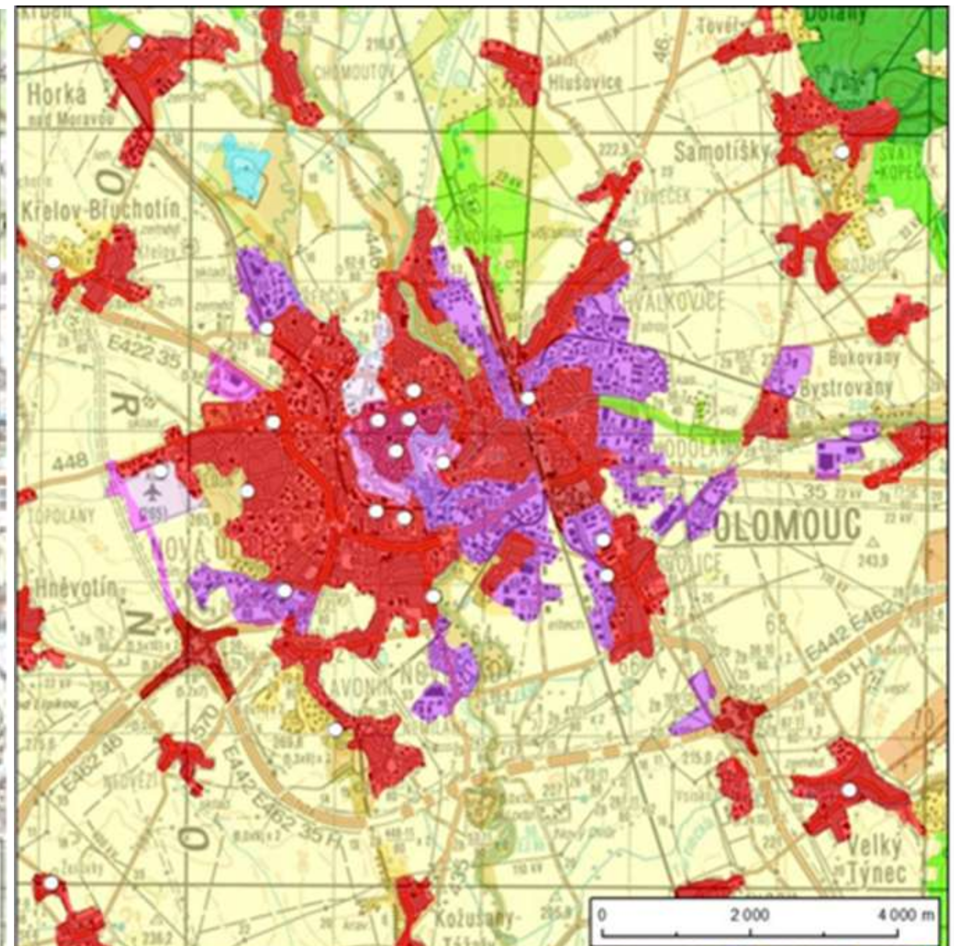


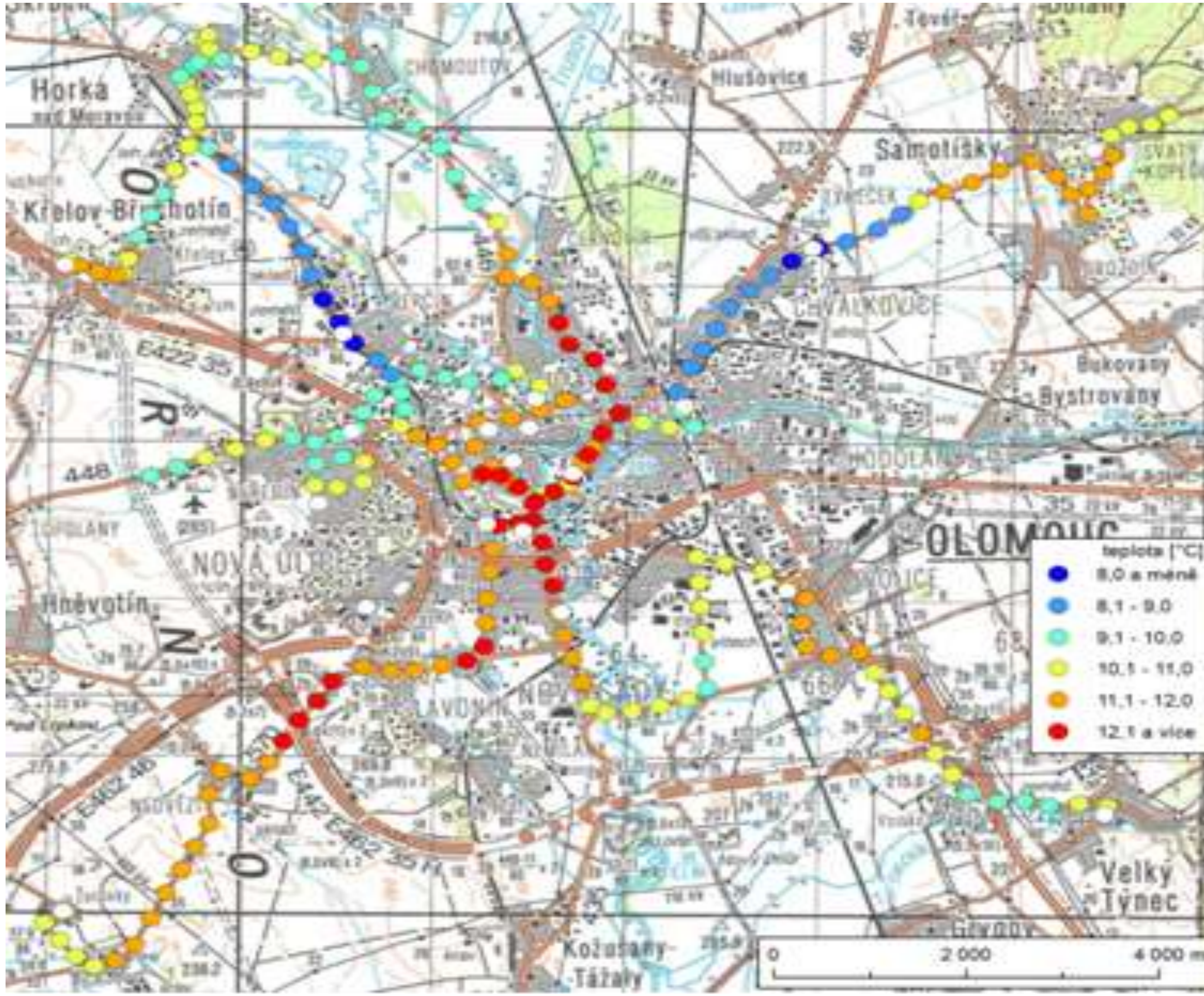


Level 3: Mobile measurement

Profiles and active surface (land use)



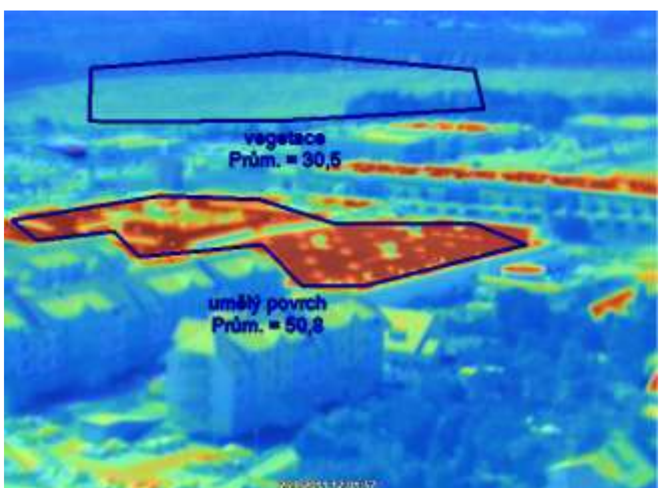


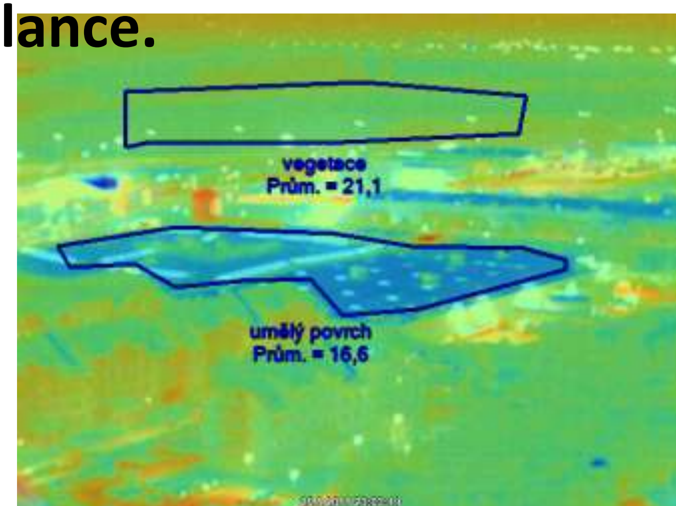


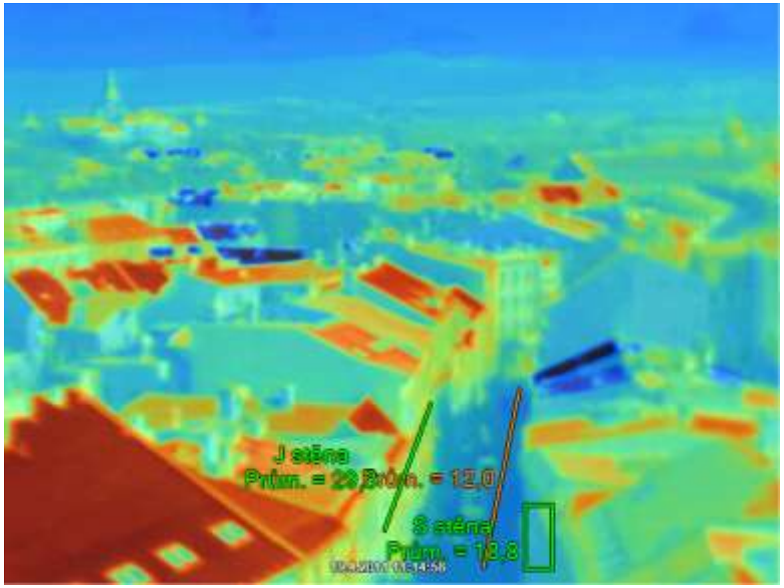
- **Example: Air temperature profiles of routes on April 4, 2010**

Level 4: Surface thermal monitoring

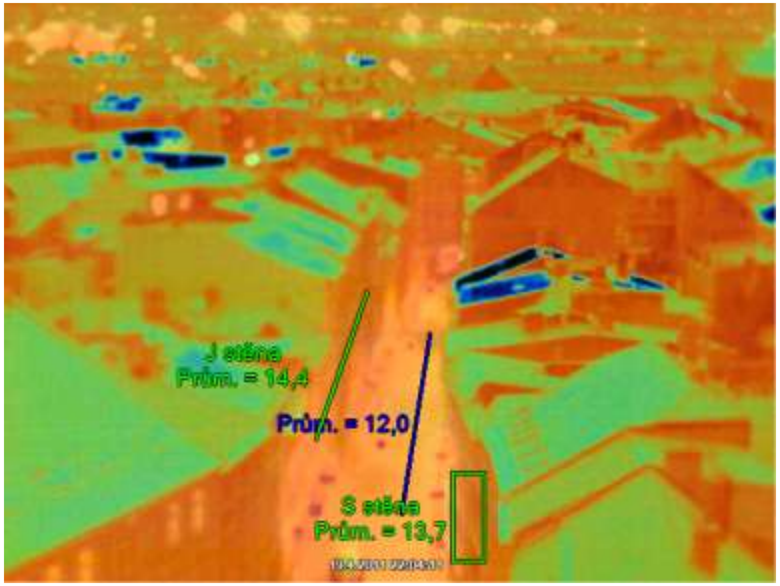
- Temperature field was studied on the basis of analysis of thermograms gained by thermal camera during the seasons of the year, and in time of positive and negative energetic balance.







day

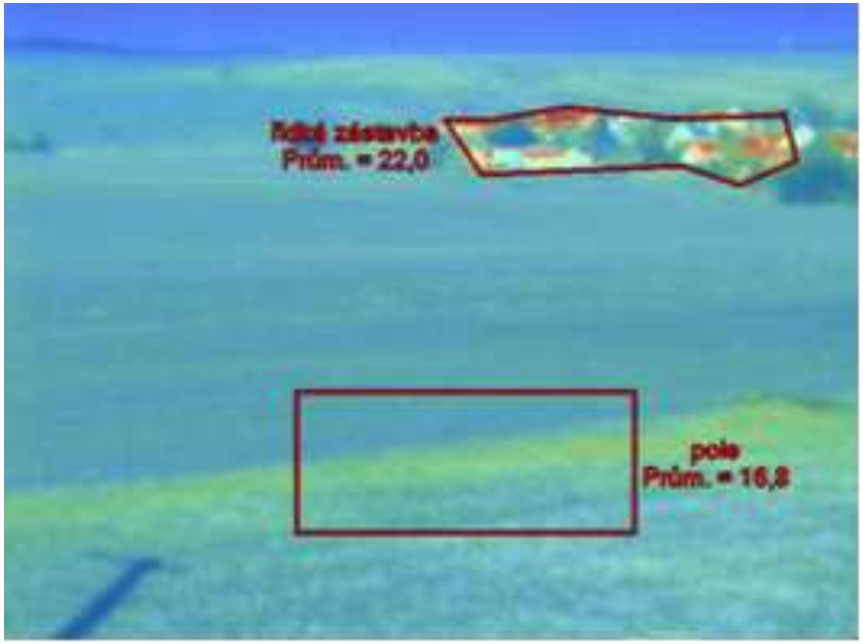


night

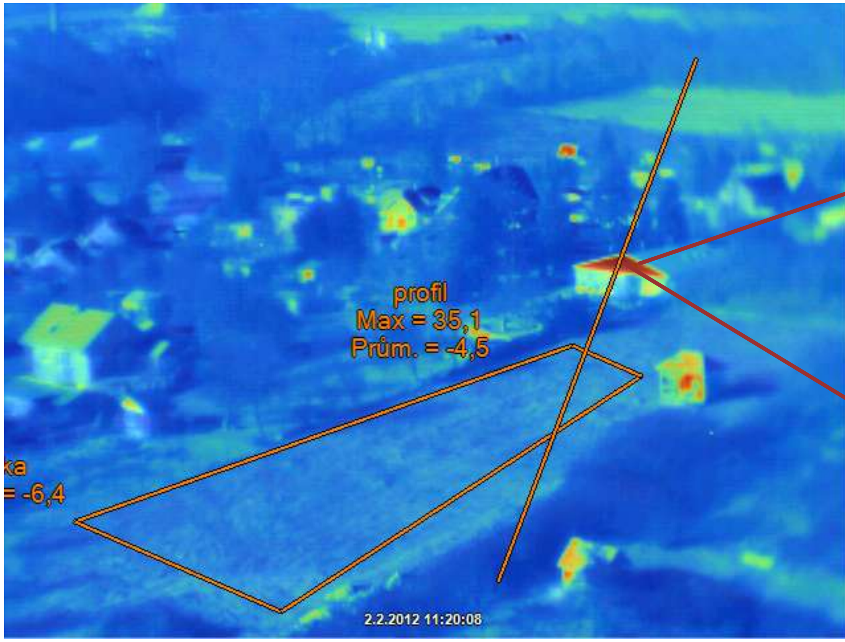
place	day	night	difference
profile	12,0	12,0	0,0
S wall	29,3	14,4	14,9
N wall	18,8	13,7	5,1

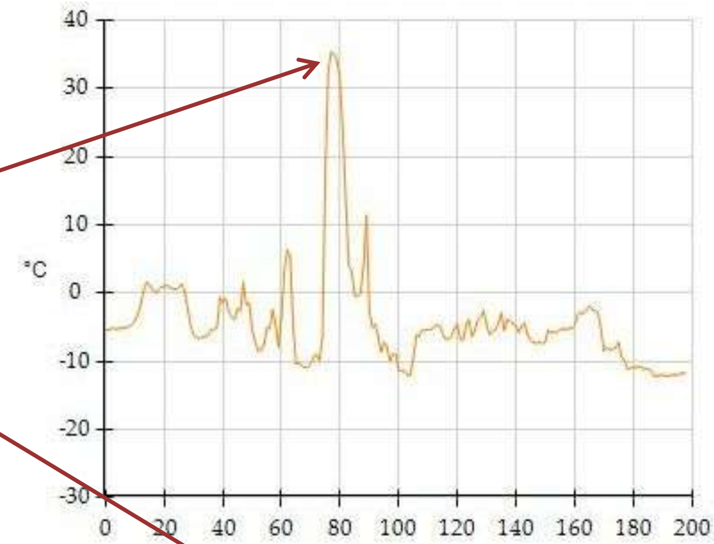
- Method can be accepted for description of **spatial and temporal changes of surface temperatures** in landscape types with a high geodiversity as in **urban** and **suburban** landscape.

Suburban landscape daily surface temperature differences

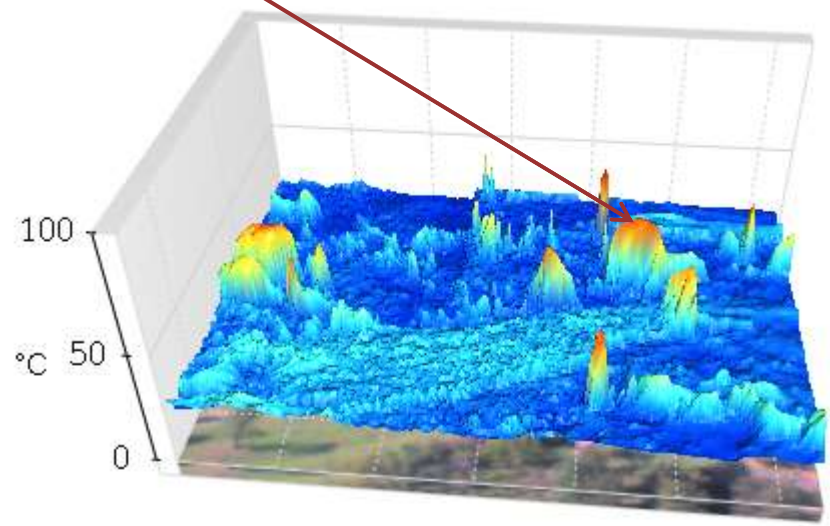


- **Builded area is warmer about 5,2 °C than open landscape**





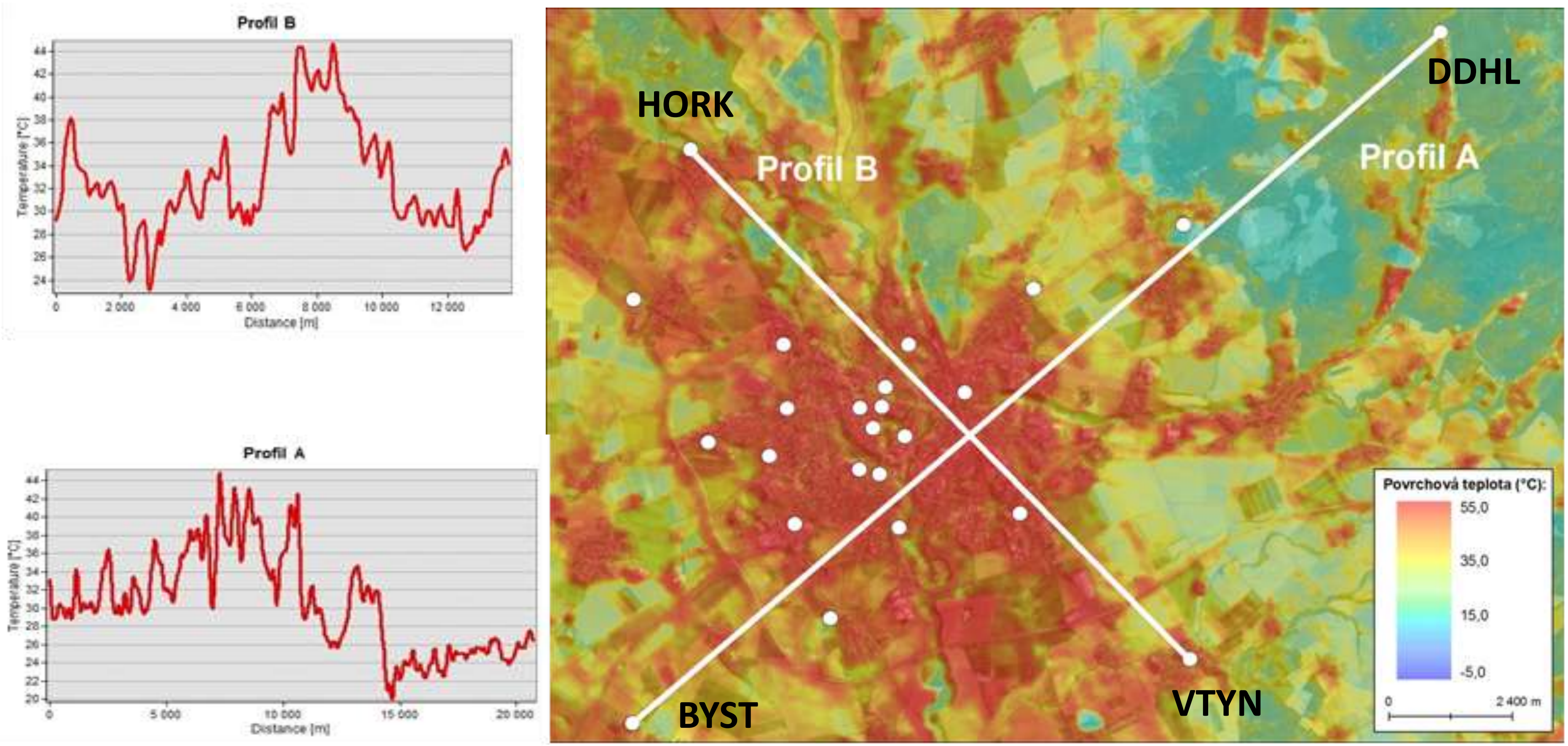
- **Thermal profile in suburban landscape**



Level 5: Satellite thermal monitoring

- Results constituted a basis for subsequent studies of the temperature regime:
  - mobile measurement,
  - stationary meteorological measurement,
  - surface thermal monitoring

Satellite (senzor)	Date/Time	Resolution[m]
TERRA (ASTER)	28. 9. 2009, 9:52 UTC	90
LANDSAT-5 (TM)	27. 9. 2009, 9:34 UTC	120
LANDSAT-5 (TM)	12. 7. 2010, 9:35 UTC	120
LANDSAT-5 (TM)	22. 8. 2010, 9:29 UTC	120



- **Surface temperature field in Olomouc and surroundings on July 12, 2010 (LANDSAT-5 TM) and profile of the surface temperature between the stations a) BYST-DDHL b) HORK-VTYN**

The classification of Local Climate Zones: Introduction to the topic

General background

- *With the development of computing capabilities new perspectives have opened up for the measurement, analysis and modeling of the regime of meteorological variables that are critical for the study of urban climate.*
- *In spite of this technical progress, the expected shift in the knowledge acquired in the study of urban climate onto a wider level of application has not occurred yet* (Grimmond 2006)

General background

- *Up to a third of the papers dealing with UHI (urban heat islands) provide no quantitative or qualitative description of the measurement sites defining the magnitude of a UHI* (Steward and Oke 2009a)
- *Up to three quarters of UHI studies fail in the field of documentation and the presentation of metadata* (Steward 2011a)

General background

- Critique → Answer = standardized metadata protocol (last widely recognized modification was made by Muller et al. 2013)

Station	Start-up date	Status	Sensor type	Sensor accuracy	Active surface in immediate surroundings (20 m)	Altitude (above sea level)	Latitude	Longitude
BOT_PdF	8/4/2010	working	SHT75K (Sensirion)	±0.3 ˚C	grass, buildings, trees	211 m	49° 36.016' N	17° 15.457' E
CHVA	24/3/2009	working	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees, buildings	216 m	49° 37.010' N	17° 17.882' E
CMSE	27/4/2007	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, pavement, buildings, bushes	237 m	49° 35.591' N	17° 15.243' E
DOMI	8/4/2010	working	SHT75K (Sensirion)	±0.3 ˚C	grass, trees, pavement, buildings	220 m	49° 35.810' N	17° 15.044' E
EINS	1/2/2010	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees, asphalt, pavement, buildings	243 m	49° 35.326' N	17° 13.558' E
HODO	1/1/2009	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, asphalt, buildings	214 m	49° 35.994' N	17° 16.738' E
HOLI	8/5/2009	working	SHT75K (Sensirion)	±0.3 ˚C	grass, asphalt, buildings	217 m	49° 34.664' N	17° 17.578' E
HORL	1/2/2010	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees, gravel, asphalt, buildings	233 m	49° 34.606' N	17° 13.949' E
KOJE	30/5/2007	working	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees, asphalt, buildings, pavement	210 m	49° 34.545' N	17° 15.625' E
KREL	1/12/2007	working	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees	250 m	49° 37.010' N	17° 11.239' E
LETO	27/3/2007	working	SHT75K (Sensirion)	±0.3 ˚C	grass, asphalt, buildings	257 m	49° 35.482' N	17° 12.582' E
PRAZ	1/2/2010	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, pavement, buildings, trees	227 m	49° 35.817' N	17° 13.863' E
VVMU	30/4/2009	stopped (1/1/2012)	MicroLog EC750 (Fourier)	±0.2 ˚C	grass, trees, gravel, asphalt, buildings, pavement	225 m	49° 35.816' N	17° 15.394' E

- Metadata minimum of selected Metropolitan Station System Olomouc stations

General background

- Environment of the stations should be comparable all around the world

↓

- Development of **L**ocal **C**limate **Z**ones clasification (Stewart, Oke 2012)

LCZ backround

- **U**rban **T**errain **Z**ones (Ellefsen 1991)

↓

- **U**rban **C**limate **Z**ones classification (Oke 2004)

↓

- **L**ocal **C**limate **Z**ones classification (Stewart, Oke 2012)

LCZ Introduction

Main goals

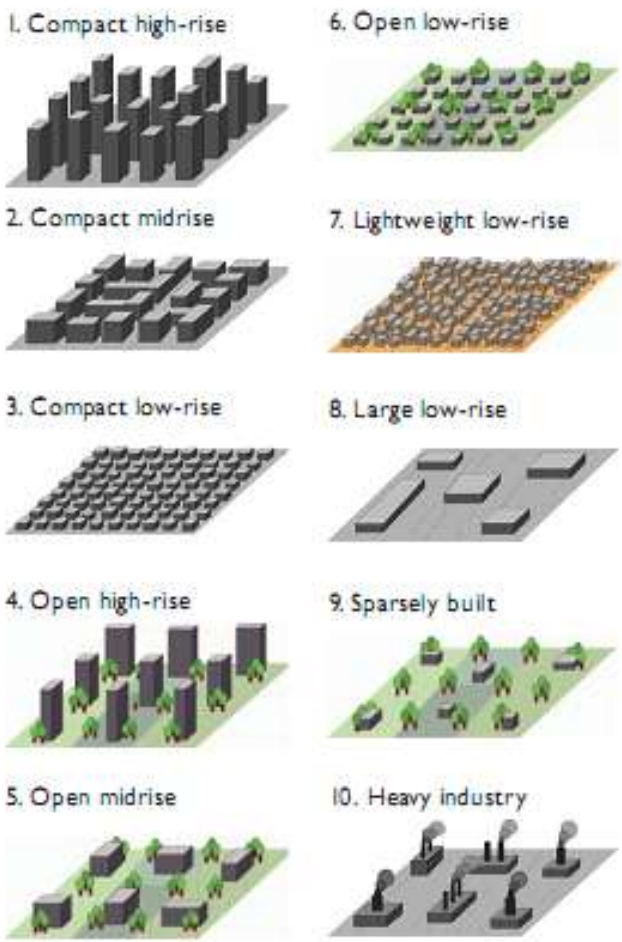
- Get beyond urban-rural dichotomy in UHI research
- Standardize description of surface structure and cover of (urban) climate sites
- Supposed to be universally used across world regions

a) b)

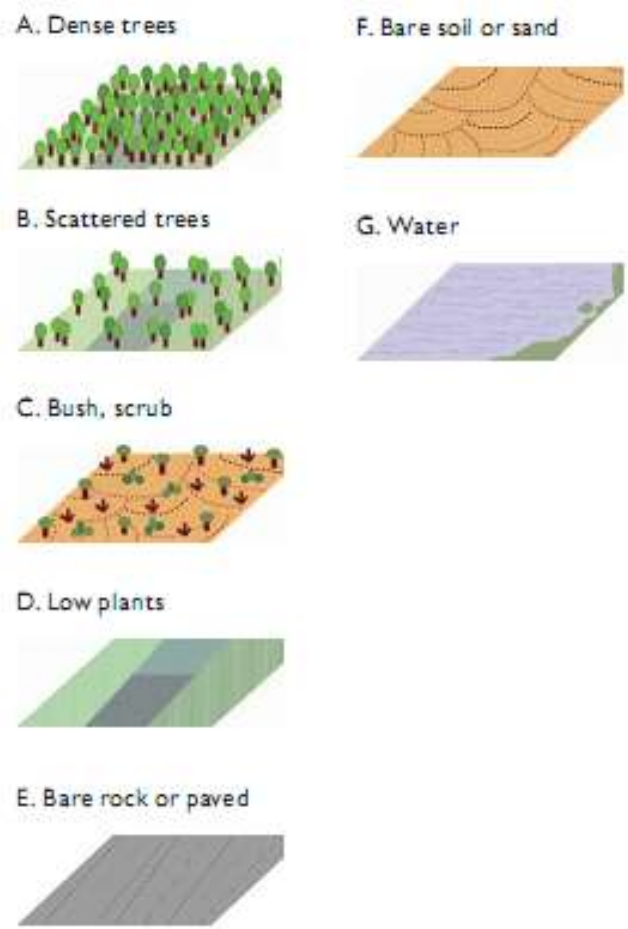
- Two very different environments of MESSO network stations a) EINS and b) LETO

Subset of classes

Built types



Land cover types



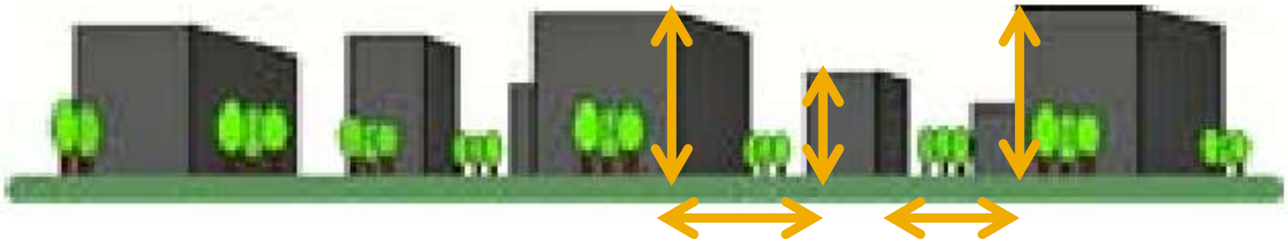
Measurable criteria

- **Each class can be characterized with typical range of all physical properties**
  - **Values of geometric and surface cover properties**
    - Sky view factor
    - Aspect ratio
    - Building surface fraction
    - Impervious surface fraction
    - Pervious surface fraction
    - Height of roughness elements
    - Terrain roughness class
  - **Values of thermal, radiative and metabolic properties**
    - Surface admittance
    - Surface albedo
    - Anthropogenic heat flux

Sky view factor

Aspect ratio

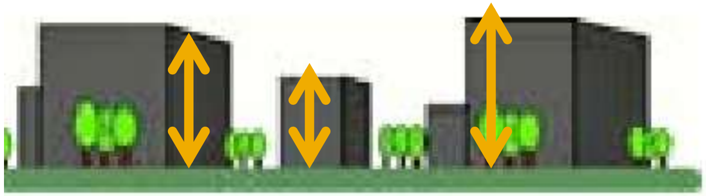
- Mean height-to-width ratio of street canyons (LCZs 1–7), building spacing (LCZs 8–10), and tree spacing (LCZs A–G)



Building/pervious/impervious surface fraction

Height of roughness elements

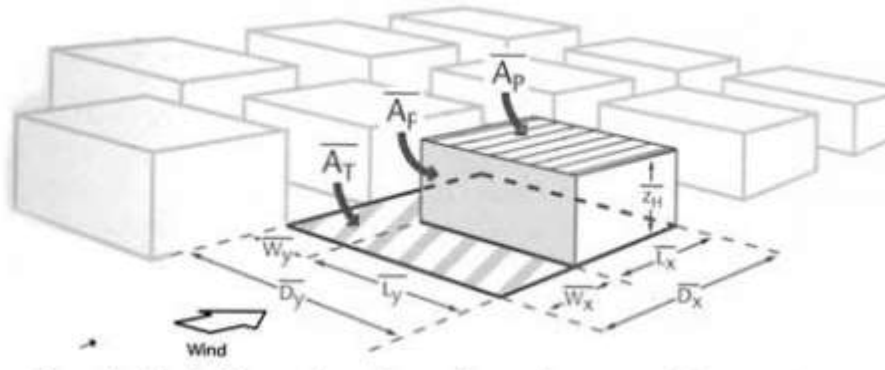
- Geometric average of building heights (LCZs 1–10) and tree/plant heights (LCZs A–F) (m)



vs.

Terrain roughness class

- Revised classification of effective terrain roughness (Davenport et al. 2000)



Class (m)	Landscape Description
1: Sea (0.0002)	Open water, tidal flat, snow, with free fetch $\geq$ 3km.
2: Smooth (0.005)	Featureless land with negligible cover, or ice.
3: Open (0.03)	Flat terrain with grass or very low vegetation, and widely separated low obstacles, airport runway.
4: Roughly Open (0.10)	Cultivated area, low crops, occasional obstacles separated by more than 20 obstacle heights H.
5: Rough (0.25)	Open landscape, crops of varying height, scattered shelter belts, *etc.*, separation distance of 15 H.
6: Very Rough (0.5)	Heavily used landscape with open spaces = 10 H; bushes, low orchards, young dense forest.
7: Closed (1.0)	Full obstacle coverage with open spaces = H, *e.g.*, mature forests, low-rise built-up areas.
8: Chaotic ($\geq$ 2.0)	Irregular distribution of very large elements: city centre, big forest with large clearings.

Surface admittance; Surface albedo and Anthropogenic heat flux

Surface admittance

- Ability of surface to accept or release heat ($J\ m^{-2}\ s^{-1/2}\ K^{-1}$)

Surface albedo

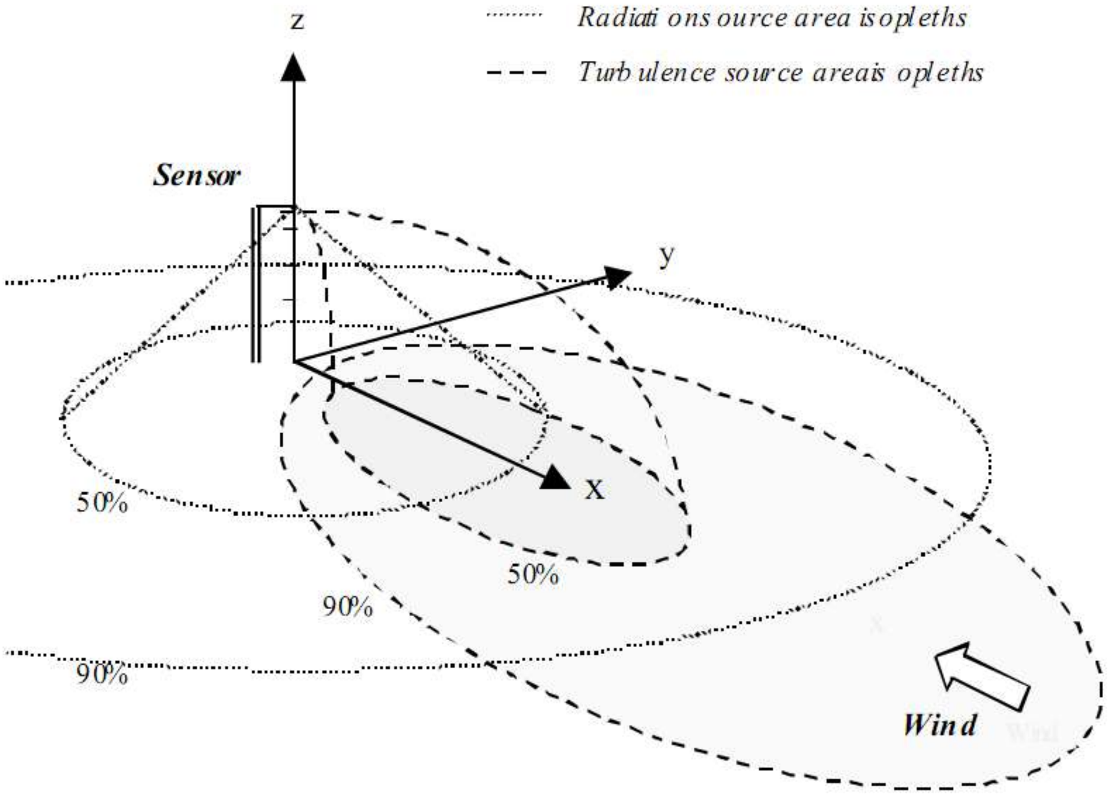
- Ratio of the amount of solar radiation reflected by a surface to the amount received by it

Anthropogenic heat flux

- Mean annual heat flux density ($W\ m^{-2}$) from fuel combustion and human activity

Measurable criteria

- **Source area (circle of influence)**



- Conceptual representation of source areas contributing to sensors for radiation and turbulent fluxes or concentrations (Oke 2006)

Measurable criteria

- It is not necessary to calculate all parameters
- We should find those which are both easily measurable and sufficiently representative for determination of LCZ

Classification process

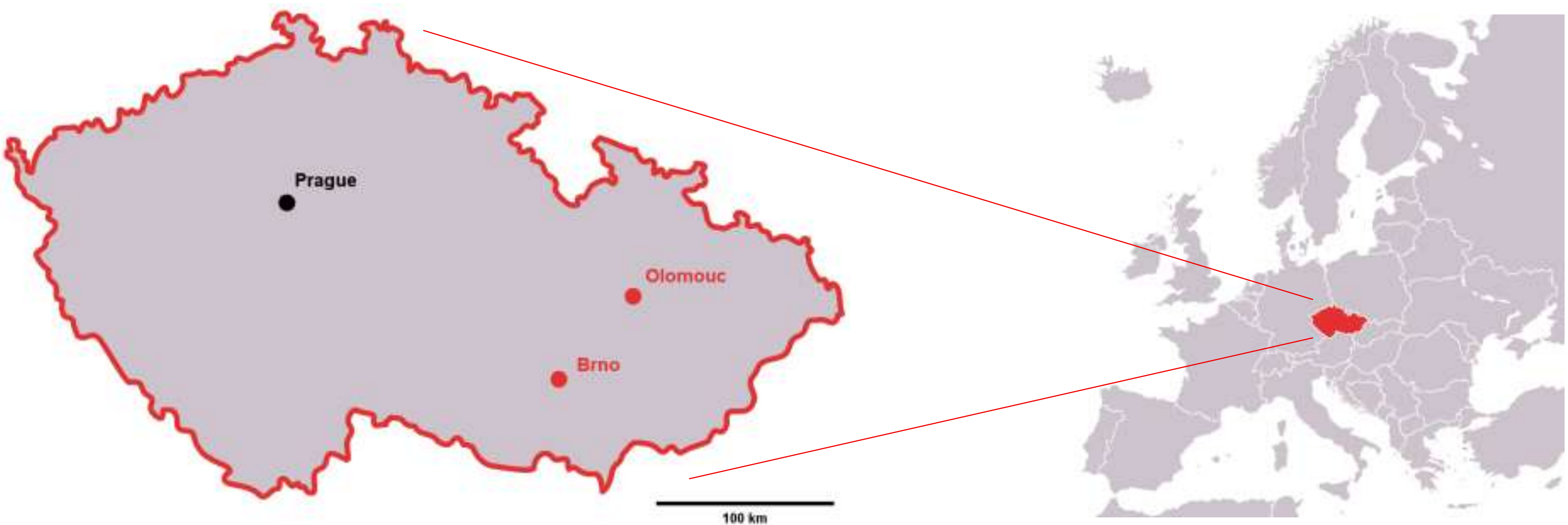
- Standard process of classification has not been established yet
- Two approaches are distinguishable in current literature:
  - Expert based knowledge (e.g. Stewart at al. 2013, Fenner at al. 2014)
  - Exact (automatized) classification procedure (Bechtel et al. 2012, Lelovics at al. 2014)

Classification of Local Climate Zones: Case study of medium-sized Central European cities and their surroundings

Geletič J., Lehnert M (2014): Prospects and problems of the classification of Local Climate Zones through the example of medium-sized Central European cities and their surroundings. IGU Regional conference 2014, Krakow 19/8/2014.

Introduction

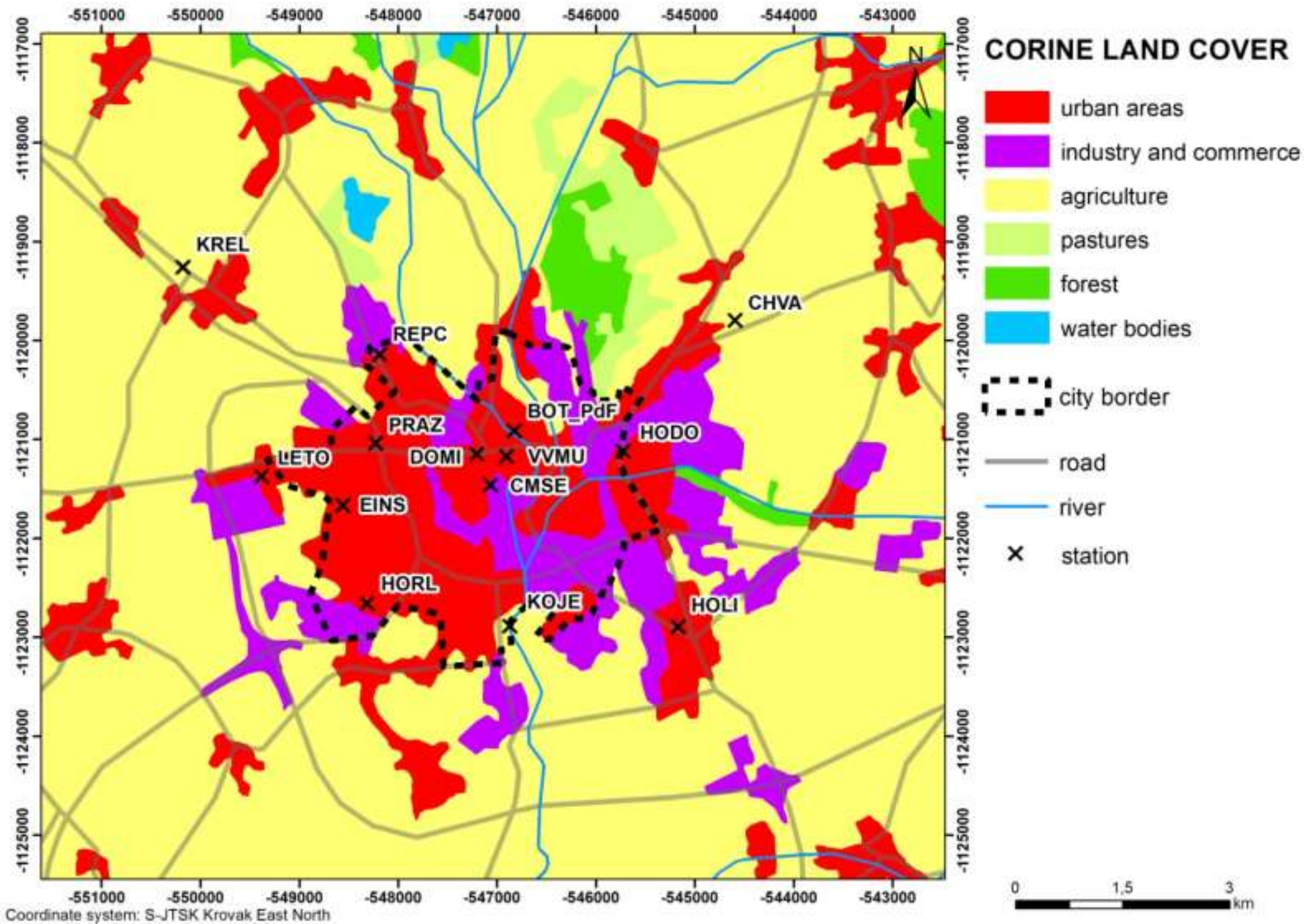
- Olomouc
  - Population 100 000
  - Area: 103 km^2
  - Mean altitude: 230 MASL
  - Stations*: 14
- Brno
  - Population: 380 000
  - Area: 230 km^2
  - Mean altitude 250: MASL
  - Stations*: 16



Main objectives

- Calculate values of geometric and surface cover properties
- Apply LCZ classification
- Evaluation of LCZ classification on the example of medium-sized Central European cities

Olomouc sites



Introduction

- Main objectives:
  - Calculate values of geometric and surface cover properties
  - Apply LCZ classification Evaluation of LCZ classification on the example of medium-sized Central European cities
  - Get a better idea about spatial temperature variability

Methods

- Values of six geometric and surface cover properties were calculated

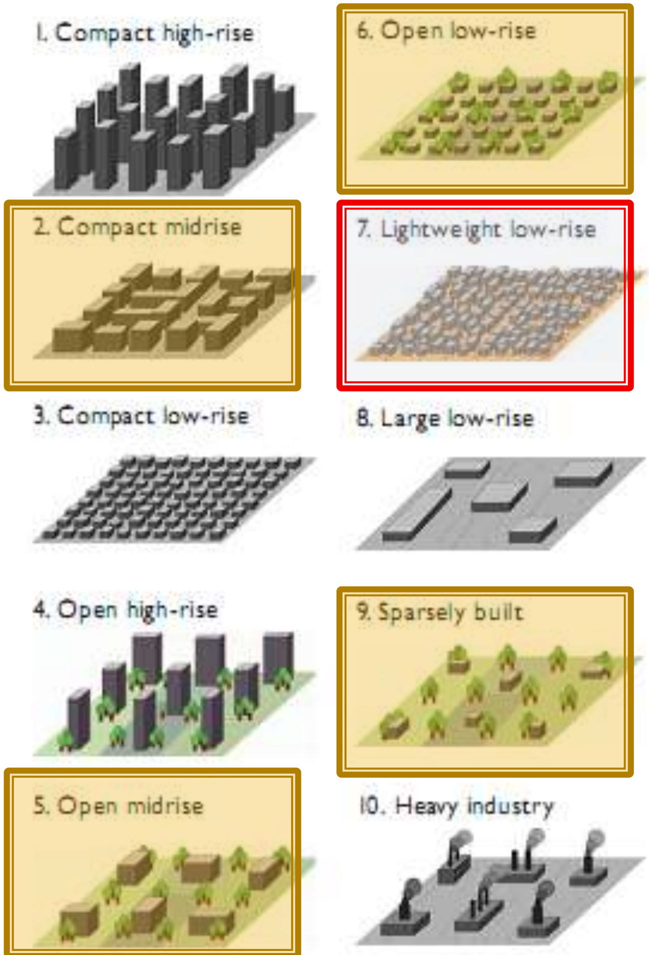
Surface and cover properties	Method	Source area
Sky view factor	fish-eye photo-based calculation	in the place
Aspect ratio	GIS calculation with 3D layer of the development/field investigation	immediate surroundings (50 meters - average of neighbor pixels)
Building surface fraction	calculation over satellite image	200 m radius circle
Impervious surface fraction	calculation over satellite image	200 m radius circle
Pervious surface fraction	calculation over satellite image	200 m radius circle
Height of roughness elements	GIS calculation with 3D layer of the development/field investigation	200 m radius circle

Classification process

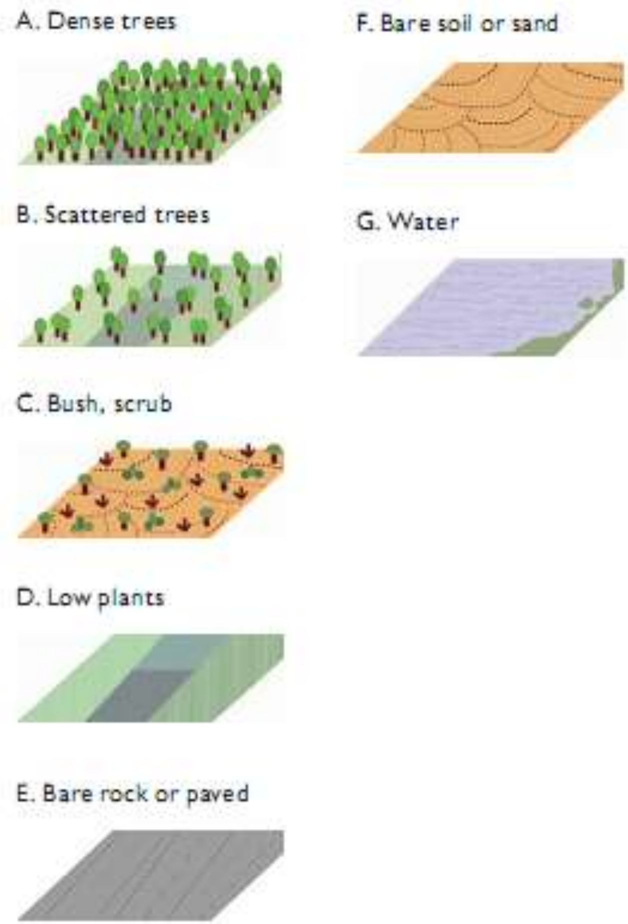
Step	Sample	Decision	Method	Parameter
1	All sites	Subset of classes	Sum of absolute differences of parameters from the nearest outer limit of intervals of typical values	BSF, ISF, PSF
2a	Built types	LCZ	Sum of absolute differences of parameters from the nearest outer limit of intervals of typical values	BSF, ISF, PSF, HRE
2b	Land cover types	LCZ	HRE value in relation to interval of typical values, description of vegetation	HRE
3	All sites	Subclass/reclassification	Evaluation of land cover properties and geometric layout of development in the immediate surroundings of a station	-
4	All sites	Site representativeness	Value of AR and SVF in relation to the suggested intervals	SVF, AR

Results

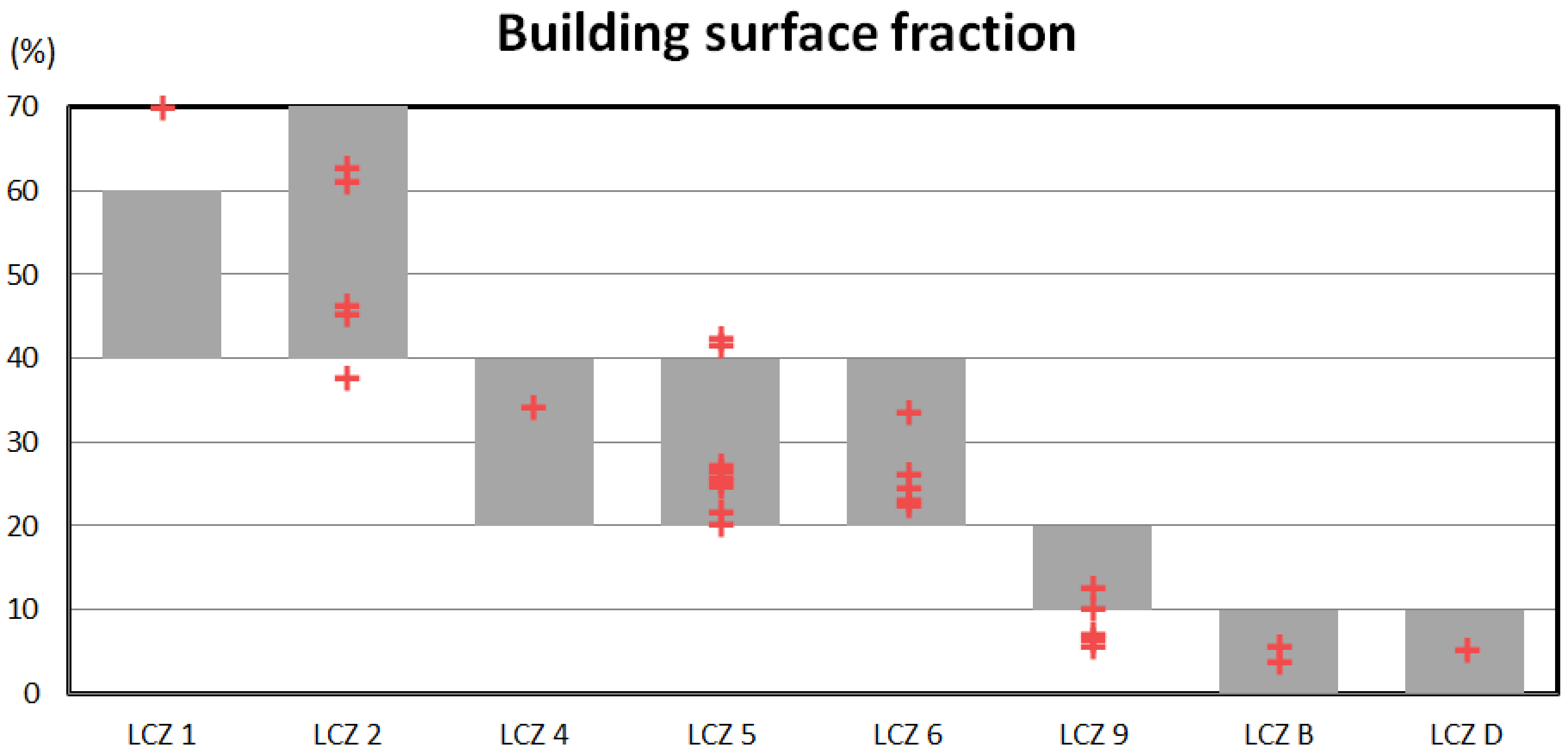
Built types



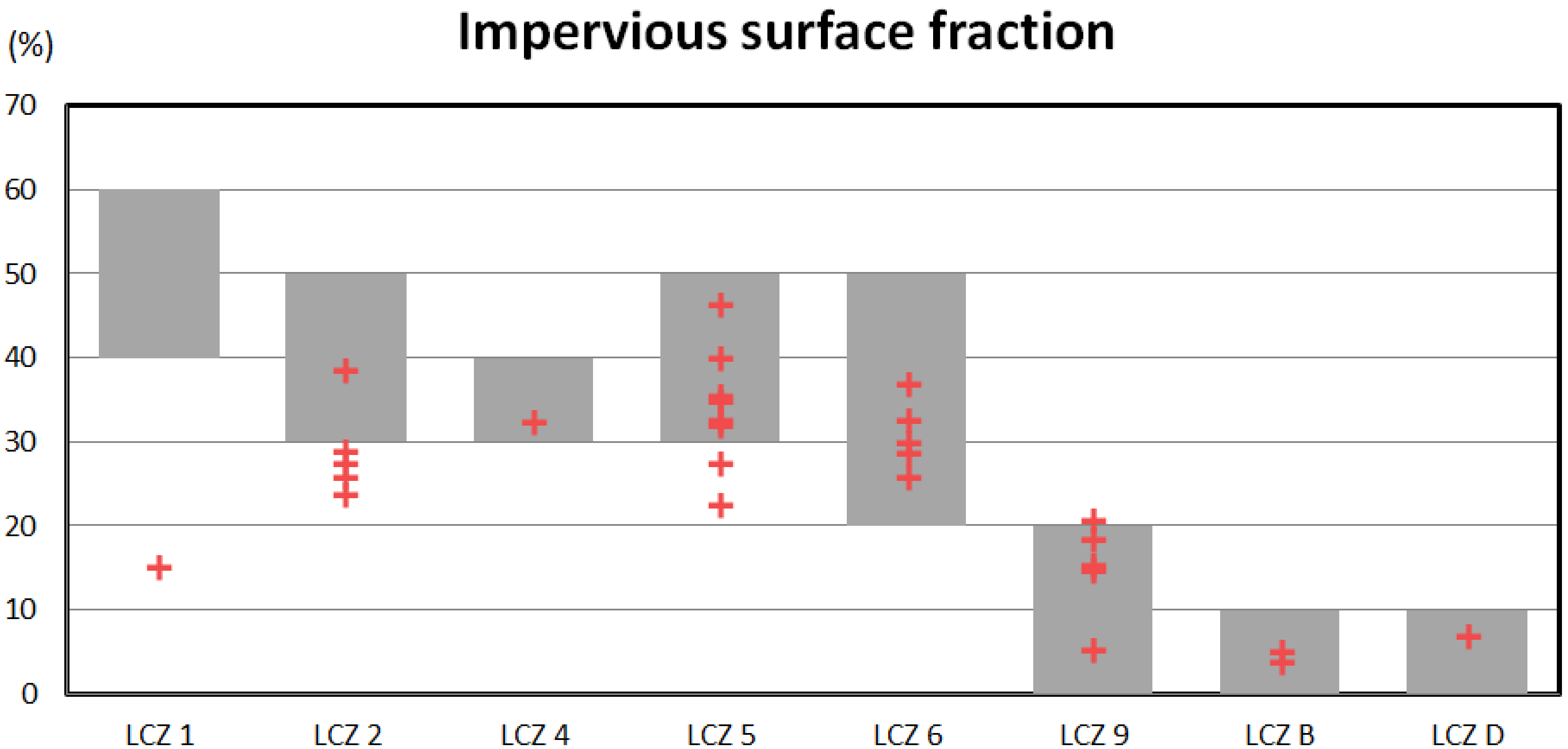
Land cover types



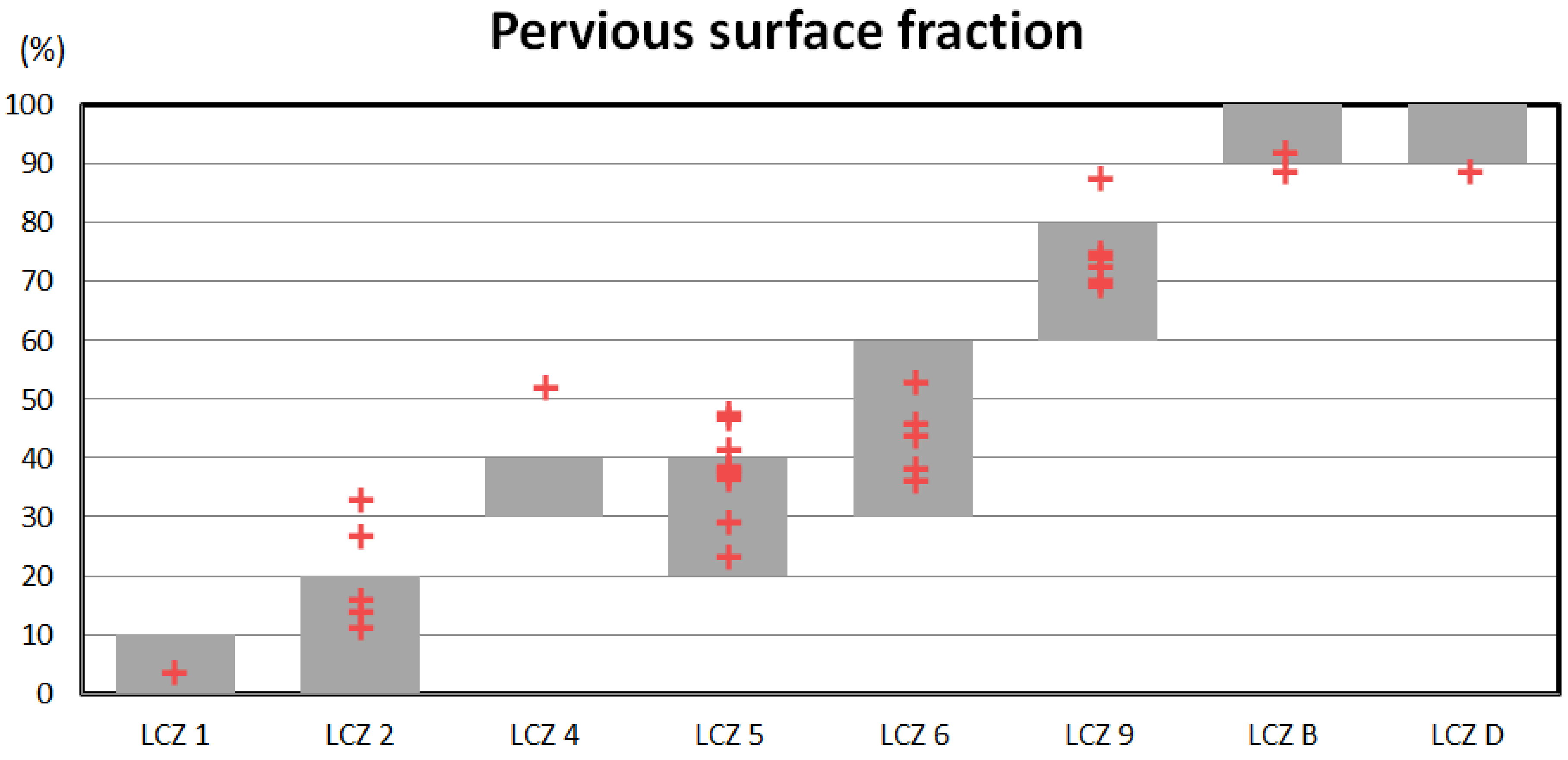
Results


Building surface fraction
(%)
70
60
50
40
30
20
10
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D

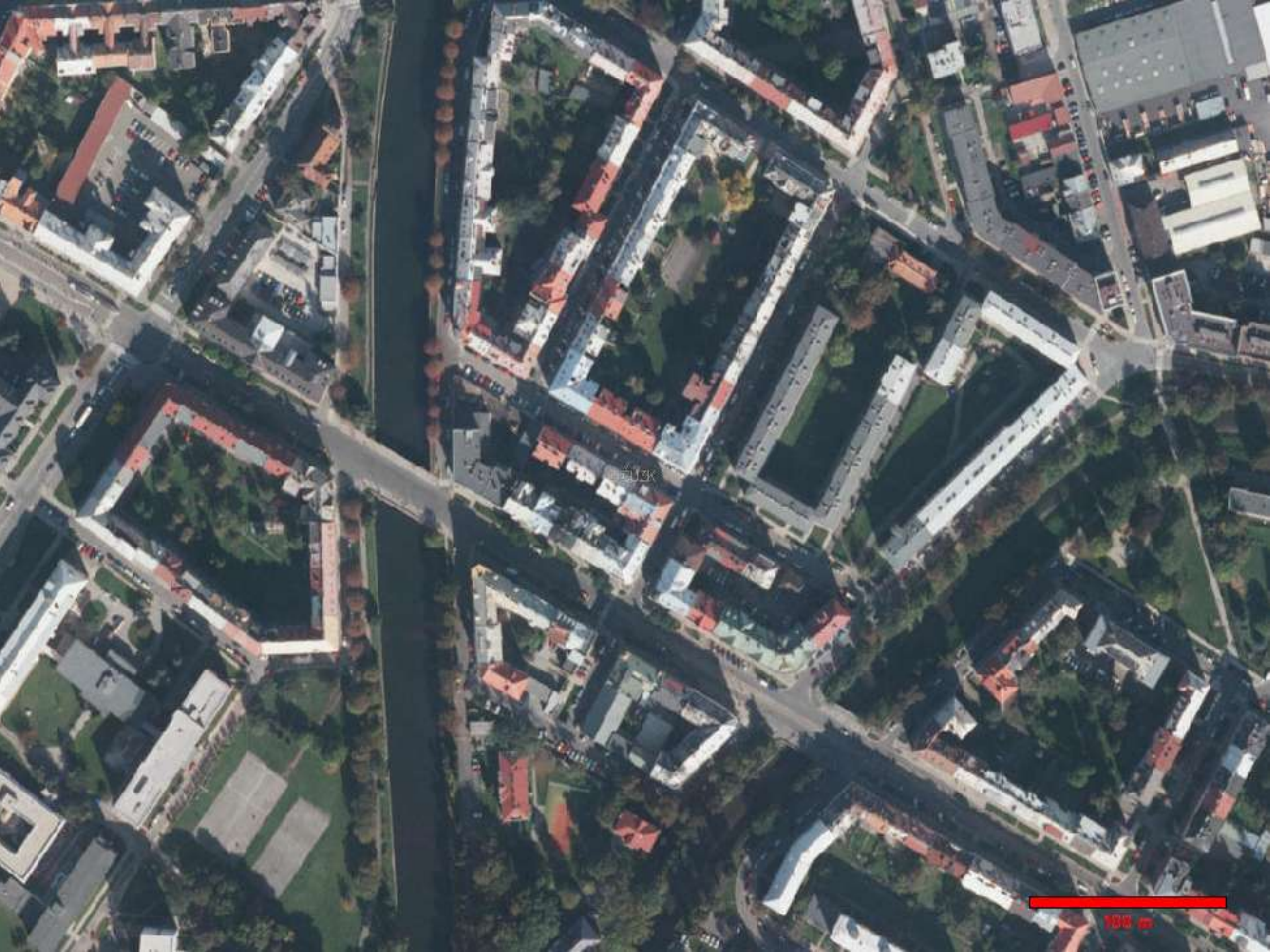
Results


Impervious surface fraction
(%)
70
60
50
40
30
20
10
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D

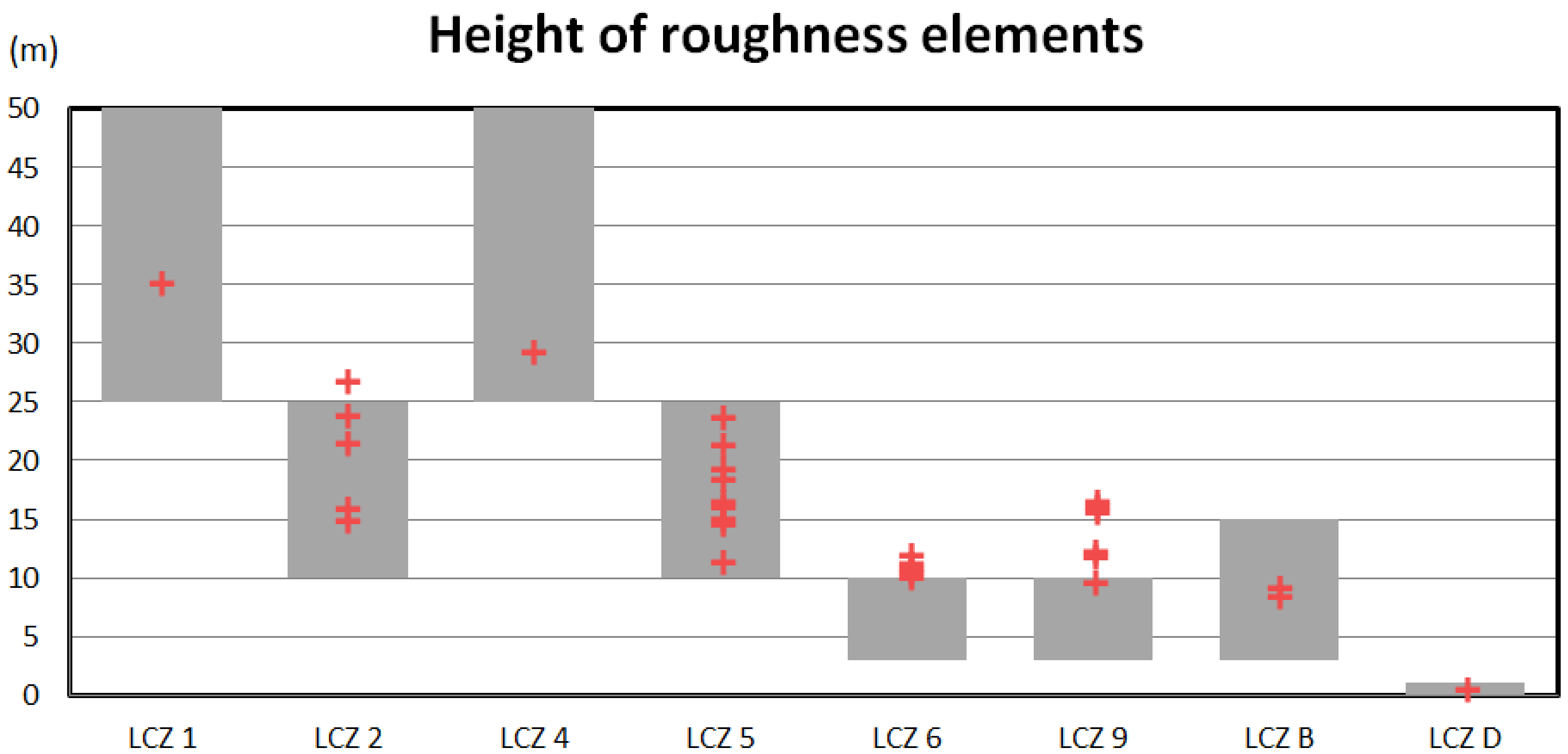
Results



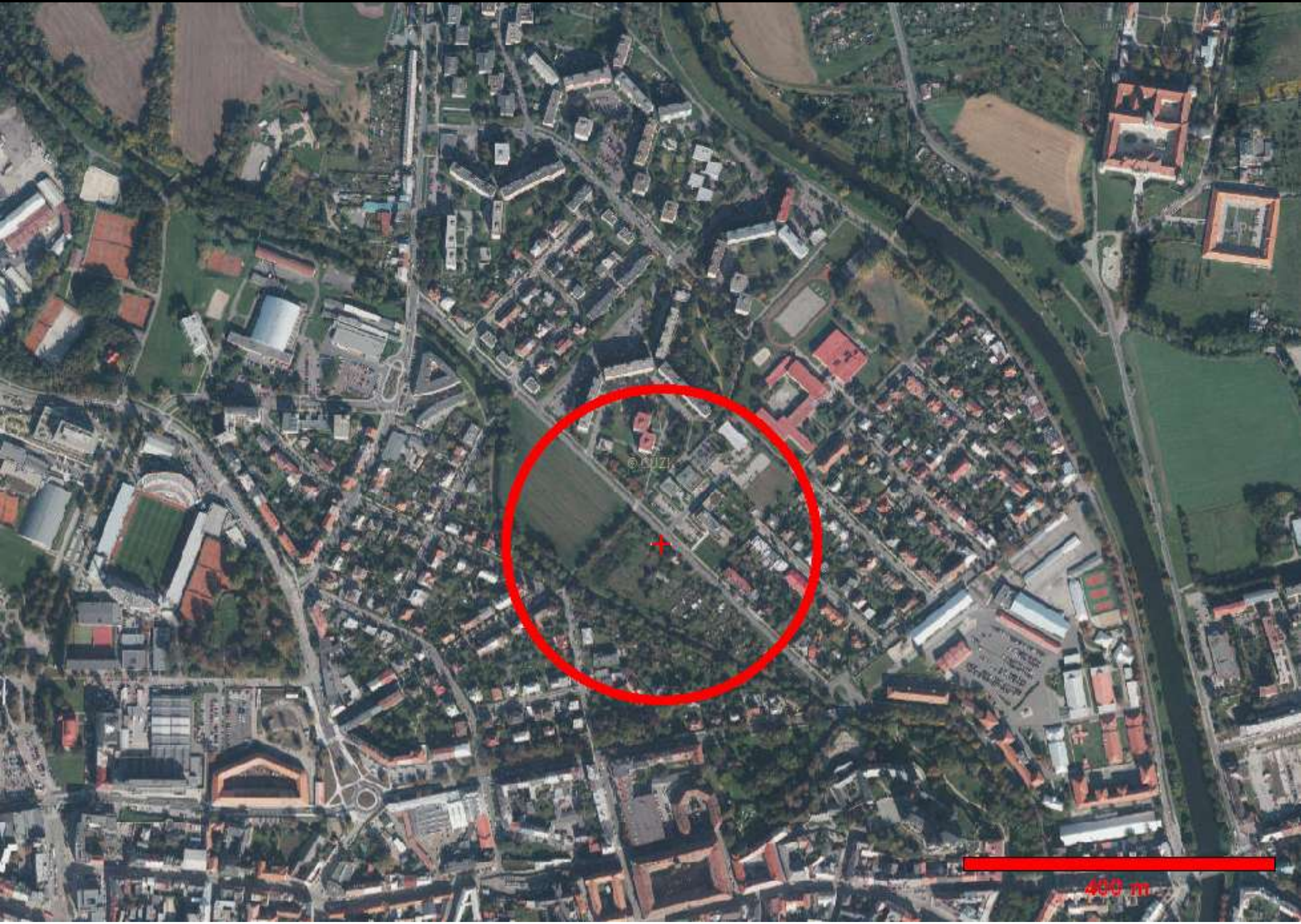
Pervious surface fraction
(%)
100
90
80
70
60
50
40
30
20
10
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D


100 m

Results



Height of roughness elements
(m)
50
45
40
35
30
25
20
15
10
5
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D

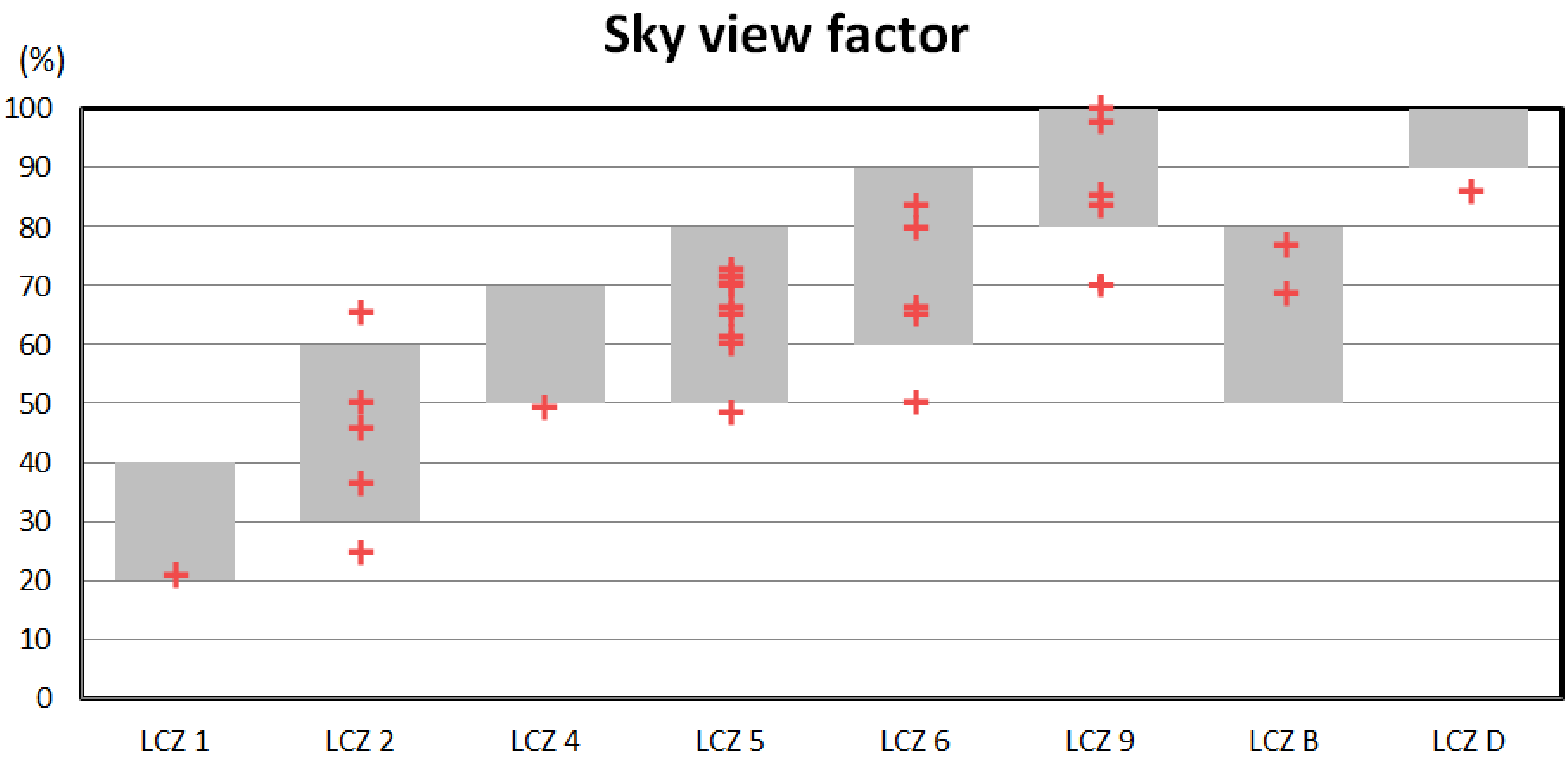

400 m

Results

Station	Parent class	Subclass
VERO	1	-
CMSE	2	-
VVMU	2	-
FILO	2	-
BISK	2	-
KAPU	2	-
HORL	4	-
DOMI	5	-
HODO	5	-
PRAZ	5	-
MEND	5	-
BOTA	5	-
GEON	5	5_B
KRAV	5	5_6
VETE	5	5_B
ZIDE	5	-

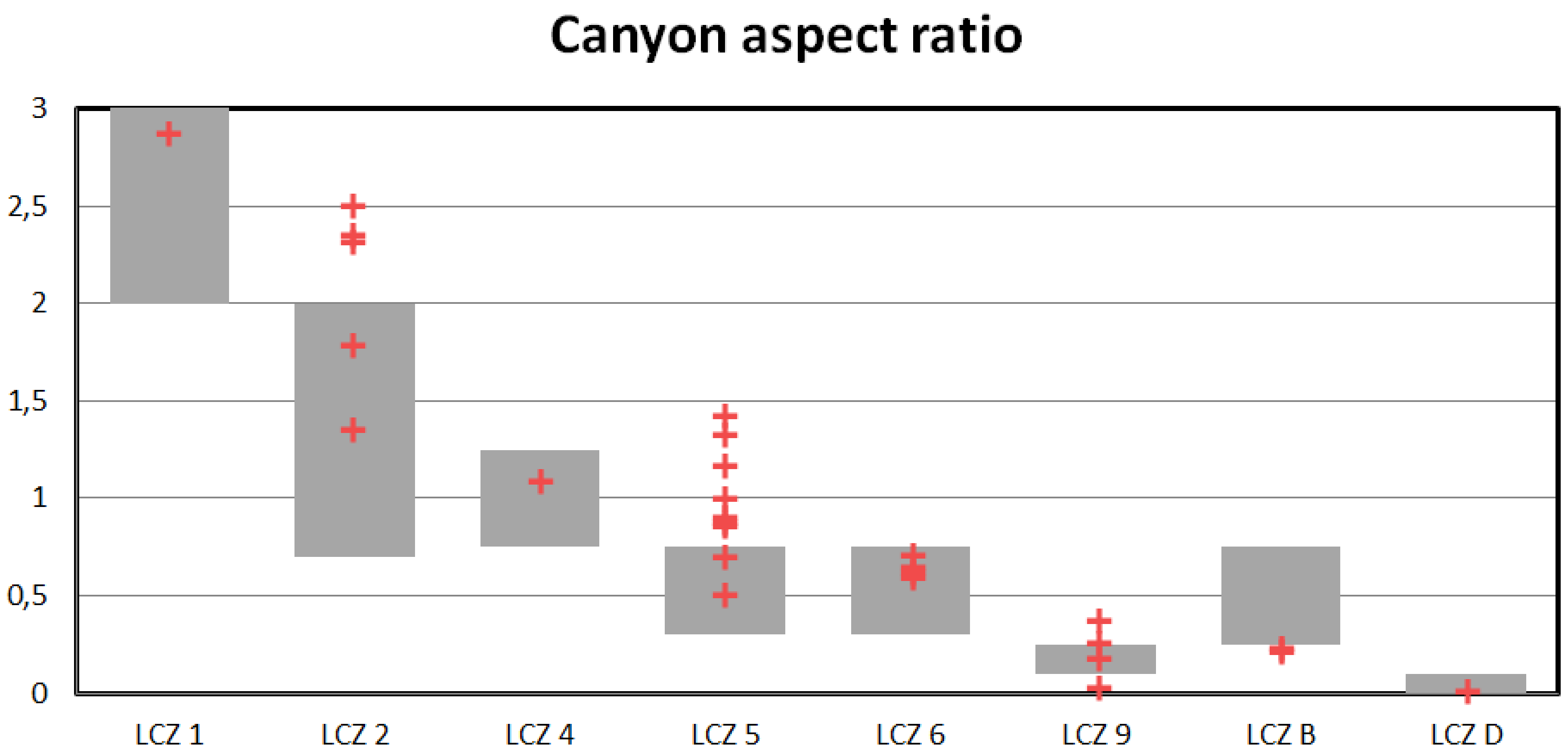
Station	Parent class	Subclass
EINS	6	-
HOLI	6	-
REPC	6	6_5
UKZU	6	6_5
ZABO	6	6_5
BOT_PdF	9	9_5
KOJE	9	9_5
LETO	9	9_5
JUND	9	9_B
TROU	9	9_5
TURA	9	-
CHVA	B	B_D
KREL	B	B_D
LISK	D	-

Results



Sky view factor
(%)
100
90
80
70
60
50
40
30
20
10
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D

Results


Canyon aspect ratio
3
2,5
2
1,5
1
0,5
0
LCZ 1
LCZ 2
LCZ 4
LCZ 5
LCZ 6
LCZ 9
LCZ B
LCZ D

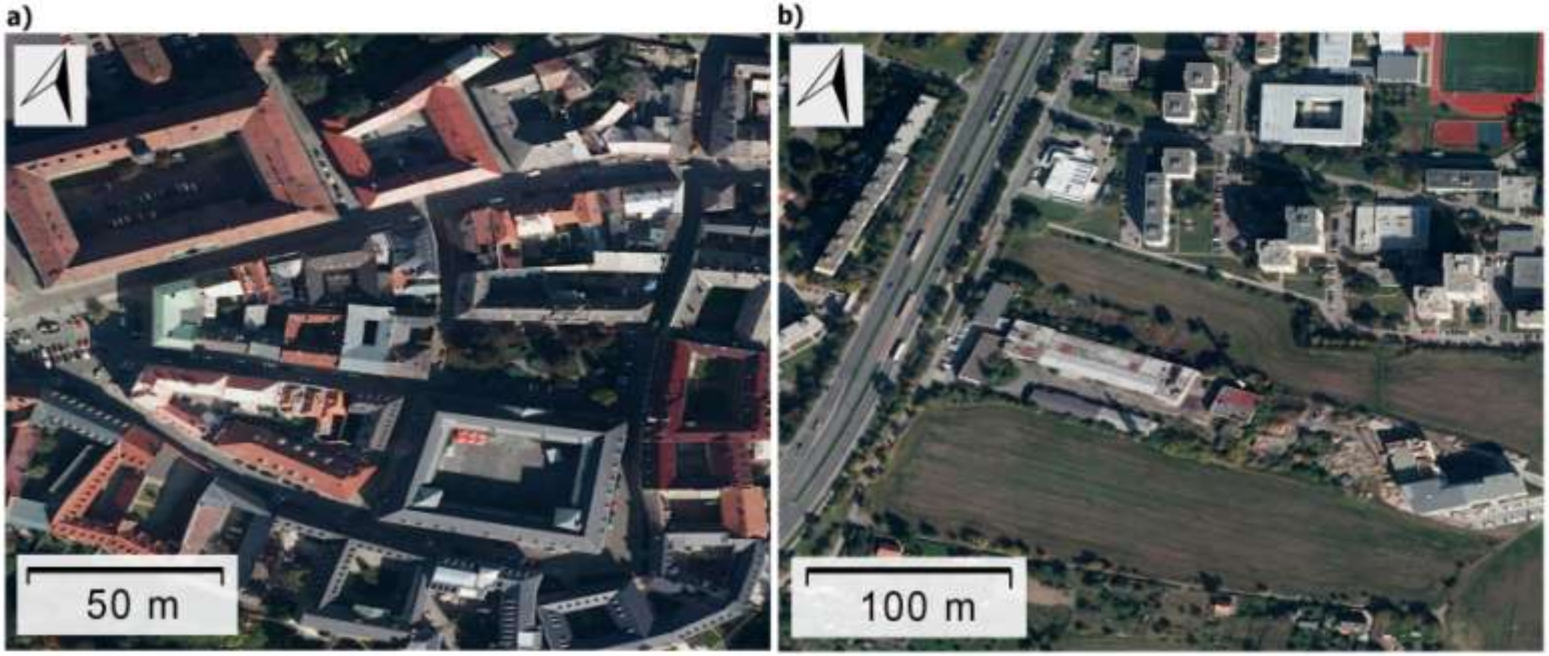
Discussion and conclusion

- Calculating parameters of geometric and surface cover properties classification of LCZ can be easily applied
- Most of the parameters of geometric and surface cover properties found for the MESSO stations corresponded to the values suggested by Stewart and Oke (2012)
- The classification showed certain insensitivity to the structure of a Central European city; *corresponds with Bechtel et al. (2012)*

Part I – Conclusion

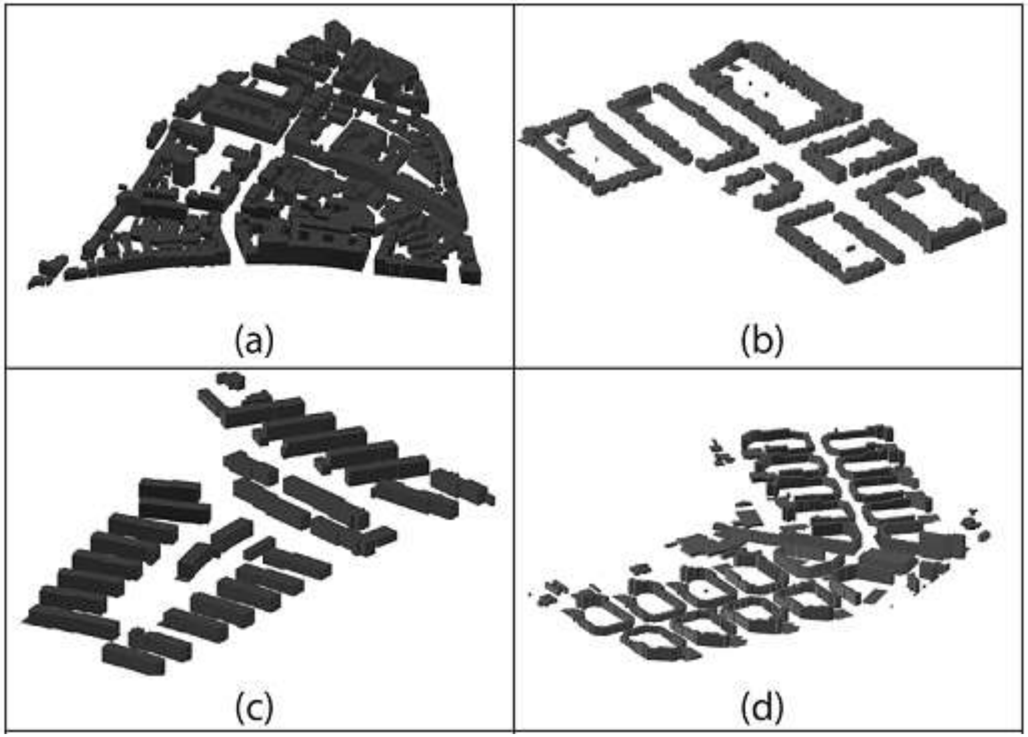
- Central European cities specifics:
  - Higher percentage of impervious surface fraction – greenery (public spaces, courtyards and gardens)
  - Building surface fraction corresponds to LCZ 6 or LCZ 9; however height of roughness elements indicate LCZ 5
  - Homogeneity of development is frequently disturbed or/and homogenous areas are smaller than source area of the sensor

Discussion and conclusion



- The character of development in Olomouc

Discussion and conclusion



- Different development morphologies in Central European cities (Bechtel and Danake 2012; modified)

Discussion and conclusion

- **The very problem of courtyards**
  - Oke (2006b) considers courtyards to be a typical example of a microclimate
  - The local climate is highly relevant to the LCZ
  - How to resolve the location of the stations in the area where courtyards with a similar geometric layout represent the same proportion of the surface cover as the street or even a larger one???
  - We (Lehnert et al. 2015) suggest subclasses *cc* (closed courtyard) and *oc* (open courtyard)
  - The location of a station in a courtyard should reflect the ratio of ISF and PSF and the geometric layout typical of the development surrounding the courtyards

Temperature differences throughout Local Climate Zones in Olomouc

Main objectives

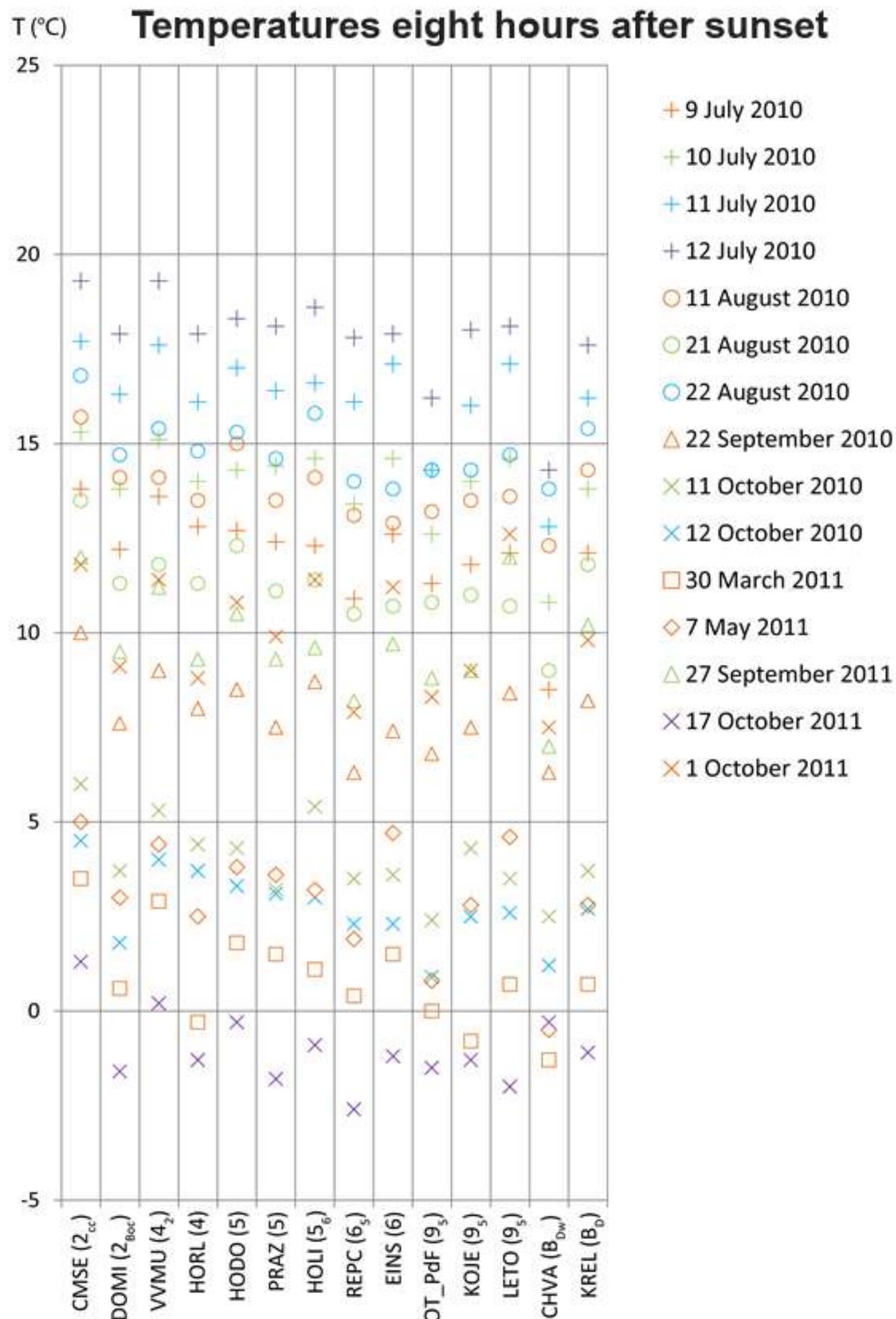
- To exterminate intrazonal temperature relations between particular station
- To exterminate interzonal temperature relations
- Get a better idea about spatial temperature variability

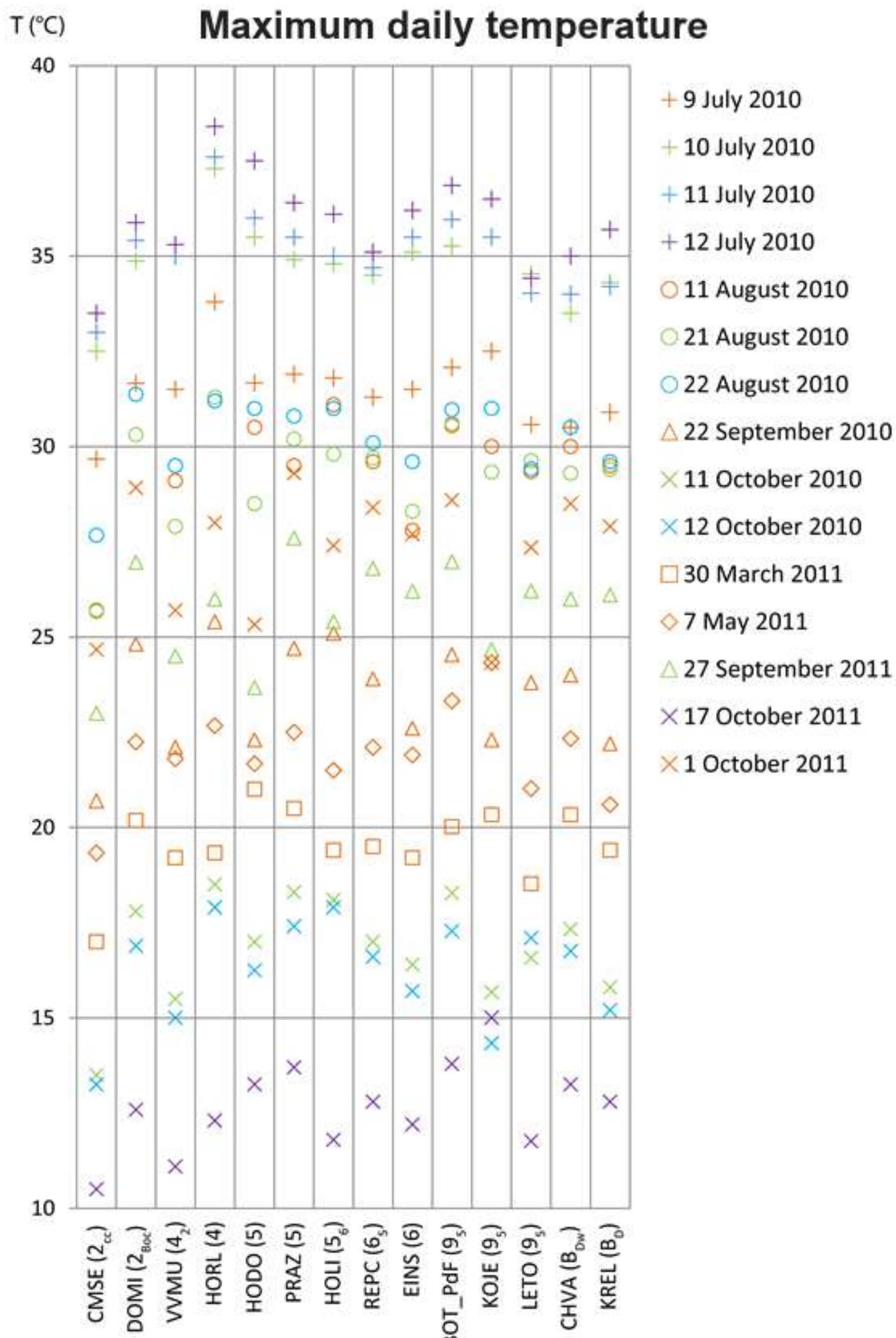
Methods

- Selected temperature data from Olomouc were treated for case study
- **Temperature measurement specification:**
  - 1.5 m above ground
  - White radiation shelters
  - Not actively ventilated
  - Sensor Accuracy
    - 0.2 °C MicroLog EC750 (Fourier)
    - 0.3 °C SHT75K (Sensirion)

Methods

- **Case study**
  - Days with radiation weather regime that followed another day with radiation weather regime in 2010 and 2011
- **Temperature characteristic**
  - Temperature 8 h after sunset
  - Maximum daily temperature


Temperatures eight hours after sunset
T (°C)
25
20
15
10
5
0
-5
CMSE (2cc)
DOMI (2Boc)
VVMU (42)
HORL (4)
HODO (5)
PRAZ (5)
HOLI (56)
REPC (65)
EINS (6)
OT_PdF (95)
KOJE (95)
LETO (95)
CHVA (BDw)
KREL (BD)
9 July 2010
10 July 2010
11 July 2010
12 July 2010
11 August 2010
21 August 2010
22 August 2010
22 September 2010
11 October 2010
12 October 2010
30 March 2011
7 May 2011
27 September 2011
17 October 2011
1 October 2011


Maximum daily temperature
T (°C)
40
35
30
25
20
15
10
CMSE (2_{cc})
DOMI (2_{Boc})
VVMU (4_2)
HORL (4)
HODO (5)
PRAZ (5)
HOLI (5_6)
REPC (6_5)
EINS (6)
BOT_PdF (9_5)
KOJE (9_5)
LETO (9_5)
CHVA (B_{Dw})
KREL (B_D)
9 July 2010
10 July 2010
11 July 2010
12 July 2010
11 August 2010
21 August 2010
22 August 2010
22 September 2010
11 October 2010
12 October 2010
30 March 2011
7 May 2011
27 September 2011
17 October 2011
1 October 2011

Discussion and conclusion

- During the night hours, areas with compact rise are the warmest (LCZ 2); *in agreement with Lelovics et al. (2014)*
- Maximum temperatures in compact rise (LCZ 2) are lower than in open rise (LCZ 5/6) and rural surroundings (LCZ B/D); *in agreement with Houet and Pigeon (2011)*
- Maximum temperature in LCZ B/D could be higher than in LCZ 5/6; *in agreement with Stewart et al. (2013)*

Discussion and conclusion

- Air temperature variability within a city indicates a necessity to overcome the urban-rural dichotomy

↓

- LCZ classification appears to be an essential tool for the new concept of UHI studies.
- Necessary to follow more detailed recommendations regarding the location of the stations that are to represent a particular LCZ

LCZ Ostrava ???

Děkujeme za pozornost!