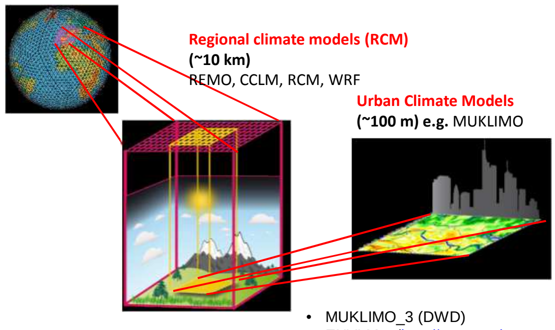
URBAN CLIMATOLOGY

IX. Urban climate modelling

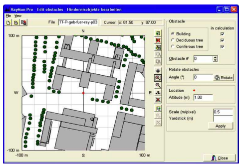
9.1. Hierarchy of climate models

Global circulation models (GCM)
Earth System Models (ESM)
(~100 km), GCM + IPCC scenarios

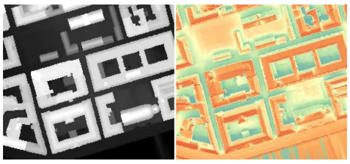


- MUKLIMO_3 (DWD)
- ENVI-Met (http://www.envi-met.com/)

9.2 Urban Climate Models



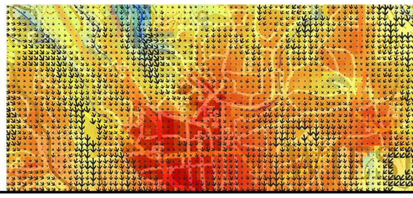
- Rayman
  - http://www.urbanclimate.net/rayman/
- ENVI-Met
  - (http://www.envi-met.com/)
- The Urban Multi-scale Environmental Predictor (**UMEP**)
  - http://www.urban-climate.net/umep/UMEP
- MUKLIMO_3 (DWD)

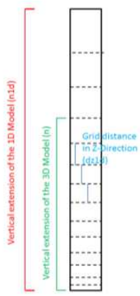


Input DSM (left) and irradiance image (right) in Gothenburg using data from 1977.

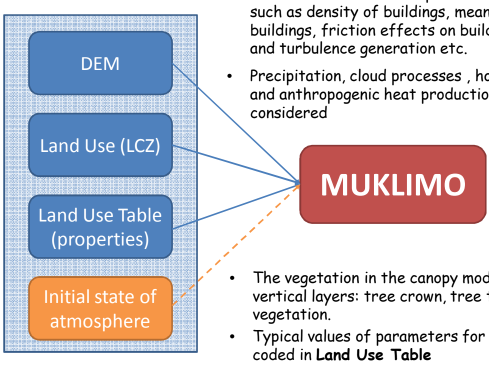
9.3 Model MUKLIMO_3

- Mikroskaliges Urbanes Klima-Modell, 3-dim
- Developed in DWD (Deutscher Wetterdienst), intensively used in Austria weather service (ZAMG)
- Model simulates simulate atmospheric flow fields in the presence of buildings (air temperature field, relative humidity and 3D field of wind speed an direction)
- Horizontal resolution: 100 m, variable vertical resolution 10-100 m



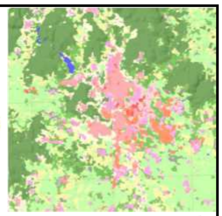


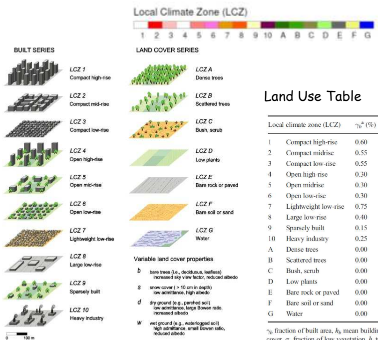
Model MUKLIMO_3 – input parameters



- Model considers several parameters of buildings such as density of buildings, mean height of buildings, friction effects on building surfaces and turbulence generation etc.
- Precipitation, cloud processes , horizontal runoff and anthropogenic heat production are not considered
- The vegetation in the canopy model has three vertical layers: tree crown, tree trunk and low vegetation.
- Typical values of parameters for each LCZ are coded in **Land Use Table**

Brno – Local Climate Zones





Land Use Table

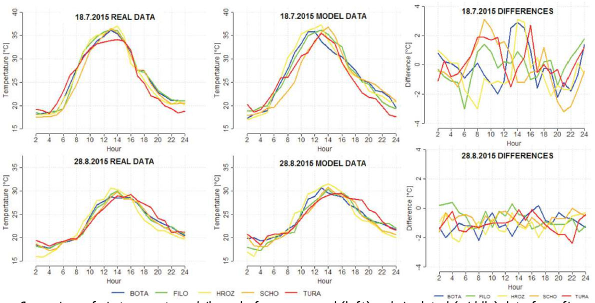
Local climate zone (LCZ)		γ_b[a] (%)	h_b[a] (m)	w_b	v[a] (%)	σ_t[a] (%)	σ_c[a] (%)	h_t (m)	h_c (m)
1	Compact high-rise	0.60	25	6.67	0.40	0.0	0.01	0	0.3
2	Compact midrise	0.55	15	4.50	0.30	0.0	0.08	0	0.3
3	Compact low-rise	0.55	7	2.33	0.20	0.0	0.13	0	0.3
4	Open high-rise	0.30	25	7.00	0.35	0.0	0.25	0	0.3
5	Open midrise	0.30	15	4.50	0.35	0.0	0.21	0	0.3
6	Open low-rise	0.30	7	2.33	0.35	0.0	0.25	0	0.3
7	Lightweight low-rise	0.75	3	1.80	0.15	0.0	0.03	0	0.3
8	Large low-rise	0.40	7	1.40	0.45	0.0	0.08	0	0.3
9	Sparsely built	0.15	7	2.80	0.10	0.0	0.60	0	0.3
10	Heavy industry	0.25	10	3.00	0.30	0.0	0.14	0	0.3
A	Dense trees	0.00	0	0.00	0.00	0.8	0.18	17	0.5
B	Scattered trees	0.00	0	0.00	0.00	0.4	0.54	9	0.5
C	Bush, scrub	0.00	0	0.00	0.00	0.0	1.00	0	1.5
D	Low plants	0.00	0	0.00	0.00	0.0	1.00	0	0.5
E	Bare rock or paved	0.00	0	0.00	0.95	0.0	0.01	0	0.3
F	Bare soil or sand	0.00	0	0.00	0.00	0.0	0.01	0	0.3
G	Water	0.00	0	0.00	−1.00	0.0	0.01	0	0.3

γ_b fraction of built area, h_b mean building height, w_b wall area index, v fraction of pavement, σ_t fraction of tree cover, σ_c fraction of low vegetation, h_t tree height, h_c height of the low vegetation

[a] Relative to total grid cell area

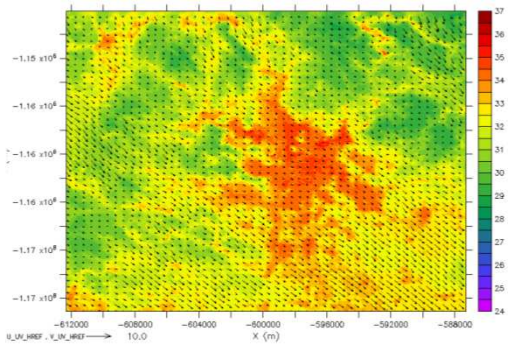
Model MUKLIMO_3

- **The 1D model** calculates **the daily cycle** of temperature, relative humidity and wind for the reference station located outside of the urban area

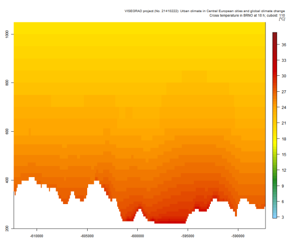


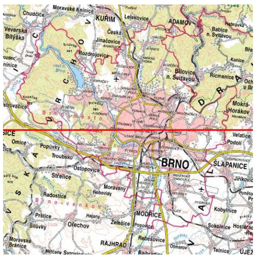
Comparison of air temperature daily cycle from measured (left) and simulated (middle) data from five stations in Brno (for 18. 7. and 28. 8. 2015). Figures on the right side show differences between measured and modelled air temperatures

Model simulation of air temerature and wind filed, an ideal case, 16 h GMT



Cross-section of air temerature in Brno area



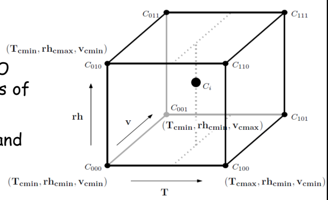


Model MUKLIMO_3

- The 1D simulation is run for 24 h after which the values for air temperature, relative humidity and wind are used to initialize the 3D model taking into account terrain height and soil type.
- The meteorological fields given as the output of the 3D model are used for the analysis of the UHI effect and the calculation of climate indices.
- Model is used to evaluate particularly the urban heat load in summer period.
- For that purpose, the climate indices, such as mean annual number of summer days (Tmax ≥ 25 °C), hot days (Tmax ≥ 30 °C) and tropical nights (Tmin ≥ 20 °C), are calculated.
- **The climate indices** are calculated with the cuboid method (Früh et al. 2011). **The cuboid method** enables the calculation of heat load on a longer temporal scale by using a limited number of urban climate model simulations.

CUBOID method

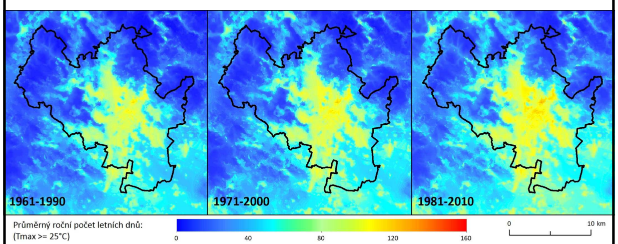
- Model simulations in MUKLIMO are done only for eight corners of a cuboid.
- These corners represent min and max values
- Method uses 3D interpolation.



Meteorological data from the reference station located behind the city determine the range of mean daily air temperature (T), relative humidity (rH) and wind speed (v)

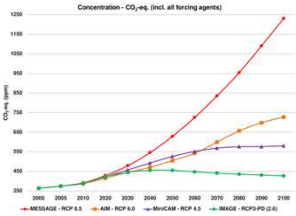
135	315	NE and SW
15,0	25,0	T
40,0	80,0	r_H
0,3	3,0	v

Simulated number of summer days in Brno (recent climate)



Mean number of summer days (Tmax >= 25°C) for three different decades of recent climate in Brno area

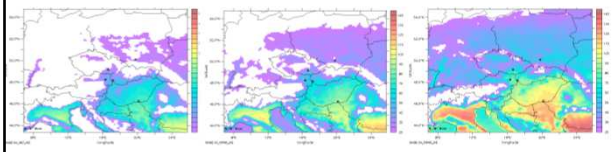
9.4 Future climate



- Modelling of future climate is based on the use of different scenarios that estimate future level of green house gass concentrations
- Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014
- They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come
- The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2, respectively)

Future climate

- In model MUKLIMO outputs from Regional Climate Models instead of contemporary real measurements may be used
- RCP4.5 a RCP8.5 resulting from the project EURO-CORDEX (Coordinated Downscaling Experiment) - European Domain were used to model the climate of Brno in 21st Century

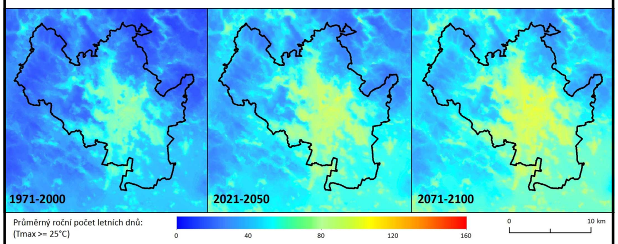


1971-2000 2021-2050 2071-2100

Mean annual number of summer days (Tmax ≥ 25°C) simulated for RCP8.5 scenario; avearage from an ensemble of eleven regional climate models

Brno – future climate, RCP4.5

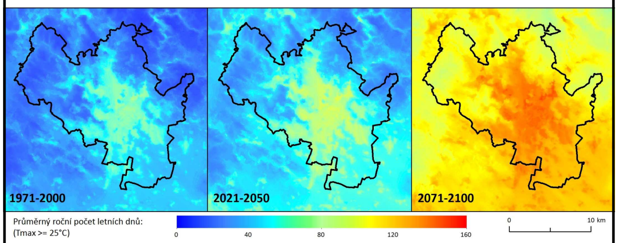
Mean number of summer days (Tmax >= 25°C)



Period	MIN	MAX	AVG
1971-2000	10,5	83,4	37,2 (100 %)
2021-2050	23,9	93,6	51,8 (140 %)
2071-2100	27,4	102,1	59,3 (160 %)

Brno – future climate, RCP8.5

Mean number of summer days (Tmax >= 25°C)



Period	MIN	MAX	AVG
1971-2000	10,5	83,4	37,2 (100 %)
2021-2050	17,8	93,2	52,3 (140 %)
2071-2100	40,7	121,3	81,4 (220 %)

9.5 Final remarks and questions

- Model is able to simulate main features of spatial distribution of several climate indices which characterize potential heat load in Brno area
- Parts of the city with the highest heat load correspond with the recent knowledge that is based on real measurements
- Future climate simulations show significant increase of heat load (e.g. number of summer days will be 40% higher compared to the present in the mid-21st century
- Results from Brno are comparable with those from other Central European Cities (Vienna, Frankfurt)
- Further model valiadation is needed

Final remarks and questions

1. What is the main purpose of urban climate models?
2. What aspects of urban climate would be useful to simulate?
3. Is there any other method how to do projections of future climate?
4. What is a difference between "projection" and "prediction"?