Anita Bokwa (1), Petr Dobrovolny (2), Tamas Gal (3), Jan Geletic (2), Agnes Gulyas (3), Monika J. Hajto (4), Brigitta Hollosi (5), Rafal Kielar (4), Michal Lehnert (6), Nora Skarbit (3), Pavel Stastny (7), Marek Svec (7), Janos Unger (3), Miroslav Vysoudil (6), Jakub P. Walawender (4,1), Maja Zuvela-Aloise (5), Libor Burian (8)

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(6) Palacky University Olomouc, Olomouc, Czech Republic, (7) Slovak Hydrometeorological Institute, Bratislava, Slovakia,
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Impact of global climate change on the number of hot days in urban areas of Central Europe





DISASTER RISK REDUCTION Conference, Warsaw, 15-16 October 2015

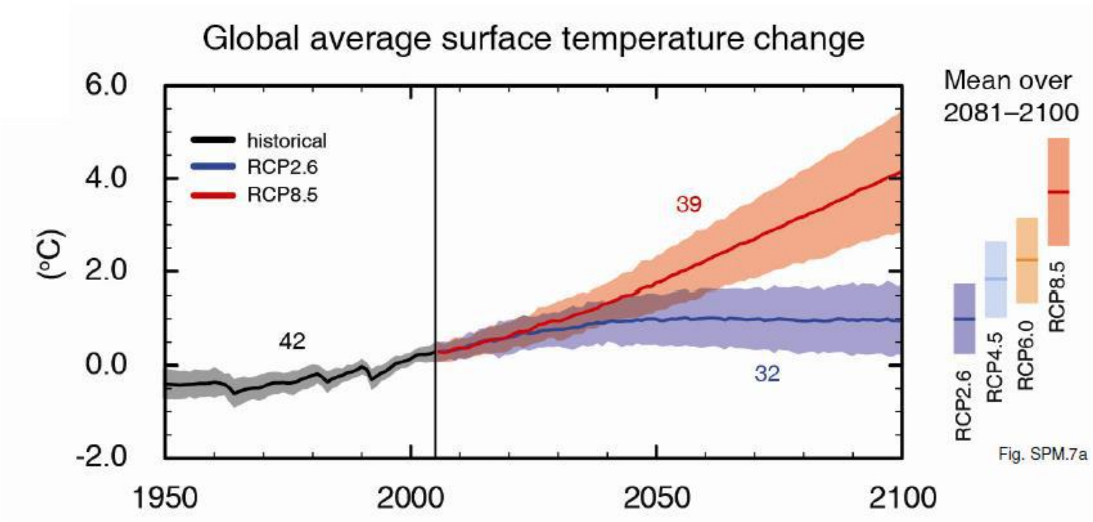
Introduction:

1. Global surface temperature change: likely to exceed 1.5°C by the end of the 21st century (IPCC 2013)

2. Heat load in urban areas: supposed to increase

3. Urban areas: among those most endangered with the potential global climate changes

4. Studies on the impact of global changes on local climate of cities: high significance for the urban inhabitants' health and wellbeing



Krakow, Poland

5. Adaptation actions in particular cities:

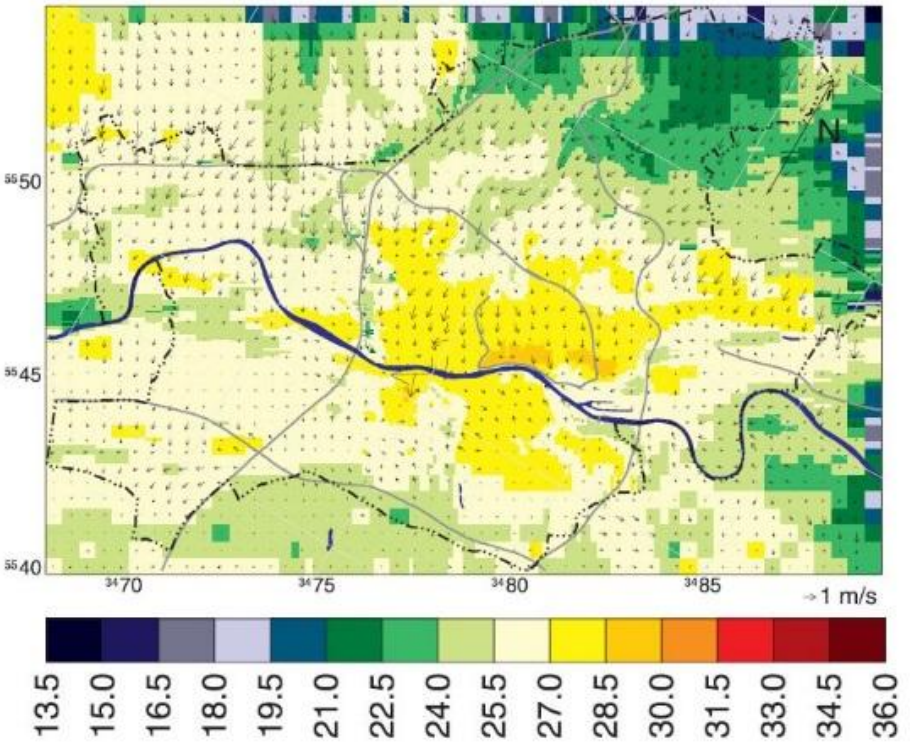
- Recognition of the possible range of heat load increase;
- Aspects of the increase: magnitude and spatial extent;
- Both land use and land form influences should be included. Vienna, Brno, Bratislava and Krakow: located in areas with diversified relief

6. Aim:

Evaluation of the expected heat load increase in the Central European cities: Vienna, Brno, Bratislava, Kraków, Szeged

Methods:

- **MUKLIMO_3:** 3D **M**ikroskaliges **U**rbanes **KLI**ma**MO**dell *(Sievers and Zdunkowski, 1986; Sievers, 1990; Sievers, 1995)*
- Application for assessment of heat load in urban areas and urban planning
- Horizontal resolution: 100 m, vertical resolution: 10–100 m, finer resolution near surface
- Output data: diurnal cycles of air temperature, wind speed and direction, relative humidity and heat fluxes
- Application for Frankfurt *(Früh et al. 2011)* and Vienna *(Zuvela-Aloise et al. 2014)*

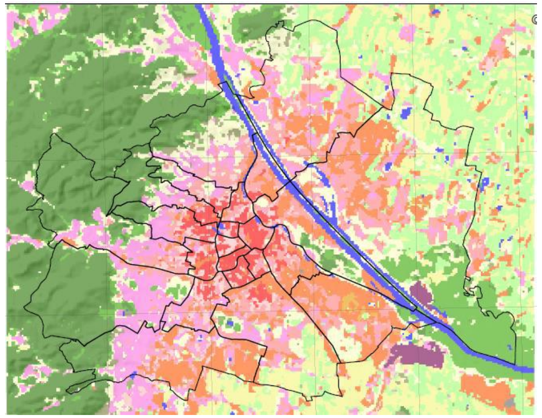


(b) T in °C, 02 CEST

Air temperature and horizontal wind vectors in Frankfurt at 5-m height for flow from the NE initialized with $T_{c.max}$ = 25°C, $rh_{c.min}$ = 42%, and $v_{c.min}$ = 0.7 m s^{-1} (Fruh et al. 2011)

Input parameters for the model:

- Land use and building height data; thresholds for land use and built-up parameters defined for **Local Climate Zones** by *Stewart and Oke (2012)* were applied
- Mapping procedure: methodology proposed by the World Urban Database and Access Portal Tools (**WUDAPT**) *(Bechtel and Daneke, 2012, Bechtel et al. 2015)*;
- Several **Landsat 7** images were used; obtained from USGS (earthexplorer.usgs.gov);
- LCZ **training areas** were located using Google Earth;
- Landsat images and vector file: preprocessed in SAGA-GIS;
- The classification was conducted with the built in **random forest classifier**;
- For each LCZ class, a **common value** was assigned for all of the necessary input parameters of MUKLIMO for all the cities.

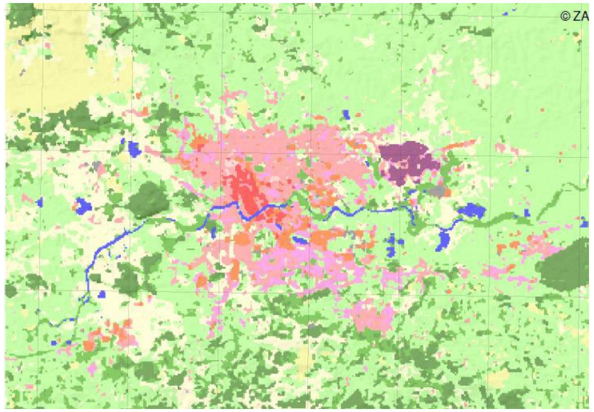


Vienna

Inhabitants: 1 800 000

140-580 m a.s.l.

Grid size: 316x247x39

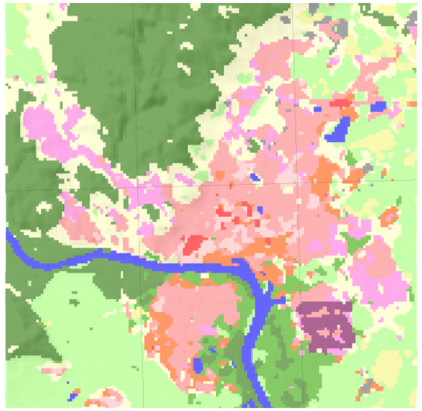


Krakow

Inhabitants: 760 000

145–460 m a.s.l.

Grid size: 389x275x39

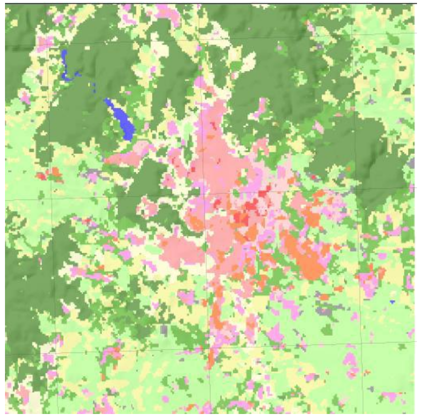


Bratislava

Inhabitants: 500 000

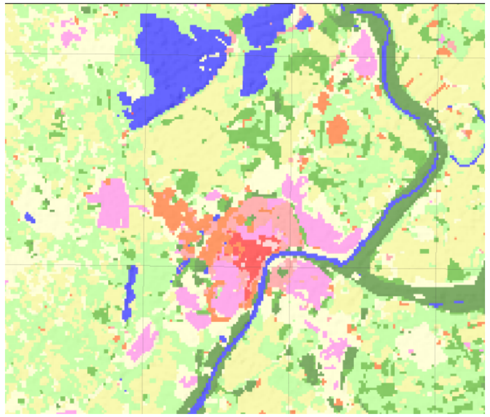
120-450 m a.s.l.

Grid size: 160x160x39



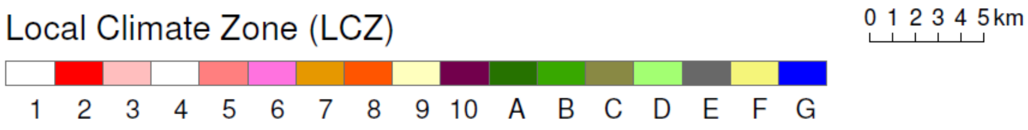
Brno, Inhabitants: 380 000, 200-525 m a.s.l.,

Grid size: 250x250x39



Szeged, Inhabitants: 170 000, 45-145 m a.s.l.,

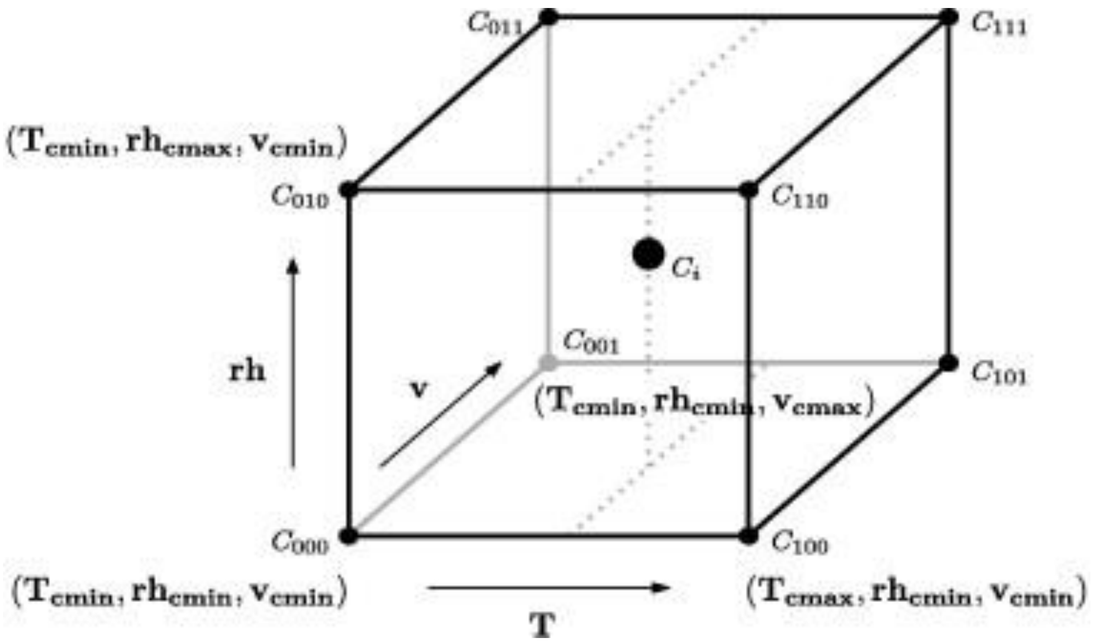
Grid size: 213x181x25



LCZ classification: Stewart and Oke, 2012
Method: Bechtel and Daneke, 2012

Calculation of climate indices:
"**cuboid method**" *(Früh et al. 2011):*

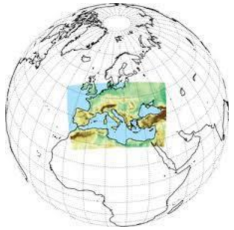
- To conduct urban scale simulations for several 30-yr time periods would lead to an enormous computational effort; instead, cuboid method is used
- Limits of the cuboid are chosen to encompass almost all regional climate conditions favorable for the occurrence of urban heat load situations;
- For each cuboid corner, the daily cycle of T, rh and v was simulated with MUKLIMO_3 for each prevailing wind direction;



- Tri-linear interpolation used to assign a value to any data point C_i (T_i, rh_i, v_i) within the cuboid as a weighted average

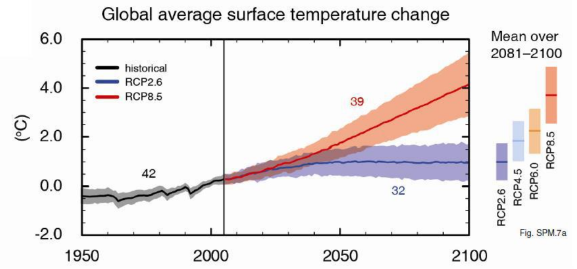
Possible climatological changes in urban heat load under future climate conditions:

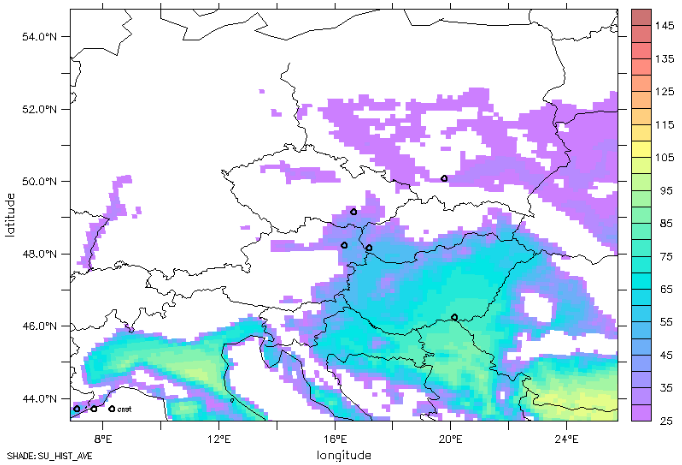
- expected increase in the number of days with maximum air temperature ≥ 25°C (i.e. summer days);
- Future climate signal is based on the data from regional climate projections of the EURO-CORDEX project;
- The model outputs were corrected using orography and the measurement data of 1971-2000 in order to avoid the systematic errors.



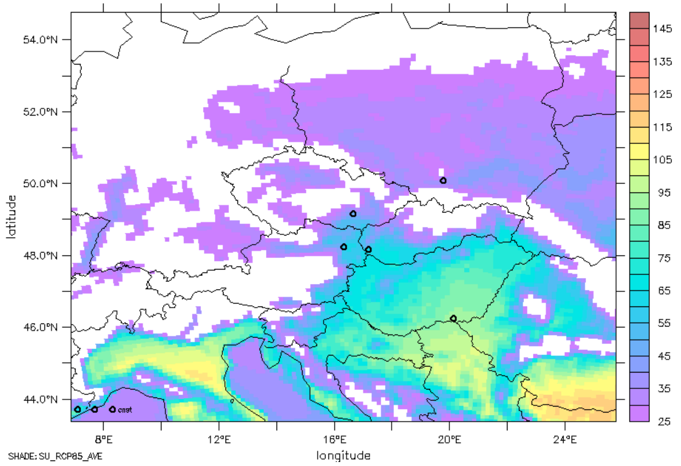
EURO-CORDEX - Coordinated Downscaling Experiment - European Domain (EUR-11)

IPCC Scenario RCP8.5

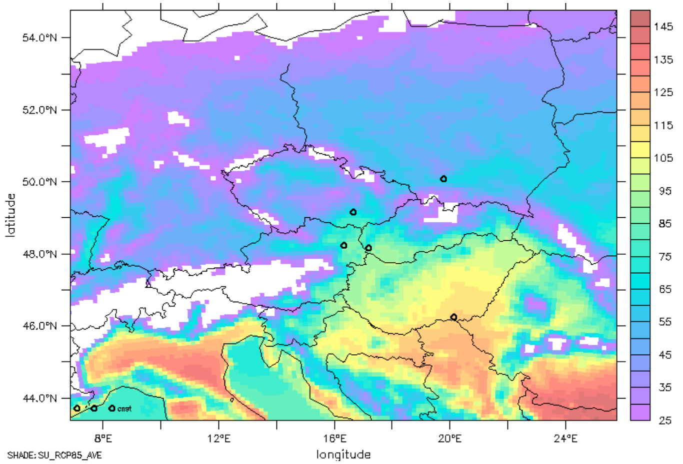




1971-2000



2021-2050



2071-2100

Mean annual number of summer days (T_{max} ≥ 25°C), model ensemble average (11 members)

	1971-2000	**2021-2050**	**2071-2100**
Vienna, AT	41.7	52.5	78.1
Brno, CZ	30.6	40.2	63.6
Bratislava, SK	47.3	58.5	84.3
Szeged, HU	78.7	91.6	115.6
Krakow, PL	23.4	31.5	51.4

Visegrad Fund www.visegradfund.org

Jagiellonian University in Krakow

ZAMG Zentralanstalt für Meteorologie und Geodynamik

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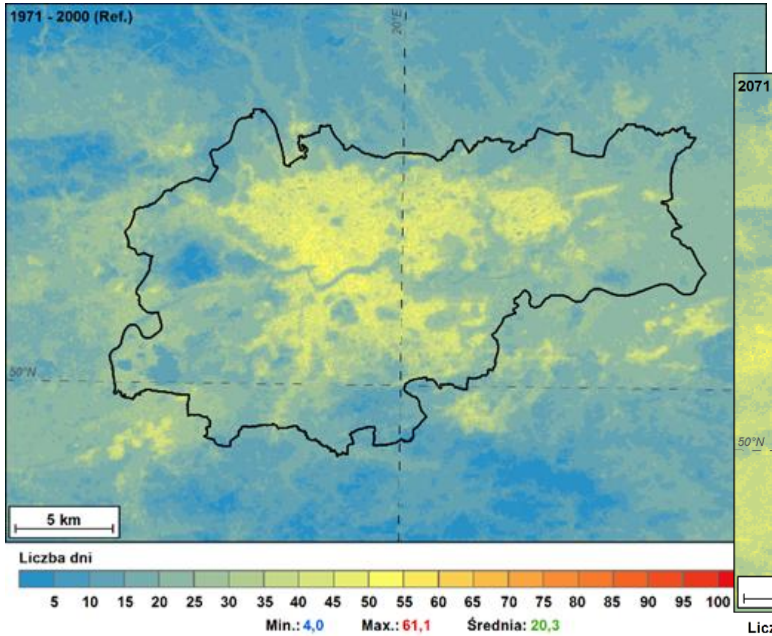
Future climate change impact (examples)

- changes in the mean annual number of summer days (i.e. max. temp. ≥ 25°C)
- according to scenarios RCP4.5 and RCP8.5
- using ensemble averages from 7 models
- predictions for the period 2071-2100, compared to 1971-2000

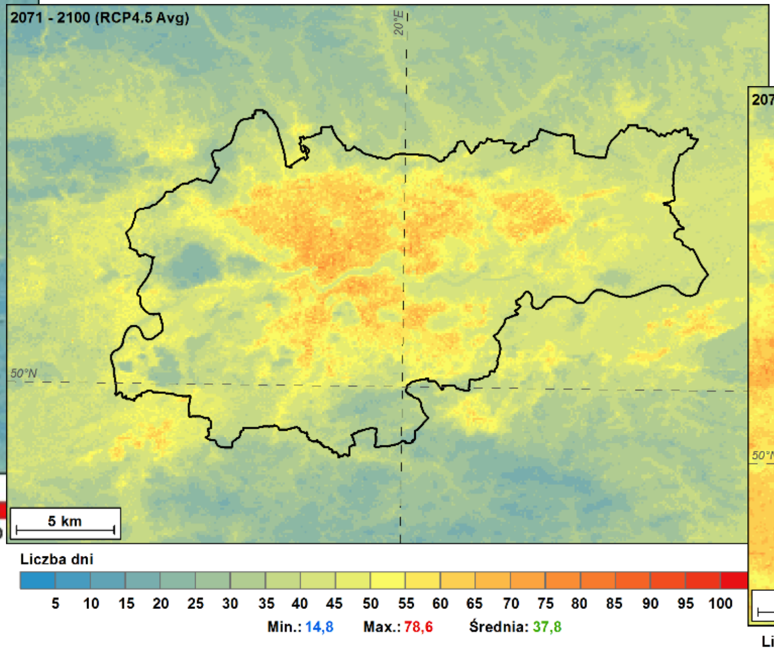
Kraków: 1971-2000 and 2071-2100, scenario RCP4.5 and RCP8.5

min.: 4.0 **max.:** 61.1 **avg: 20.3** days



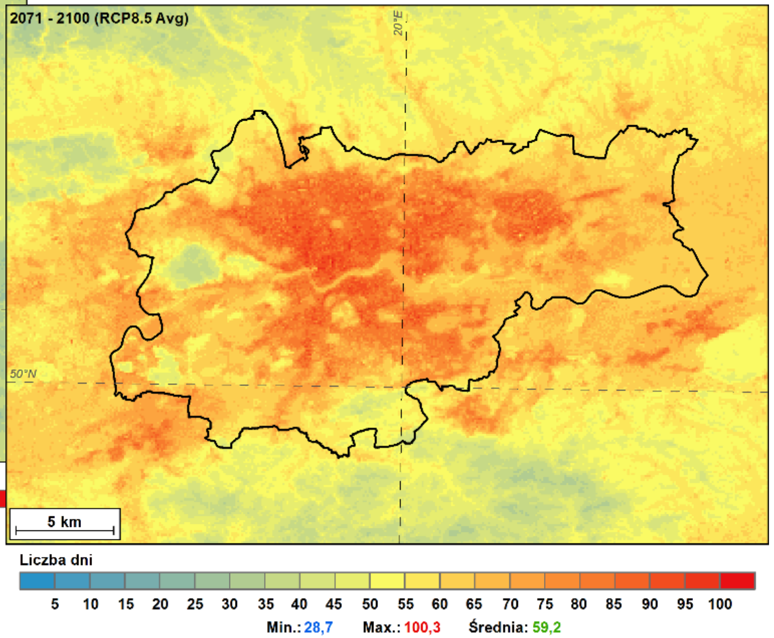
1971-2000

min.: 14.8 **max.:** 78.6 **avg: 37.8** days

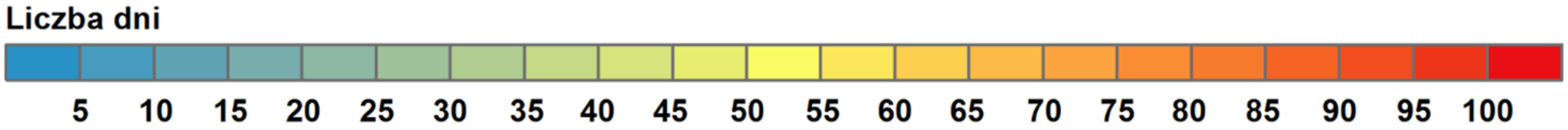


RCP4.5

min.: 28.7 **max.:** 100.3 **avg: 59.2** days



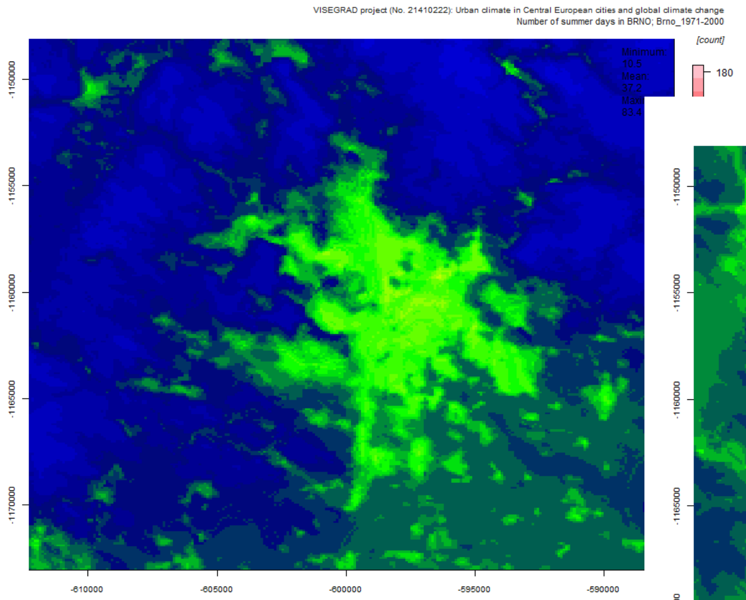
RCP8.5



"Urban climate in Central European cities and global climate change" 2014-2015

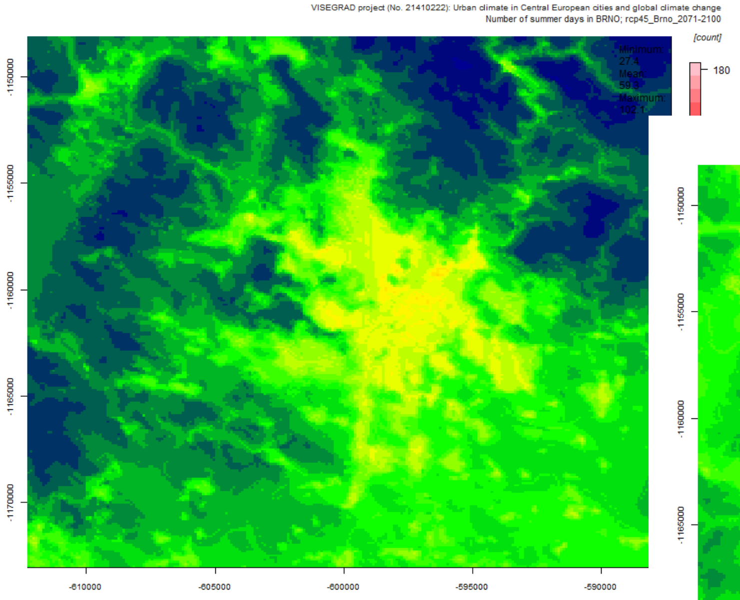
Brno: 1971-2000 and 2071-2100, scenario RCP4.5 and RCP8.5

min.: 10.5 **max.:** 83.4 **avg:** **37.2** days



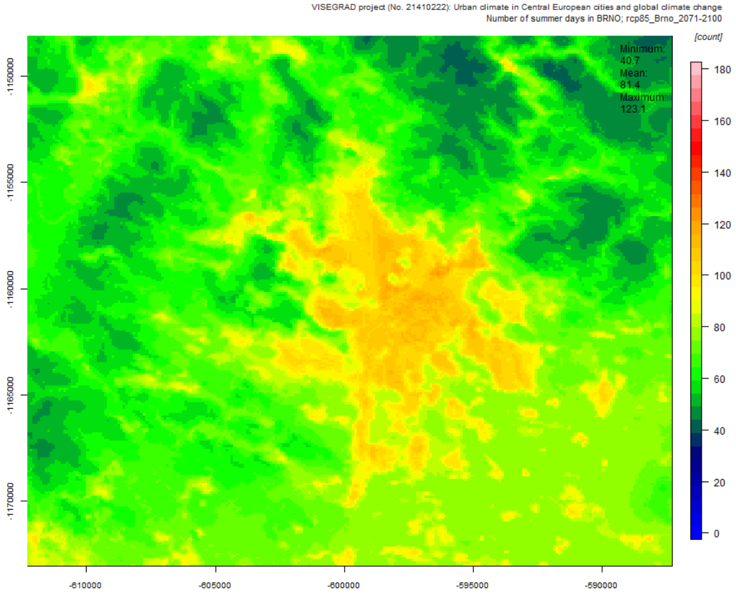
1971-2000

min.: 27.4 **max.:** 102.1
avg: **59.3** days

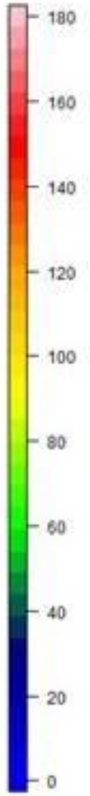


RCP4.5

min.: 40.7 **max.:** 123.1
avg: **81.4** days



RCP8.5



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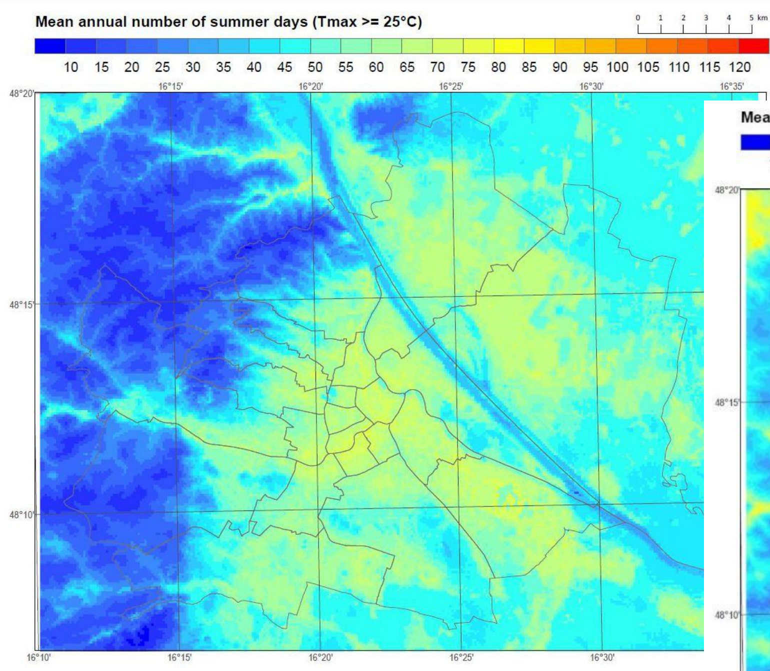
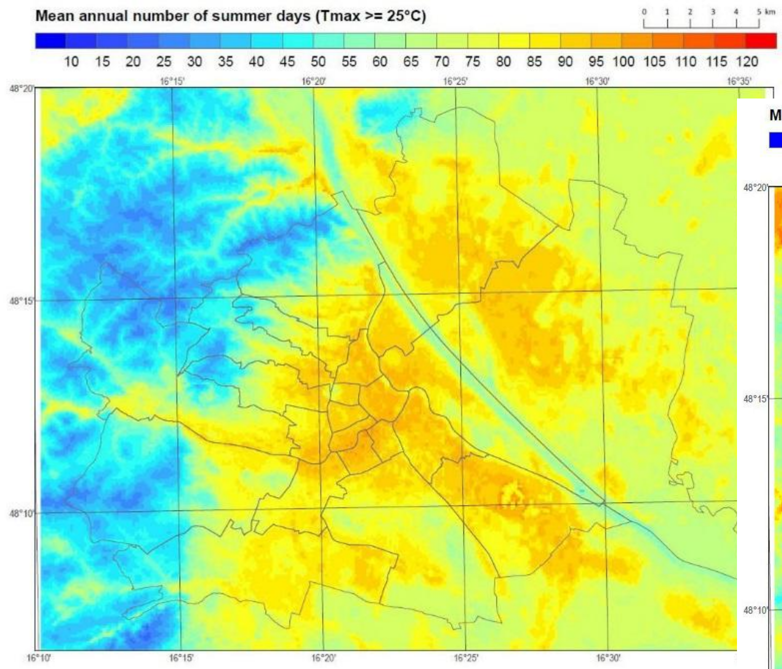
Vienna: 1971-2000 and 2071-2100, scenario RCP4.5 and RCP8.5

min.: 7.2 **max.:** 82.8 **avg:** **45.4** days



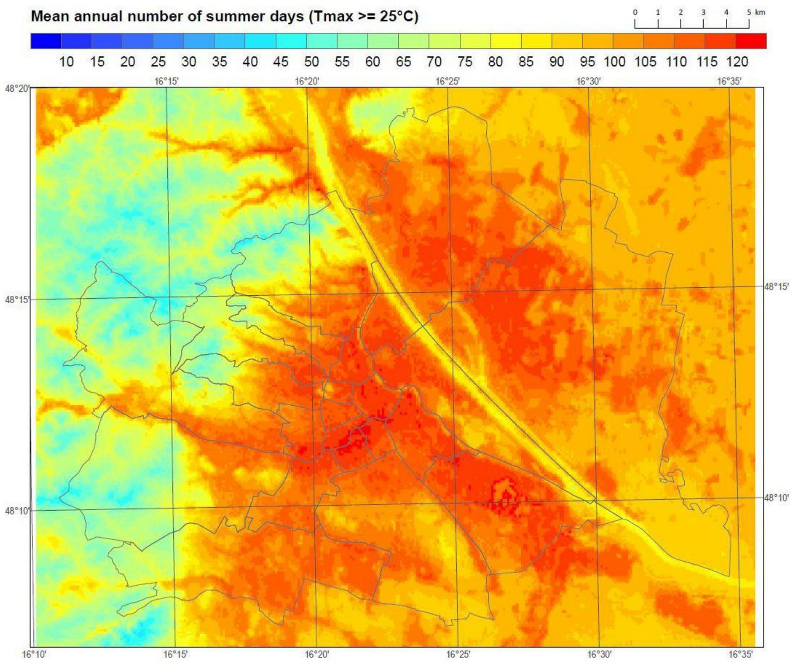
1971-2000

min.: 21.3 **max.:** 107.8 **avg:** **70.0** days

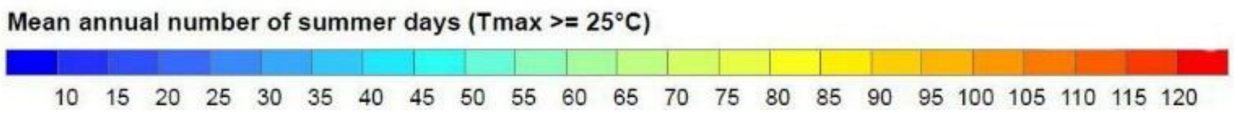


RCP4.5

min.: 40.0 **max.:** 128.8 **avg:** **93.4** days



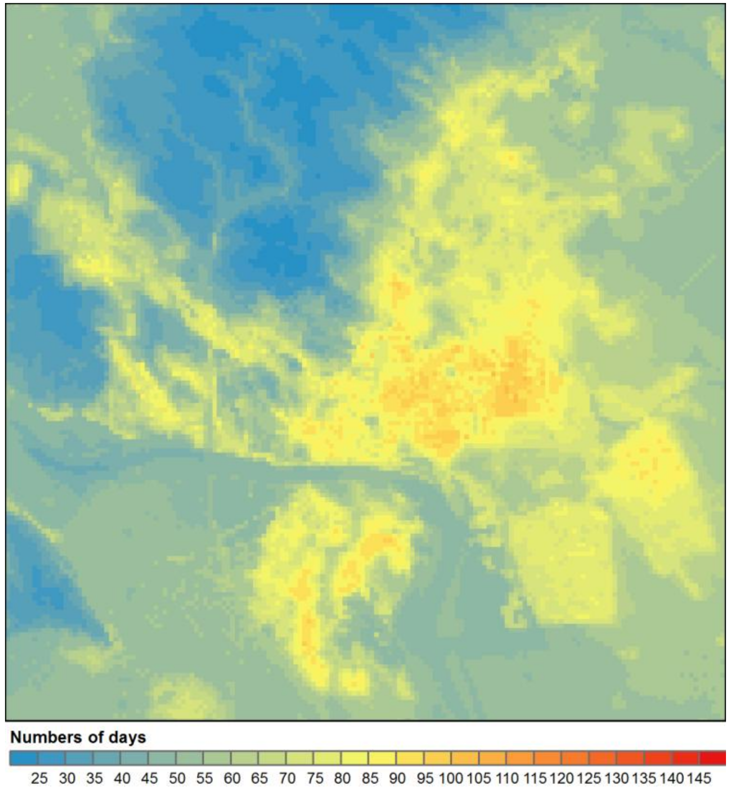
RCP8.5



"Urban climate in Central European cities and global climate change" 2014-2015

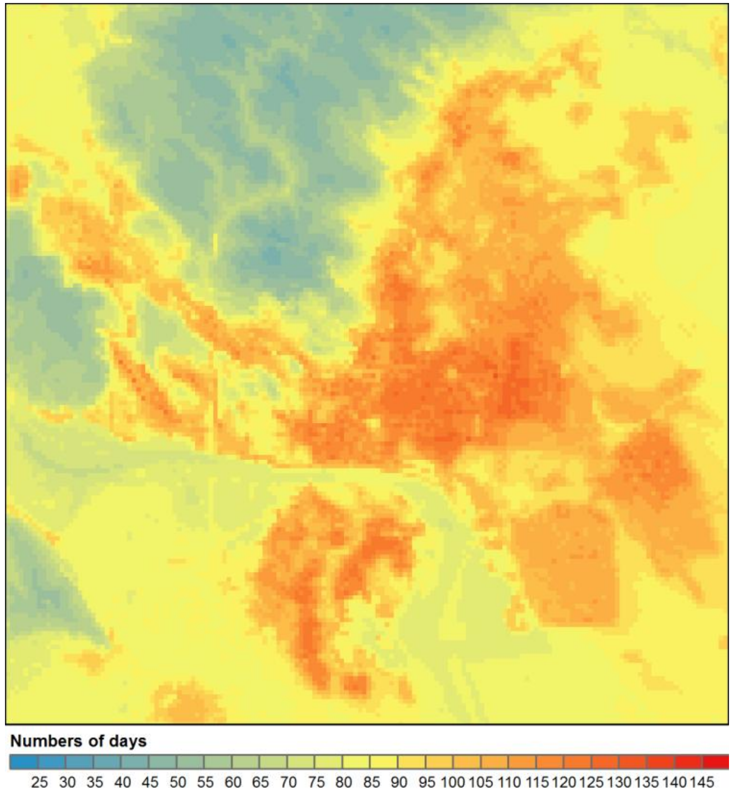
Bratislava: 1971-2000 and 2071-2100, scenario RCP4.5 and RCP8.5

min.: 20.6 **max.:** 104.1
avg: **56.4** days



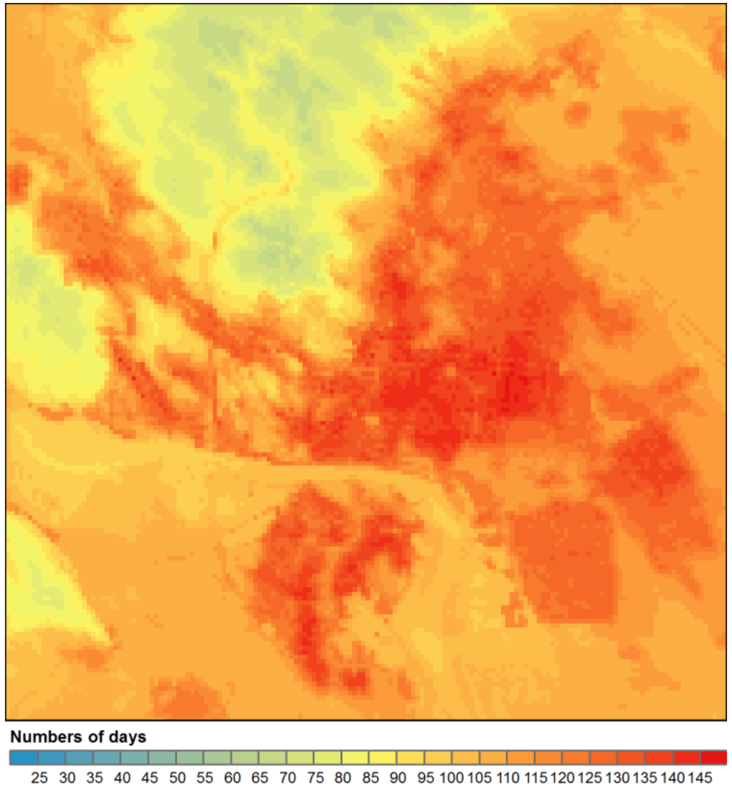
1971-2000

min.: 42.4 **max.:** 131.2
avg: **85.9** days

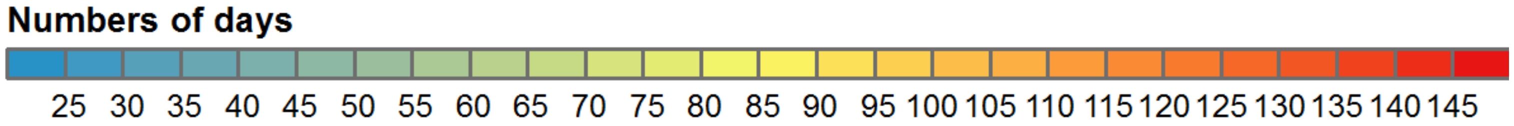


RCP4.5

min.: 65.0 **max.:** 148.9
avg: **107.8** days

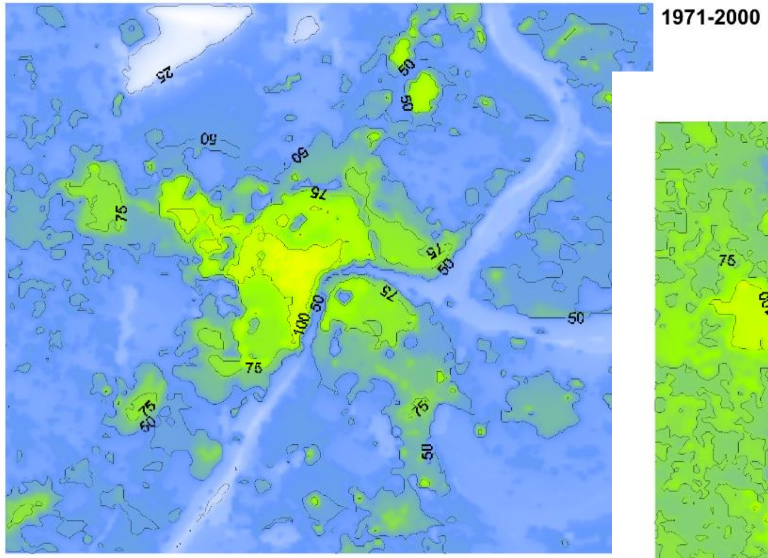


RCP8.5



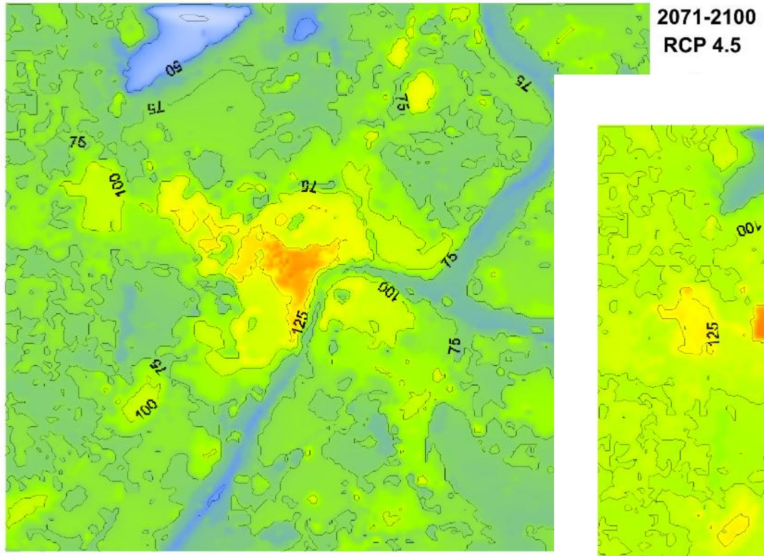
Szeged: 1971-2000 and 2071-2100, scenario RCP4.5 and RCP8.5

min.: 7.8 **max.:** 123.4 **avg:** **50.1** days



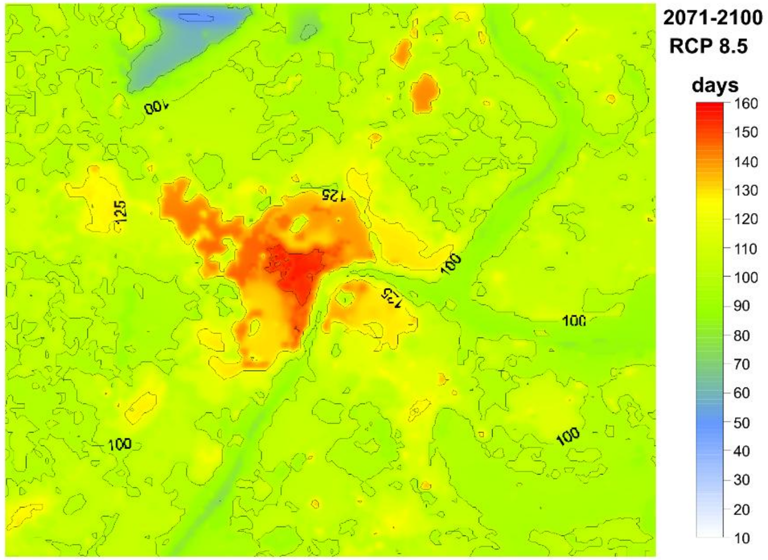
1971-2000

min.: 24.3 **max.:** 142.8
avg: **79.1** days

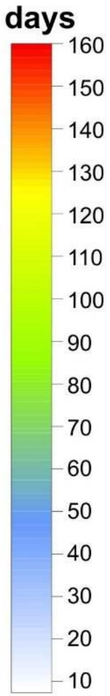


RCP4.5

min.: 19.4 **max.:** 137.4
avg: **76** days



RCP8.5



Mean annual number of summer days, 1971-2000 and 2071-2100 (RCP4.5 and RCP8.5)

Mean. max. and min. data for the whole area of the domain (i.e. a city and a surrounding area)

City	Mean			Min			Max		
	1971 - 2000	2071-2100		1971 - 2000	2071-2100		1971-2000	2071-2100	
		RCP4.5	RCP8.5		RCP4.5	RCP8.5		RCP4.5	RCP8.5
Kraków	20.3	37.8	59.2	4.0	14.8	28.7	61.1	78.6	100.3
Brno	37.2	59.3	81.4	10.5	27.4	40.7	83.4	102.1	123.1
Vienna	45.4	70.0	93.4	7.2	21.3	40.0	82.8	107.8	128.8
Bratislava	56.4	85.9	107.8	20.6	42.4	65.0	104.1	131.2	148.9
Szeged	50.1	79.1	104.3	7.8	24.3	78.5	123.4	142.8	159.1

N

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S

Increase (in number of days) of mean annual number of summer days. 1971-2000 and 2071-2100 (RCP4.5 and RCP8.5)

Mean. max. and min. data for the whole area of the domain (i.e. a city and a surrounding area)

City	Mean			Min			Max		
	1971-2000 days	2071-2100		1971-2000 days	2071-2100		1971-2000 days	2071-2100	
		RCP4.5 +days	RCP8.5 +days		RCP4.5 +days	RCP8.5 +days		RCP4.5 +days	RCP8.5 +days
Kraków	20.3	17.5	38.9	4.0	10.8	24.7	61.1	17.5	39.2
Brno	37.2	22.1	44.2	10.5	16.9	30.2	83.4	18.7	39.7
Vienna	45.4	24.6	48.0	7.2	14.1	32.8	82.8	25	46
Bratislava	56.4	29.5	51.4	20.6	21.8	44.4	104.1	27.1	44.8
Szeged	50.1	29.0	54.2	7.8	16.5	70.7	123.4	19.4	35.7

Increase (in%) of mean annual number of summer days.
1971-2000 and 2071-2100 (RCP4.5 and RCP8.5)
Mean. max. and min. data for the whole area of the domain (i.e. a city and a surrounding area)

City	Mean			Min			Max		
	1971-2000 days	2071-2100		1971-2000 days	2071-2100		1971-2000 days	2071-2100	
		RCP4.5 %	RCP8.5 %		RCP4.5 %	RCP8.5 %		RCP4.5 %	RCP8.5 %
Kraków	20.3	86	192	4.0	270	618	61.1	29	64
Brno	37.2	59	119	10.5	161	288	83.4	22	48
Vienna	45.4	54	106	7.2	196	456	82.8	30	56
Bratislava	56.4	52	91	20.6	106	215	104.1	26	43
Szeged	50.1	58	108	7.8	212	906	123.4	16	29

Conclusions:

According to the predictions presented, an **increase in heat load**, expressed in mean annual number of summer days, is expected in urban areas of Central Europe. Mean values for particular study areas are expected to increase by **20-50 days**, depending on the scenario used.

The **regional spatial pattern** of the predicted values of mean annual number of summer days shows dependence on **latitude**, i.e. for cities located in the northern part of the study area, the values are lower than for cities located in the south. The difference for mean values for particular study areas reaches about **40 days**.

The **local spatial pattern** shows the impact of both **land use/land cover and relief**. The largest values of mean annual number of summer days are observed in areas with intese built-up which are located in the valley floors. In rural areas, larger values are observed in the valleys than in the hill tops. The differences between the places with the lowest value and the largest value in particular cities reach **60-100 days**, depending on the scenario used.

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Urban climate in CE cities and global climate change

"Urban climate in Central European cities and global climate change" 2014-2015

International Visegrad Fund, Standard Grant No. 21410222

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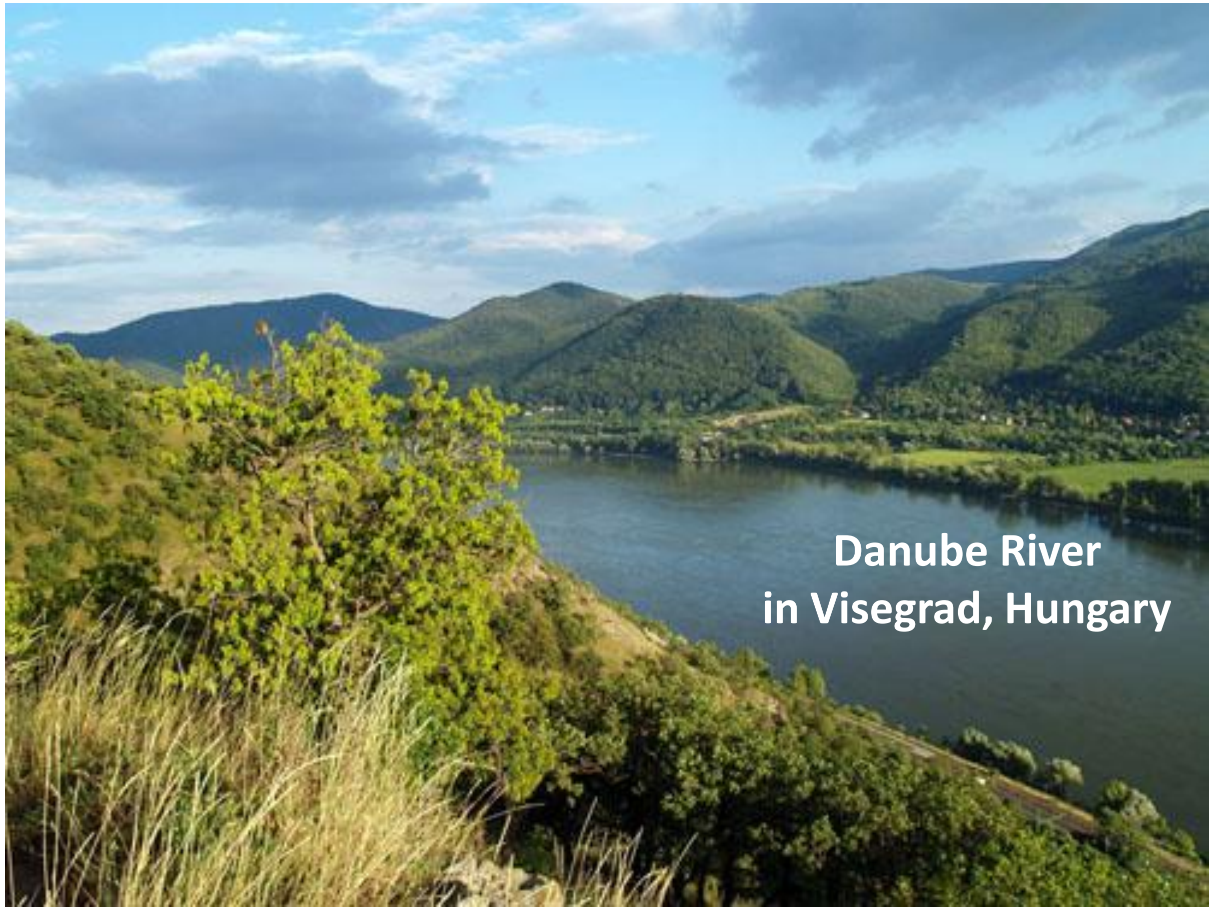

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