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

ellonian University, Krakow, Poland, (2) Global Change Research Centre AS CR, Brno, Czech Republic, (3) University of Szeged, Hungary, (4) Institute of rology and Water Management - National Research Institute, Krakow, Poland, (5) Central Institute for Meteorology and Geodynamics, Vienna, Austria acky University Olomouc, Olomouc, Czech Republic, (7) Slovak Hydrometeorological Institute, Bratislava, Slovakia, (8) Comenius University in Bratislav a

Modelling the impact of climate change on heat load increase in Central European cities

0th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environmen
Toulouse, France, July 20-24, 2015

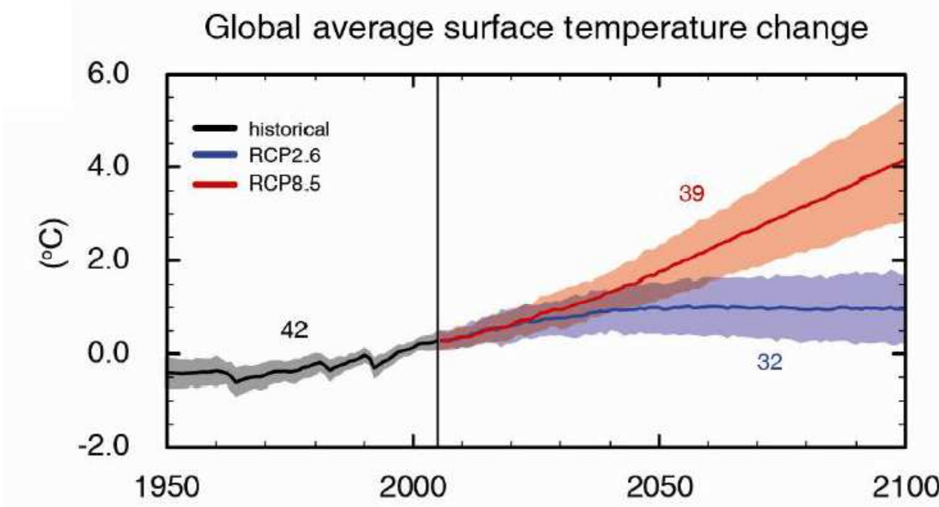
Introduction:

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

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

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.

6. Aim:

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

Methods:

1. 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

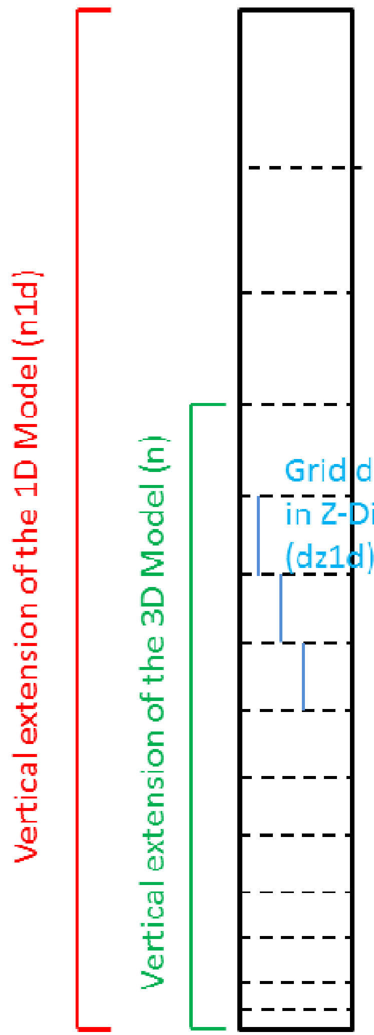
- Horizontal resolution: 100 m

- Vertical resolution: 10–100 m, finer resolution near surface

- Simulation duration: 24 h

- Input data: orography and land use

- Initial and boundary conditions: 1D vertical profile of time-varying atmospheric conditions at the referent station



- Output data: diurnal cycles of air temperature, wind speed and direction, relative humidity and heat fluxes

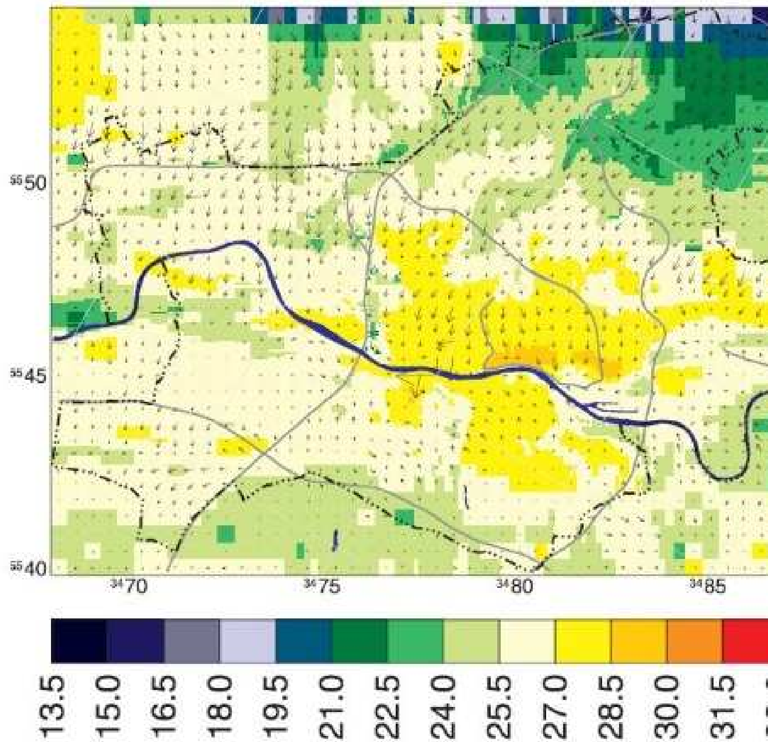
- Parameterization of buildings and vegetation

- 3-layered vegetation model

- 15-layered soil model

- Calculation of climate indices with “cuboid method” *(Früh et al. 2011)*

- Application for Frankfurt *(Früh et al. 2011)* and Vienna *(Zuvela-Aloise et al. 2014)*



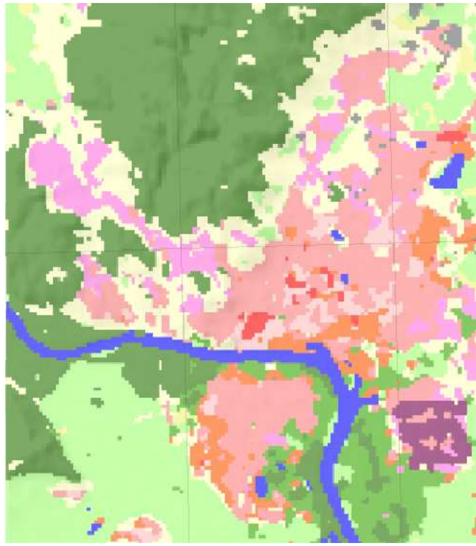
(b) T in °C, 02 CEST

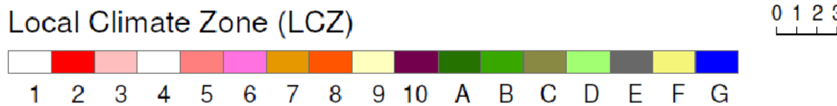
Air temperature and horizontal wind vec
in Frankfurt at 5-m height for flow from t
NE initialized with $T_{c.max}$ = 25°C, rh $_{c.min}$ =
and v $_{c.min}$ = 0.7 m s^{-1} (Fruh et al. 2011)

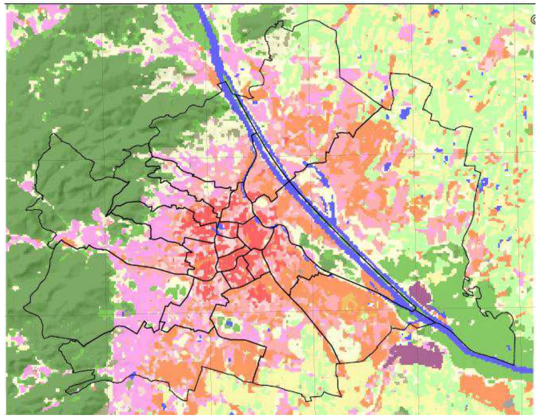
2. Local Climate Zones

- 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**;
- **Input parameters** for the model: land use and building height data; thresholds for land use and built-up parameters defined by *Stewart and Oke (2012)* were applied;
- For each LCZ class, a **common value** was assigned for all of the necessary input parameters of MUKLIMO for all the cities.

LCZ in Bratislava, Slovak

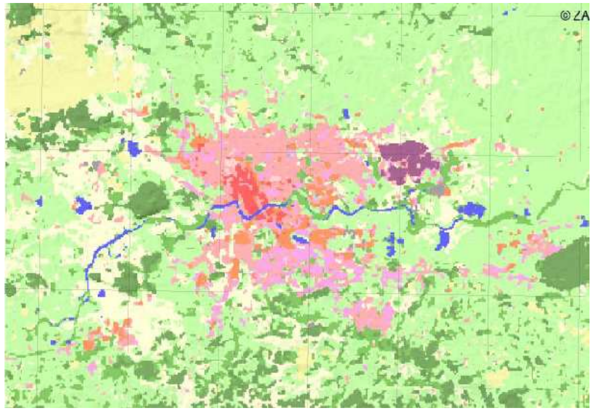






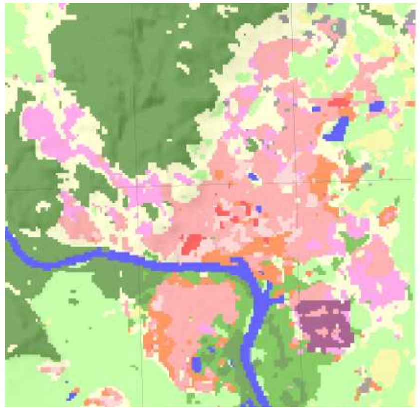
Vienna

Inhabitants: 1 800 000
140-580 m a.s.l.
Grid size: 316x247x39



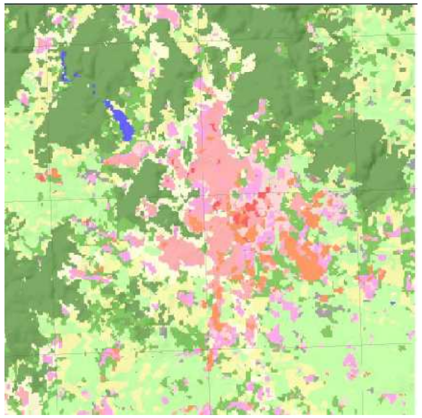
Krakow

Inhabitants: 760 000
145–460 m a.s.l.
Grid size: 389x275x39

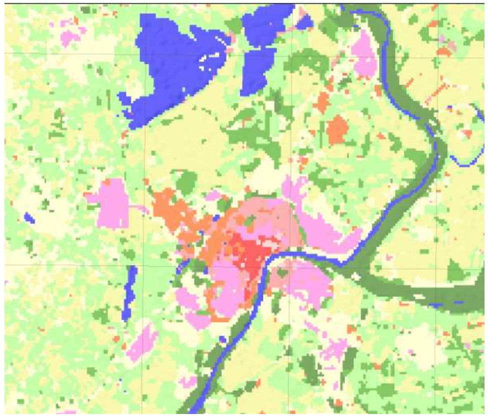


Bratislava

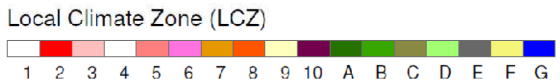
Inhabitants: 500 000
120-450 m a.s.l.
Grid size: 160x160x39



Brno, Inhabitants: 380 000, 200-525 m a.s.l.,
Grid size: 250x250x39



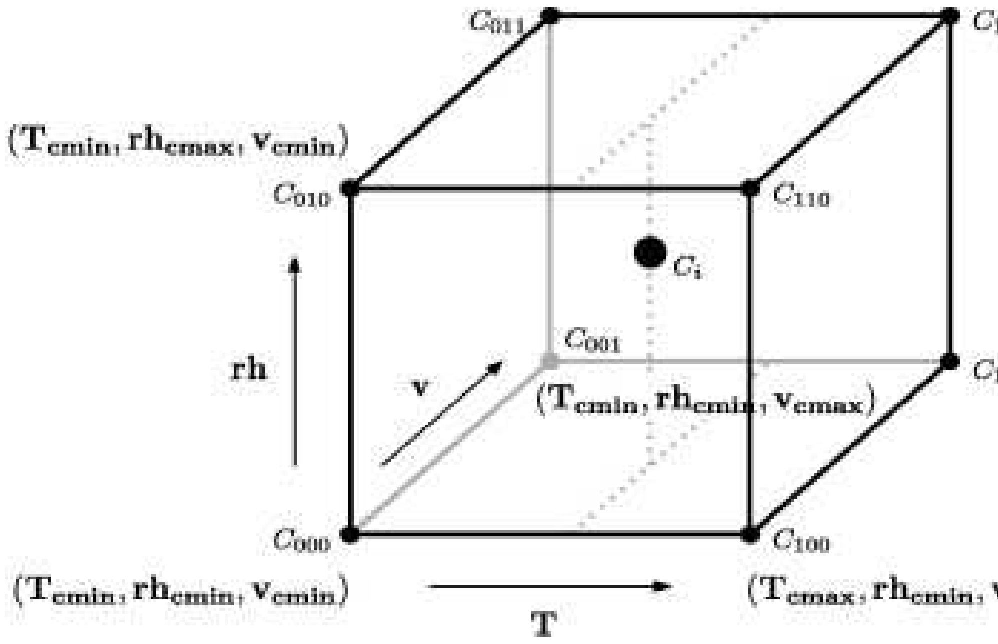
Szeged, Inhabitants: 170 000, 45-145 m a.s.l.,
Grid size: 213x181x25



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

3. Cuboid method

- Conditions potentially leading to heat stress: air temperature (T), relative humidity (rh) and wind speed (v);
- T, rh and v are representing the 3 dimensions of a cuboid structure;
- 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;
- The interpolation weight wi is computed from the distance of T_i to the two fixed points $T_{c,min}$ and $T_{c,max}$ and applied to the simulated urban scale MUKLIMO_3 fields to yield the interpolated urban scale fields of T_{int}, $T_{int,max}$ or $T_{int,min}$.

rad Fund
www.visegradfund.org
UNIVERSITY
KOW
G
alt für
ie und Geodynamik
lobe

- To identify thermally sensitive areas within the city: idealized simulations of temperature, wind and relative humidity in the urban area, based on the orograph and land use data with 100 m resolution;

- Possible climatological changes in urban heat load under future climate conditions expected increase in the number of days with:

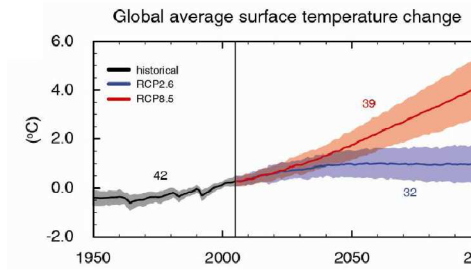
\- maximum air temperature ≥ 25°C (i.e. summer days);

\- maximum air temperature ≥ 30°C (i.e. hot days);

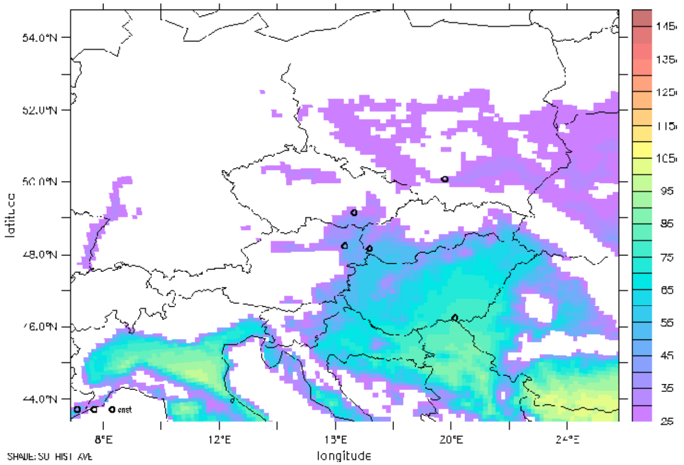
\- minimum air temperature ≥ 20°C (i.e. tropical nights);

- To conduct urban scale simulations for several 30-yr time periods would lead to an enormous computational effort;
- Instead, cuboid method is used;
- Future climate signal is based on the data from regional climate projections of the EURO-CORDEX project; 15 different climate predictions were used;
- The model outputs were corrected using orography and the measurement data of 1971-2000 in order to avoid the systematic errors.

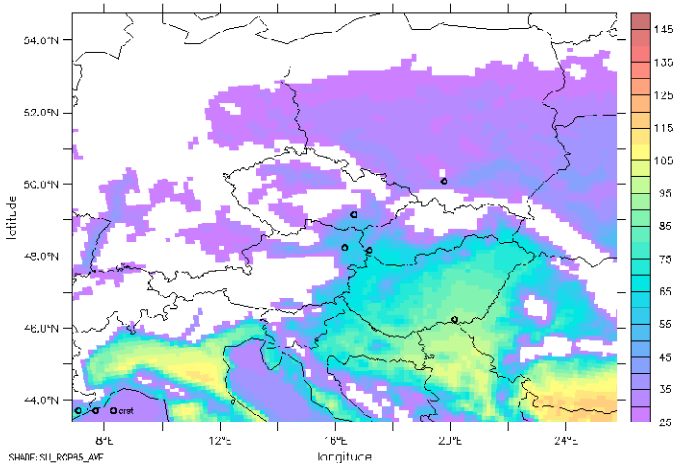
EURO-CORDEX - Coordinated Downscaling Experiment - European Domain (EUR-11)



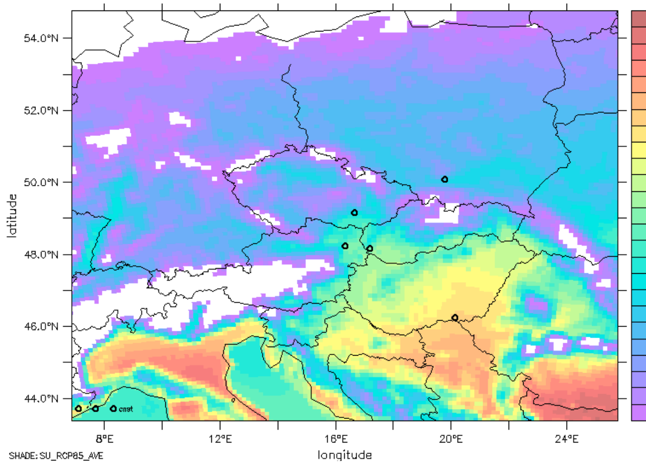
IPCC Scenario RCP8.5



1971-2000



2021-2050



2071-2100

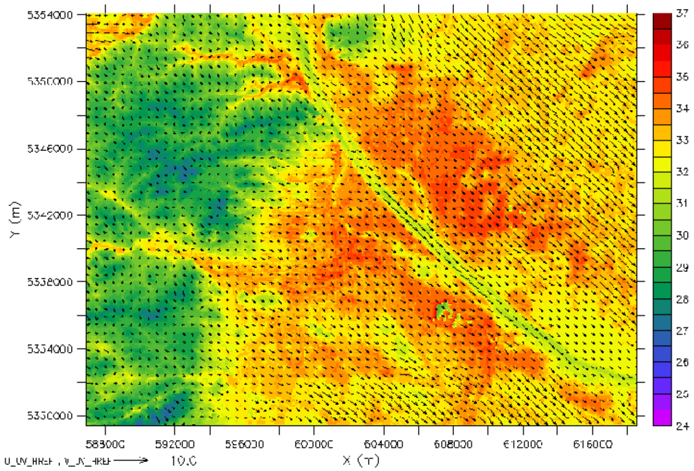
Mean annual number of summer days ($T_{max} \geq 25°C$), model ensemble average (11 members)

	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

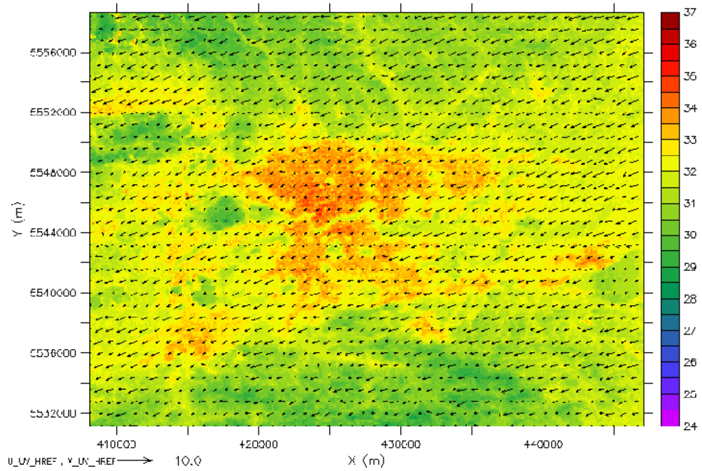
Preliminary results

- Modelling air temperatures and wind fields for all cities;
- Idealized case: the same meteorological profiles for all cities;
- Reference conditions: mean daily air temperature: 25°C, mean daily relative humidity: 40%, mean daily wind speed: 3 $m \cdot s^{-1}$ (i.e. cuboid point 101);
- Upper wind direction: NW, except Krakow (NE).

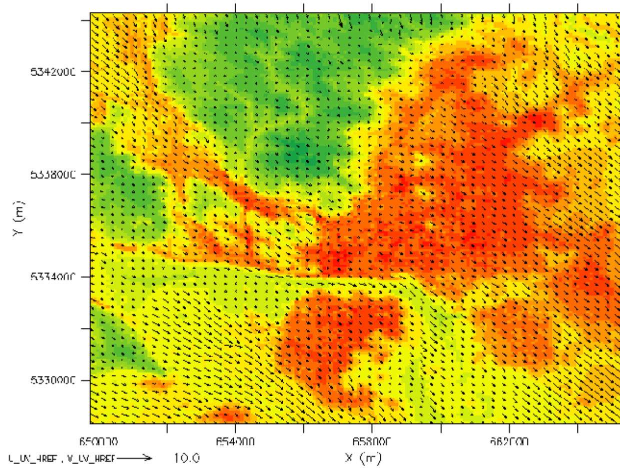
Idealized simulations for air temperatures and wind fields at h=5 m, at t=1600h MESZ (UTC +



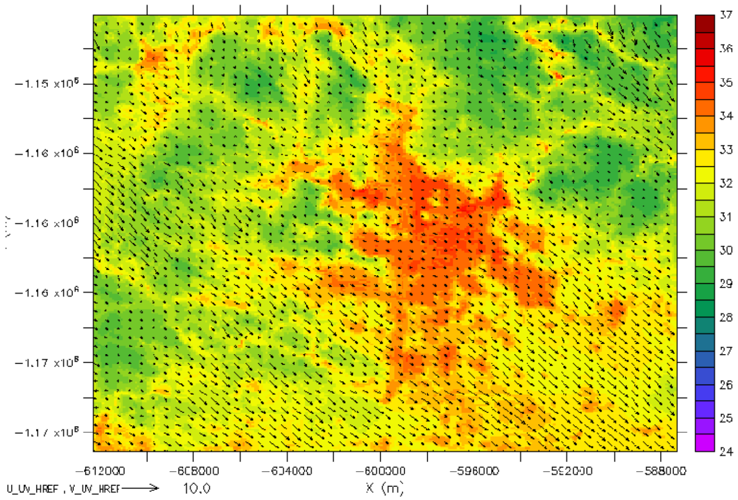
Vienna, Austria



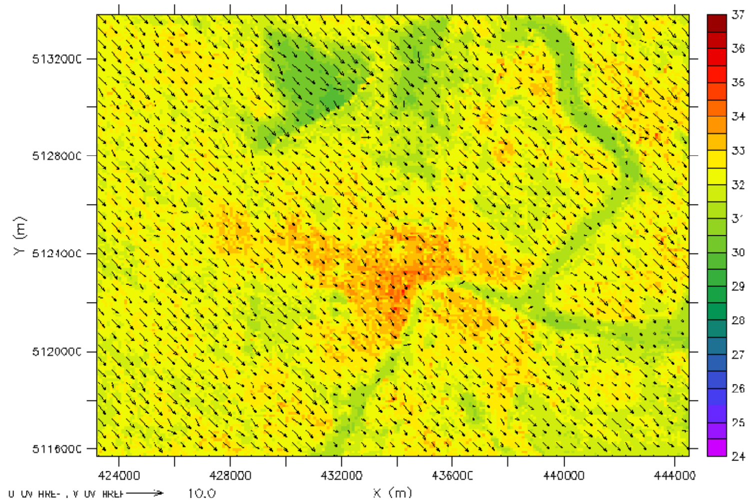
Krakow, Poland



Bratislava, Slovakia



Brno, Czech Republic



Szeged, Hungary

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

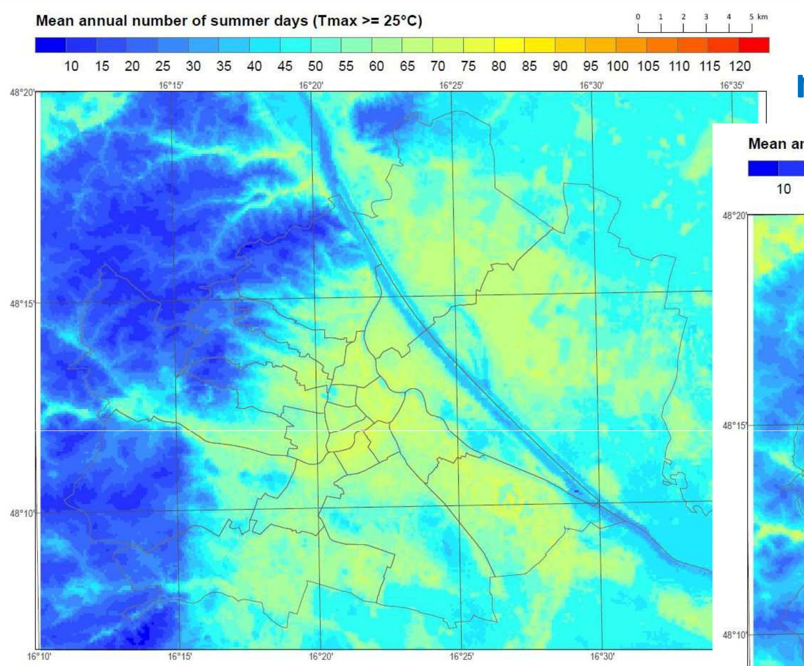
Future climate change impact
(preliminary results)

Example:

- 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 periods 2021-2050 and 2071-2100, compared to 1971-2000

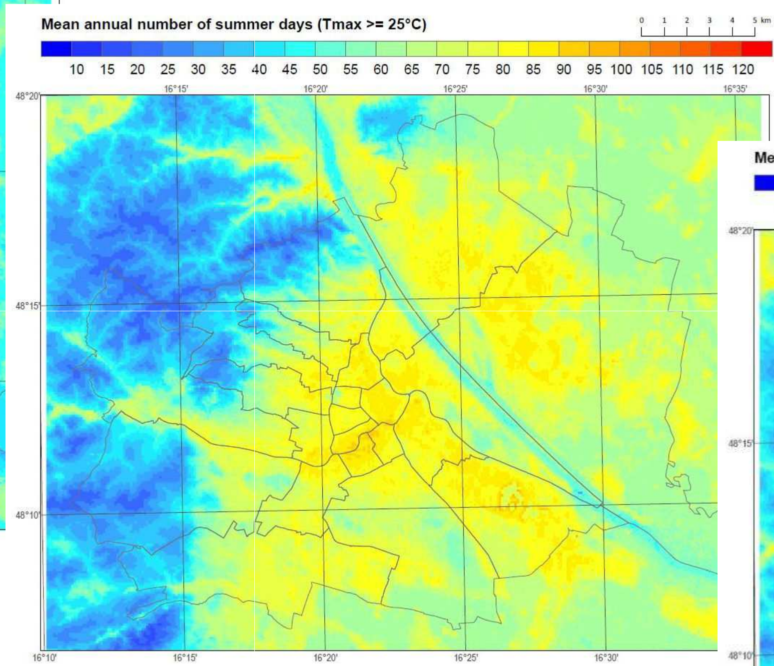
Vienna: Scenario RCP4.5

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



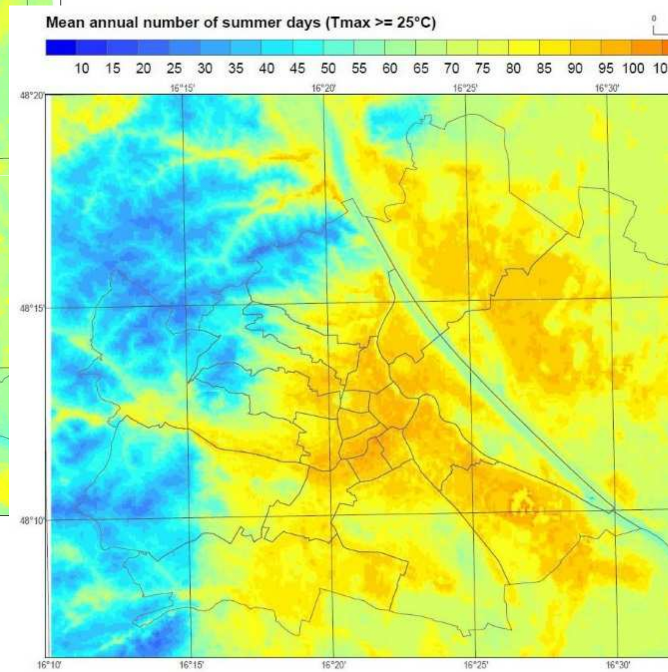
1971-2000

min.: 16.0 **max.:** 99.0 **avg:** **61.6** days

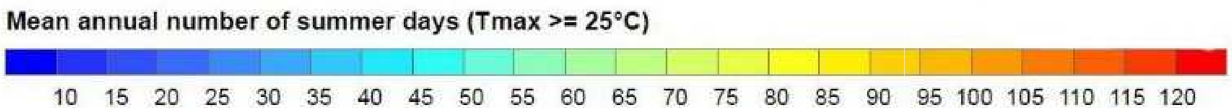


2021-2050

min.: 21.3 **max.:** 107.8 **avg:** **70**



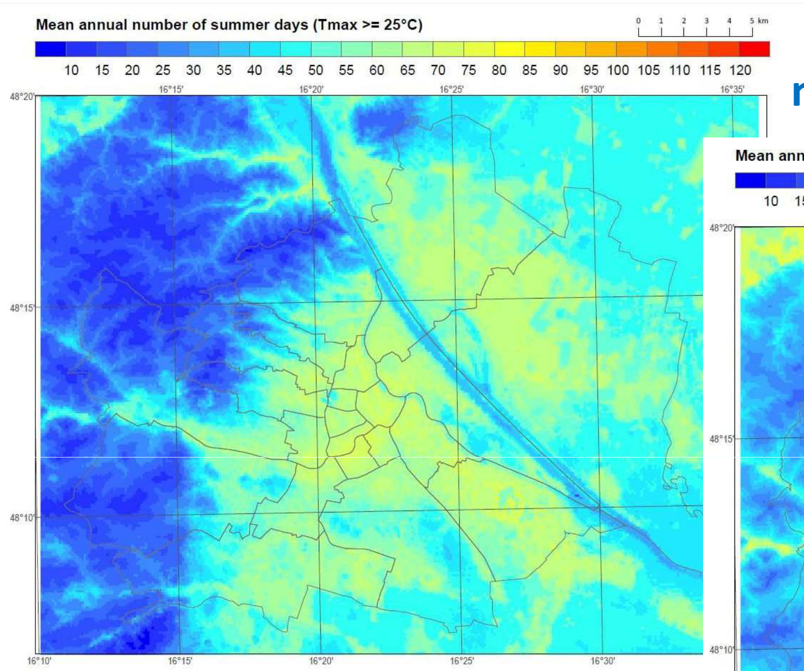
2071-2100



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

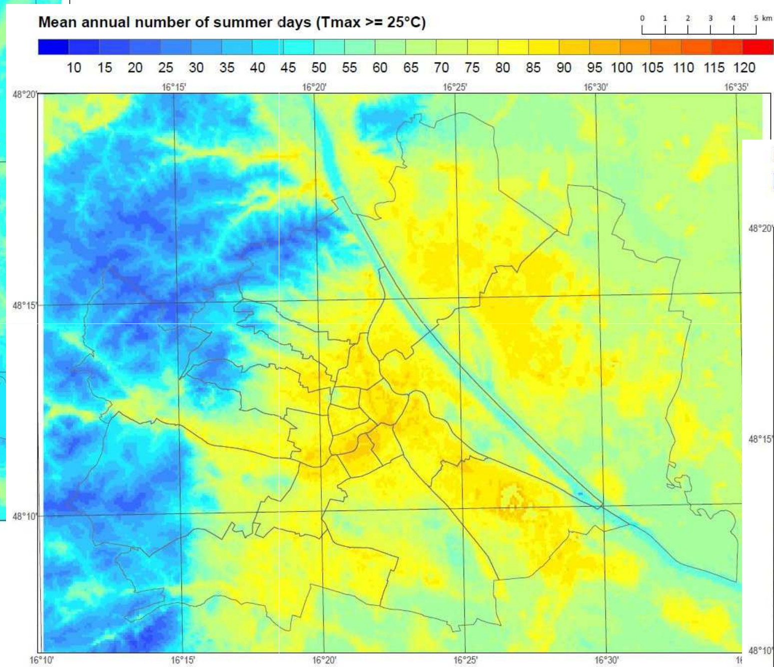
Vienna: Scenario RCP8.5

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



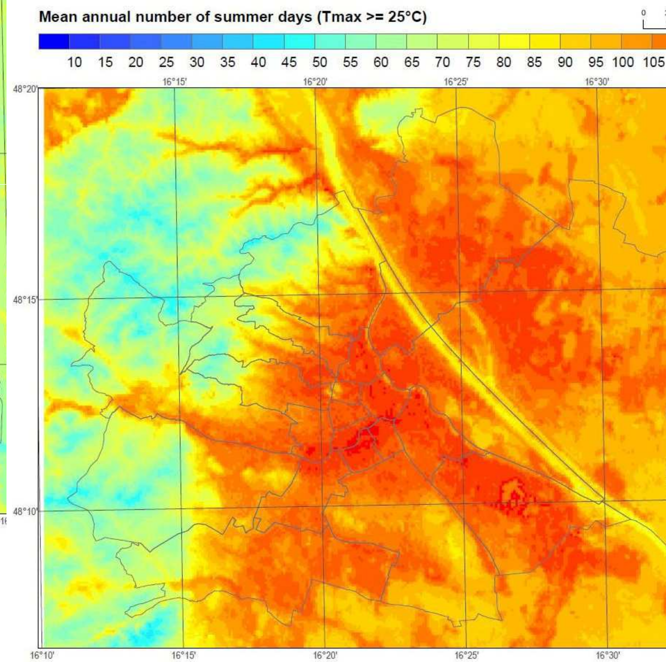
1971-2000

min.: 16.1 **max.:** 101.9 **avg:** **63.0** days



2021-2050

min.: 40.0 **max.:** 128.8 **avg:** **93**



2071-2100

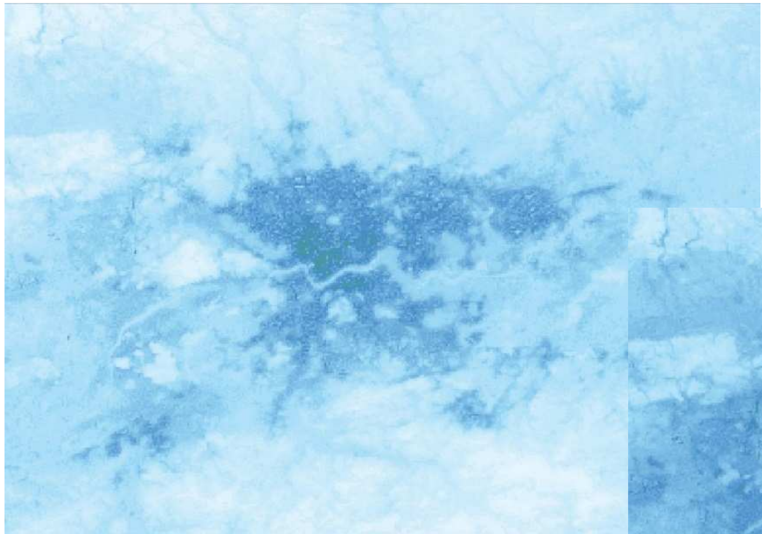
Mean annual number of summer days (Tmax >= 25°C)

10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

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

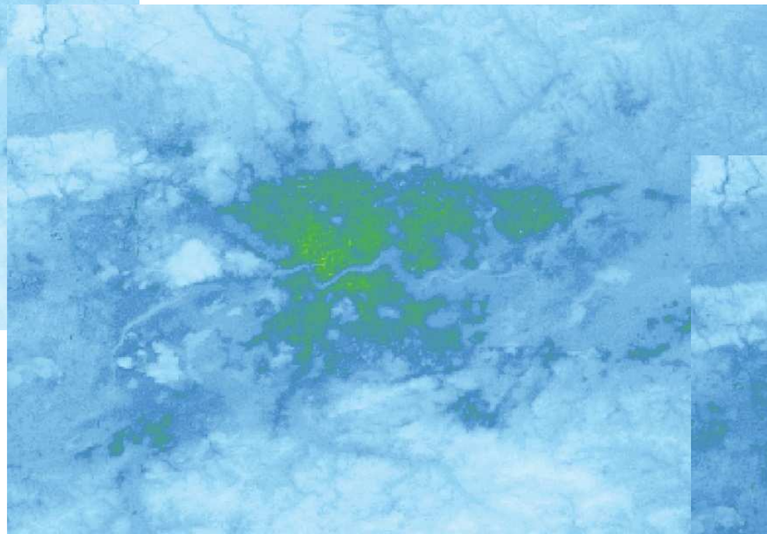
Krakow: Scenario RCP4.5

min.: 3.6 **max.:** 58.8 **avg: 17.6** days



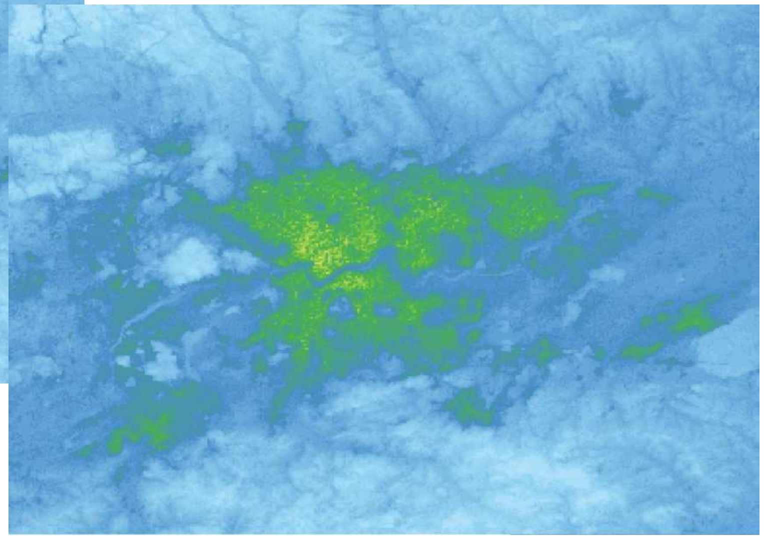
1971-2000

min.: 9.3 **max.:** 76.1 **avg: 29.1** days



2021-2050

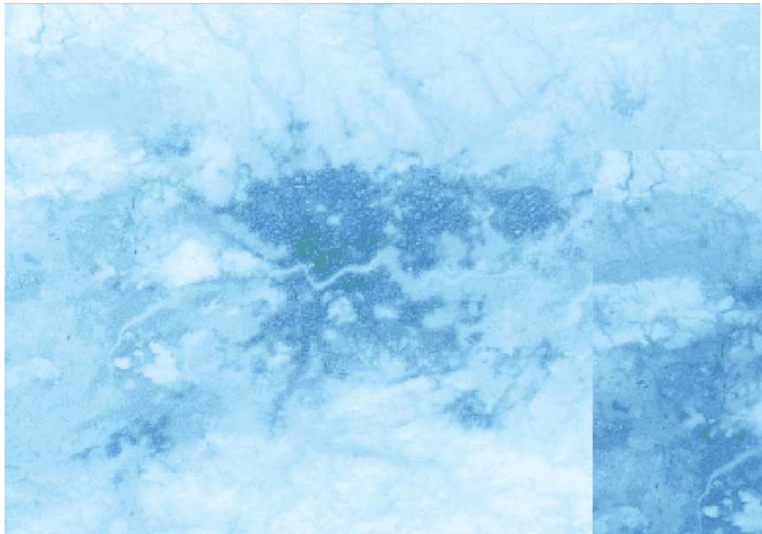
min.: 13.9 **max.:** 86.1 **avg: 36.2** da



2071-2100

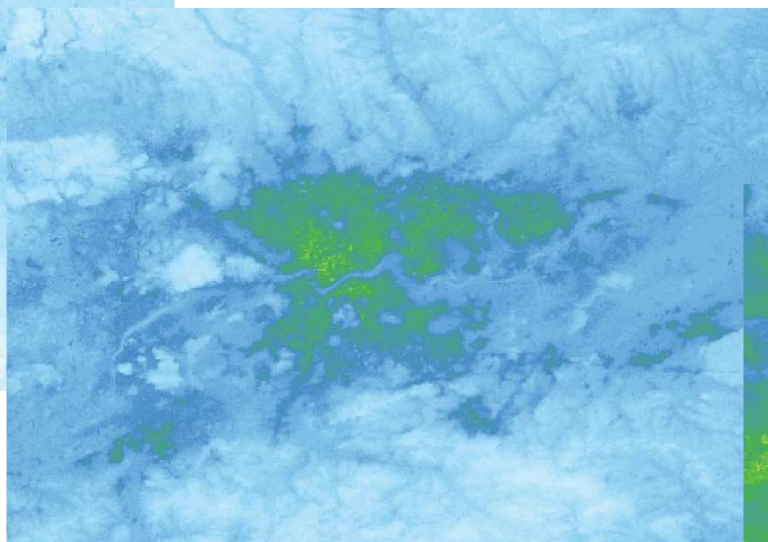
Krakow: Scenario RCP8.5

min.: 3.6 **max.:** 58.8 **avg:** **17.6** days



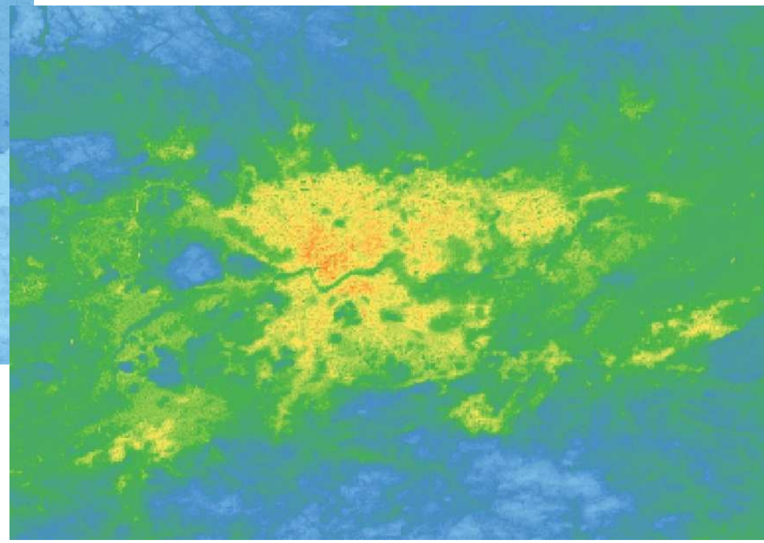
1971-2000

min.: 9.3 **max.:** 78.1 **avg:** **29.9** days



2021-2050

min.: 27.4 **max.:** 108.1 **avg:** **57.2** da

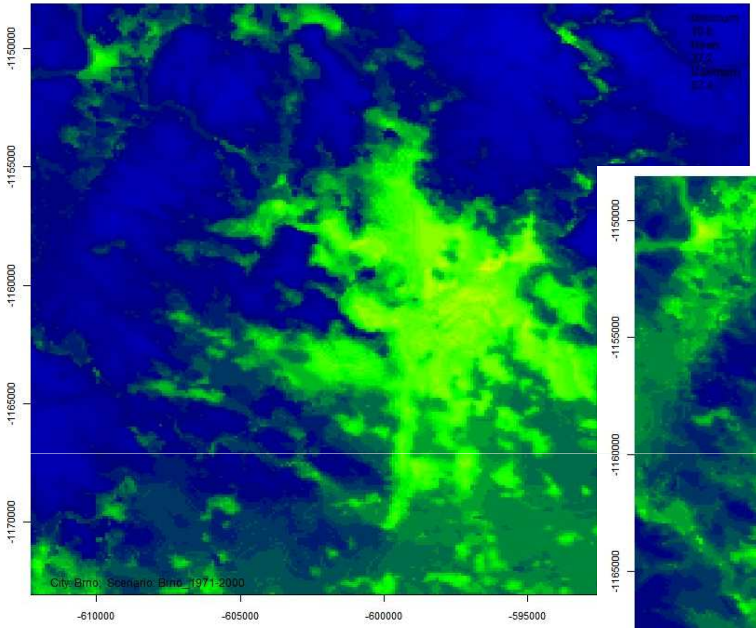


2071-2100

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

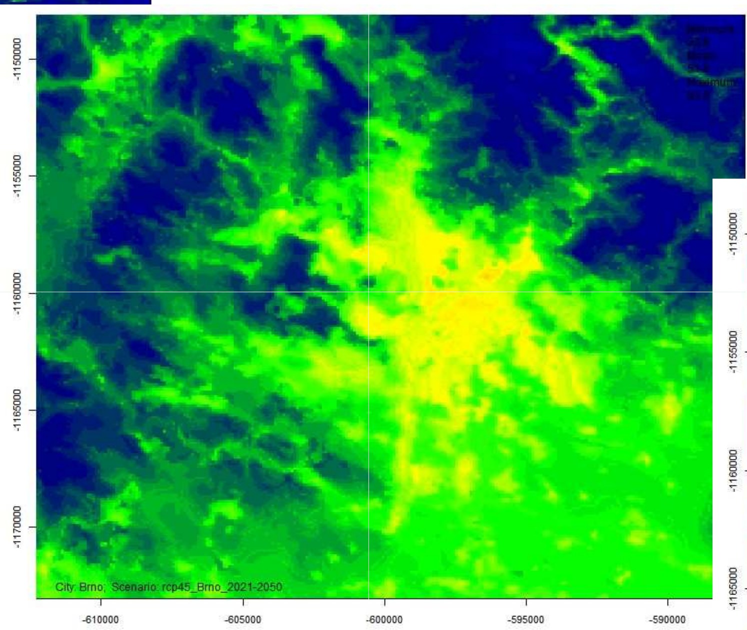
Brno: Scenario RCP4.5

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



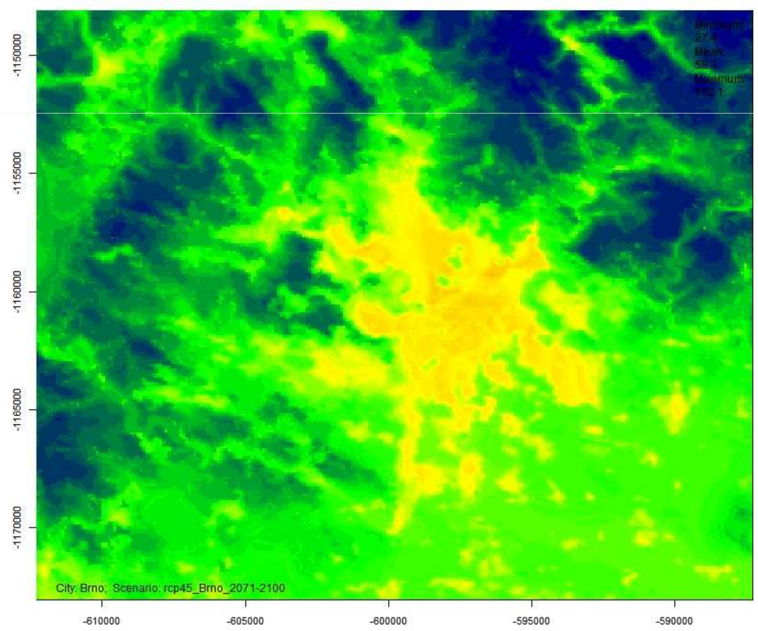
1971-2000

min.: 23.9 **max.:** 93.6 **avg:** **51.8** days



2021-2050

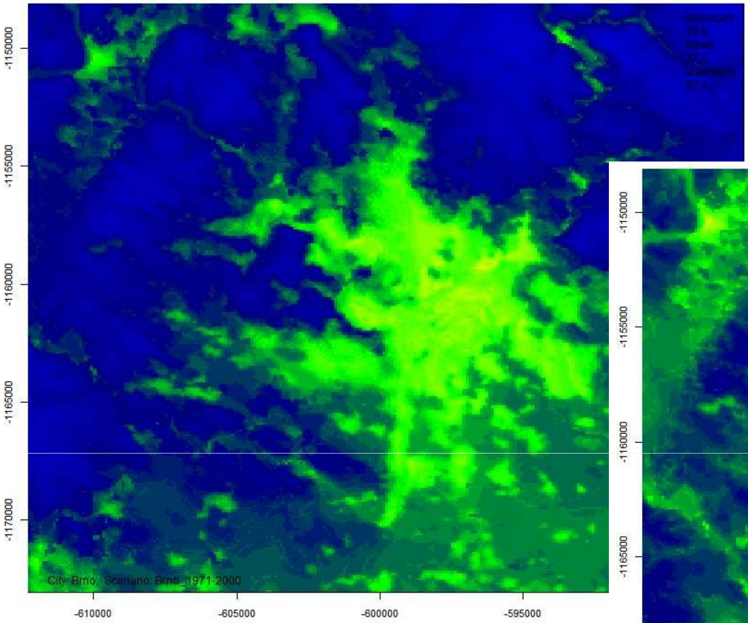
min.: 27.4 **max.:** 102.1 **avg:** **59.3** da



2071-2100

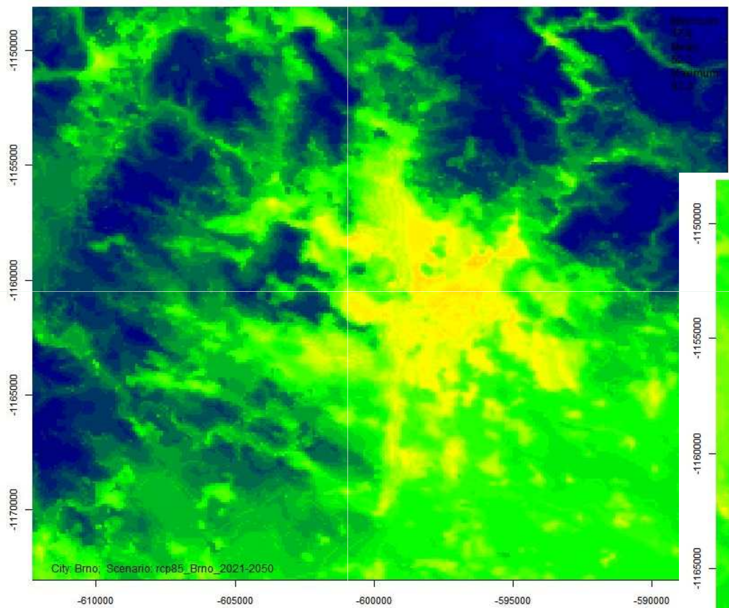
Brno: Scenario RCP8.5

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



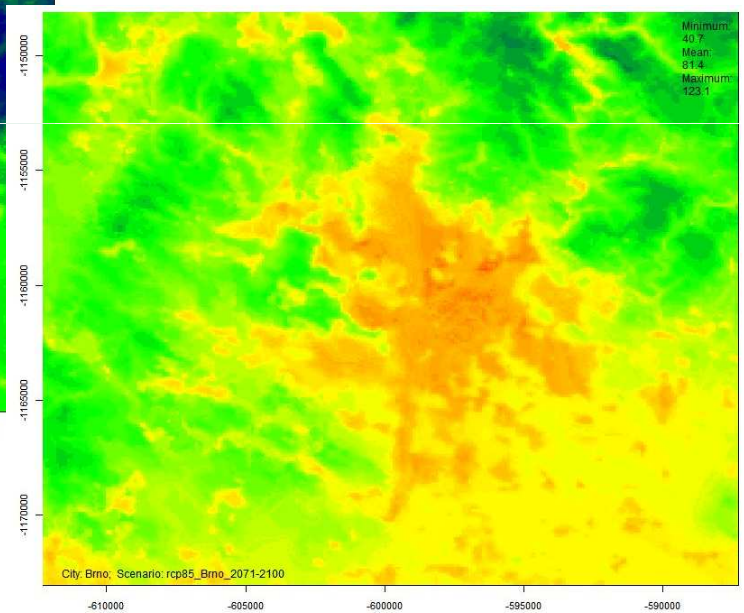
1971-2000

min.: 17.8 **max.:** 93.2 **avg: 52.3** days



2021-2050

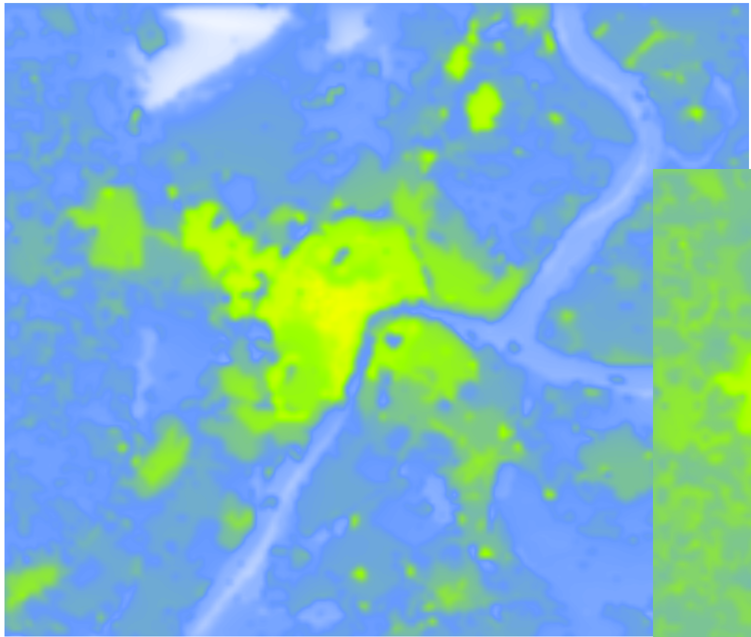
min.: 40.7 **max.:** 123.1 **avg: 81.4** da



2071-2100

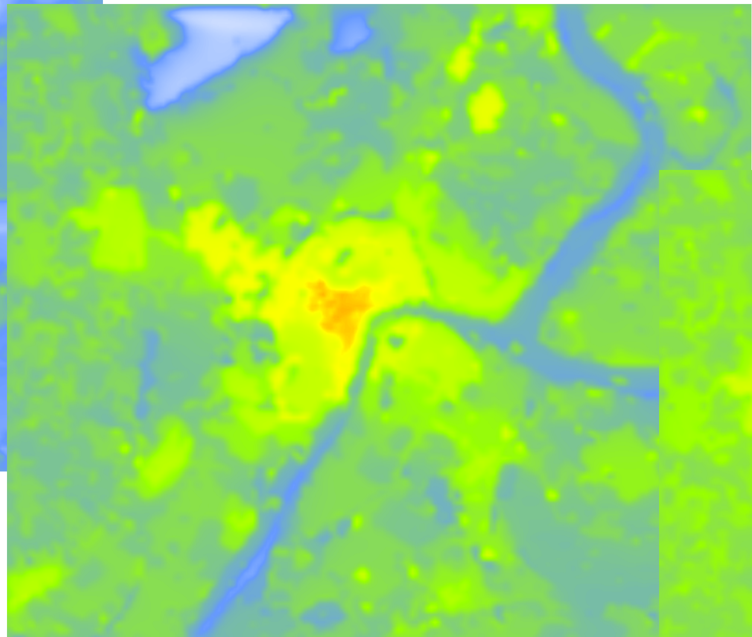
Szeged: Scenario RCP4.5

min.: 4.7 **max.:** 115.1 **avg:** **46.5** days



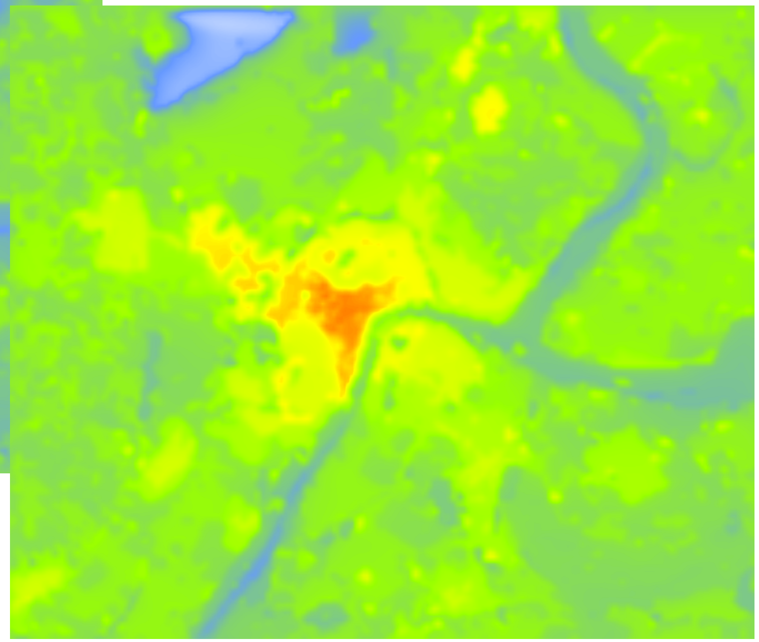
1971-2000

min.: 13.7 **max.:** 129.9 **avg:** **66.1** days



2021-2050

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

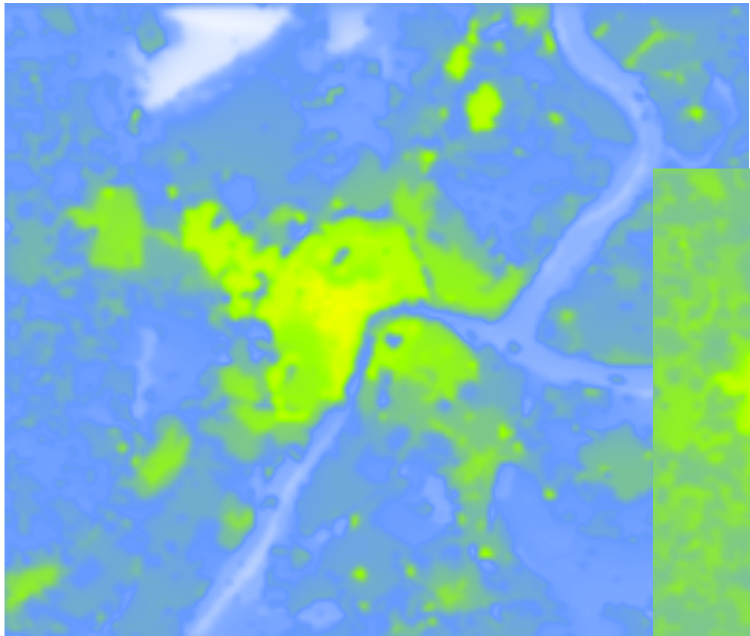


2071-2100

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

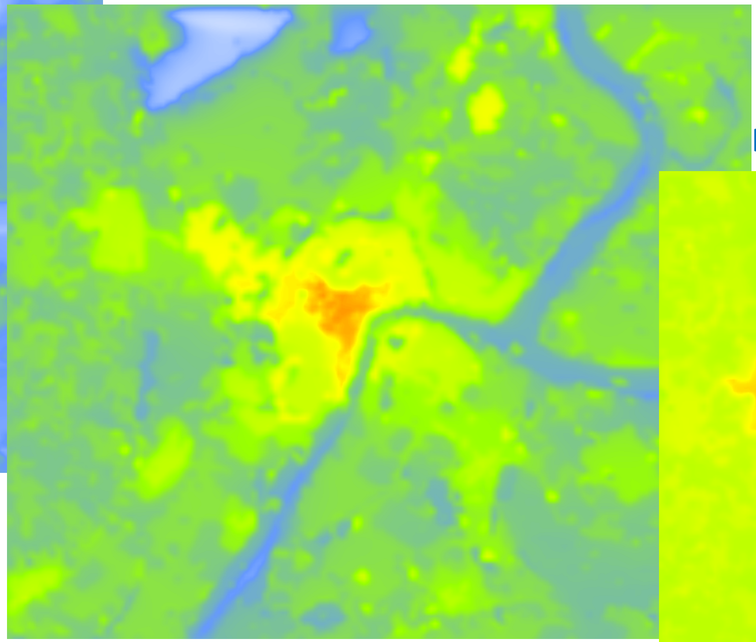
Szeged: Scenario RCP8.5

min.: 4.7 **max.:** 115.1 **avg:** **46.5** days



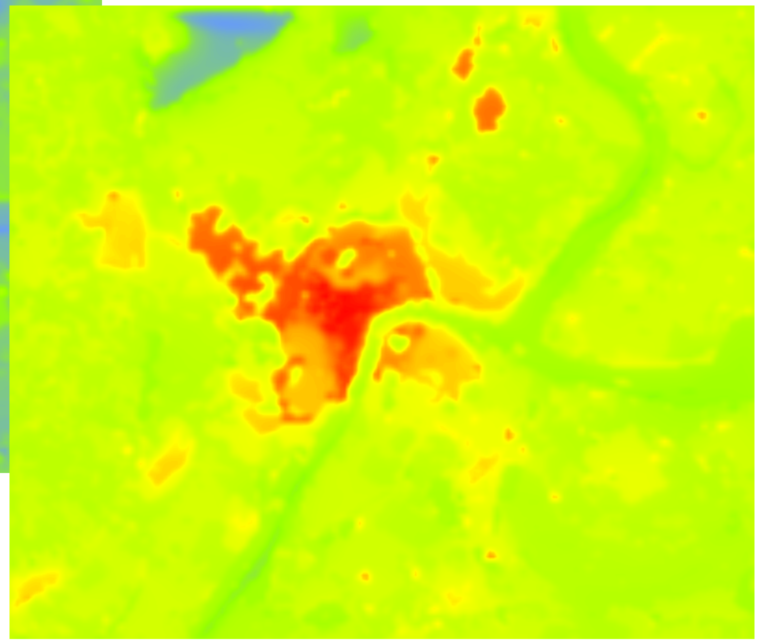
1971-2000

min.: 14.7 **max.:** 133.9 **avg:** **67.9** days



2021-2050

min.: 42.1 **max.:** 153.9 **avg:** **101.7**



2071-2100

Further research:

- model evaluation for each city with the available observational data

- comparison of the scenarios between the cities and discussion of the addec value from the downscaling method

- evaluation of the predicted changes' spatial patterns in particular cities, in tl context of local conditions (e.g. land forms, land use, land cover)

Thank you for your attention!

“Urban climate in Central European cities and global climate change”
2014-2015
International Visegrad Fund, Standard Grant No. 21410222