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DO WE NEED URBAN PARAMETERIZATION IN HIGH RESOLUTION SIMULATIONS ?

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PRAHA
PRAGUE
PRAGA
PRAG

Outline

1. Motivation and projects
2. Urban processes and their parameterizations
3. Multi-model experiments and results comparison
4. Weather forecast potential
5. Anthropogenic heating
6. Conclusions

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Motivation

World:

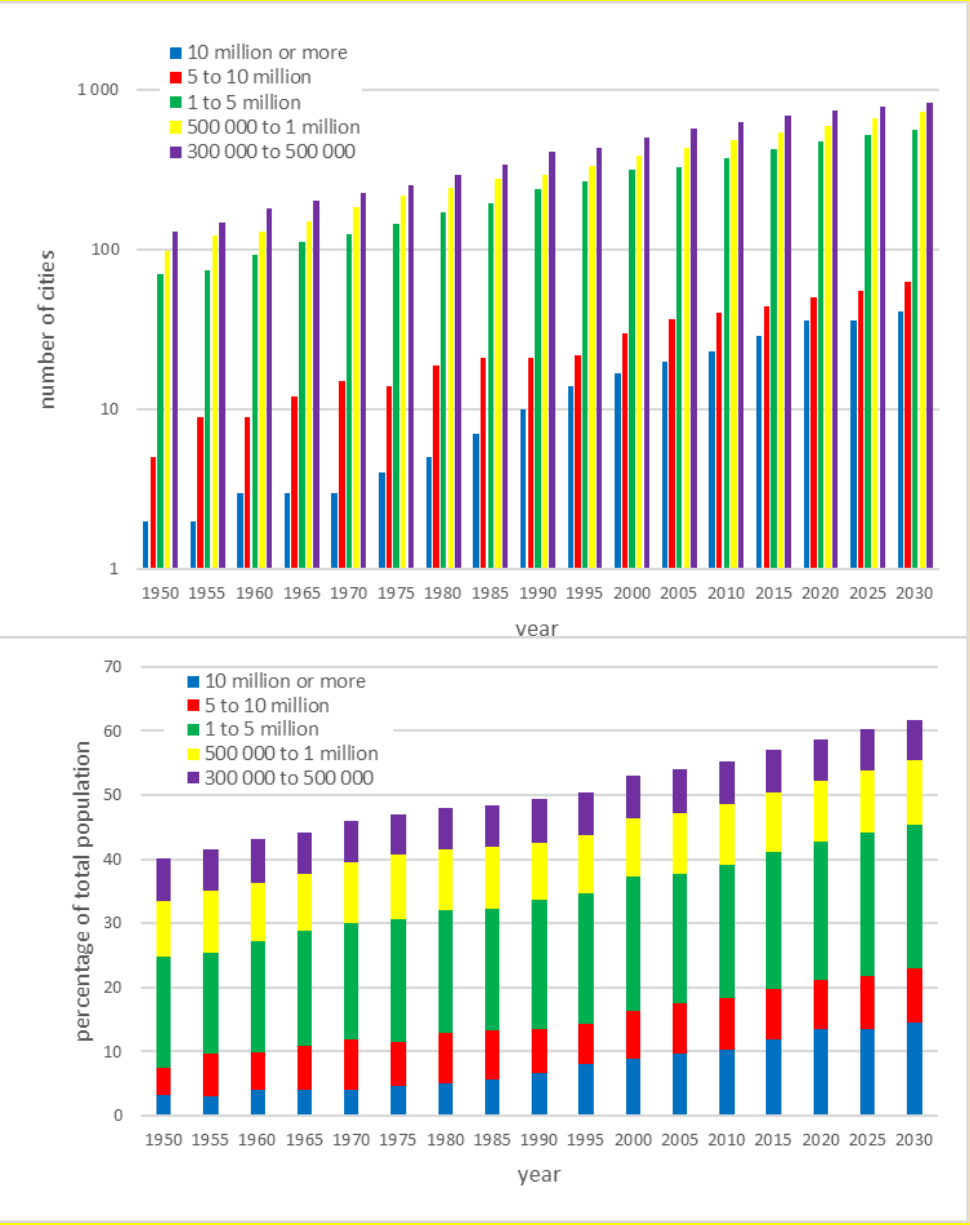
- From 2009 - more than 50% of the world's population living in cities (UN, 2009)
- less than 0.1% of the Earth's surface

Europe:

- 2008 - 73% of the population in cities
- mid 21th century - 84%, representing a rise from 531 to 582 millions (UN, 2008)
- in the Czech Republic, a similar change from 73.5% to 83% is projected by the Czech Statistical Office.

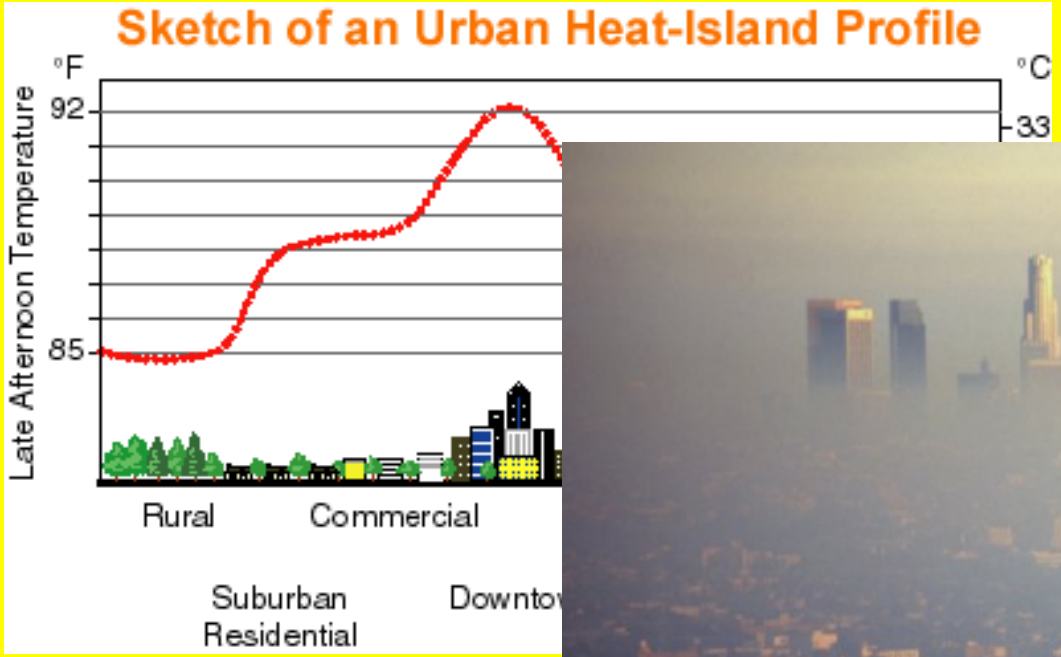
Clearly:

- Quite many atmospheric effects on population through the urban environment
- Especially thermal extreme weather effects like heat wave

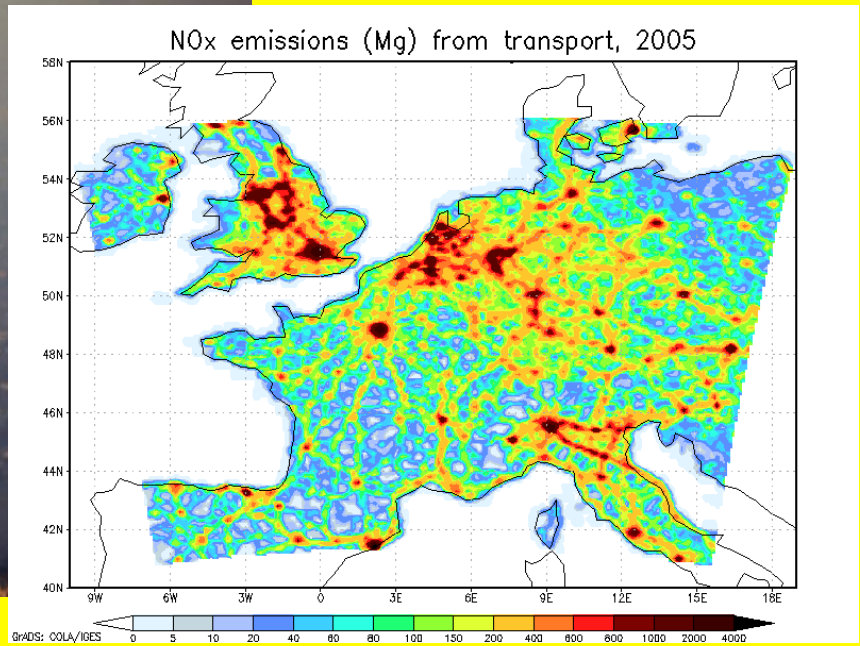


Recent challenges in modeling of urban heat island ☆
Sustainable Cities and Society, Volume 19, 2015, 200–206
http://dx.doi.org/10.1016/j.scs.2015.04.001

What we are (not) talking about …



Los Angeles smog and California climate change policy



MEGAPOLI TNO NOx emissions [Mg], 2005 from transport (S7)

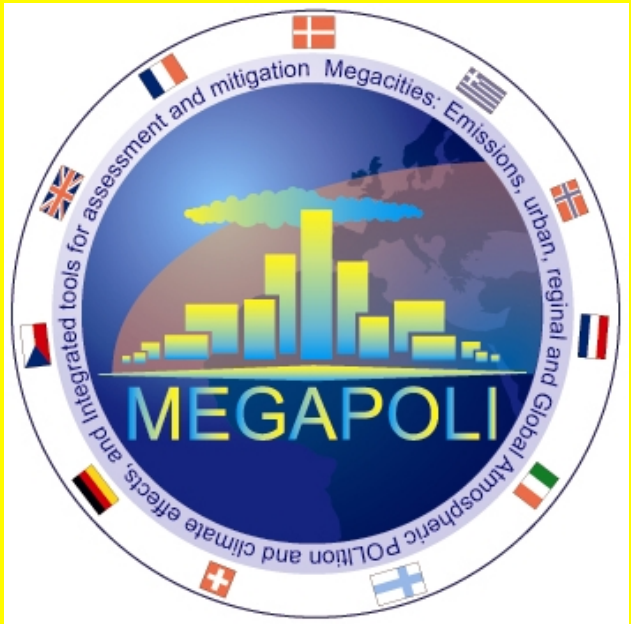
MEGAPOLI Project

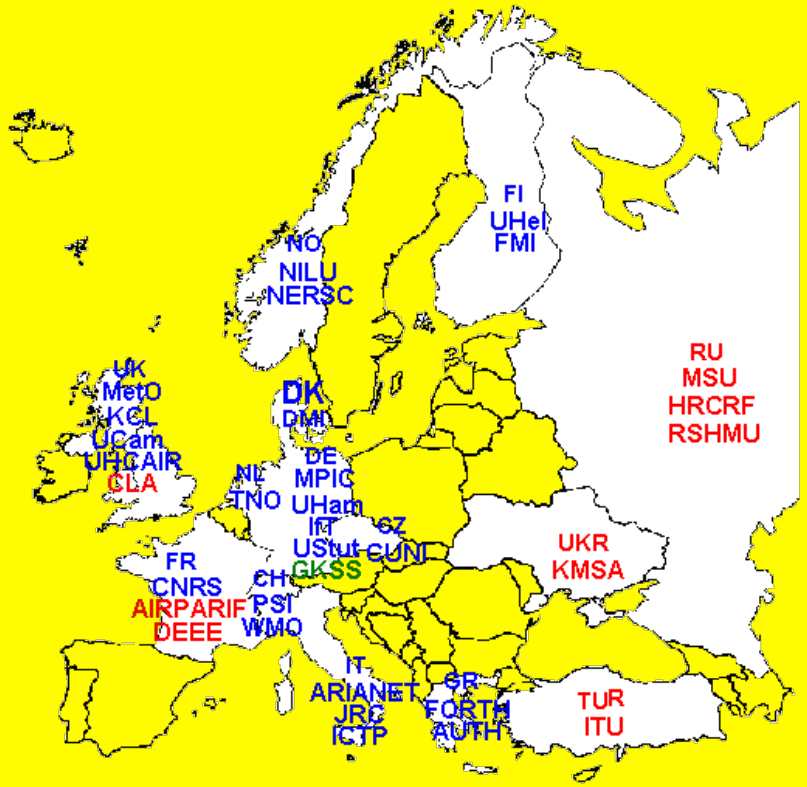
Objectives:

- to assess impacts of megacities and large air-pollution hot-spots on local, regional and global air quality,
- to quantify feedbacks among megacity air quality, local and regional climate, and global climate change,
- to develop improved integrated tools for prediction of air pollution in megacities

Duration: 1 October 2008 – 30 September 2011

Coordinator: DMI, Copenhagen, A. Baklanov





UHI Project - Development and Application of Mitigation and Adaptation Strategies and Measures for Counteracting the Global Urban Heat Island Phenomenon

Within framework of EC Operation Programme Central Europe (3CE292P3)
18 partners, coordinated by ARPA, Italy (Paolo Lauriola)

8 of the most relevant metropolitan areas and Metropolitan European Growth Areas (MEGAs) of CE area

CENTRAL EUROPE
COOPERATING FOR SUCCESS.

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project PoC CUNI

OP-Prague the Pole of Growth:
Proof of Concept CUNI – Assessment of research results commercial potential at Charles University

KK2:
Climate change impacts on Prague, potential of adaptation and mitigation options

01/2017 – 12/2018

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Project URBI PRAGENSI

- Urbanization of weather forecast
- Urabanization of air-quality forecast (connected to the above)
- Urbanization of climate change scenarios, the tool for efficiency assessment of adaptation or mitigation measures in strategic development plans
- Hot-spots simulations

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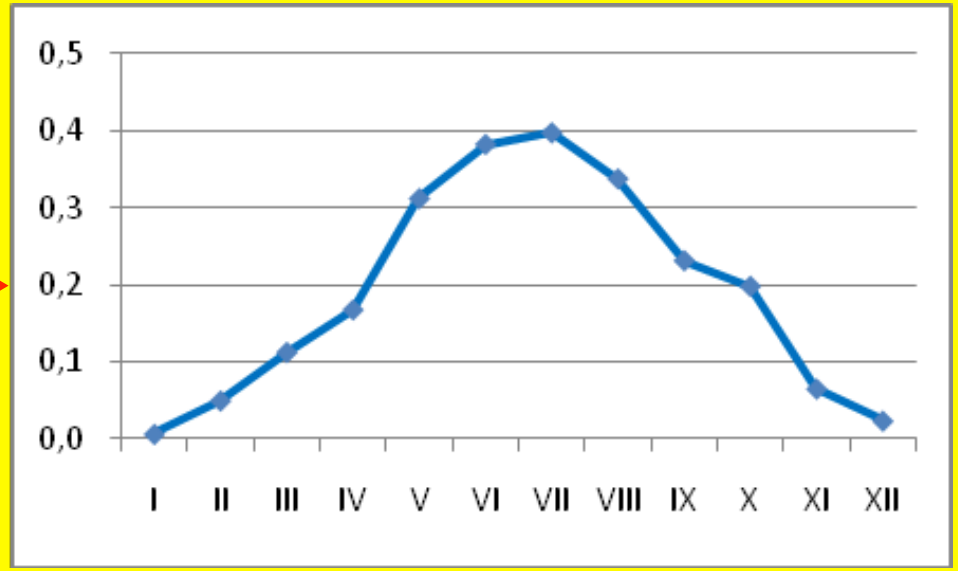
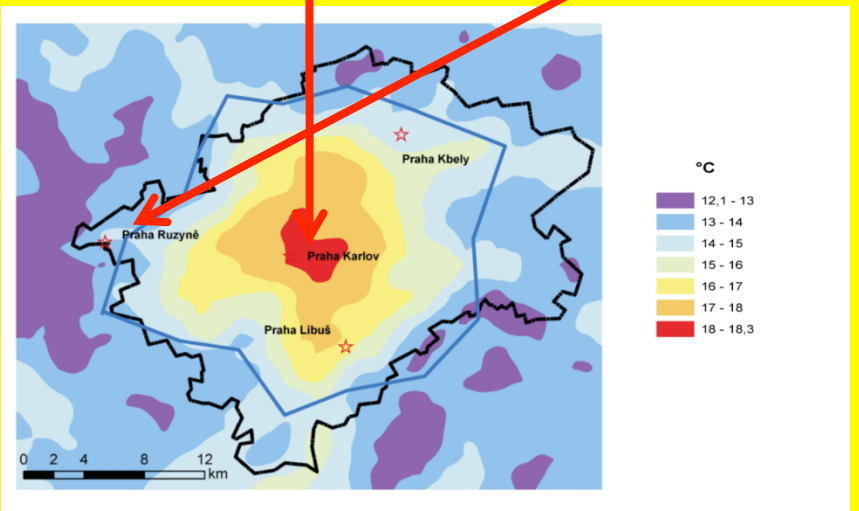
Prague heat island

period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	YEAR
1961-2009	2,2	2,3	2,2	2,2	2,2	2,4	2,3	2,2	2,0	2,0	2,2	2,2	2,2
1961-1990	2,2	2,3	2,2	2,1	2,1	2,2	2,2	2,0	1,9	2,0	2,2	2,2	2,1
1991-2009	2,2	2,3	2,3	2,3	2,4	2,6	2,6	2,4	2,1	2,2	2,2	2,2	2,3
Difference new - standard	0,01	0,05	0,11	0,17	0,31	0,38	0,40	0,34	0,23	0,20	0,07	0,02	0,19



Pretel (2010)

Klementinum vs. Ruzyne



CENTRAL EUROPE
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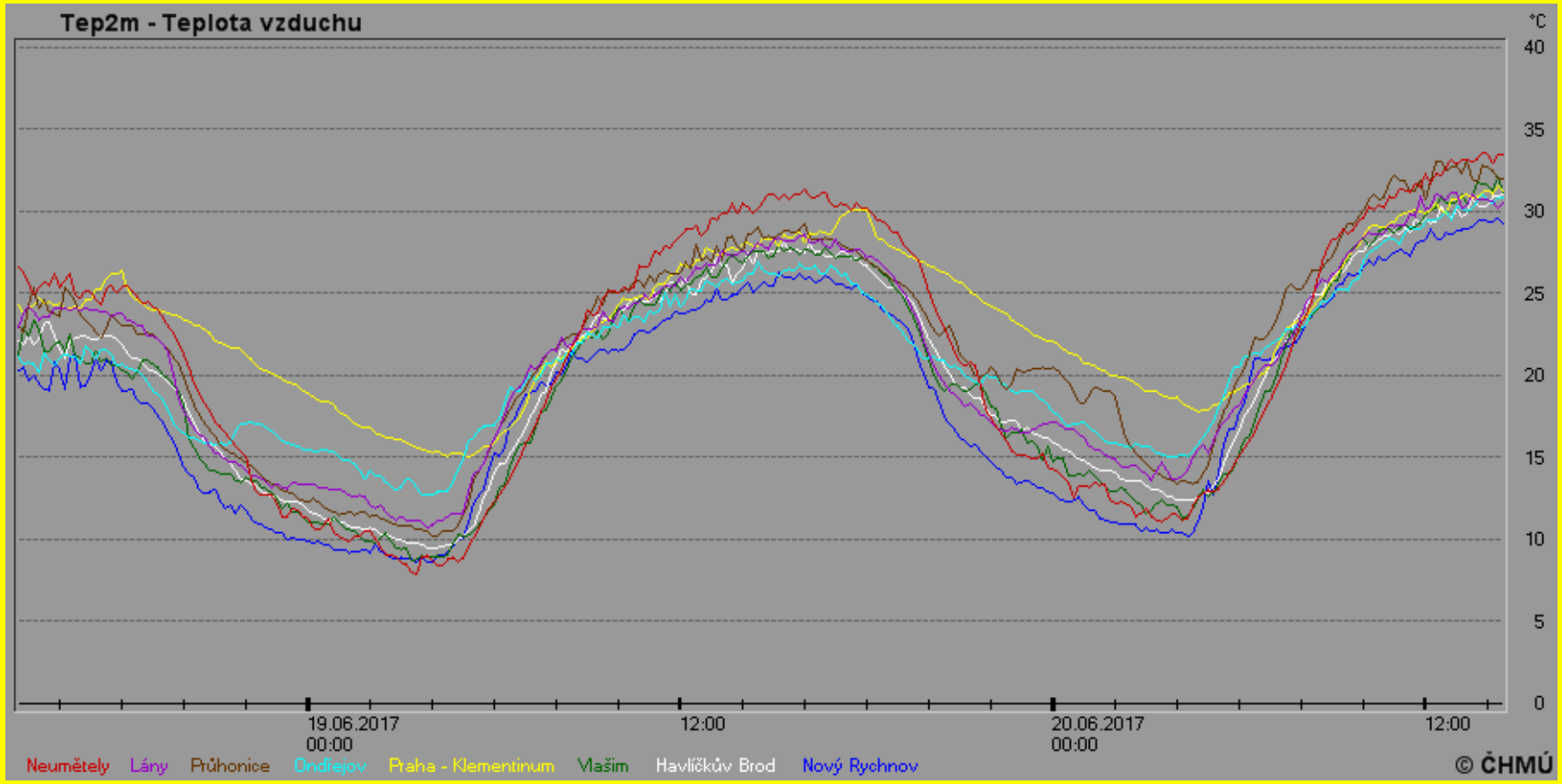
Example June 18-21, 2017



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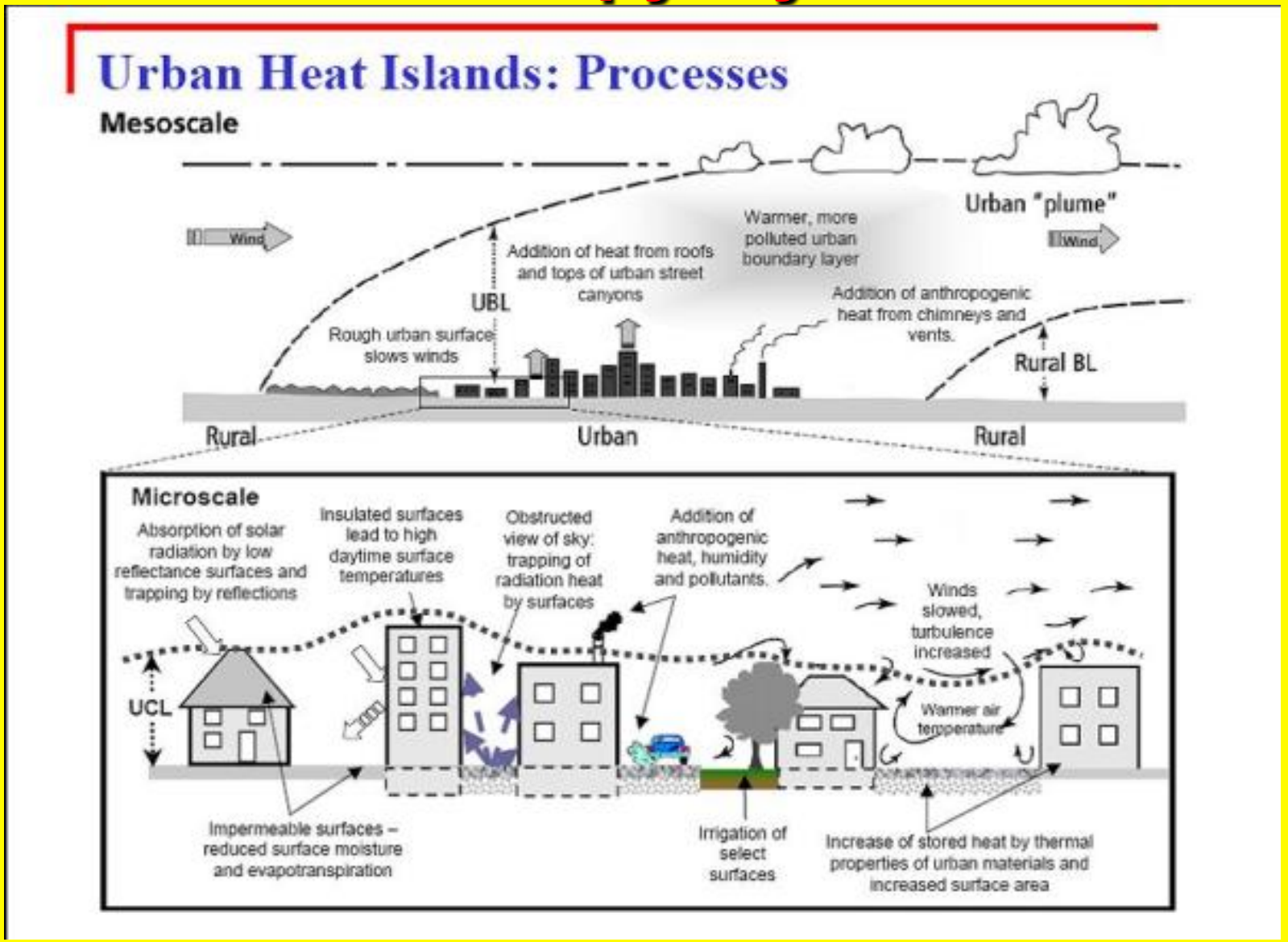
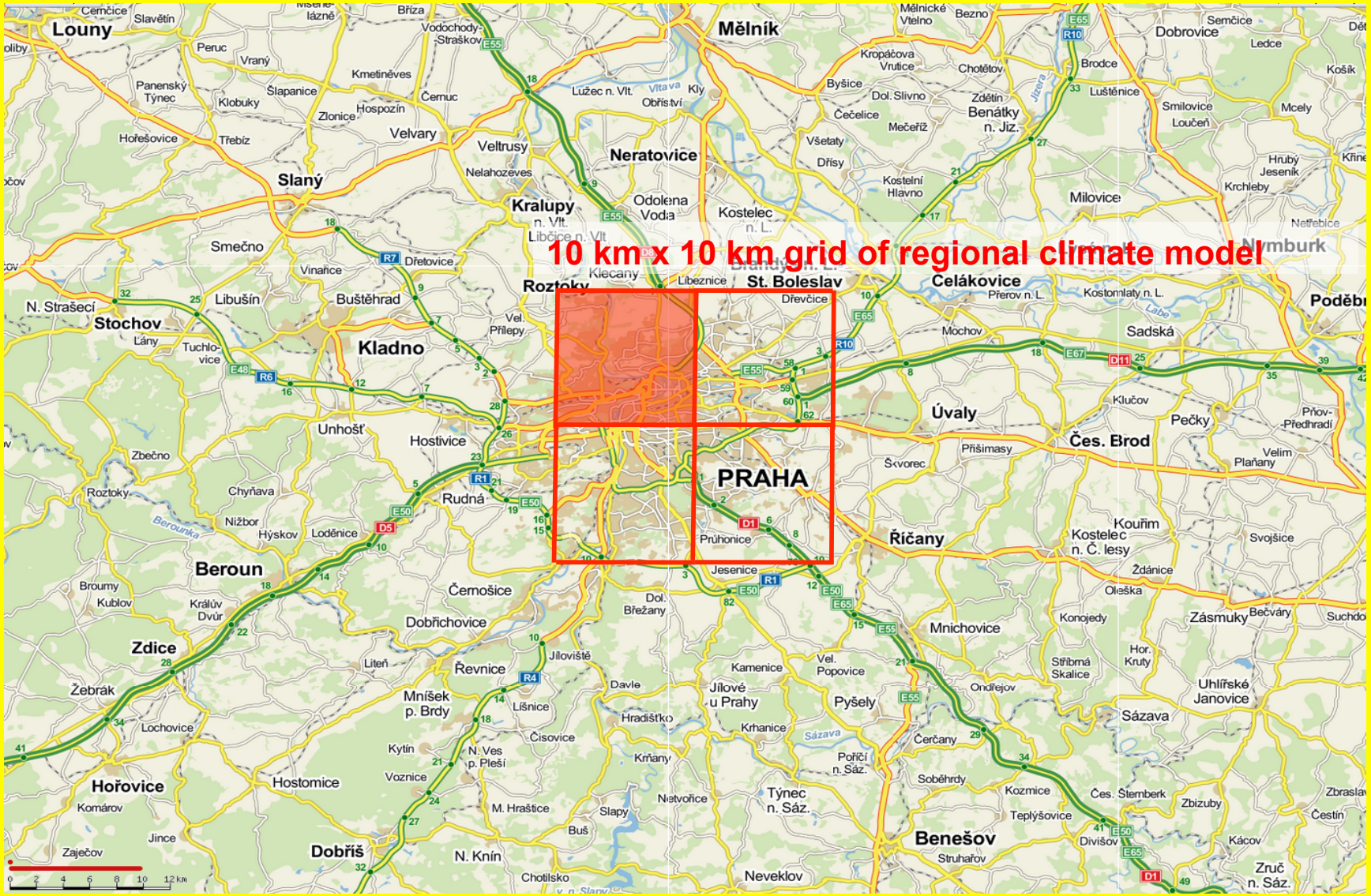
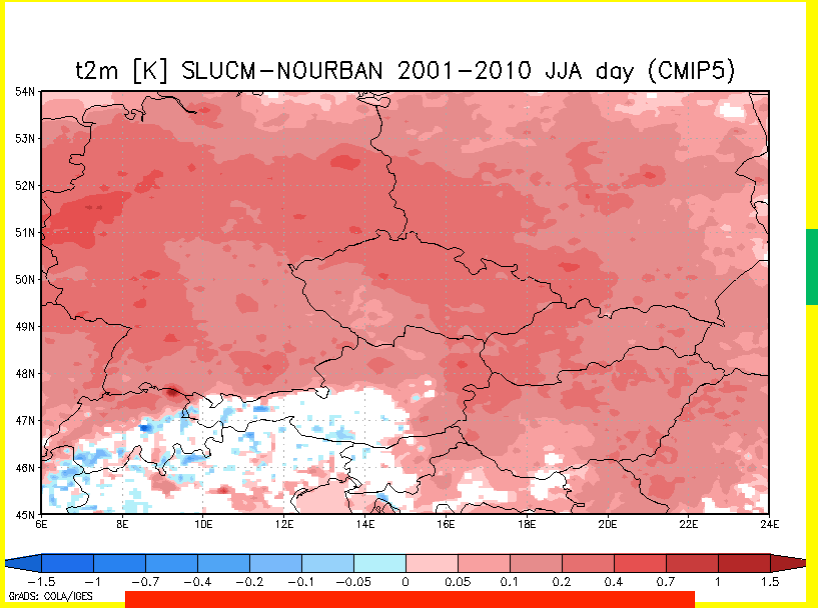
Atmospheric processes in urban canopy layer



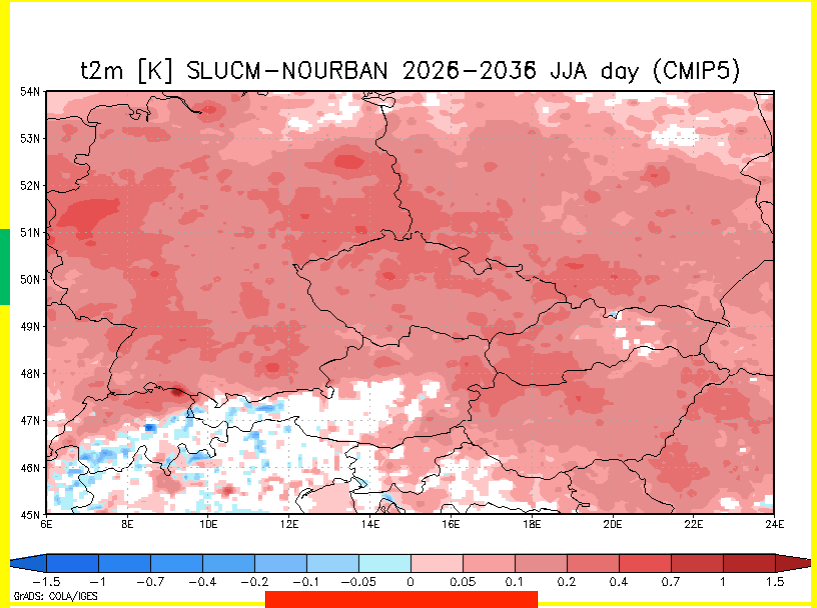
Why urban parameterizations



Climate change study - RegCM

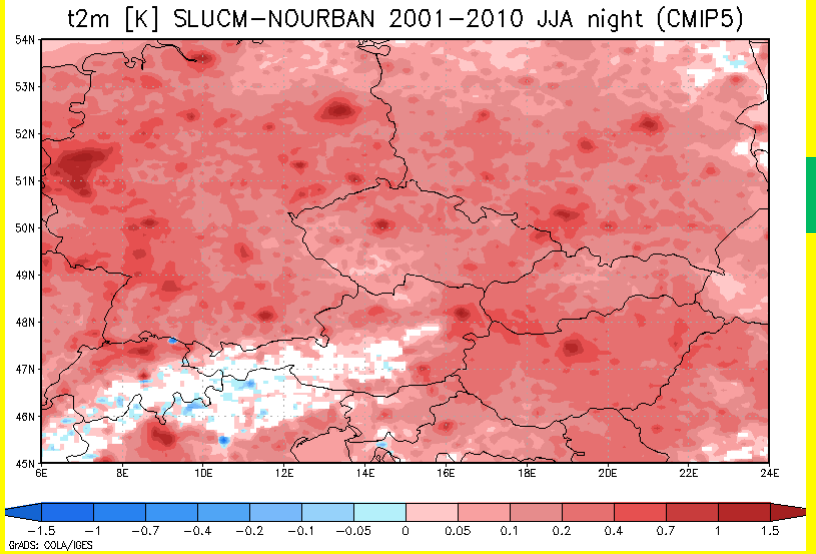


day

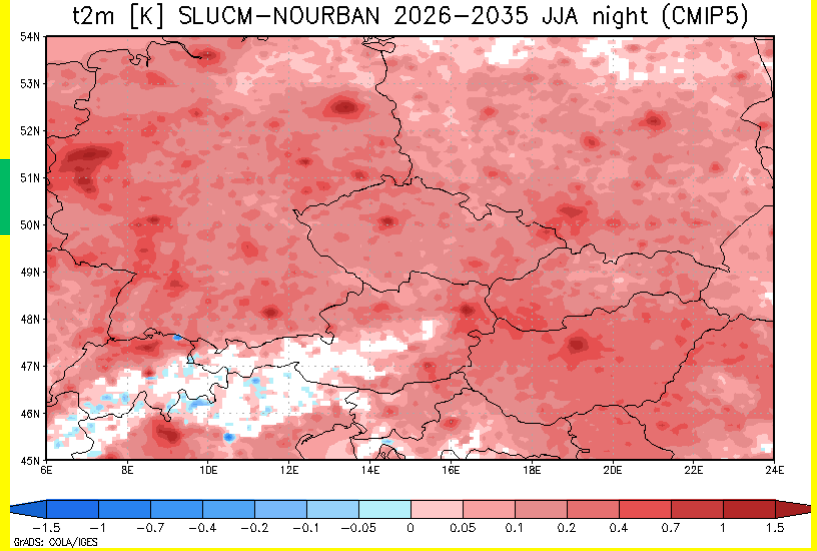


last decade

near future

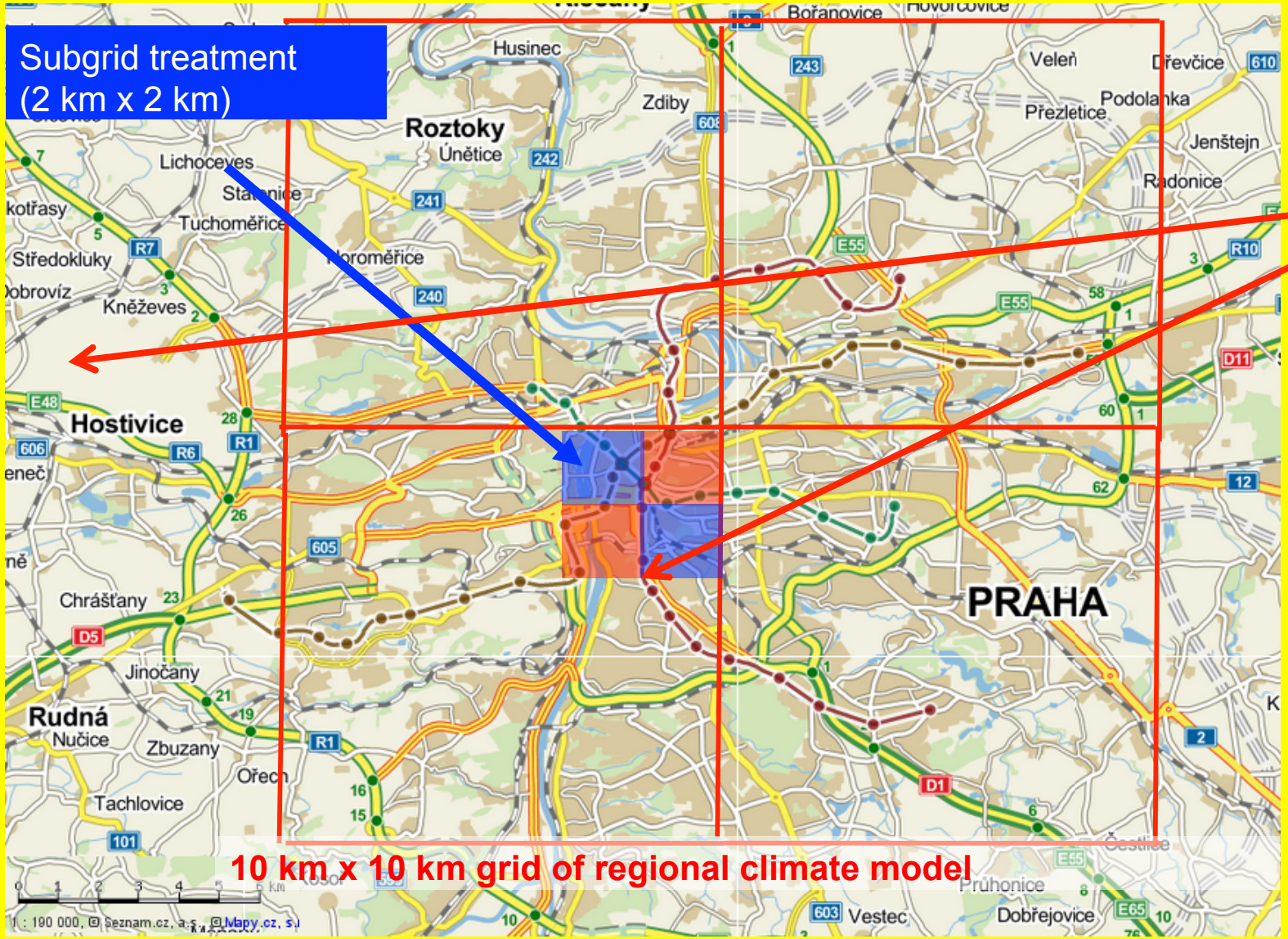


night



Huszar et al.
(ACP, 2014)

Even further in very high-resolution

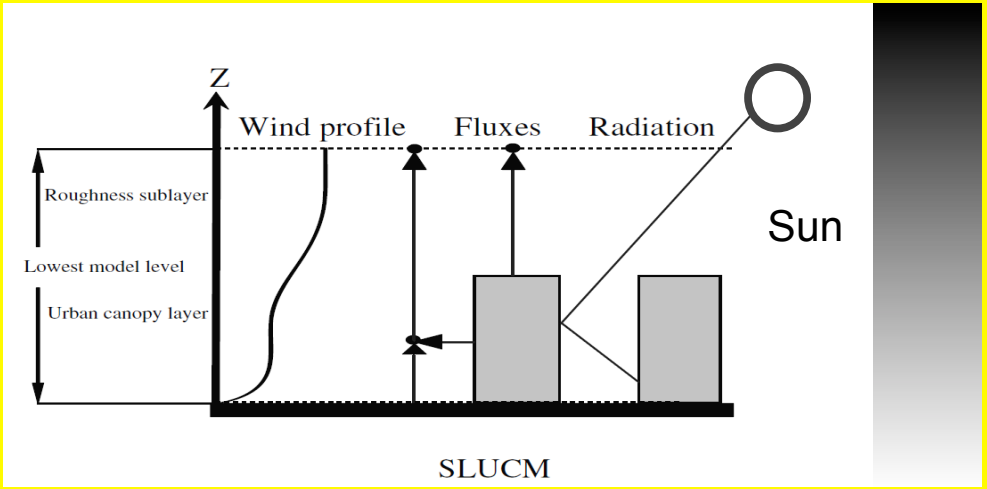


Modeling atmospheric processes in urban canopy

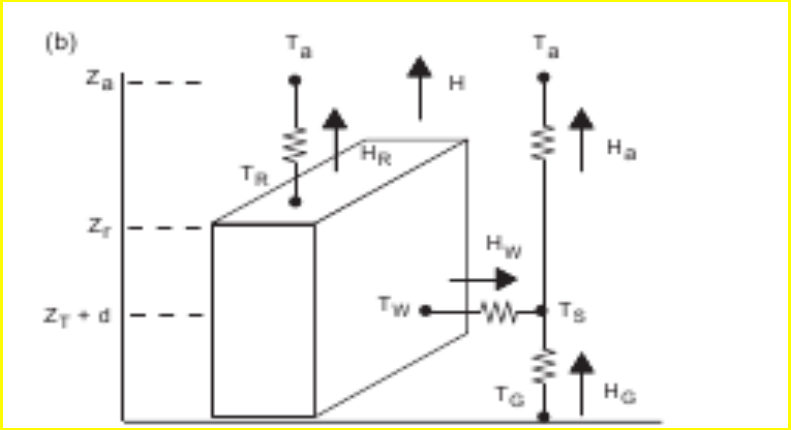
- BULK – no special parameterization, but recognizing the land-use type (albedo, emissivity and other land surface features)
- SLUCM – single-layer urban canopy model
- MLUCM – multi-layer urban canopy model

  BEP-BEM – building environment parameterization – building energy model

Modeling atmospheric processes in urban canopy RegCM4-BATS (our implementation)



- SLUCM – Single Layer Urban Canopy Model within BATS, including subgrid processes using SUBBATS by Huszar et al. (2014)
- Following Kusaka et al. (2001), as implemented into WRF (Chen et al. 2010)



from Kusaka and Kimura (2004)

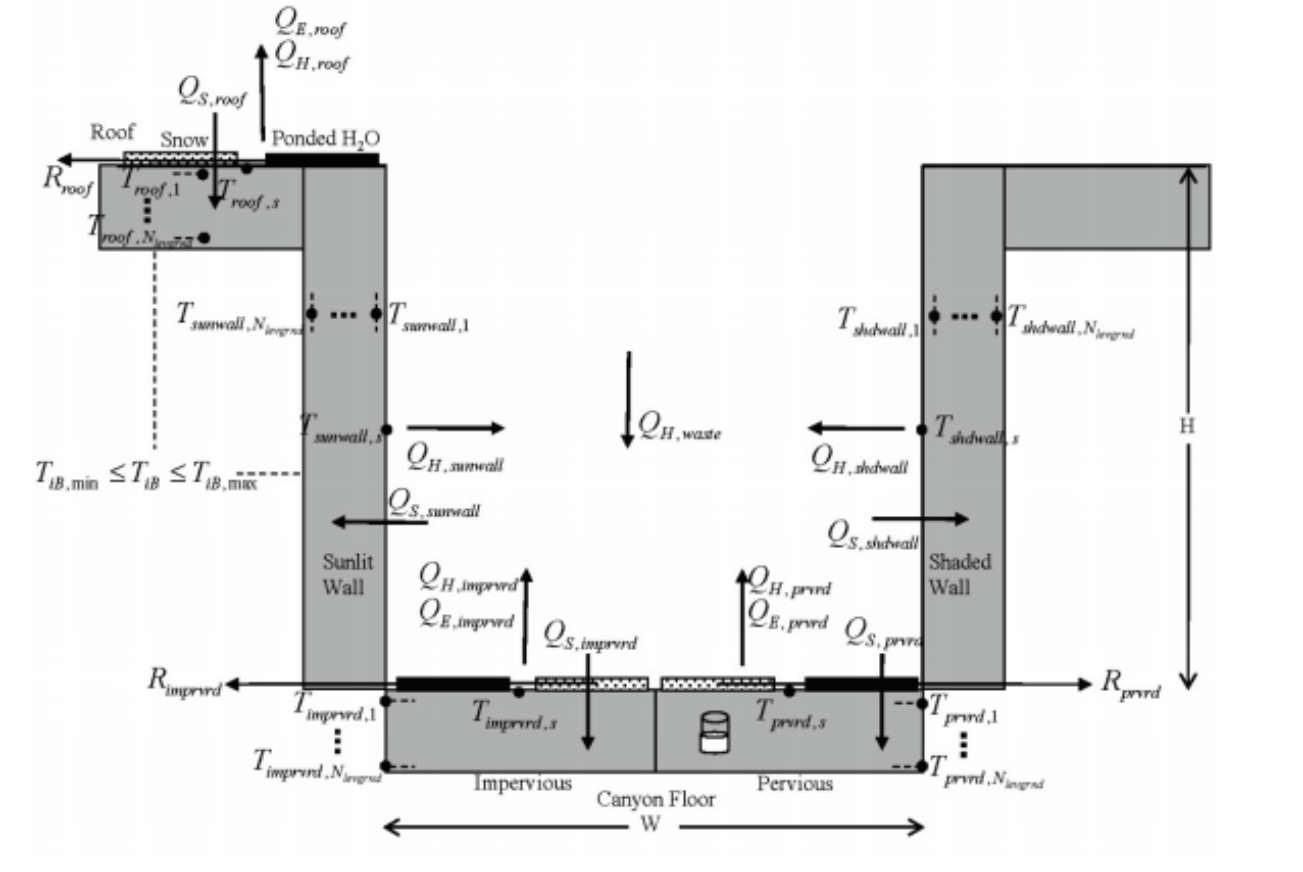
Energy fluxes and temperatures in the street canyon:

T_a - air temperature at reference height z_a
T_R - building roof temperature
T_W - building wall temperature
T_G - the road temperature
T_S - temperature defined at z_T+ d.
H - the sensible heat exchange at the reference height.
H_a is the sensible heat flux from the canyon space to the atmosphere
H_W - from wall to the canyon space
H_G - from road to the canyon space
H_R - from roof to the atmosphere

Modeling atmospheric processes in urban canopy RegCM4-CLM

- CLMUrban in CLM4.5 (Community Land Model version 4.5) – no subgrid treatment but considers fractional land-use, by Oleson et al. (2008)

Schematic representation of the urban land unit.

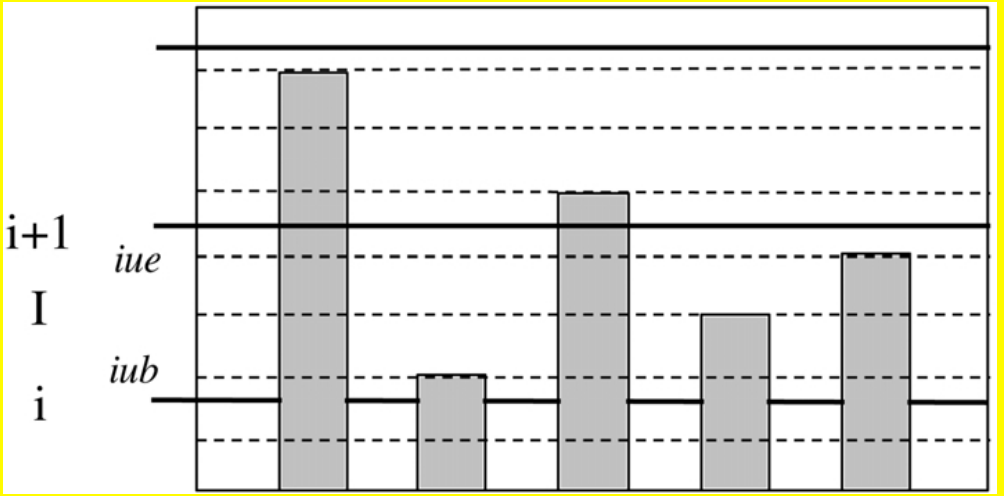


Modeling atmospheric processes in urban canopy MLUCM in WRF

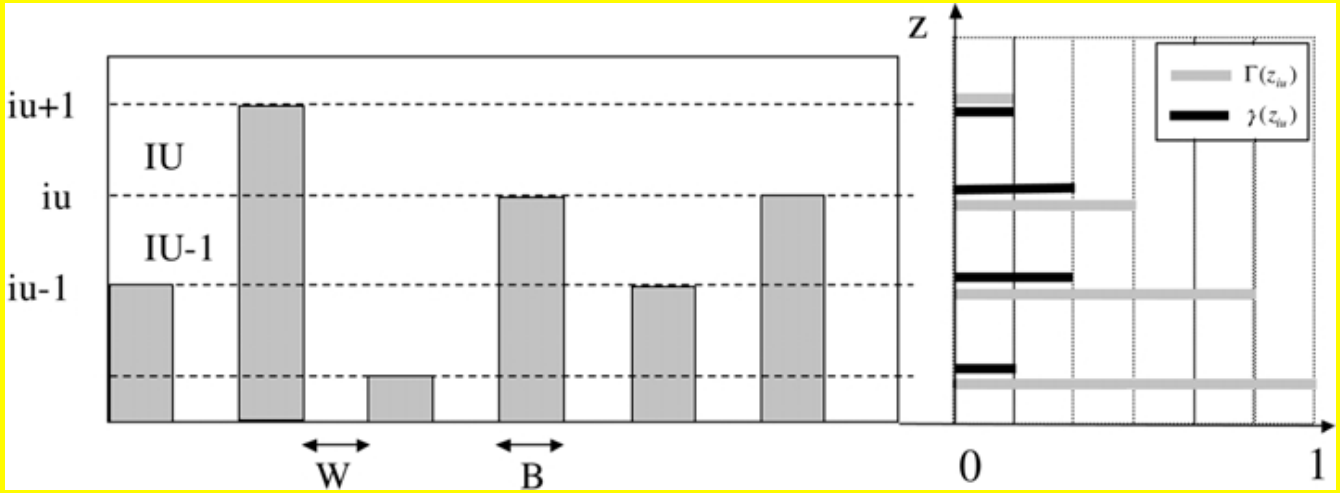
Possible urban surface parameterizations within WRF

MLUCM – no subgrid treatment but considers fractional land-use in WRF

Martilli et al. (2001)
BEP-BEM in WRF



Schematic representation of the urban land unit.



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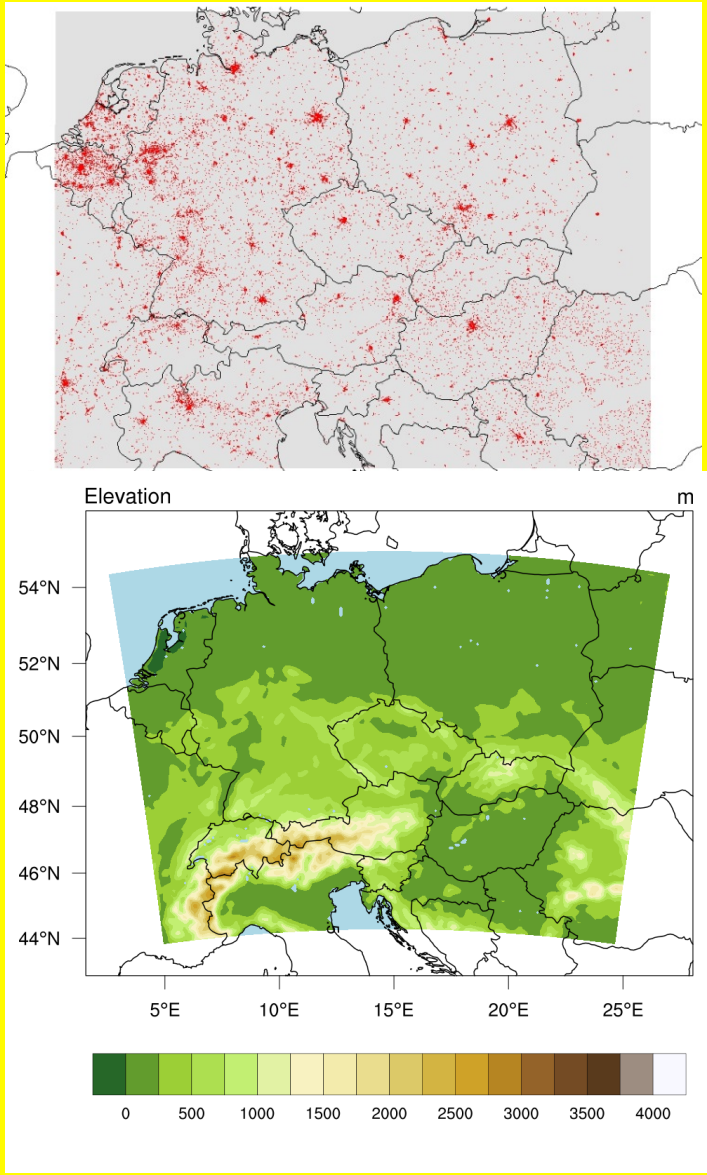
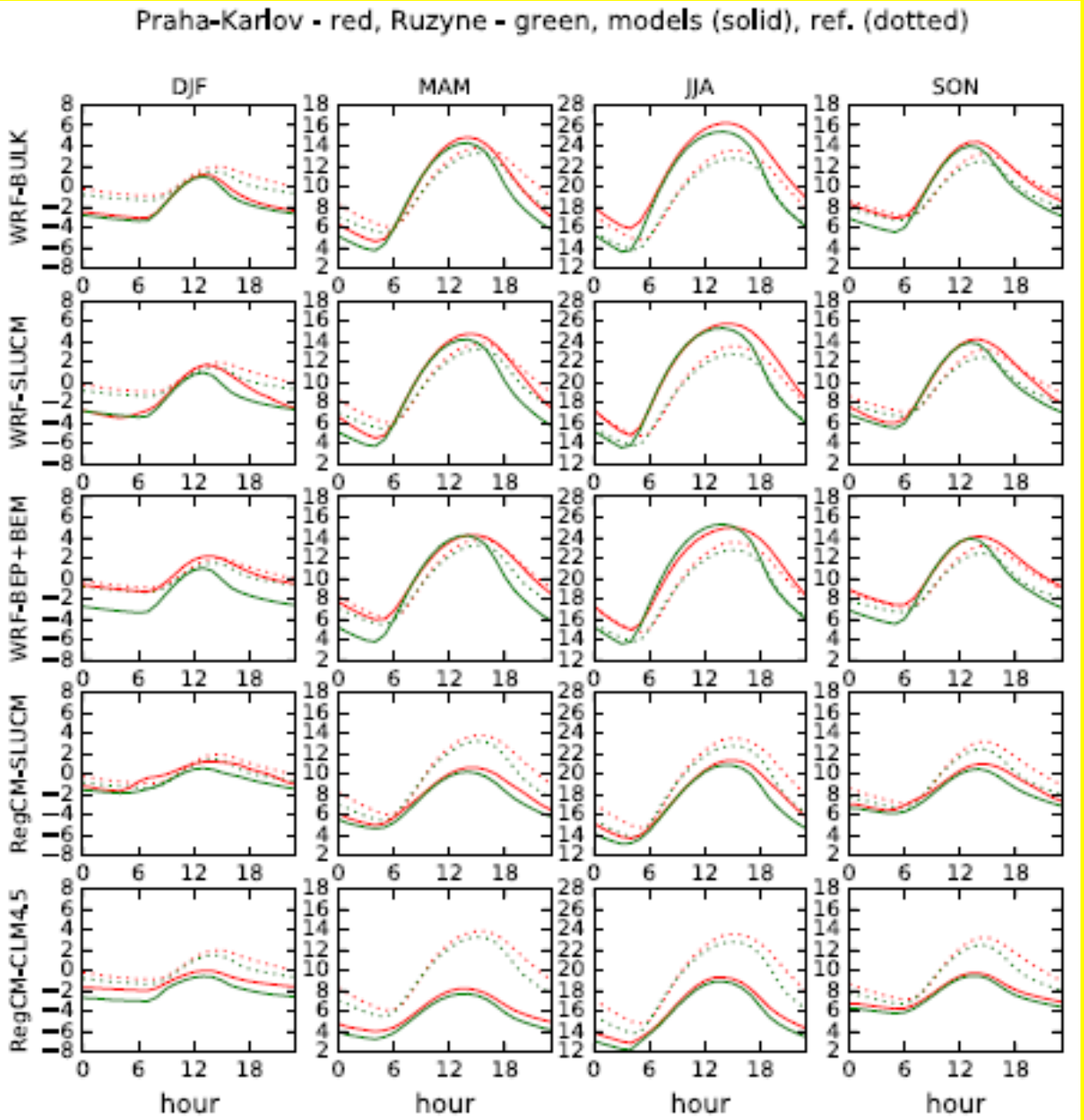
Experiments

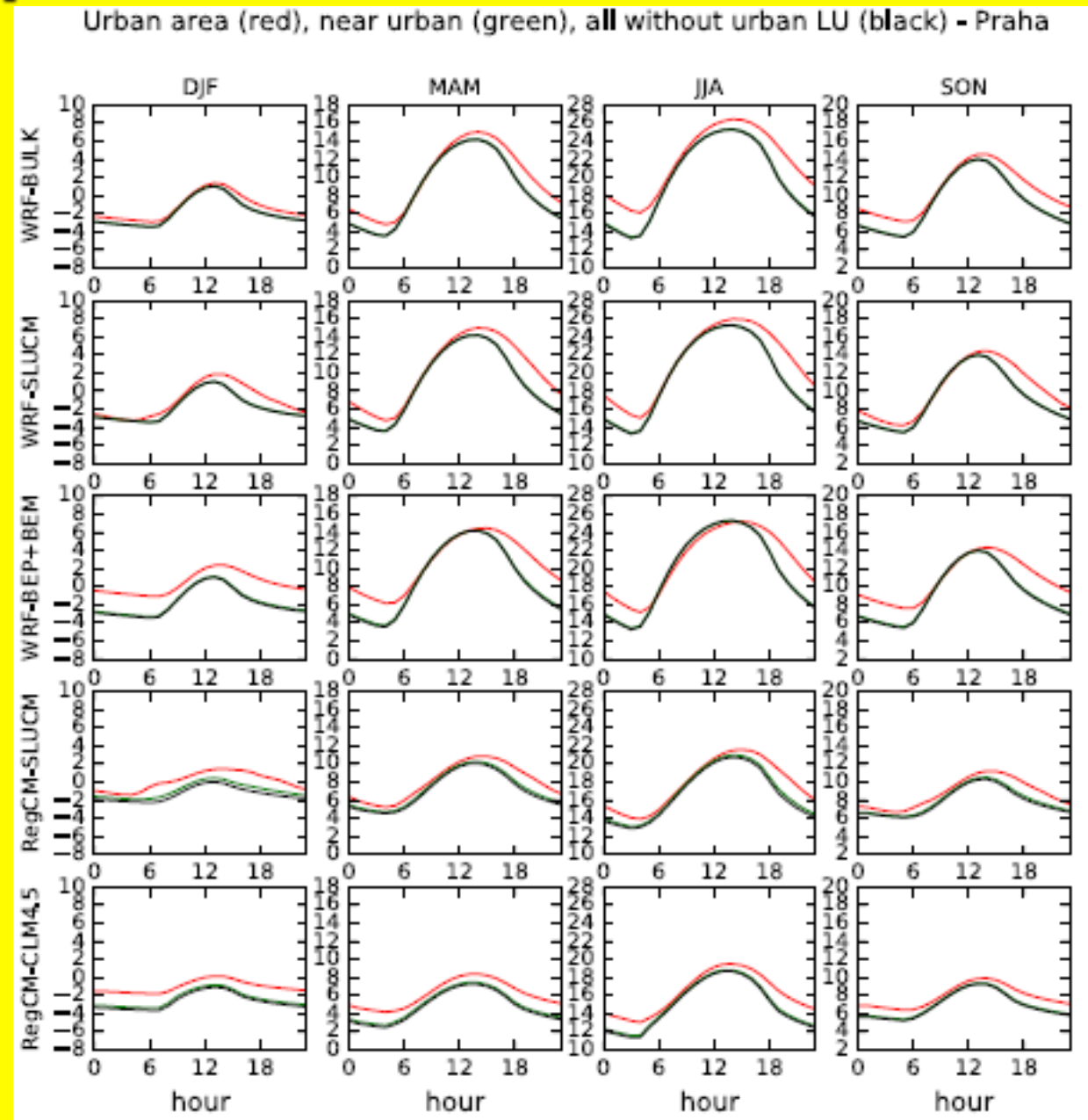
Central European domain **10 km x 10 km** (160 x 120 grid points), 23 vertical levels up to 50 hPa, subgrid for BATS – 2 km x 2 km

- 2001-2010, ICBC ERA Interim
- **Simulations:**
- RegCM4 - BATS/SLUCM
- RegCM4 - CLM4.5/CLMU
- WRF – BULK
- WRF – SLUCM
- WRF – BEP-BEM
- **Experiments:**
- **URBAN** – all urban surfaces considered;
- **NOURBAN** – no urban surfaces considered – replace by the major land use type over the grid

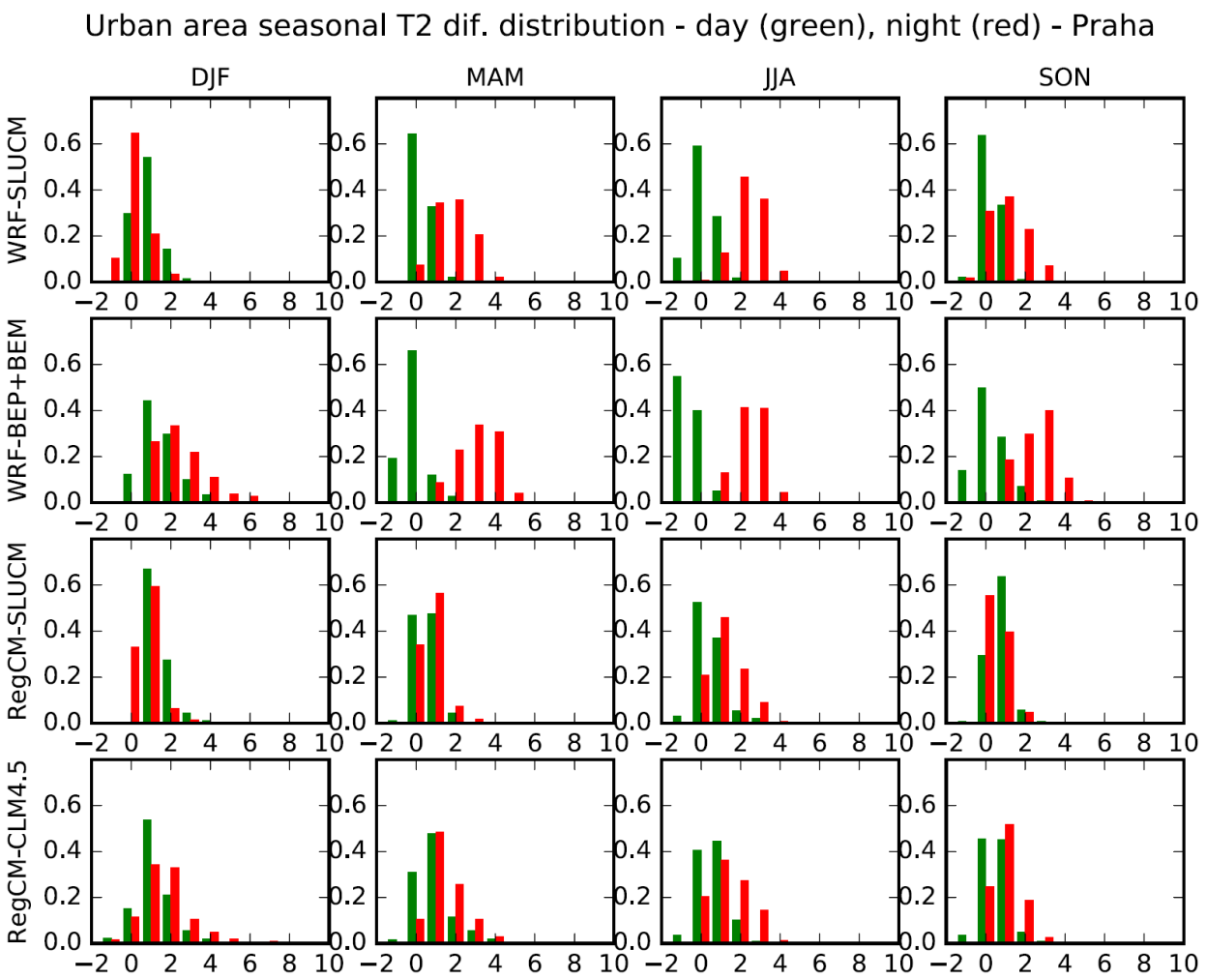


UHI temperature

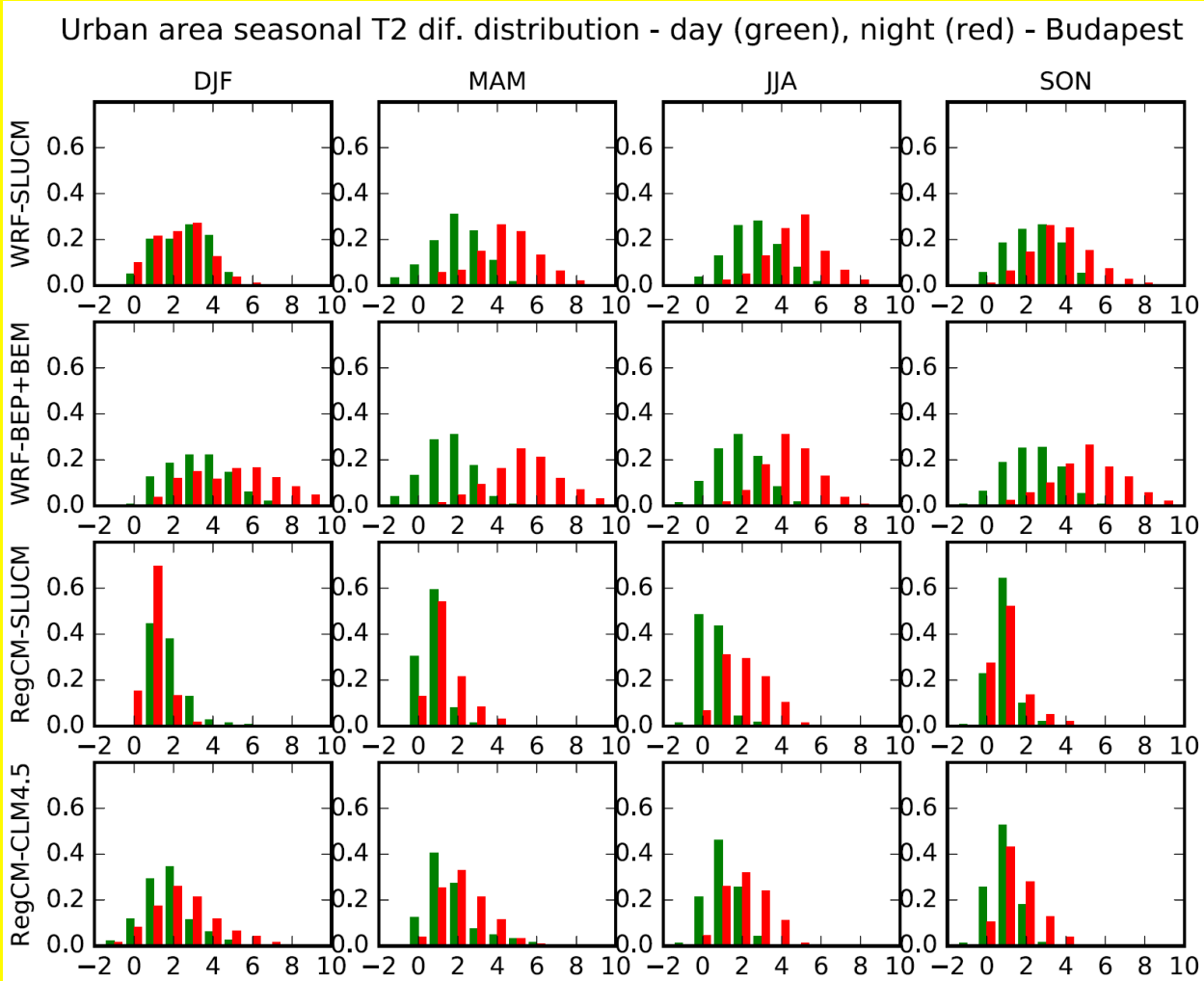




UHI intensity (day vs. night)



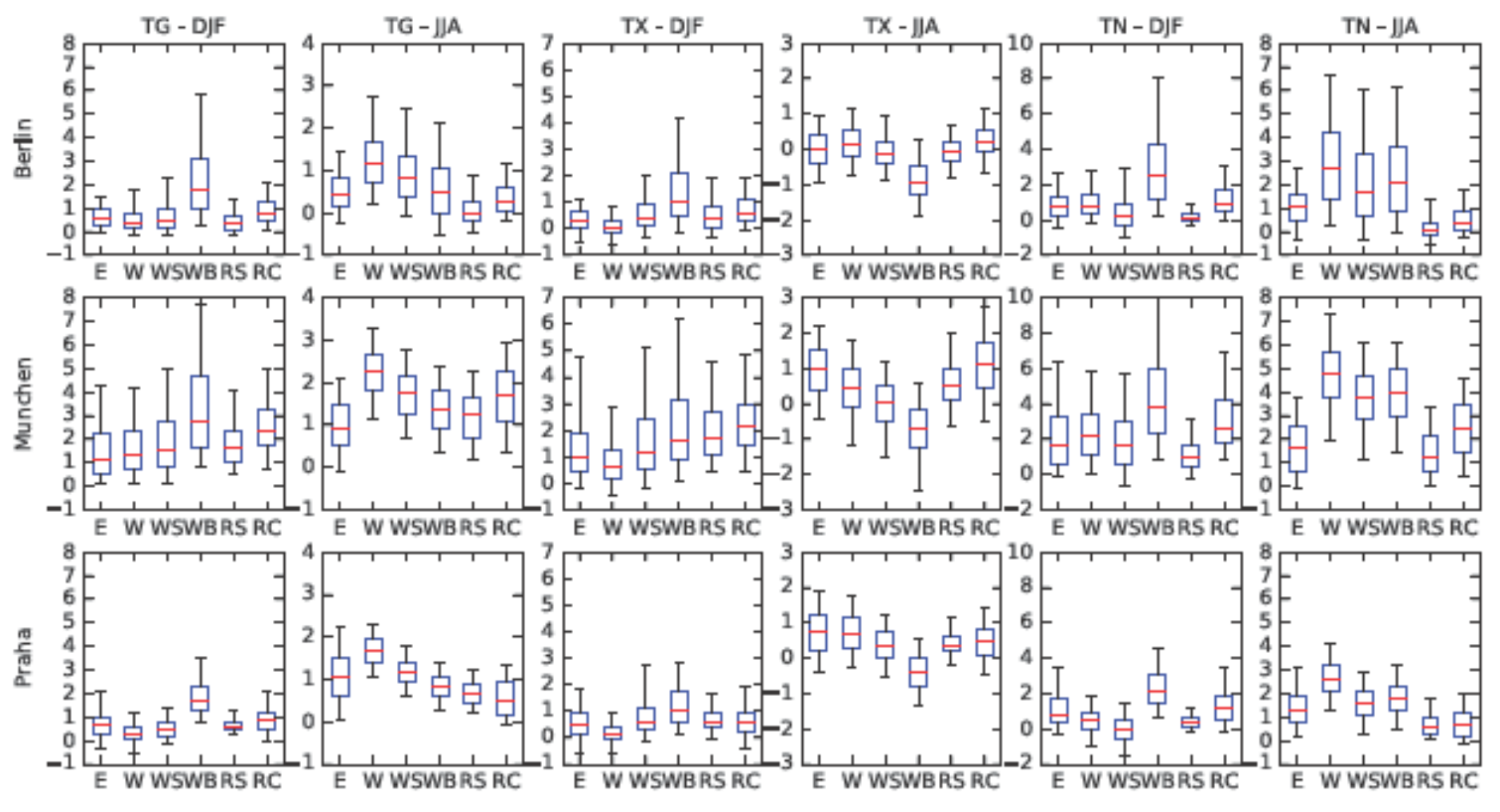
Prague



Budapest

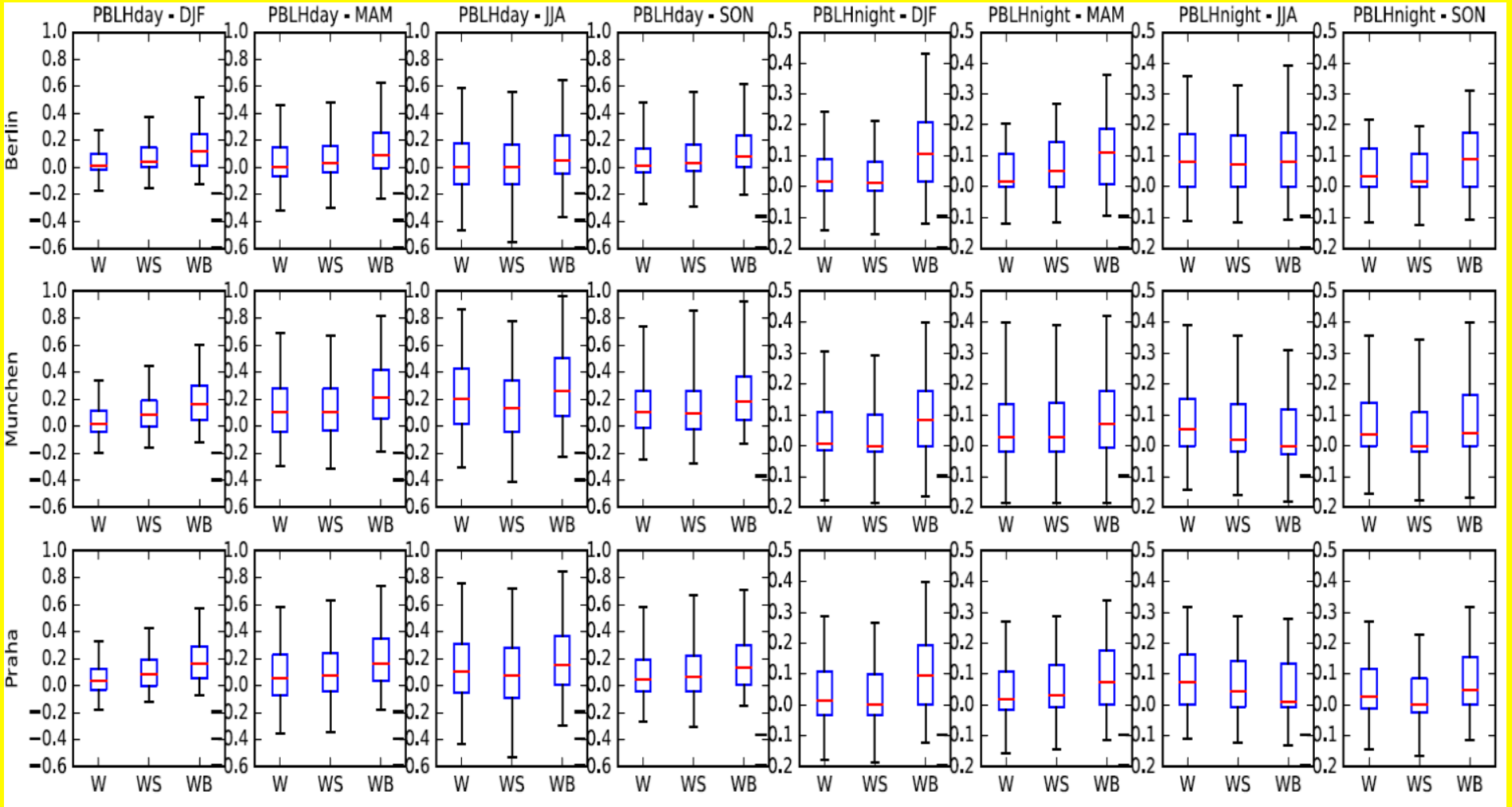
MAX vs. MIN

mean Tmax Tmin

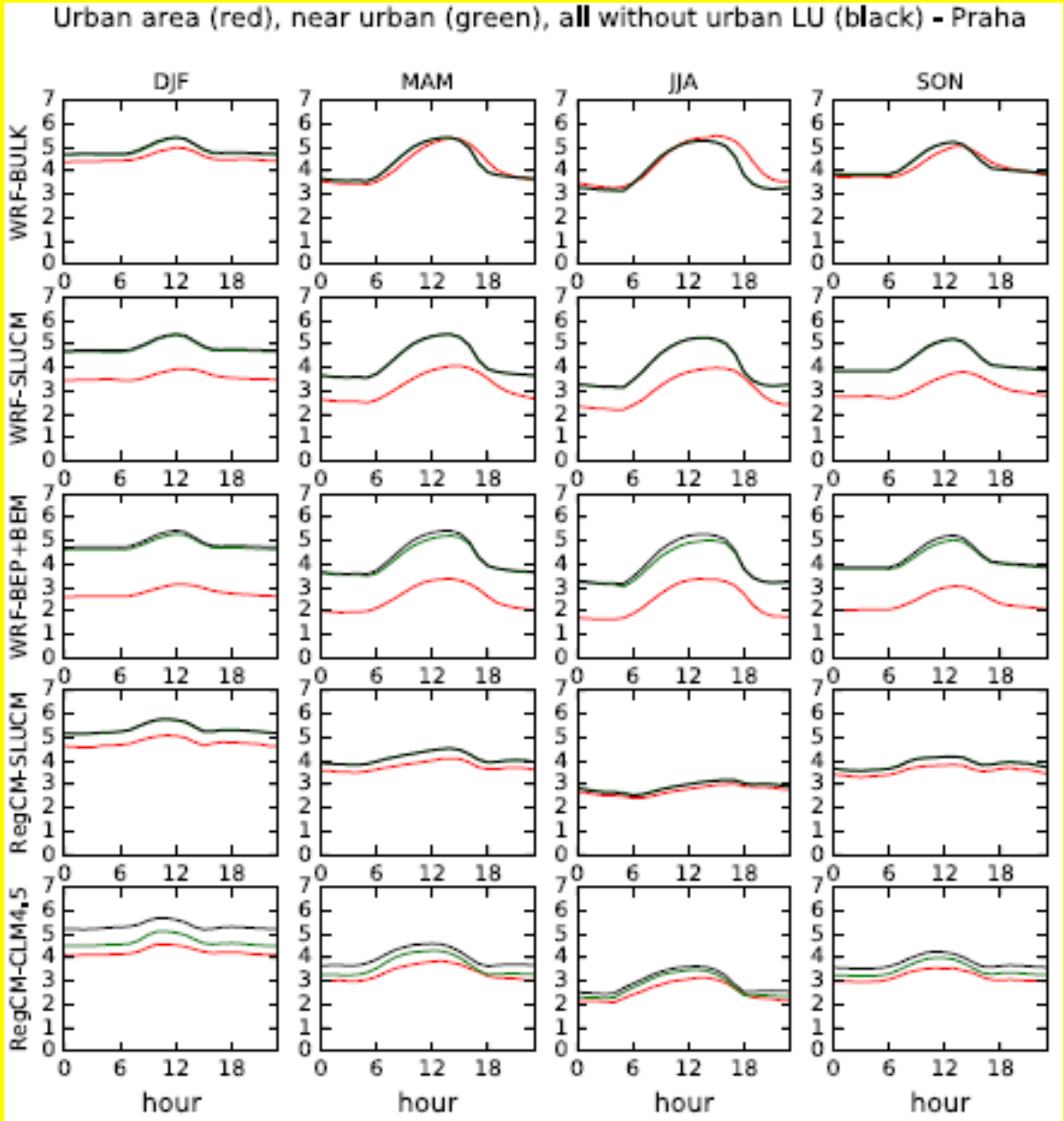


Mixing layer relative change

day night



Wind


Urban area (red), near urban (green), all without urban LU (black) - Praha
DJF
MAM
JJA
SON
WRF-BULK
WRF-SLUCM
WRF-BEP+BEM
RegCM-SLUCM
RegCM-CLM4.5
hour

Summary - Urban summer impacts

- Temperature increase over most of the domain, over urban areas (Munich, Prague, Vienna, Budapest) up to 0.6-0.8°C, over Milan > 1.5°C on average, but with quite high spread (time variability) – strong significance on impacts in extreme situations, like heat waves etc.
- Humidity decreases in cities (runoff, less evaporation) by over -0.8 g/kg in urban centers on average (not shown)
- PBL height increase up to 200 m over many urban centres, over Milan and Zürich up to 300-500 m on averages, summer extremes – not captured in BULK method
- Wind changes – not affected in BULK method (no processes connected to urban infrastructures)

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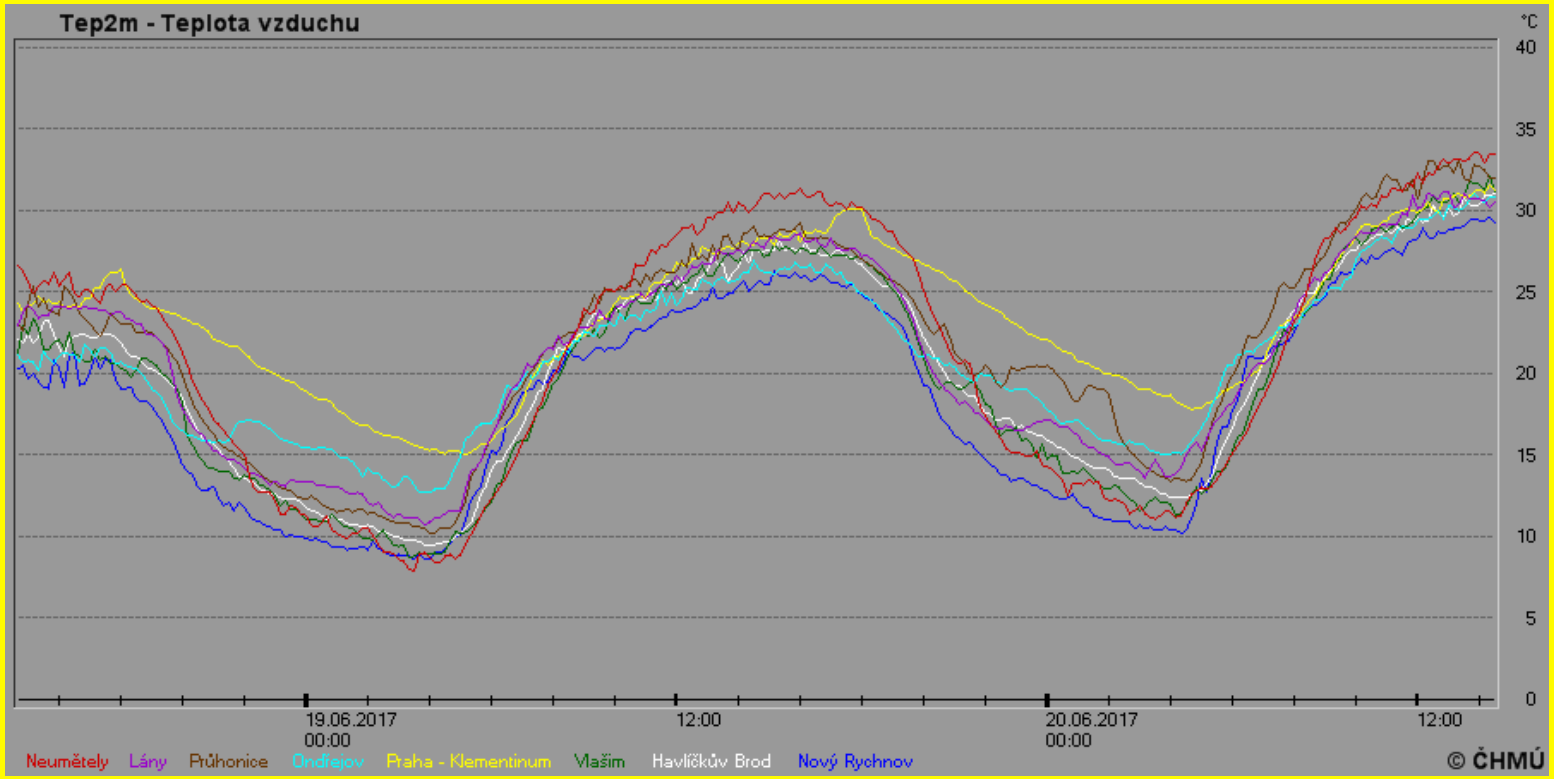
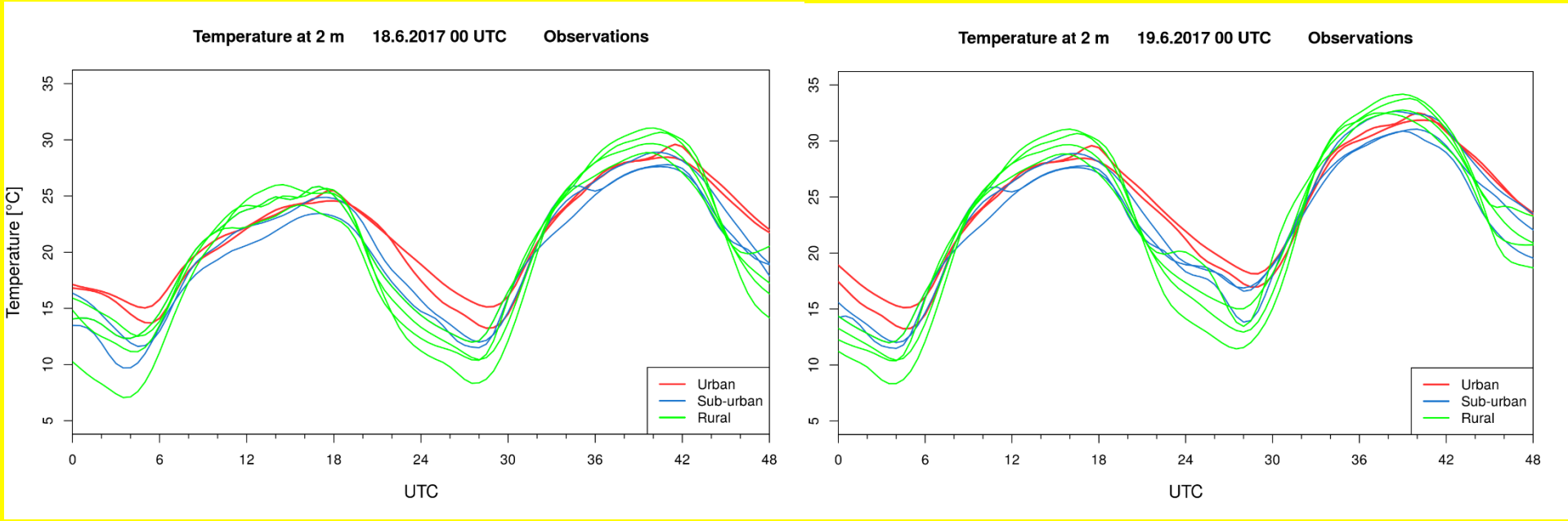
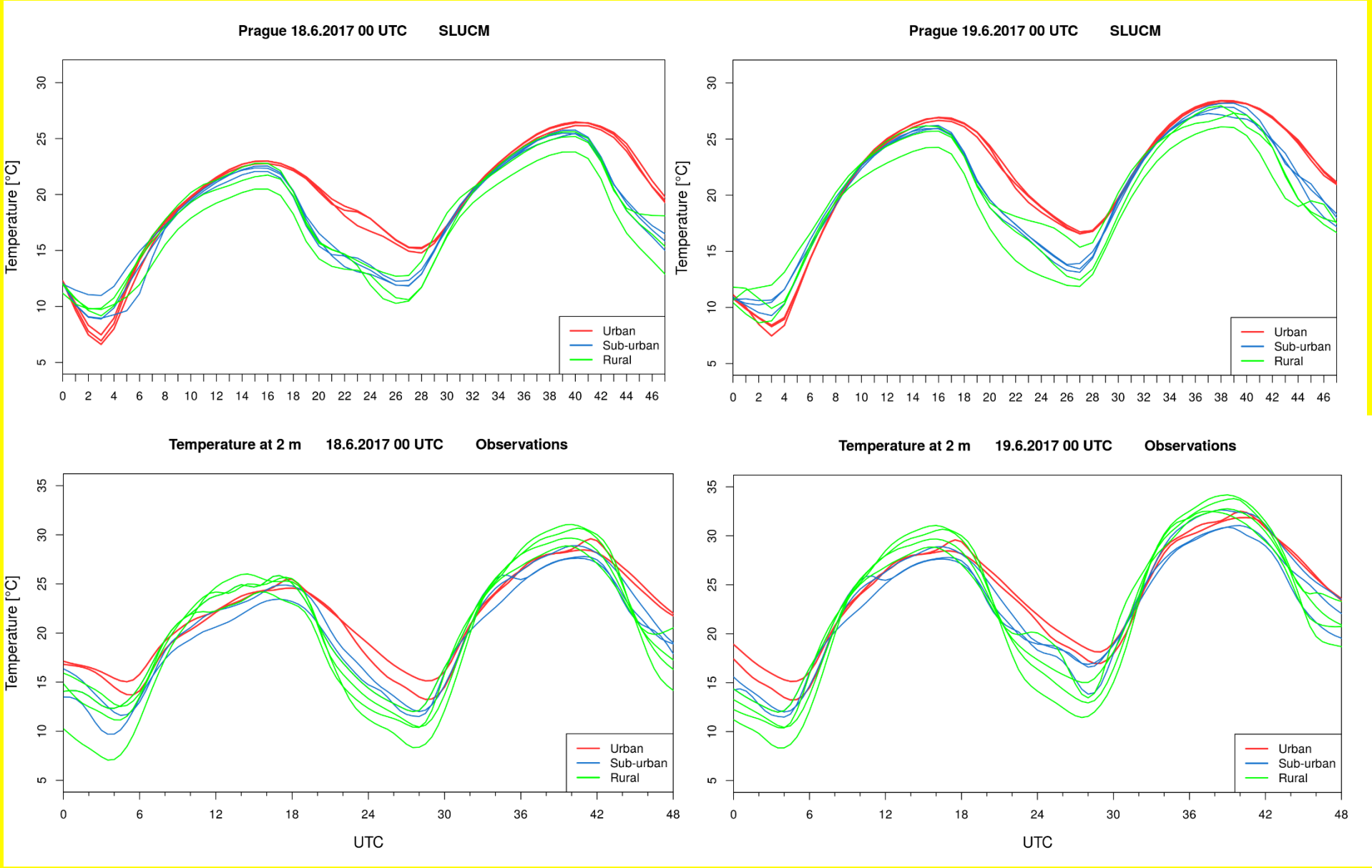
WRF forecast mode with SLUCM (3km)



WRF forecast mode with SLUCM (3km)



WRF forecast mode with SLUCM (3km)



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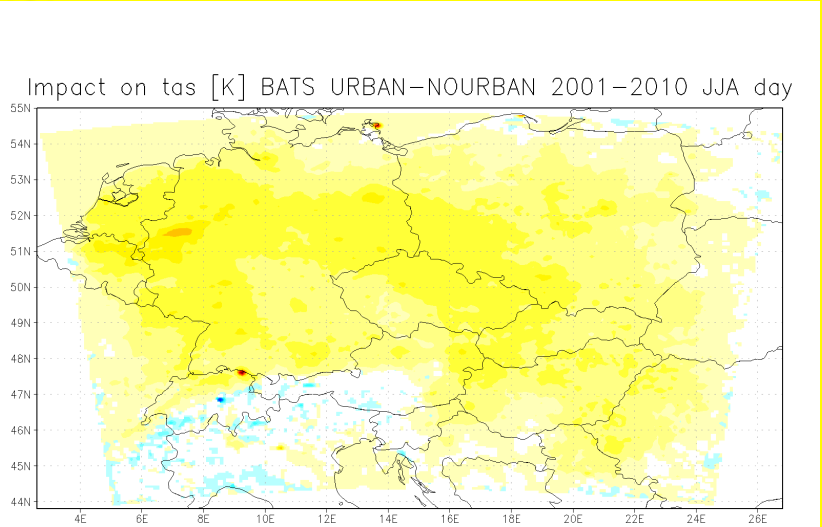
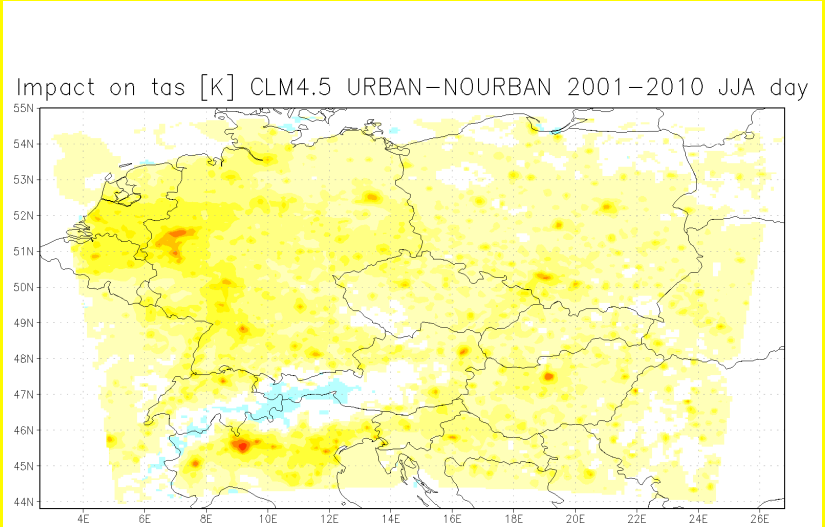
Near surface temperature

summer

day

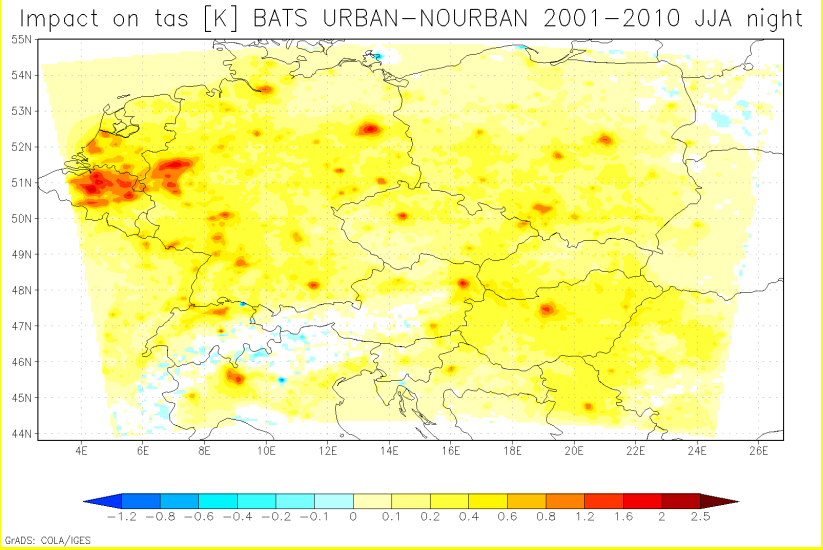


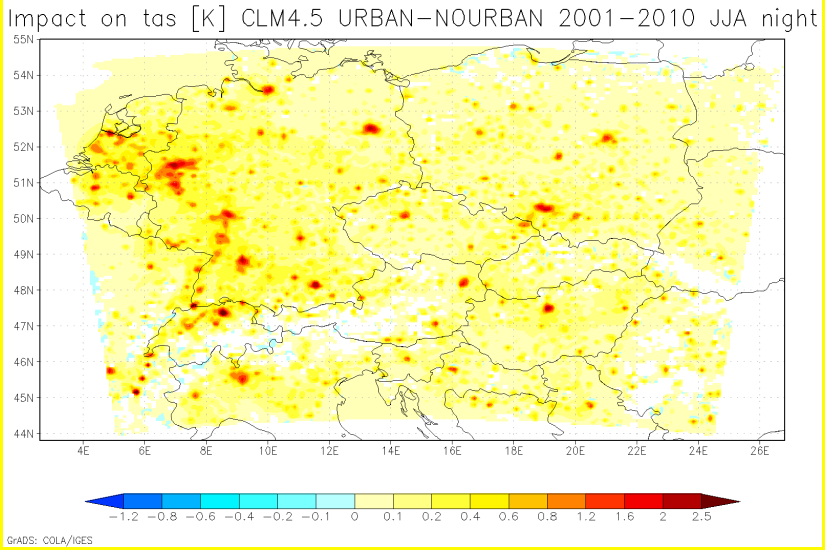


BATS/SLUCM

CLM4.5/CLMU

night

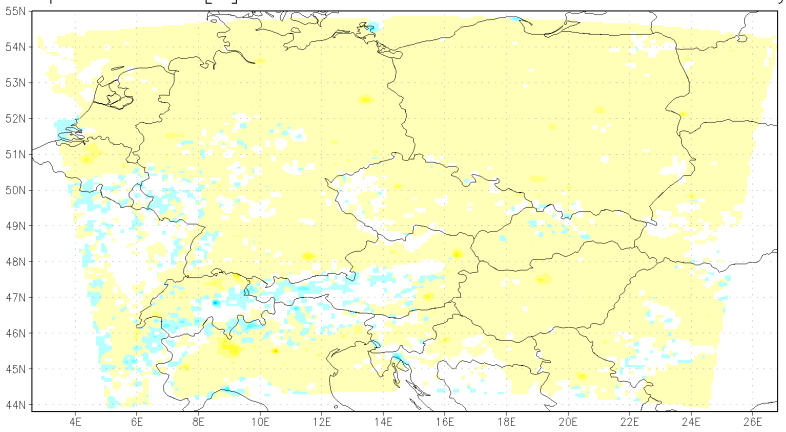




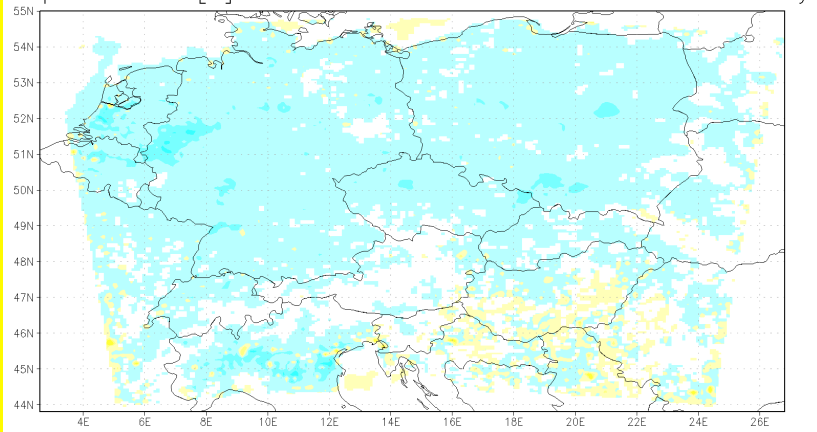
Near surface temperature

winter

day

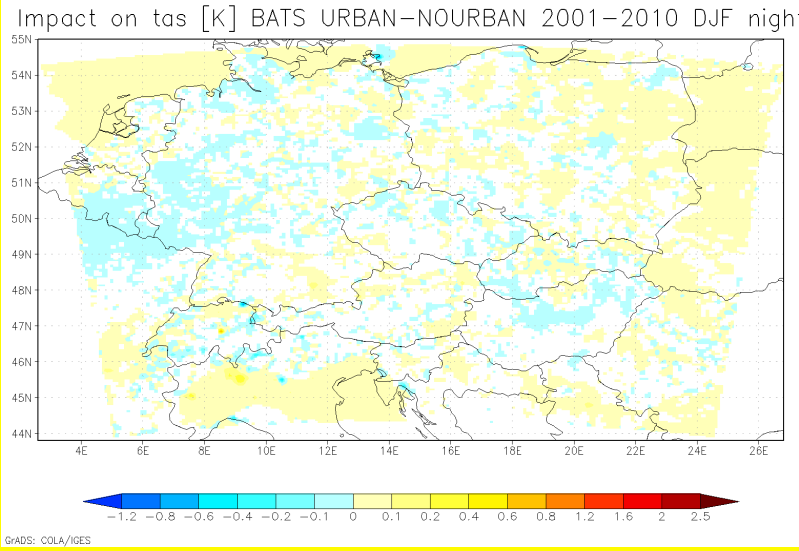


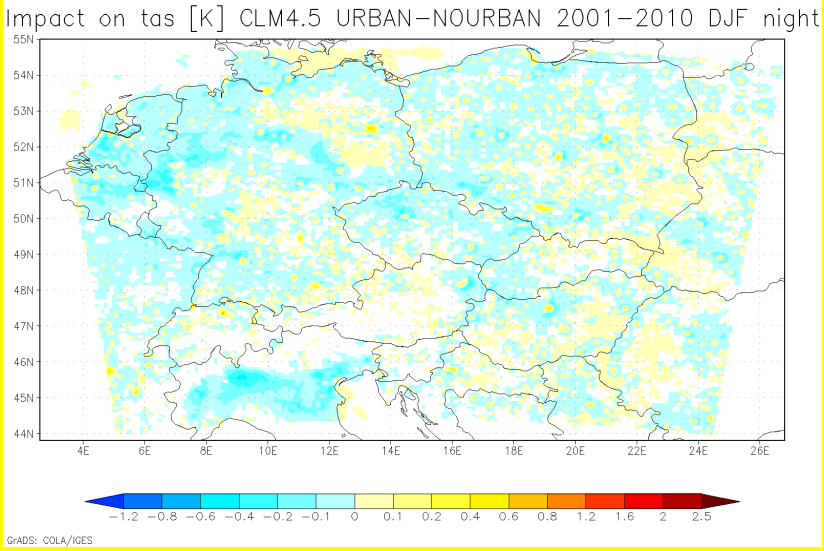
BATS/SLUCM



CLM4.5/CLMU

night





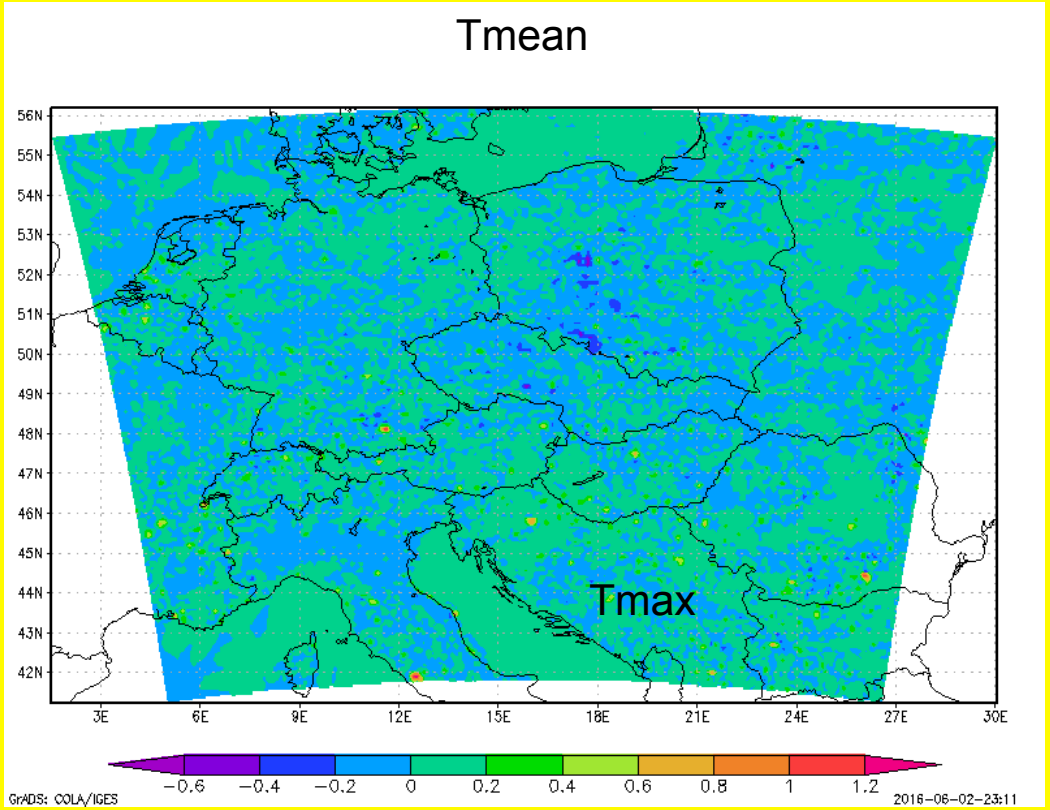
Namelists parameters

urban_hac

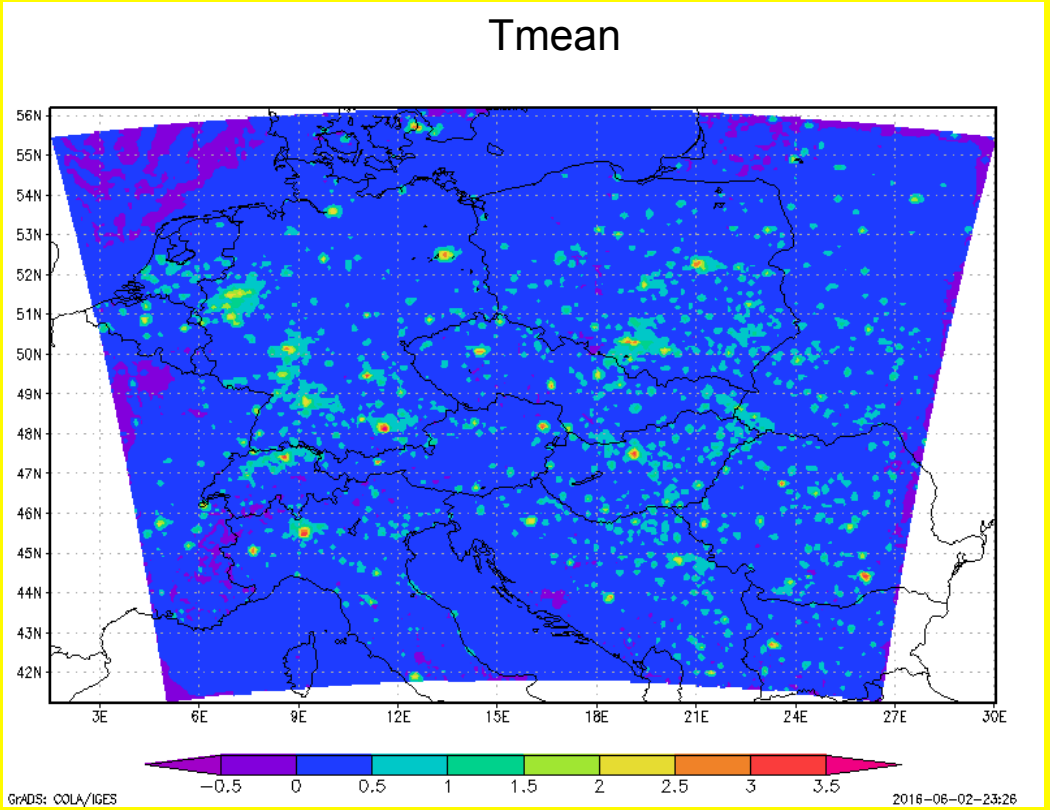
Turn urban air conditioning/heating ON or OFF and add wasteheat:
Valid Values: OFF,ON,ON_WASTEHEAT

OFF = Air conditioning/heating is OFF in buildings, internal temperature allowed to float freely
ON = Air conditioning/heating is ON in buildings, internal temperature constrained
ON_WASTEHEAT = Air conditioning/heating is ON and waste-heat sent to urban canyon

Jan 2000 test

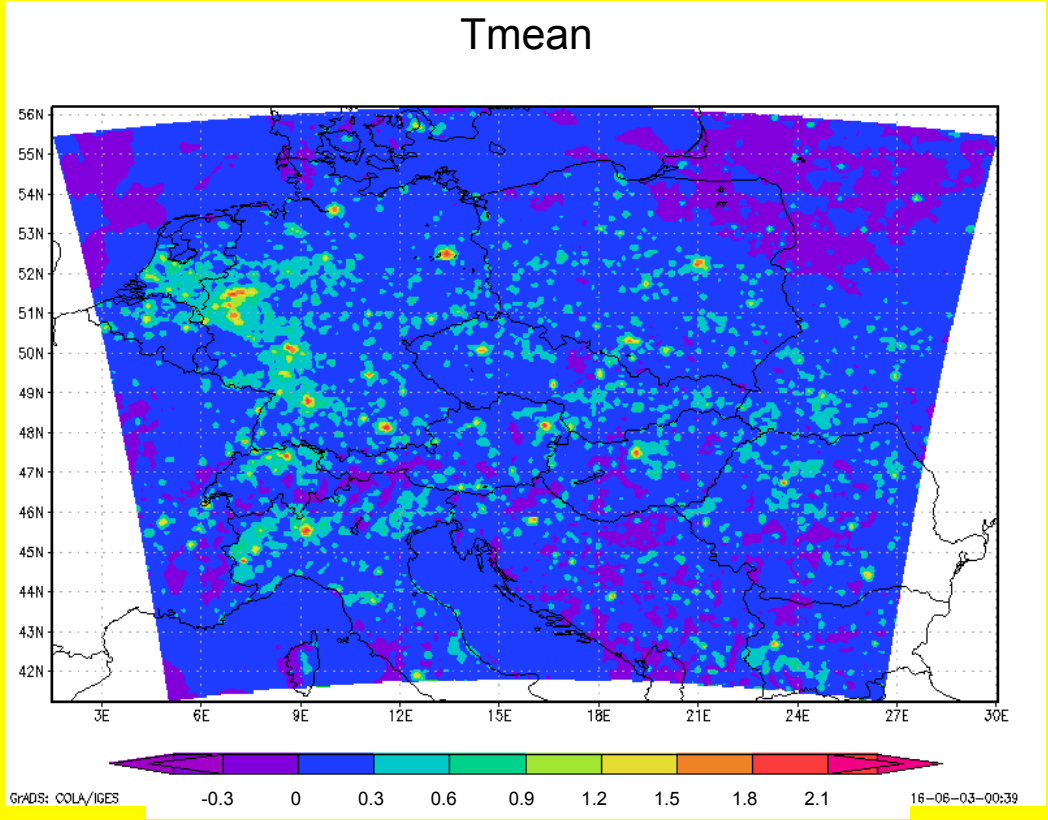


RegCM4.5/CLM4.5 (implicitly with urban) – RegCM4.5/CLM4.5 (no urban land use) for Jan 2000

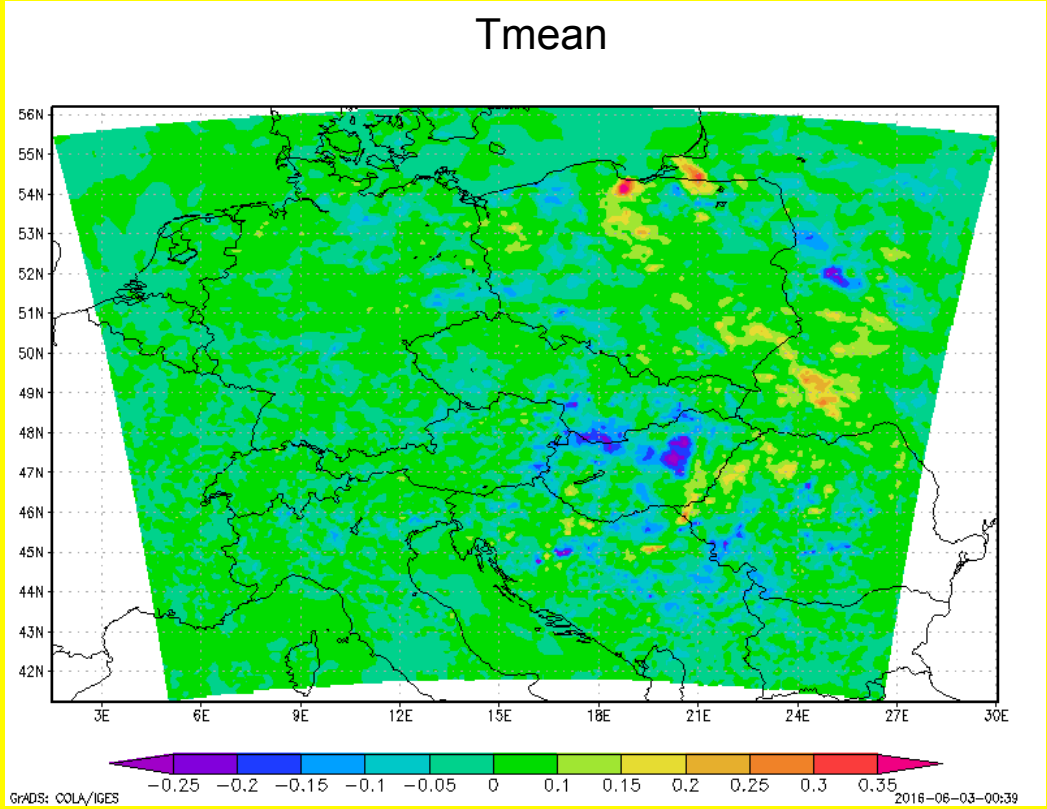


RegCM4.5/CLM4.5 (with urban + wasteheat) – RegCM4.5/CLM4.5 (no urban land use) for Jan 2000

Jul 2000 test



RegCM4.5/CLM4.5 (with urban + wasteheat) – RegCM4.5/CLM4.5 (no urban land use) for Jul 2000



RegCM4.5/CLM4.5 (with urban + wasteheat) – RegCM4.5/CLM4.5 (implicit urban land use) for July 2000

Conclusions

- Urban surfaces have significant impact on the meteorological conditions and climate in Central Europe, with increasing effects on population
- Urban heat island effect clearly identified in simulations as well, mainly during summer and nighttime, especially significant under extreme weather like heat wave
- High-resolution achieved the city's scale, no excuse to neglect it
- Higher complexity parameterization necessary to capture the effects fully, which might be important e.g. for air-quality issues

Further assessment within new project URBI PRAGENSI

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Thank you for your attention!