Univerzita Karlova
Matematicko-fyzikální fakulta
Katedra fyziky atmosféry
V Holešovičkách 2, Praha 8

PŘÍPRAVA URBANIZOVANÉHO MODELU TEPELNÉHO OSTROVA V PRAZE

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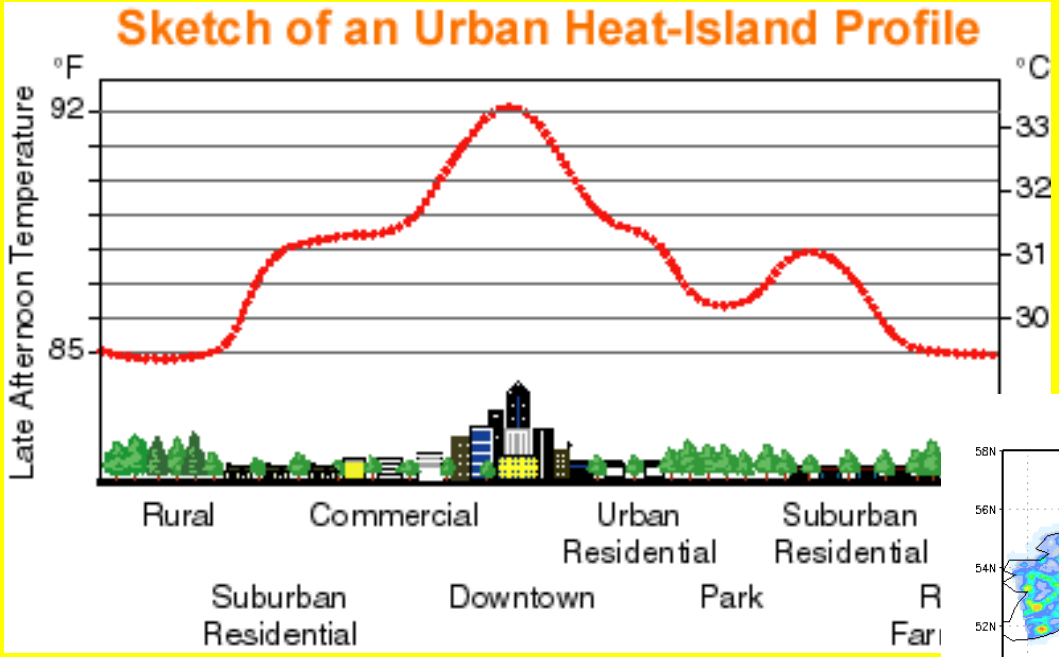
Content

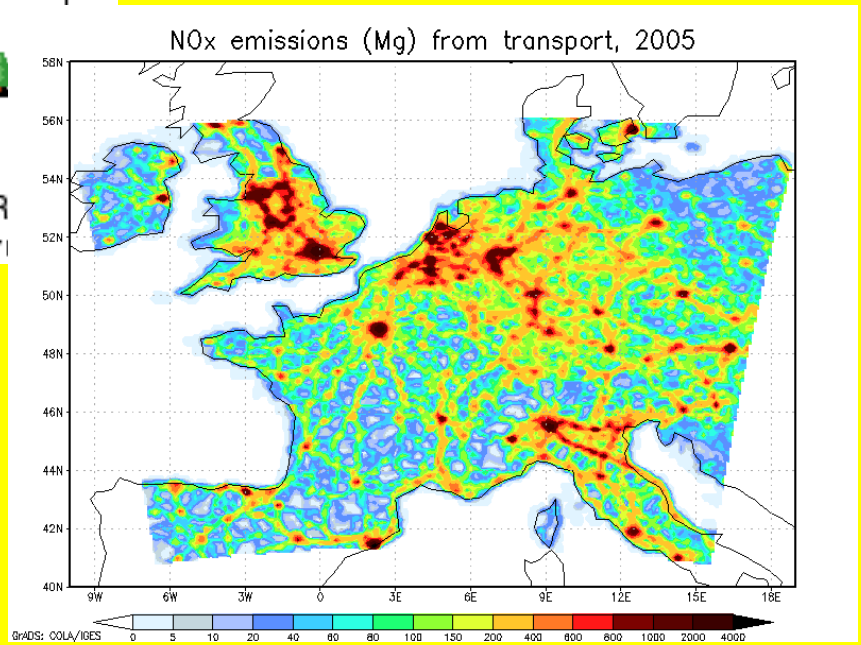
1. Motivation, projects
2. Models and urban areas implementation
3. Results and urban effects
4. Conclusions

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



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

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.

Los Angeles smog and California climate change policy

Motivation

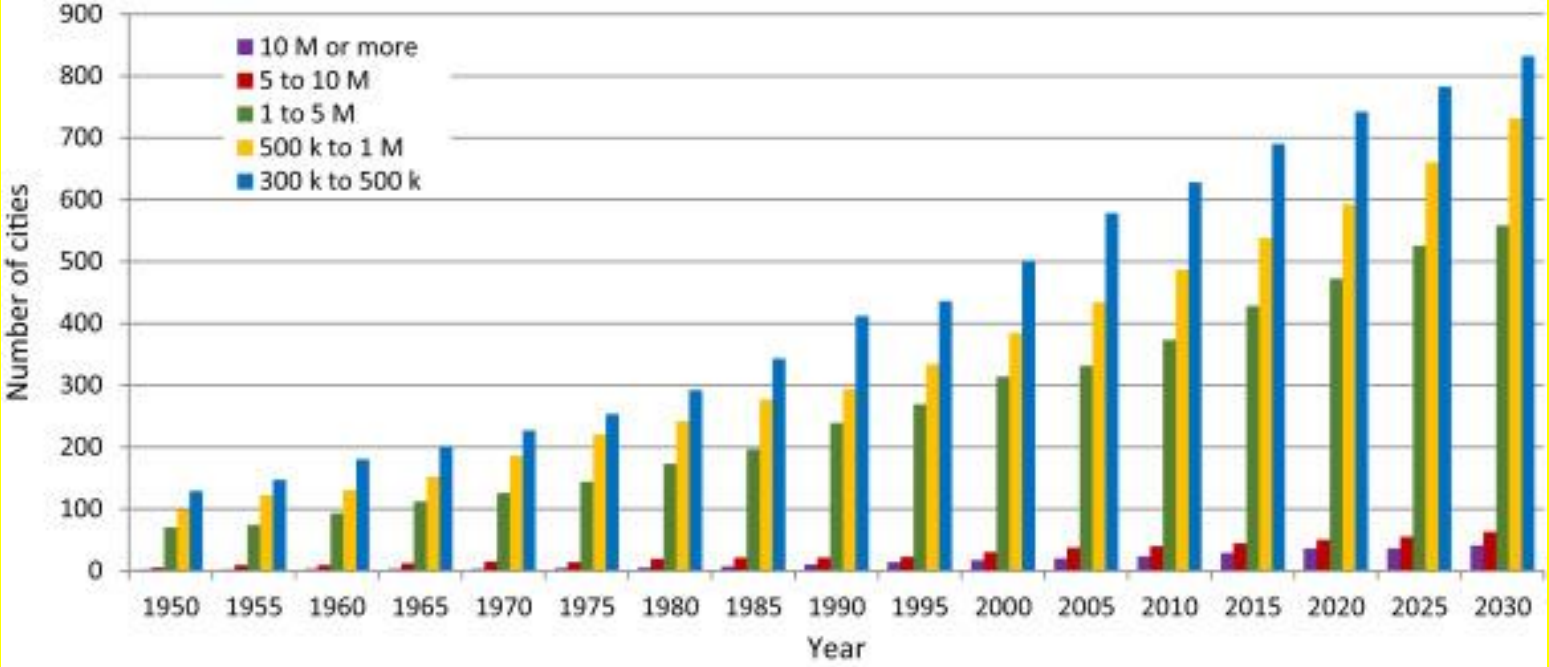


Fig. 1. The growth rate in number of cities with various populations during 1950–2030 [1].

Parham A. Mirzaei

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

Projekt PoC UK

OP-Praha pól růstu:
Proof of Concept UK -
Ověření proveditelnosti a komerčního potenciálu výsledků výzkumu Univerzity Karlovy

01/2017 – 12/2018

KK2:
Důsledky klimatické změny pro Prahu, možná adaptační a mitigační opatření

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Projekt PoC UK - CÍLE

- Kvantifikace klimatických změn a jejich neurčitosti pro Prahu na základě výsledků klimatických modelů, včetně dostupných regionálních simulací s vysokým rozlišením z aktivity EuroCORDEX
- Analýza klimatického signálu v kritických meteorologických parametrech či indexech pro Prahu s rozlišením lokálních efektů tepelného ostrova města
- Webová interpretace výsledků klimatického signálu pro scénáře RCP 2.6, 4.5 a 8.5 s příslušnými neurčitostmi a se zahrnutím tepelného ostrova města
- Modelové odhady účinnosti některých vybraných adaptačních a mitigačních opatření
- Analýza přínosu lokalizované předpovědi s vysokým rozlišením pro Prahu pro kritické meteorologické parametry či indexy

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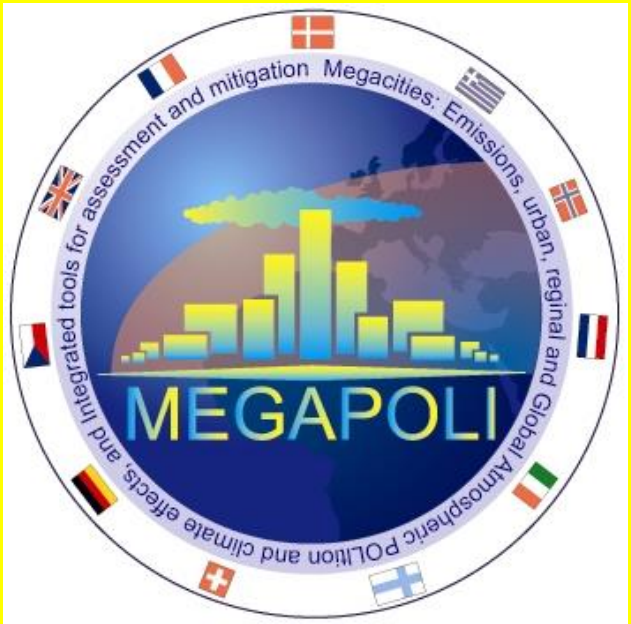
MEGAPOLI Project

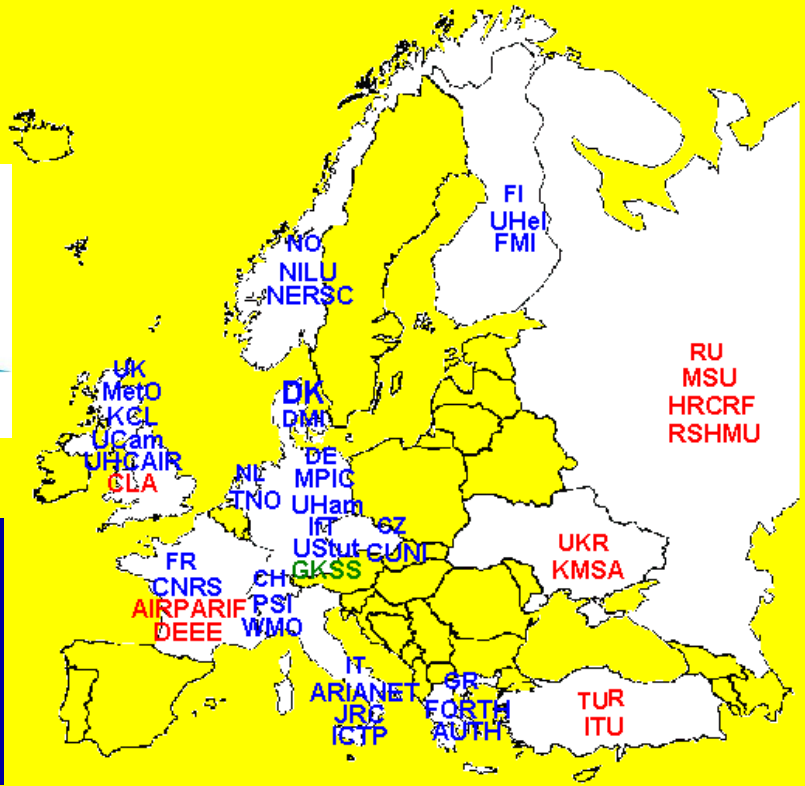
Objectives:

- 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)

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EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

The UHI project pilot areas

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

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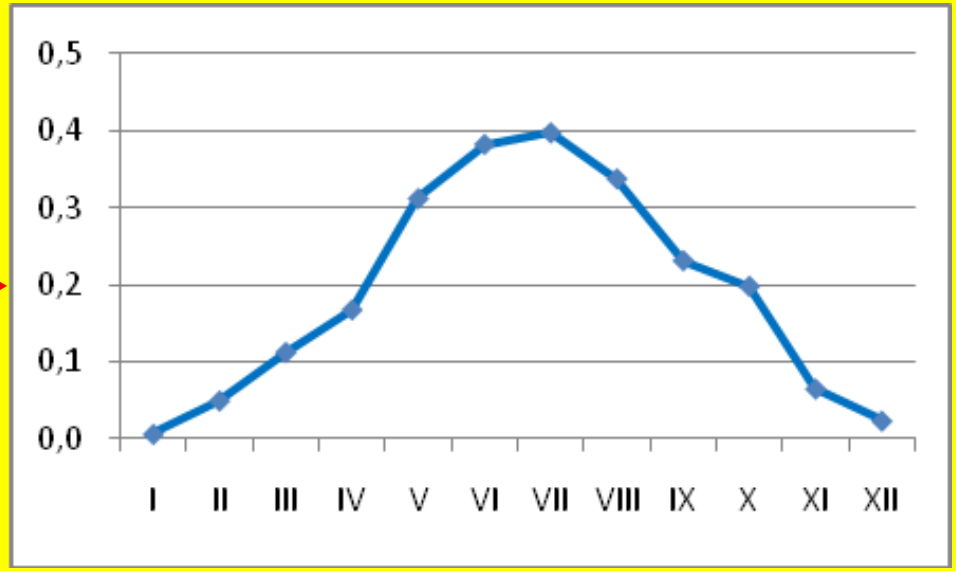
EUROPEAN REGIONAL DEVELOPMENT FUND

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



Klementinum
vs. Ruzyne

Pretel (2010)

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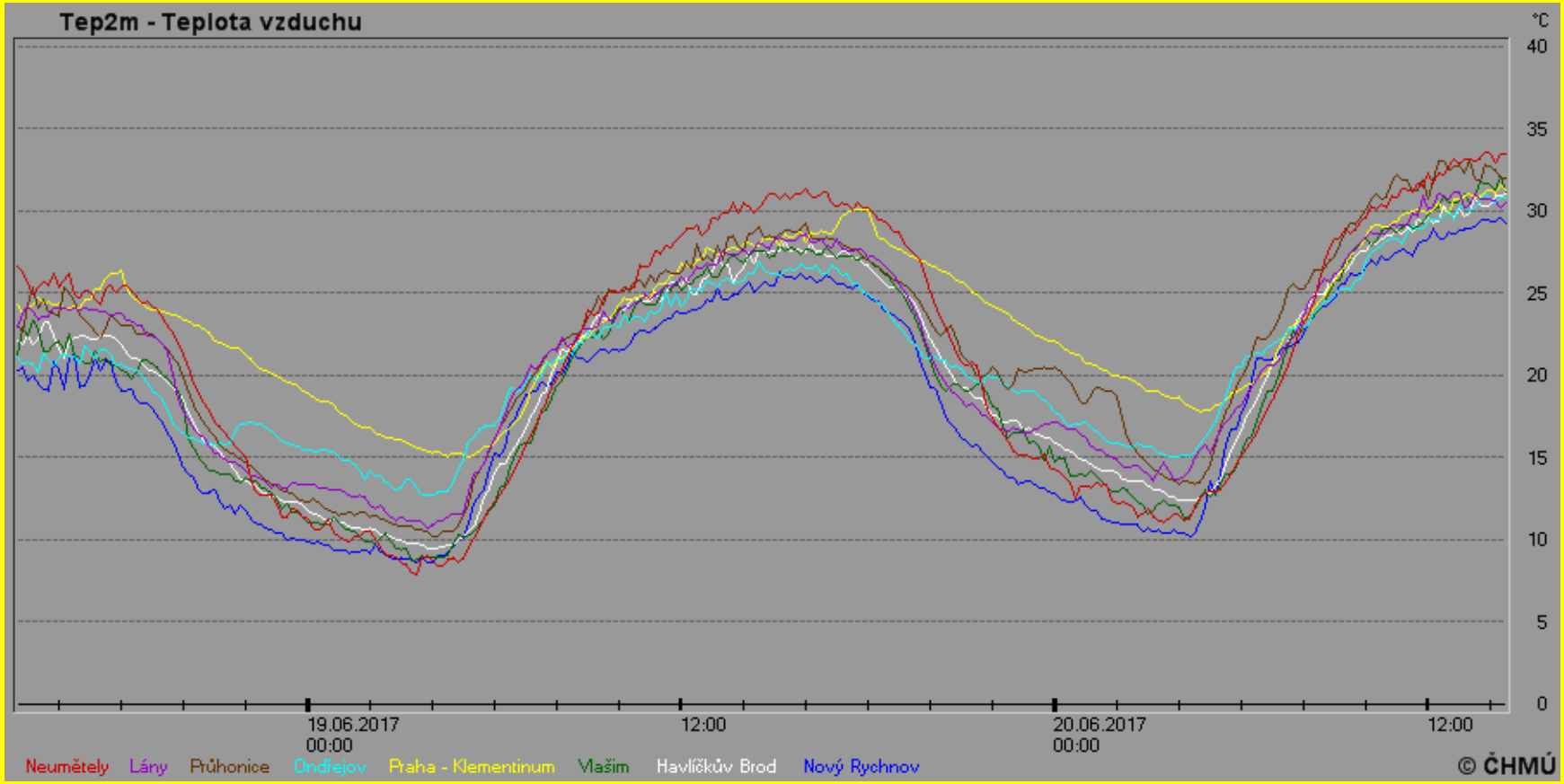
EUROPEAN REGIONAL DEVELOPMENT FUND

Ne – Po - Út


Tep2m - Teplota vzduchu
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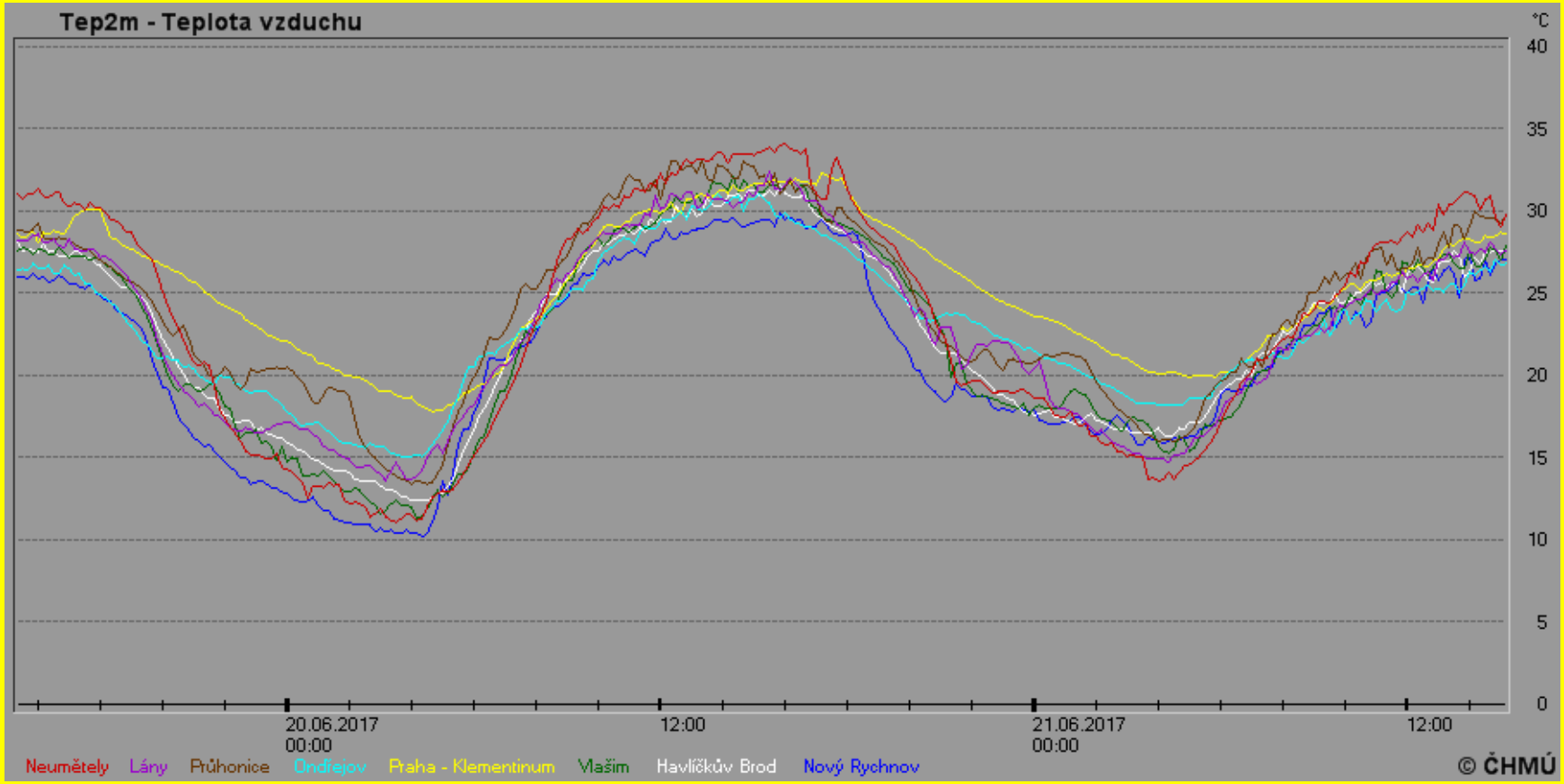
Neumětely
Lány
Průhonice
Ondřejov
Praha - Klementinum
Vlašim
Havlíčkův Brod
Nový Rychnov
© ČHMÚ

Po – Út - včera


Tep2m - Teplota vzduchu
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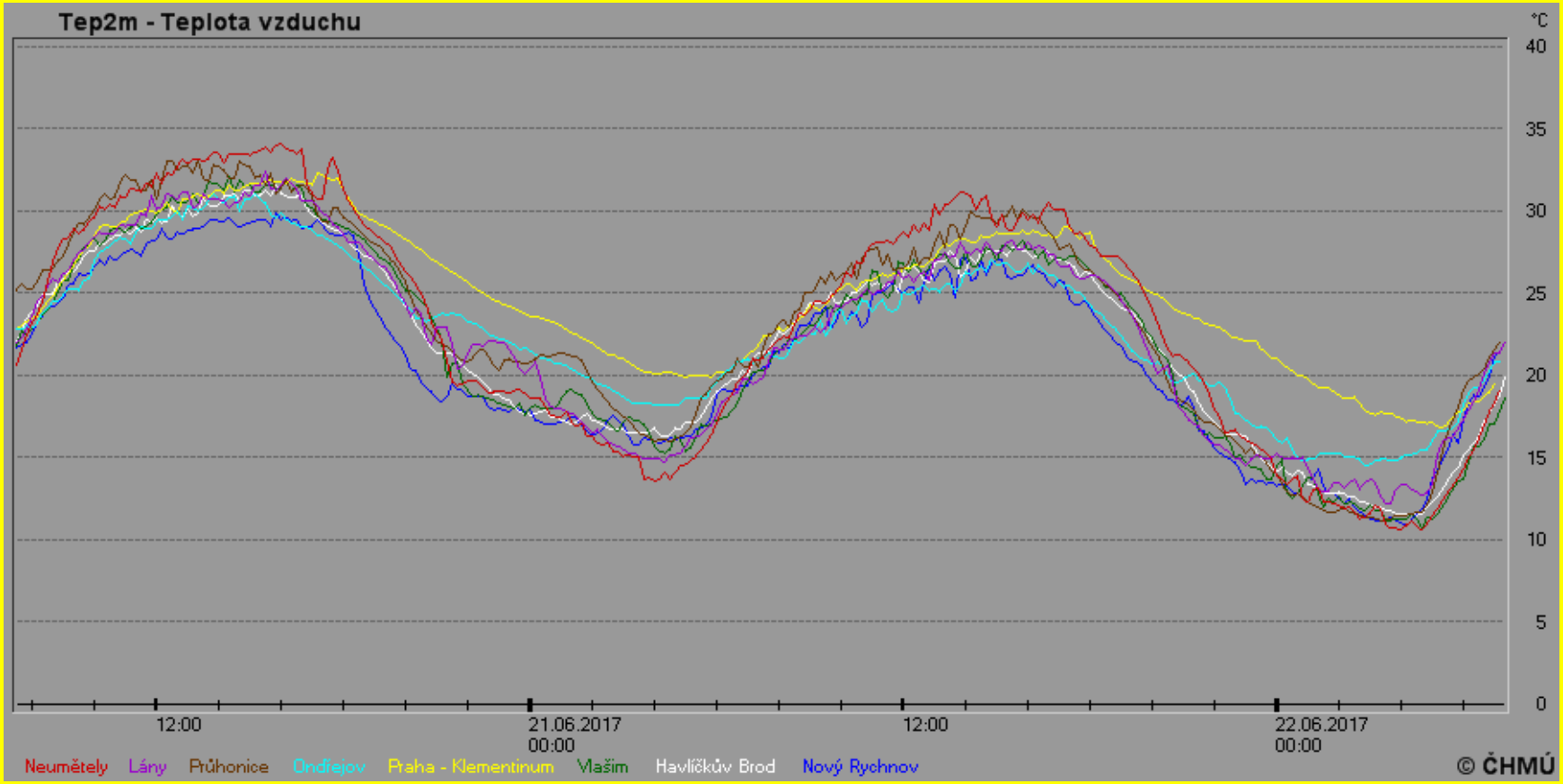
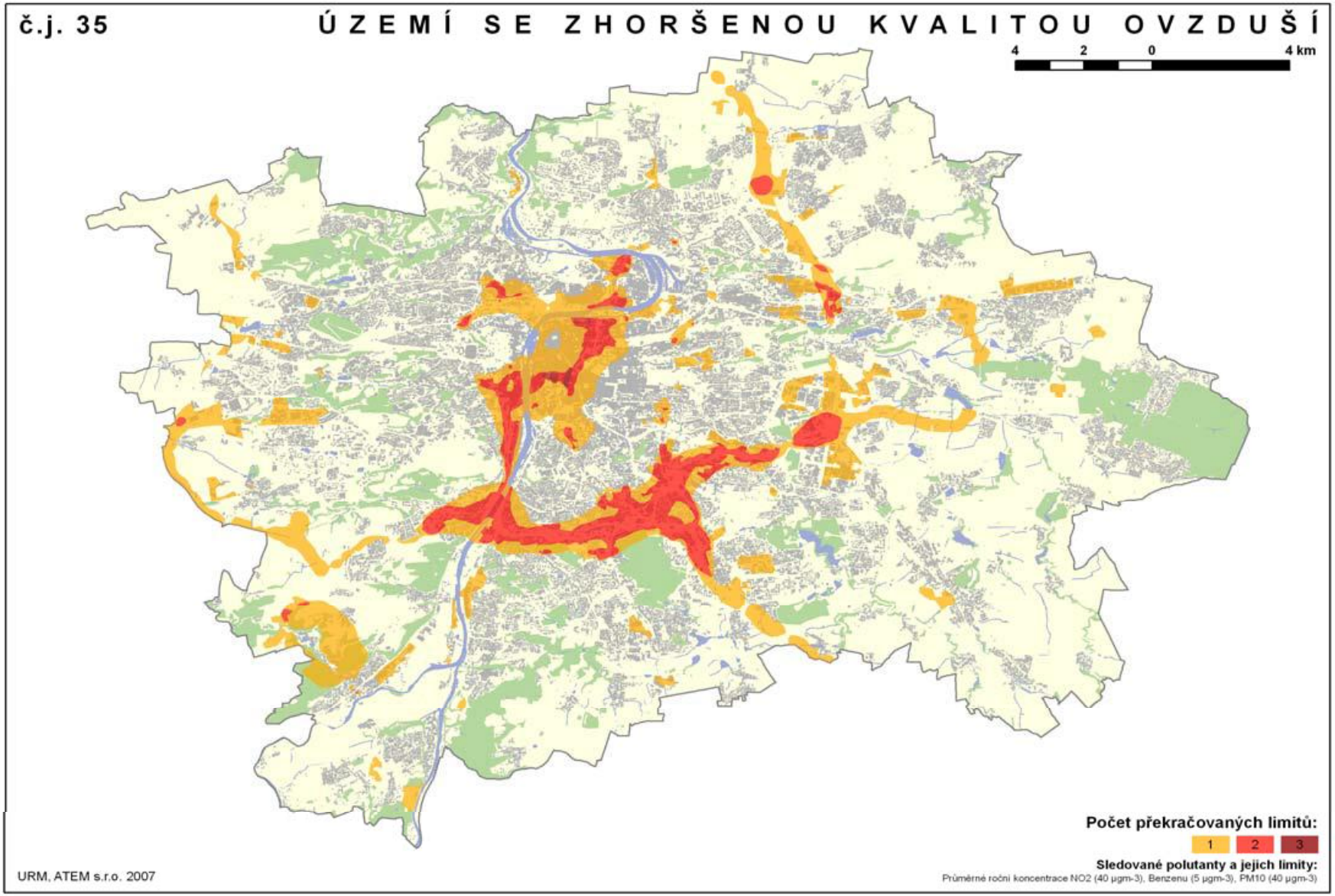
Vlašim
Havlíčkův Brod
Nový Rychnov
© ČHMÚ

Út – včera - dnes



Prague air quality



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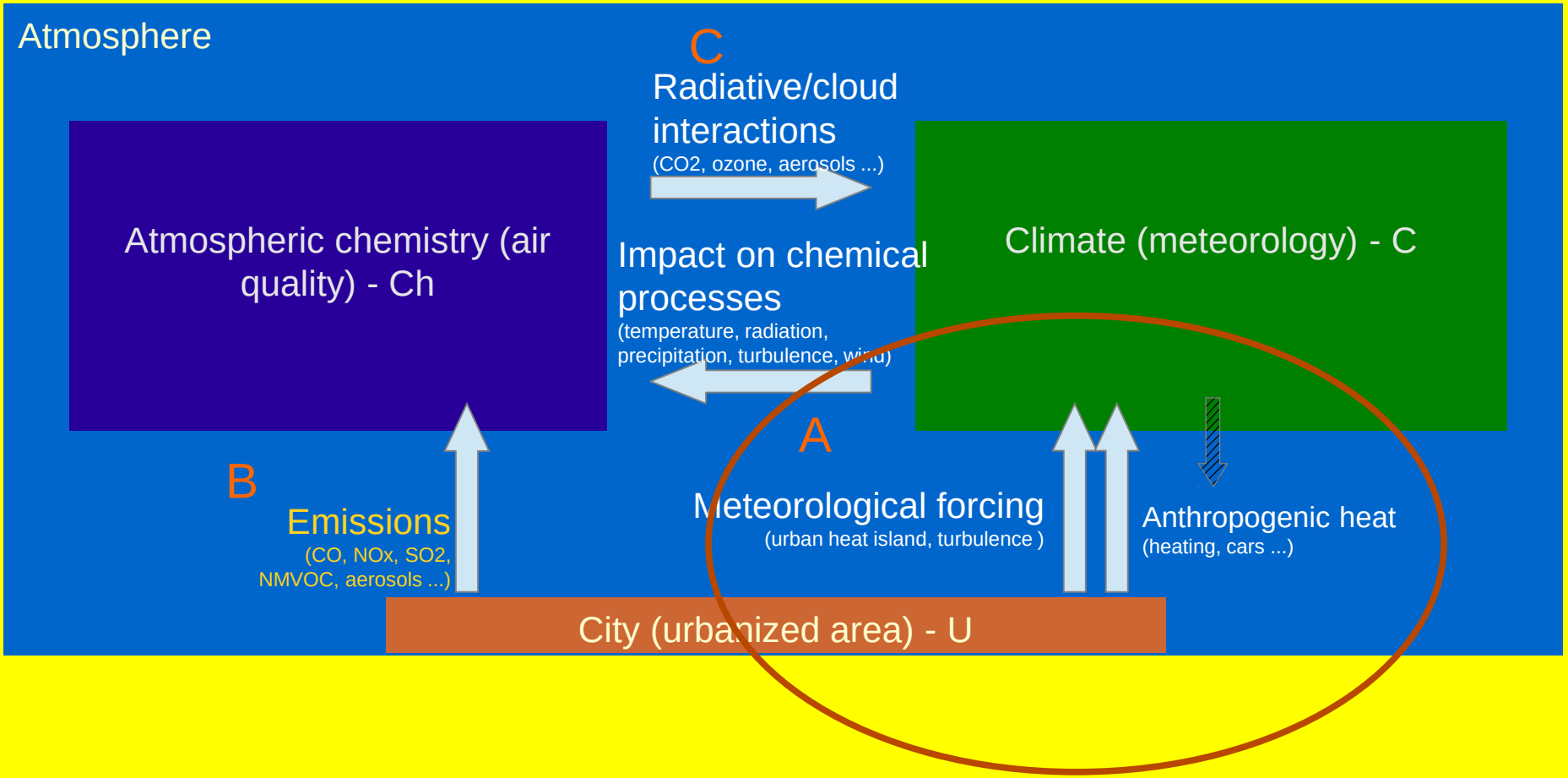
Goal

To use regional climate models and chemistry transport models to quantify the interaction:

Urban environment – climate – chemistry

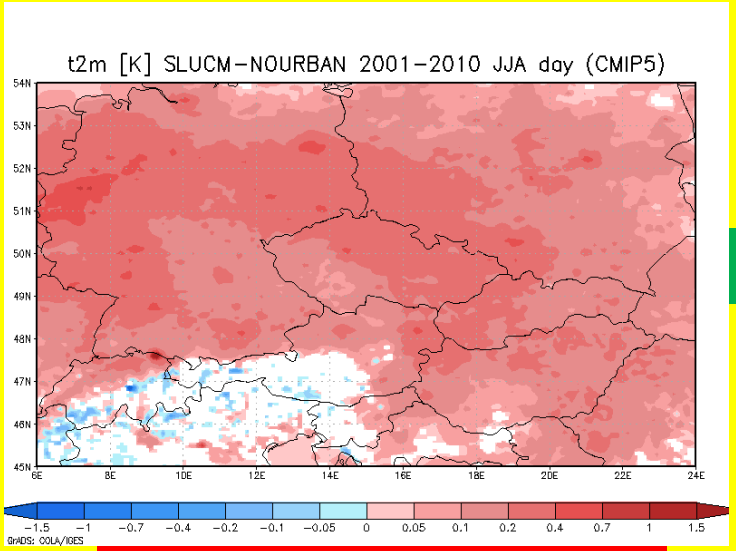
UCCh interaction (**U**rban–**C**limate–**Ch**emistry)

UCCh interaction

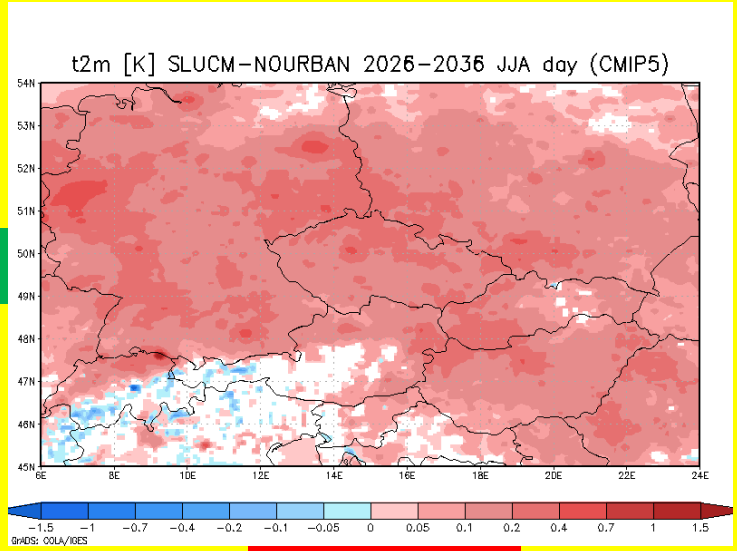


Huszar et al., ACP 2014, 2015, 2016

Climate change study

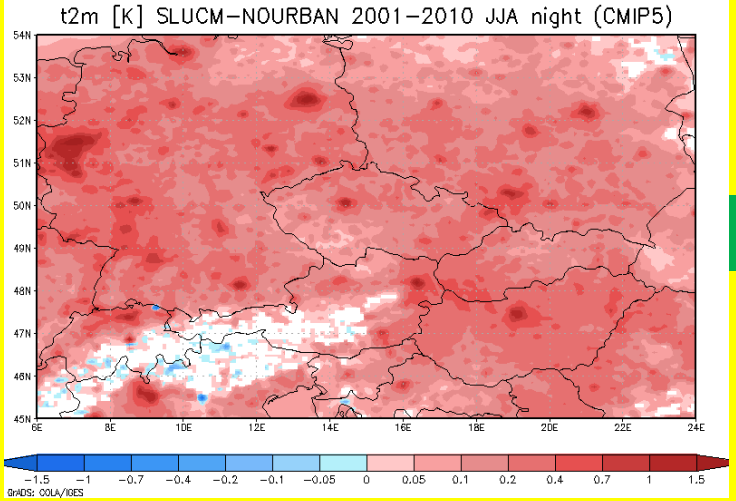


day

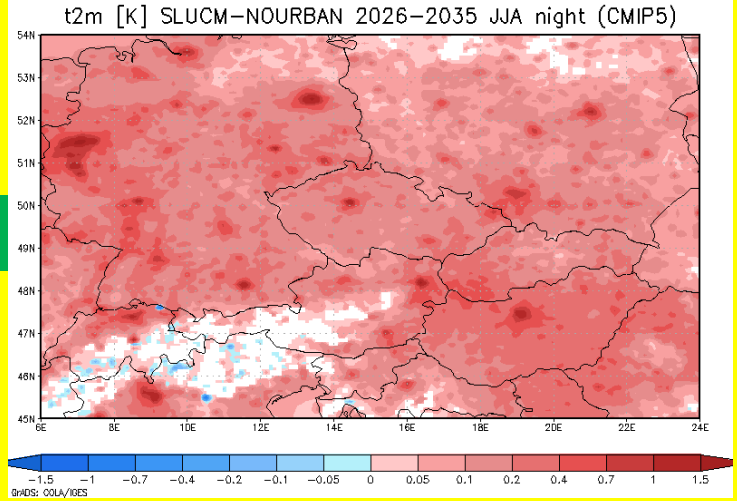


last decade

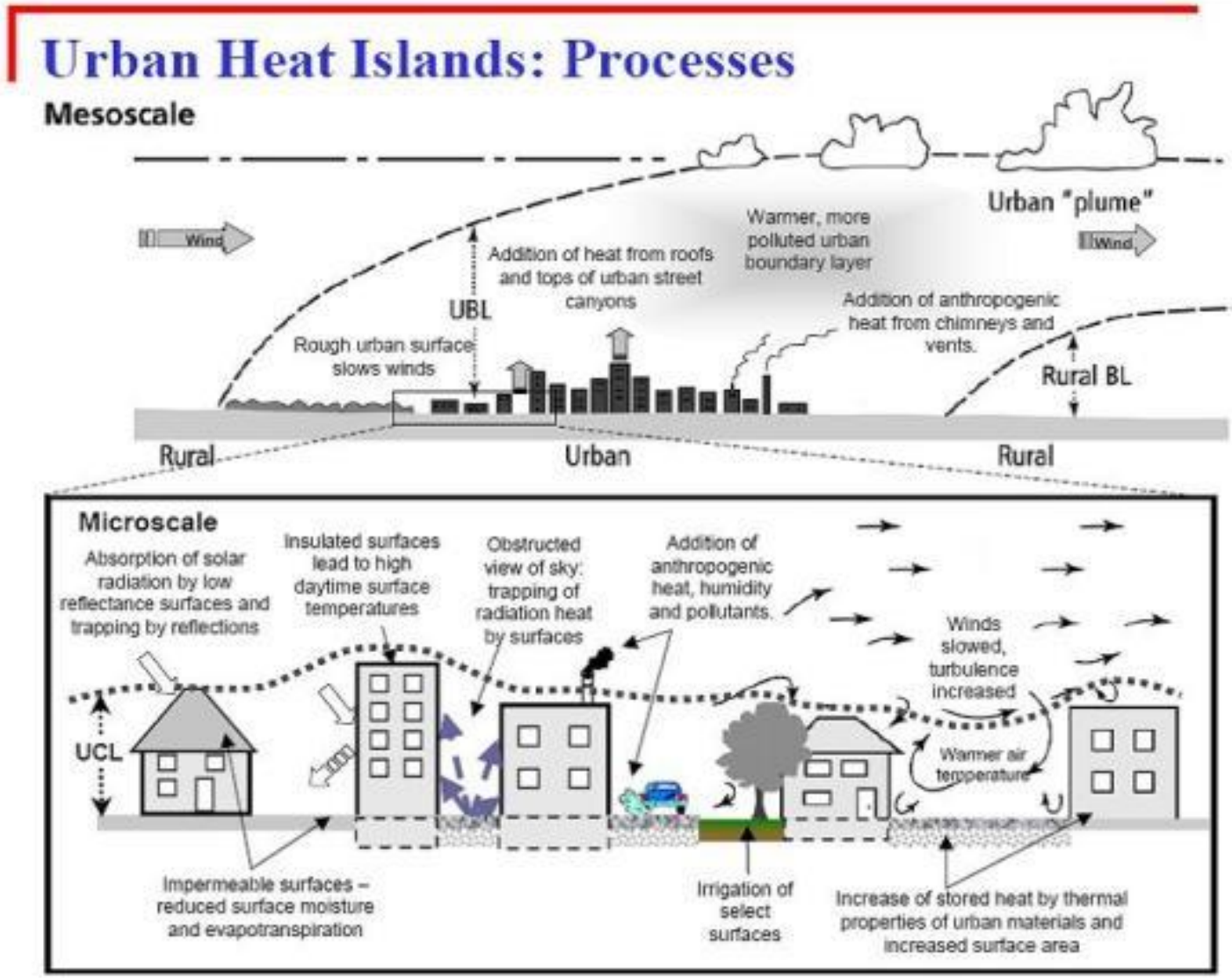
near future



night

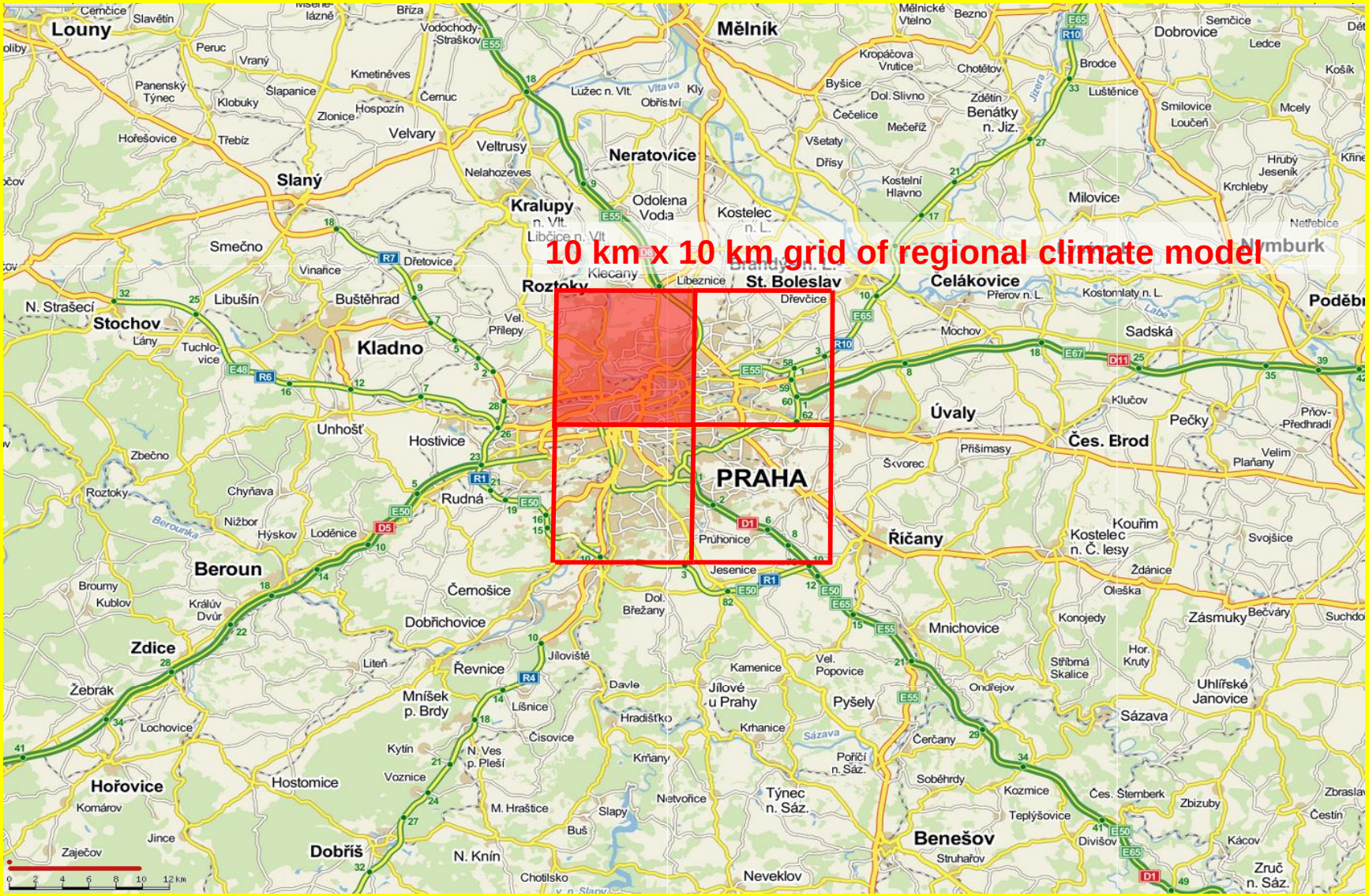


Atmospheric processes in urban canopy layer

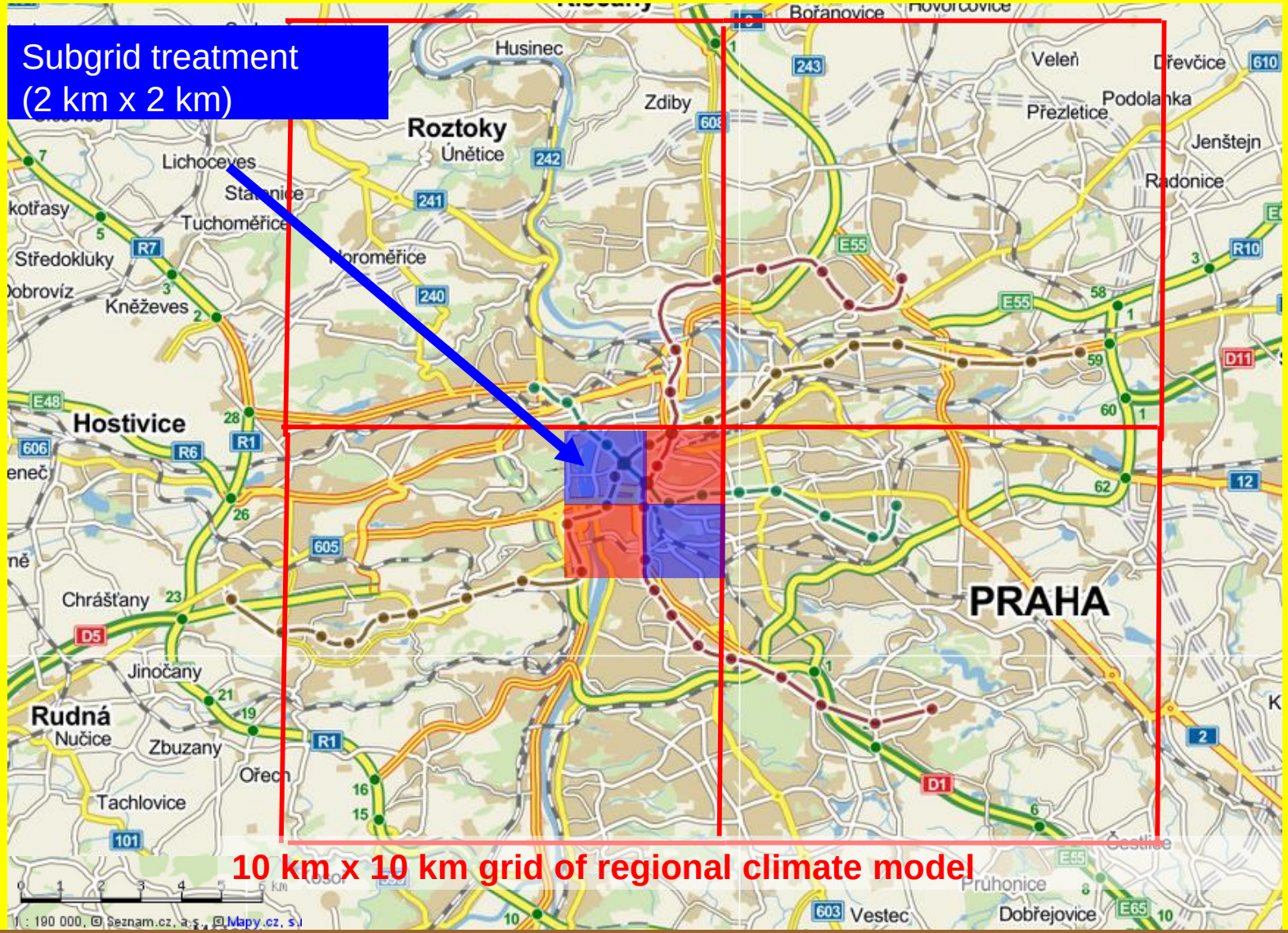


Regional climate model assessment of urban canopy meteorological effects – why we need urban parameterizations

Regional climate model used – ICTP RegCM4 model



Regional climate model assessment of urban canopy meteorological effects



Regional climate model assessment of urban canopy meteorological effects

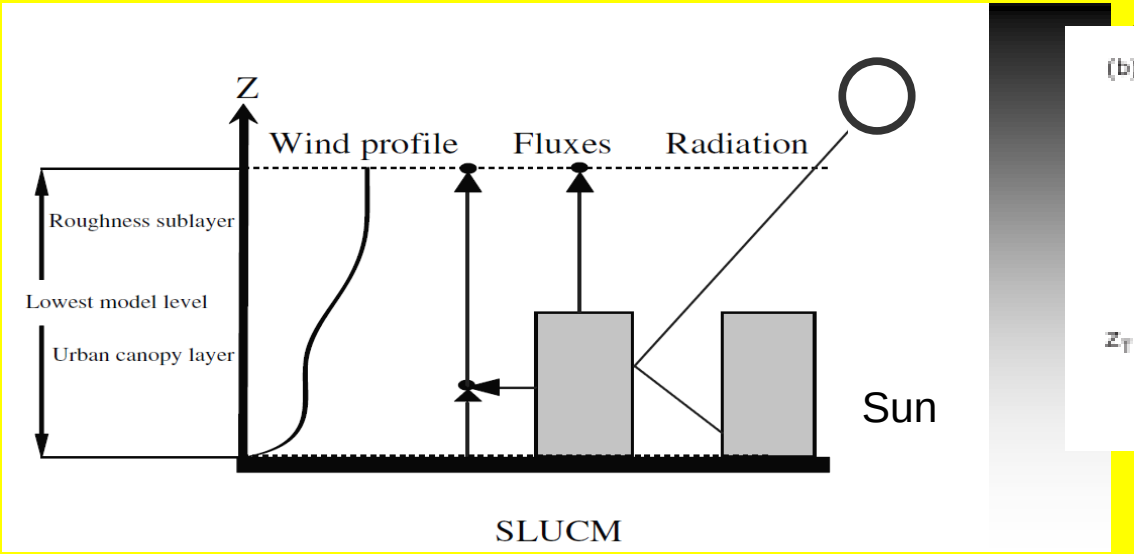
Modeling atmospheric process in urban canopy

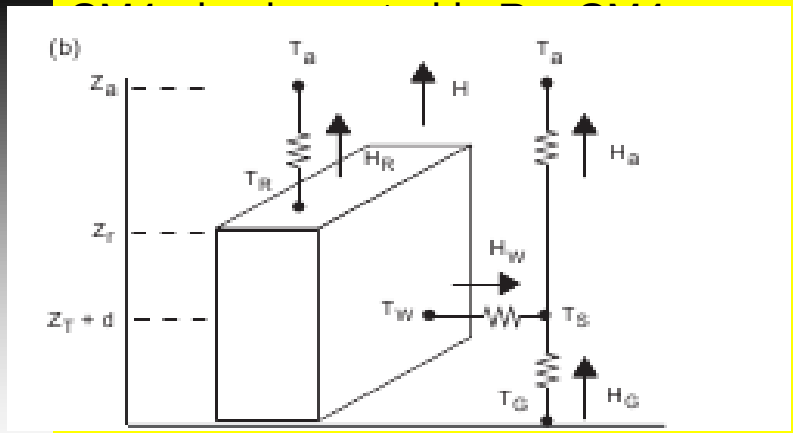
- “bulk” – no special parameterization, but recognizing the land-use type (albedo, emissivity and other land surface parameterizations)
- SLUCM – single-layer urban canopy model
- MLUCM – multi-layer urban canopy model
- BEP-BEM – building environment parameterization – building energy model

Modeling atmospheric process in urban canopy

Possible urban surface parameterizations within RegCM4

SLUCM (Single-Layer urban Canopy Model) + BATS surface model including subgrid treatment (SUBBATS)



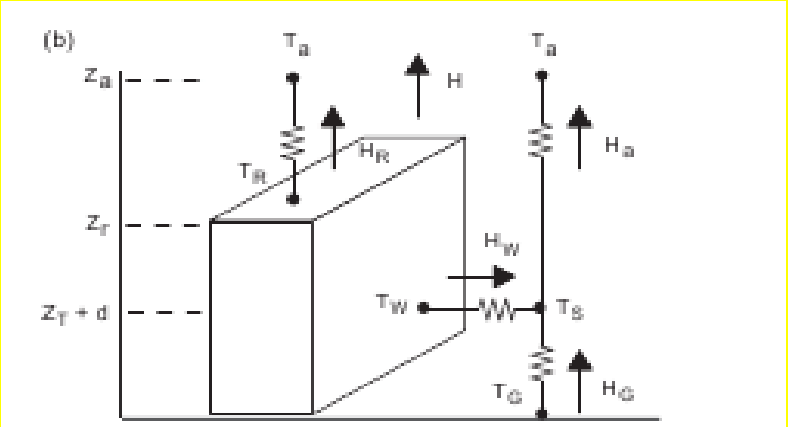


Kusaka and Kimura (2004)

Urban canopy parameterization in RegCM4

- SLUCM – Single Layer Urban Canopy Model
- Kusaka et al. (2001), as implemented into WRF (Chen et al. 2010)

Energy fluxes and temperatures in the street canyon:



from Kusaka and Kimura (2004)

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

Single Layer Urban Canopy Model

- Urban geometry - infinitely-long street canyons
- In a street canyon - shadowing, reflections, and trapping of radiation are considered
- Exponential wind profile is prescribed
- Prognostic variables: surface skin temperatures at the roof, wall, and road (calculated from the surface energy budget) and temperature profiles within roof, wall and road layers (calculated from the thermal conduction equation).
- Monin-Obuchov similarity theory for surface heat fluxes from each surface
- Canyon drag coefficient and friction velocity is computed using a similarity stability function for momentum.

Implementation into RegCM4 (RegCM4/SLUCM)

- Coupled online trough the RegCM's surface model BATS with subgrid surface treatment (SUBBATS)
- Two “urban” landuse categories defined “urban”/”suburban” - landuse created from CORINE and GLC2000 (where Corine is not available) database
- SLUCM is called by BATS when it finds subgrid boxes with “urban”/”suburban” cover. The BATS fluxes and large scale meteorological fields are passed to SLUCM
- SLUCM returns the total sensible heat flux from the roof/wall/road to BATS, as well as the total momentum flux
- The total friction velocity is aggregated from urban and non-urban surfaces and passed to RegCM's boundary layer scheme.
- Urban parameters (street canyon width, average building height, roof area, artificial heat) estimated for Prague – sensitivity tests are being run.

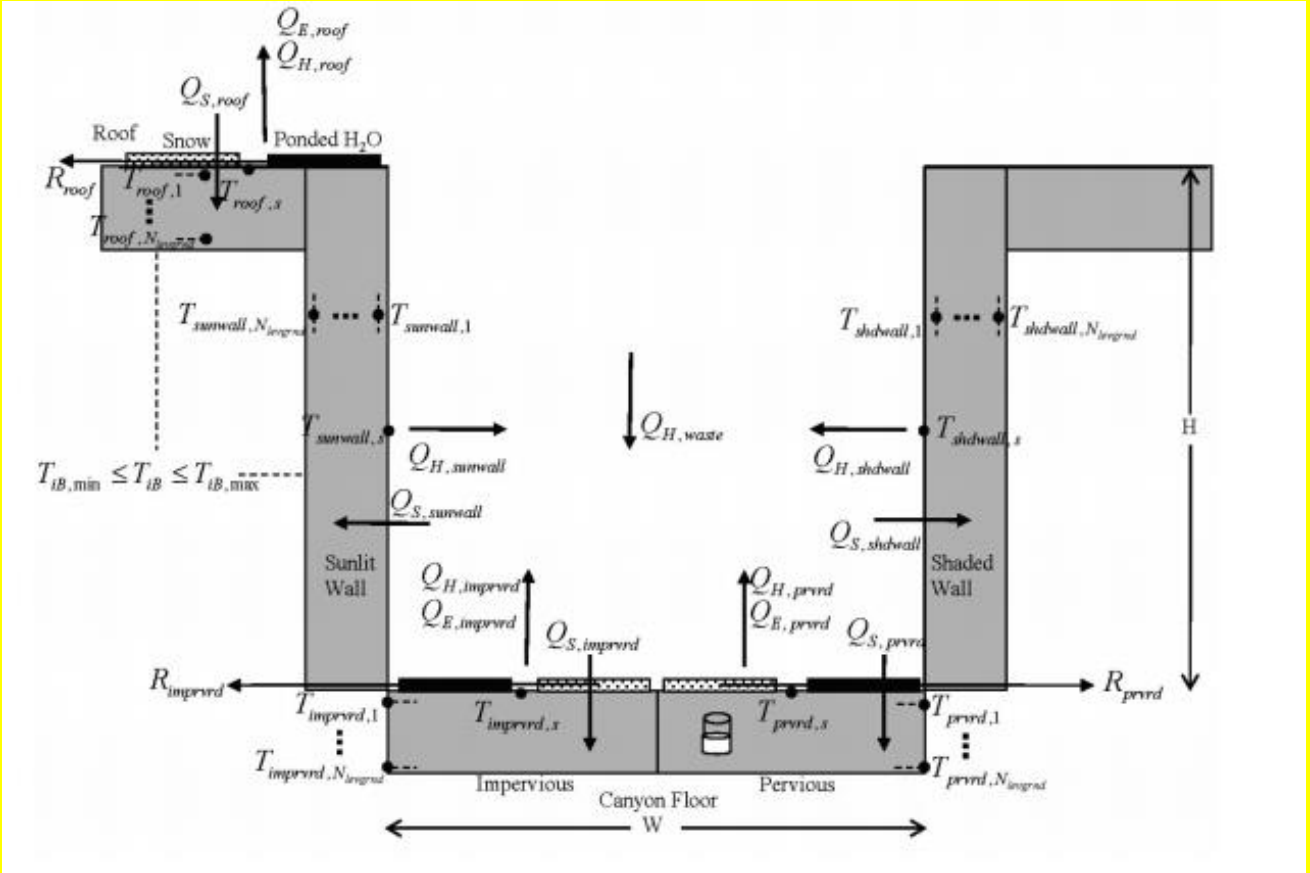
Modeling atmospheric process in urban canopy

Possible urban surface parameterizations within RegCM

CLMUrban + CLM4.5 (Community Land Model version 4.5) – no subgrid treatment but considers fractional land-use

Oleson et al. (2008)

Schematic representation of the urban land unit.

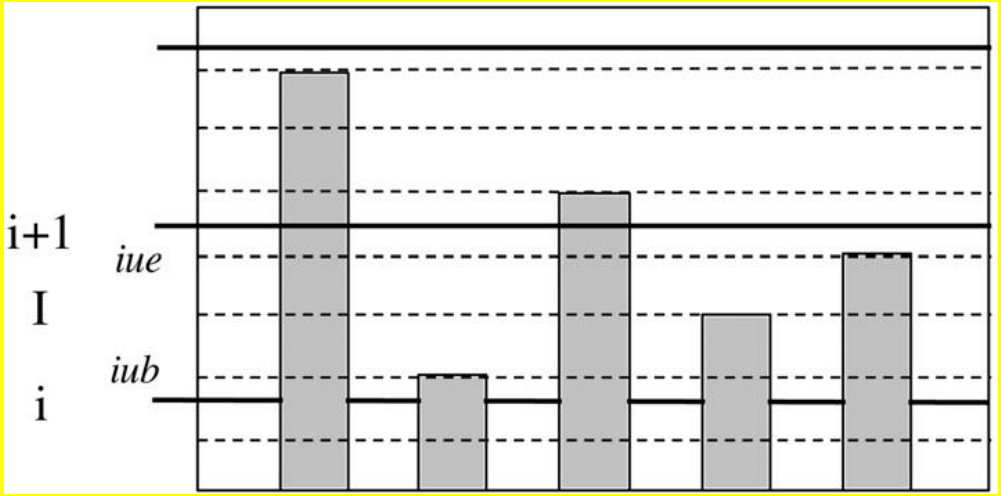


Modeling atmospheric process in urban canopy

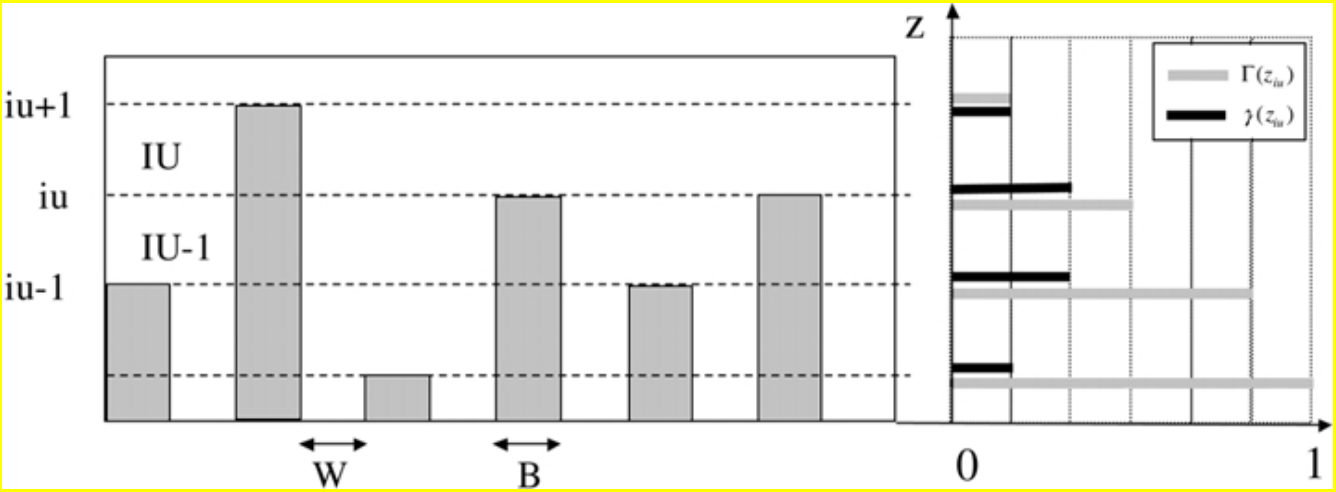
Possible urban surface parameterizations within WRF

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

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



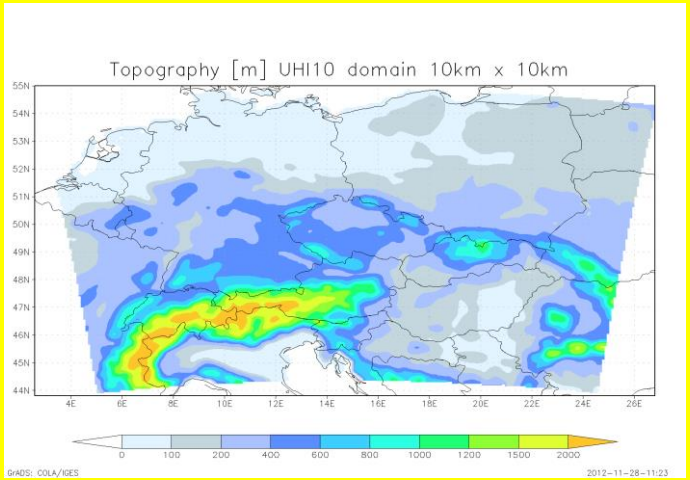
Schematic representation of the urban land unit.

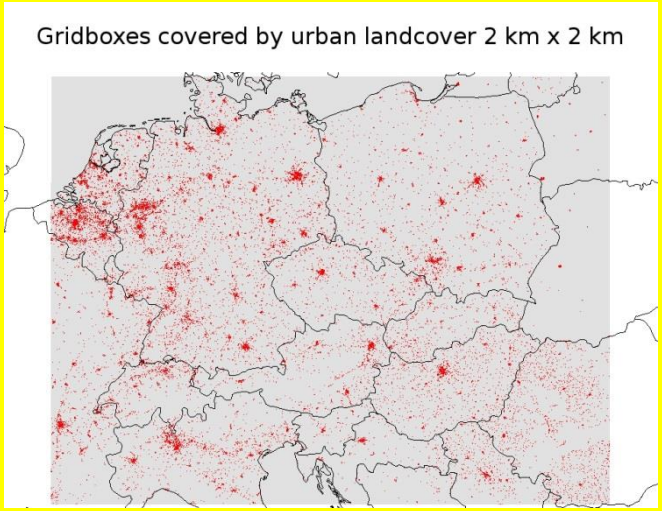


Experiments

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 – 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





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Results

Impact of urban surfaces on regional climate over central Europe

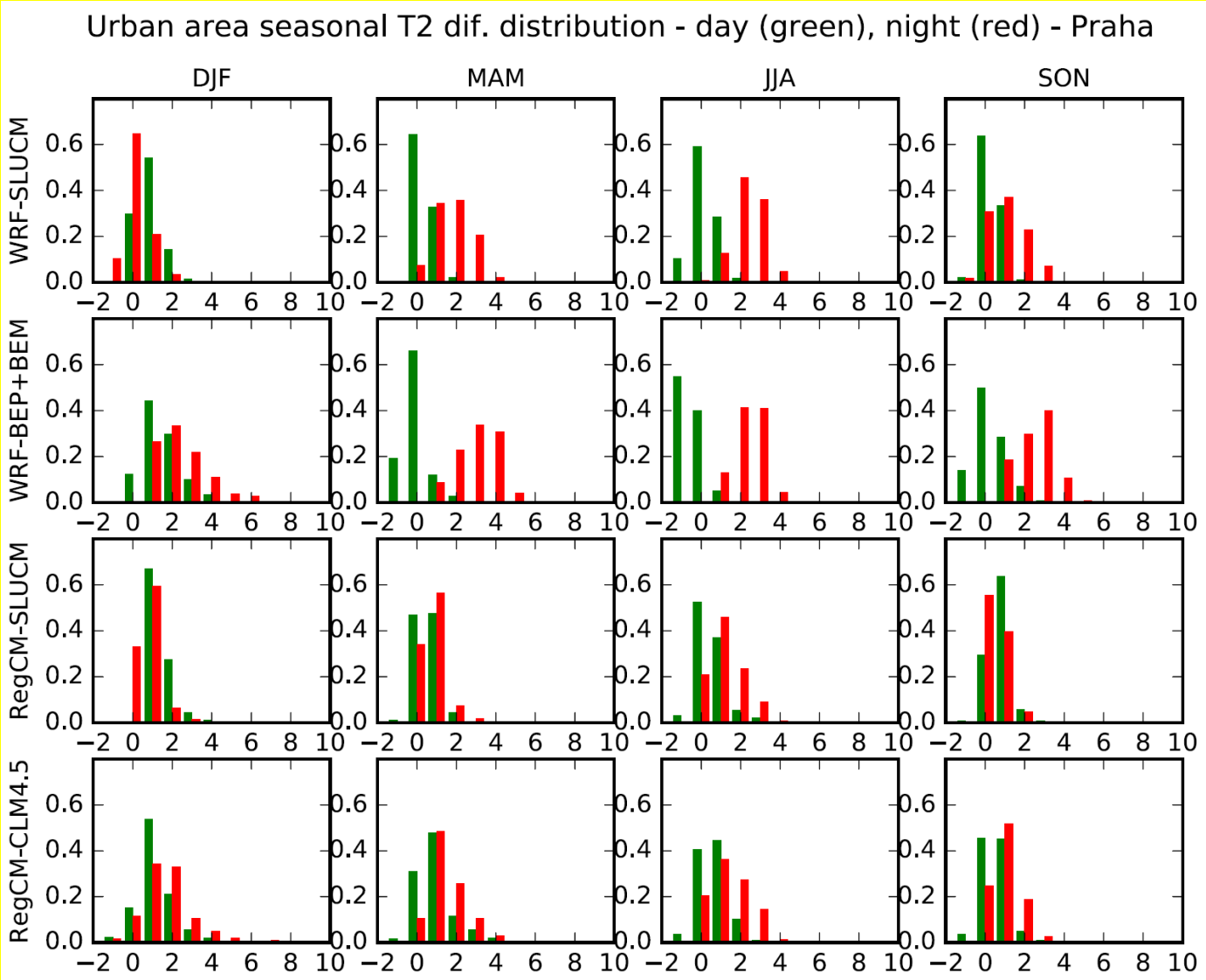
RegCM/SLUCM – NOURBAN (RegCM/BATS)

RegCM/CLM/U – NOURBAN (RegCM/CLM)

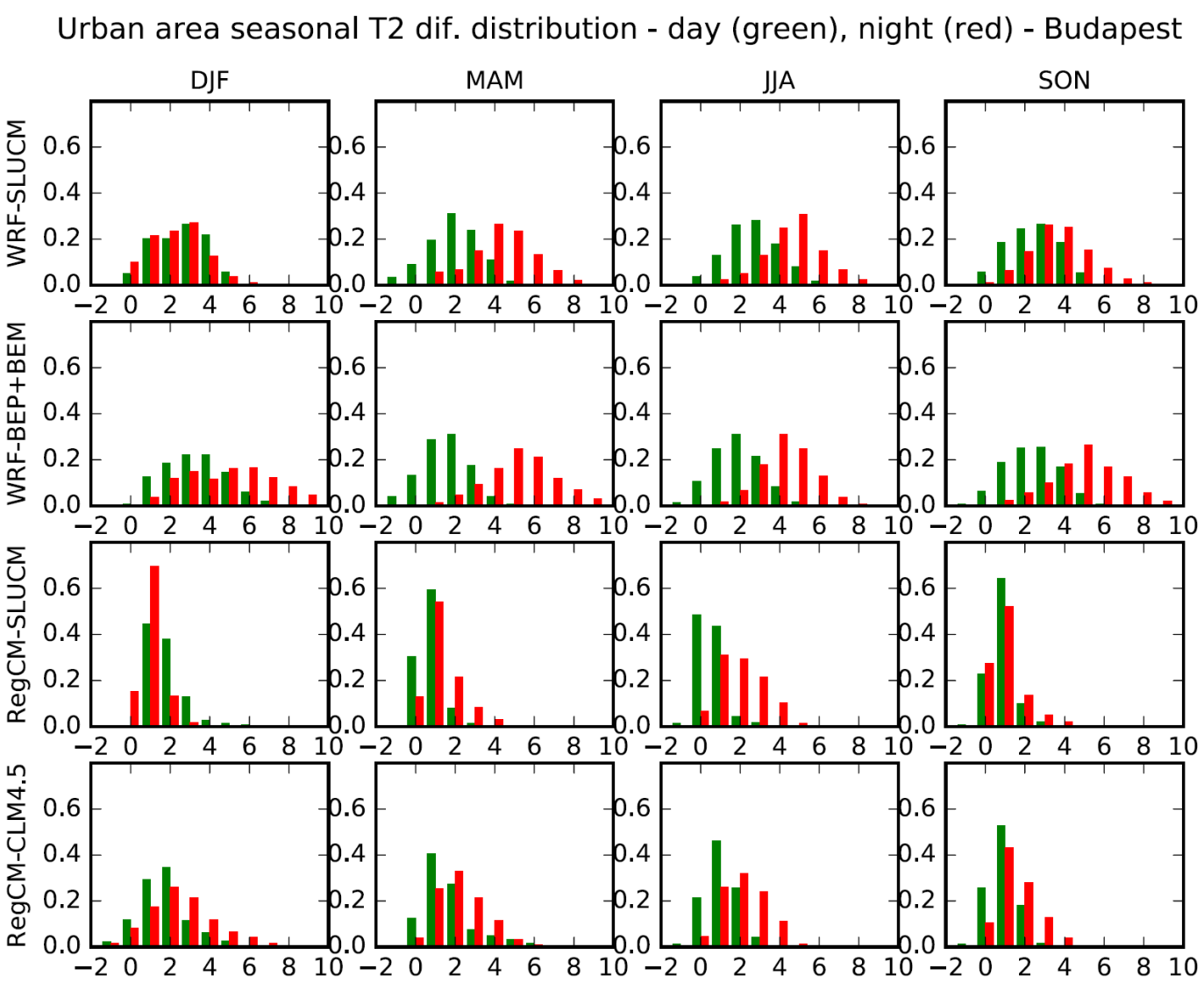
WRF/SLUCM – NOURBAN (WRF)

WRF/BEP-BEM – NOURBAN (WRF)

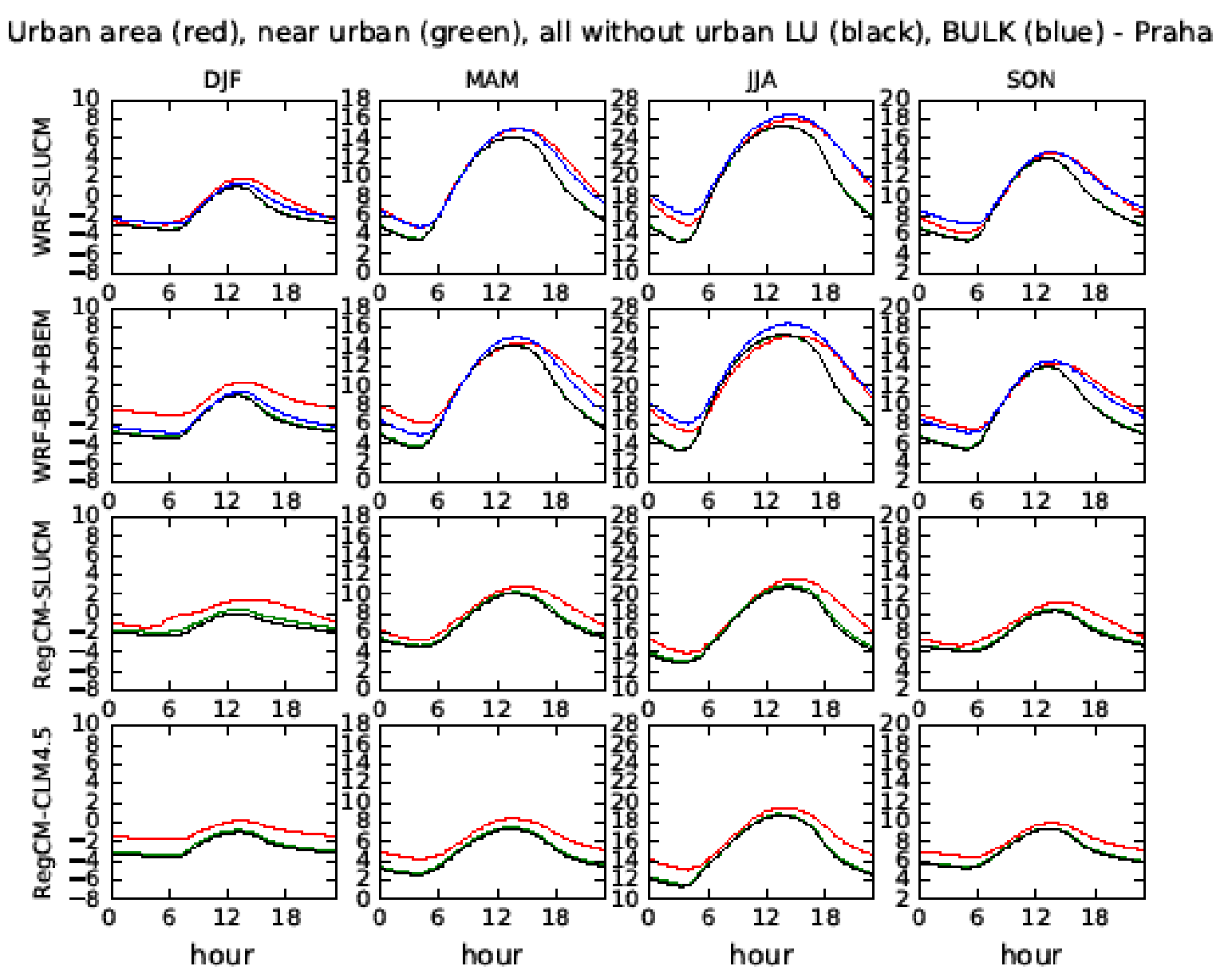
UHI intensity Prague (day vs. night)



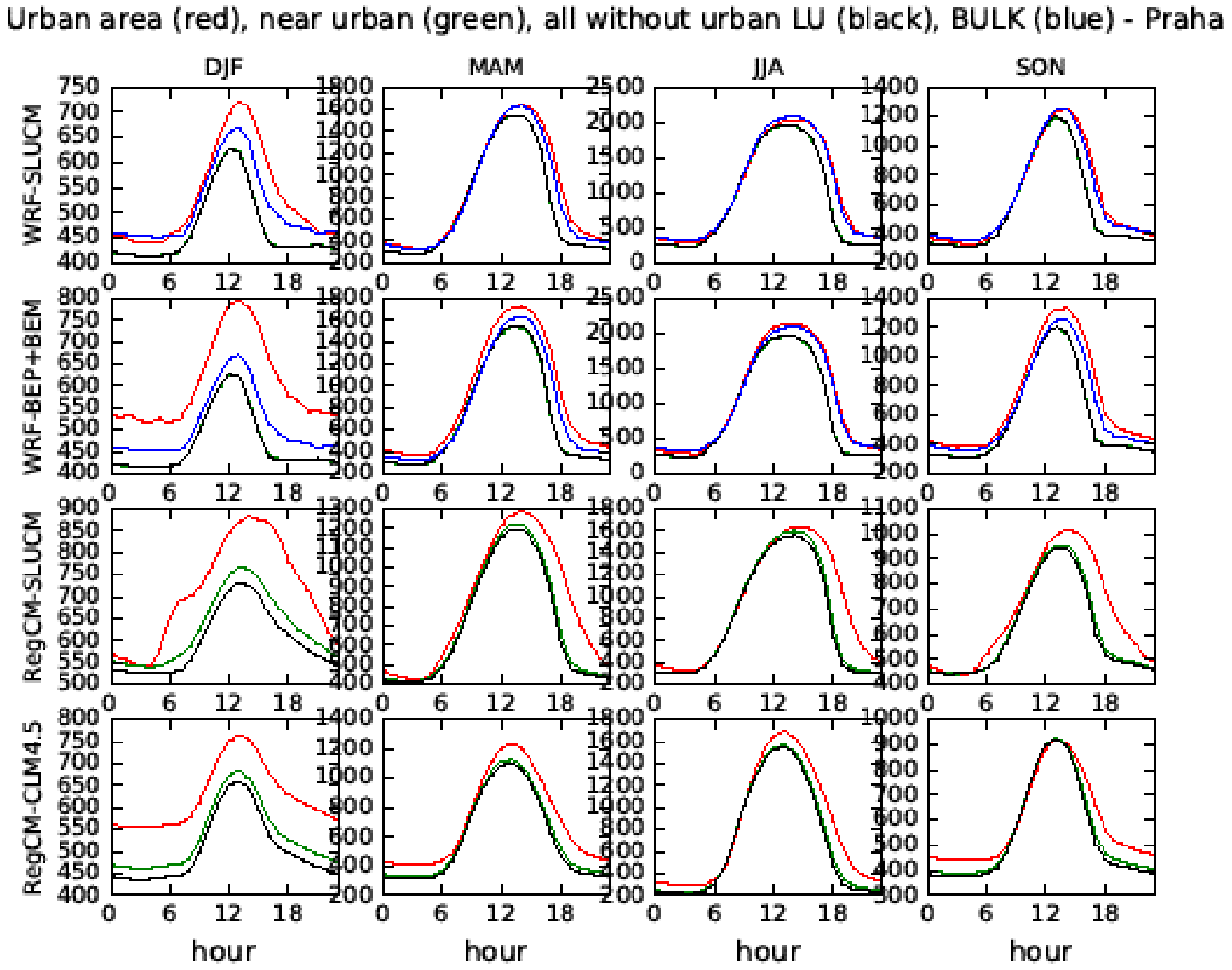
UHI intensity Budapest (day vs. night)



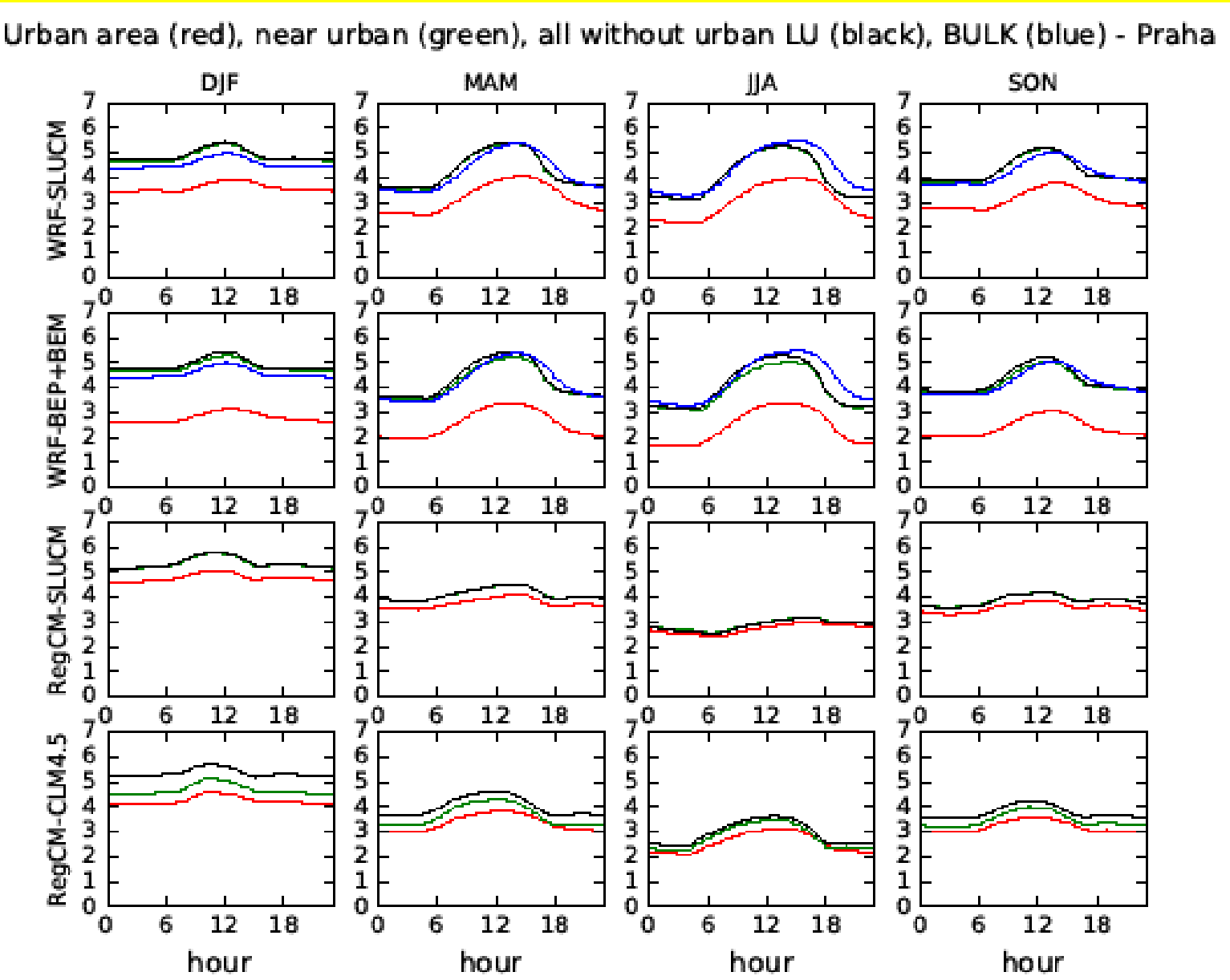
UHI temperature



Urban mixing layer



Urban wind


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

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
- PBL height increase up to 200 m over many urban centres, over Milan and Zürich up to 300-500 m on averages, summer extremes

Conclusions

- Urban surfaces have significant impact on the meteorological conditions and climate in Central Europe
- Urban heat island effect clearly identified, mainly during summer and nightime
- Significant effect of small urban units or areas, in highly populated urbanized areas like in Europe, it could affect the explanation of temperature increase under global warming, supposing the rapid development of the urbanization in the regions
- Impact on the surface concentration of ozone and NOx

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Nový projekt OP-PPR „URBI PRAGENSI“

- Urbanizovaná předpověď pro Prahu ve vysokém rozlišení
- Předpověď kvality ovzduší pro Prahu ve vysokém rozlišení – navázaná na urbanizovanou předpověď počasí
- Změna klimatu a její důsledky pro Prahu (tepelný ostrov, kvalita ovzduší), analýza a hodnocení možných adaptačních a mitigačních opatření
- Mikroměřítkové studie kritických oblastí (kvazi-operativní předpověď)

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Acknowledgement PoC

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