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**Czech Republic**

# *TEPELNÝ OSTROV MĚSTA A KLIMATICKÁ ZMĚNA*

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# Content

1. Motivation, projects
2. Models and SLUCM implementation
3. Results and urban effects
4. Sensitivity tests
5. Applications (Air quality effects, urban planning, climate change)
6. Conclusions

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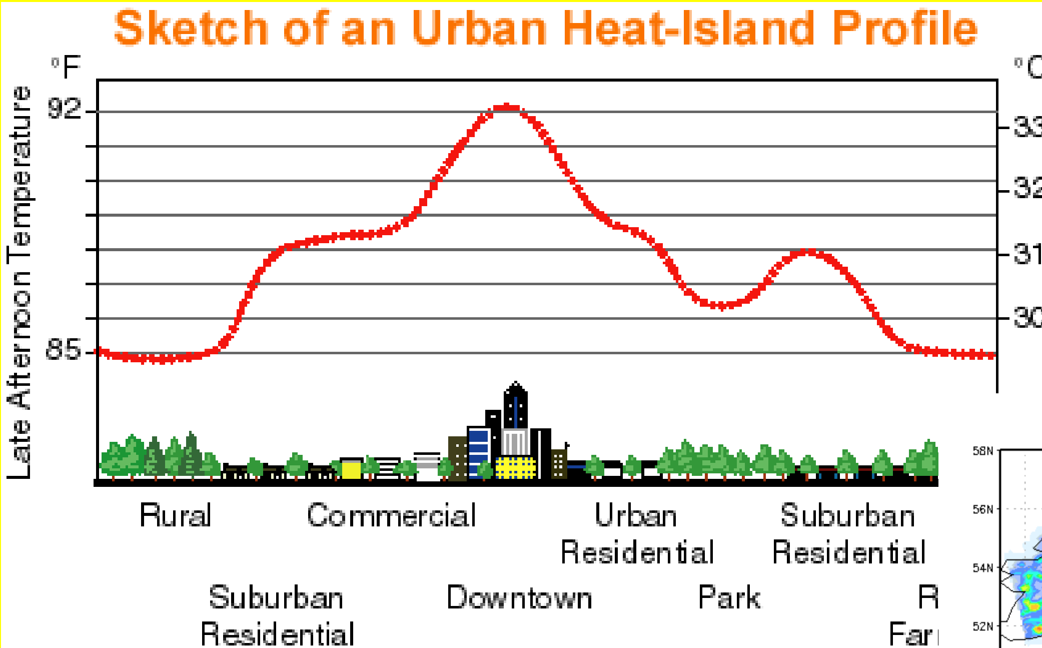
# Motivation

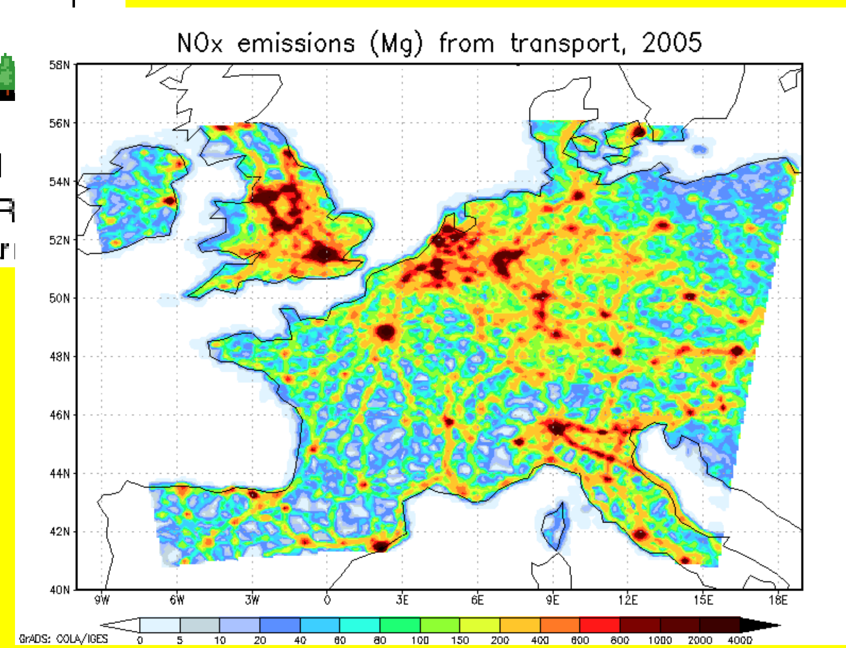



World:

- 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.




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

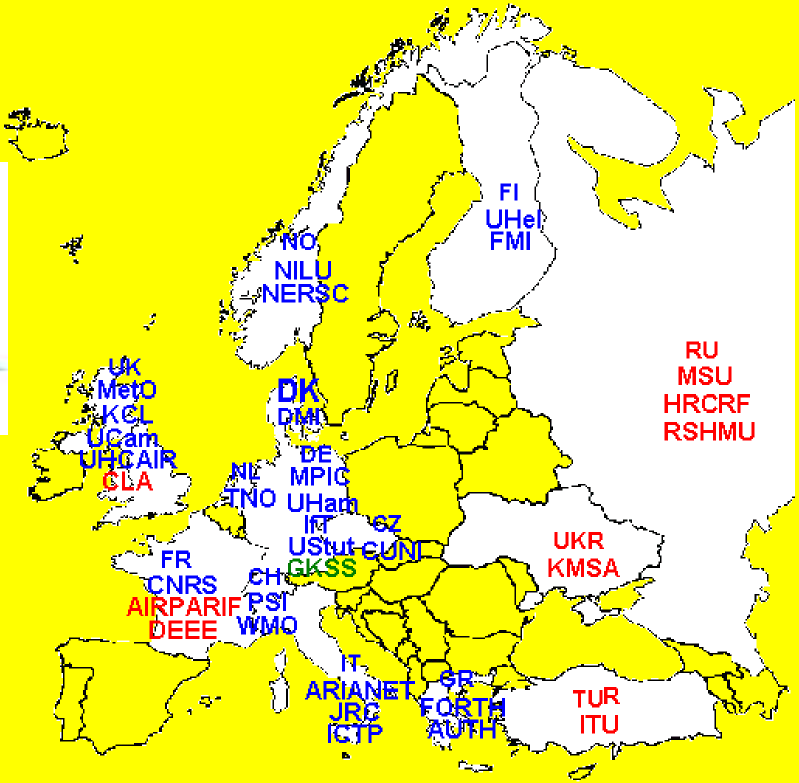
# MEGAPOLI Project

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)

# 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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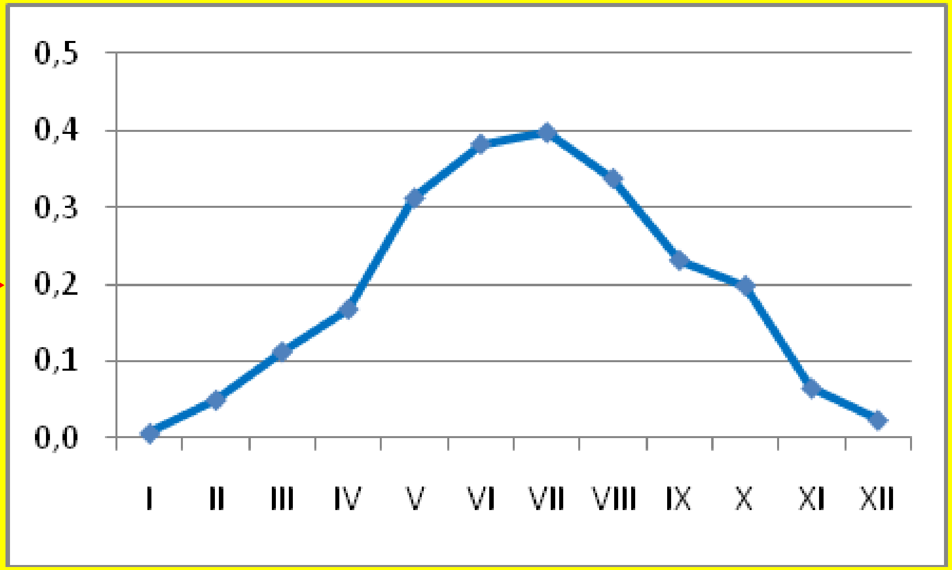
# Prague heat island

| *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 | 0,10 |




Klementinum
vs. Ruzyne

Pretel (2010)

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# Models

## RegCM

- Regional Climate Model: Giorgi et al. (1993a,b), Giorgi et al. (1999), and Pal et al. (2005).
- Being developed in ICTP, http://users.ictp.it/~pubregcm/RegCM3
- MM5 dynamical core
- 23 vertical σ-levels reaching up to 70hPa, with time step of 30 s, 10 km resolution.
- Surface scheme BATS by Dickinson et al. (1993)
- SUB-BATS (Giorgi et al 2003), **urbanisation of the parameterization**
- **RegCM-CLM-SLUCM**

## CAMx

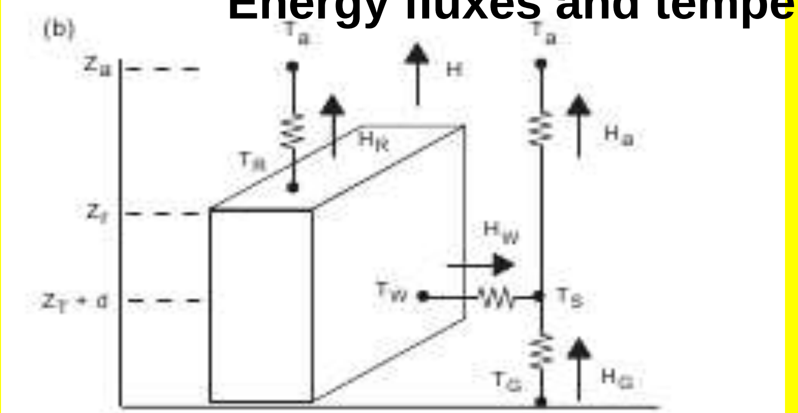
- Eulerian chemical transport model (ENVIRON Corp.)
- http://www.camx.com
- Meteorology from RegCM
- Chemistry schemes: CB-IV+Aerosols
- IC – clean conditions (background)
- BC – provided by 50km x 50km runs
- Emissions – EMEP (Europe, 50km) via TNO emission (10km) or local databases, biogenic emissions of isoprene and monoterpenes by the model

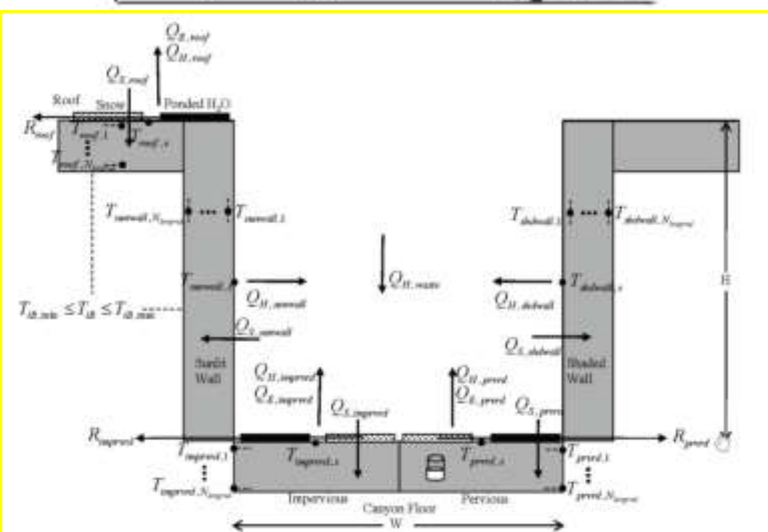
## CLWRF, WRF-Chem - urbanization

# 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:**




$T_a$ - 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)

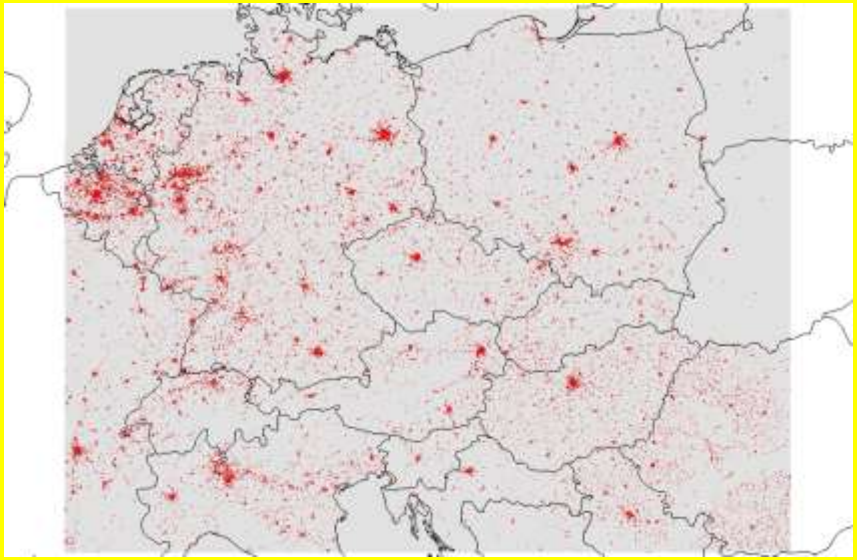
- Coupled online trough the RegCM's surface model BATS with subgrid surface treatment
- Two “urban” landuse categories defined “urban”/”suburban” - landuse created from Corine and GLC2000 (where Corine is not available) database
- SLUCM is called by BATS when it finds subgrid boxes with “urban”/”suburban” 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.

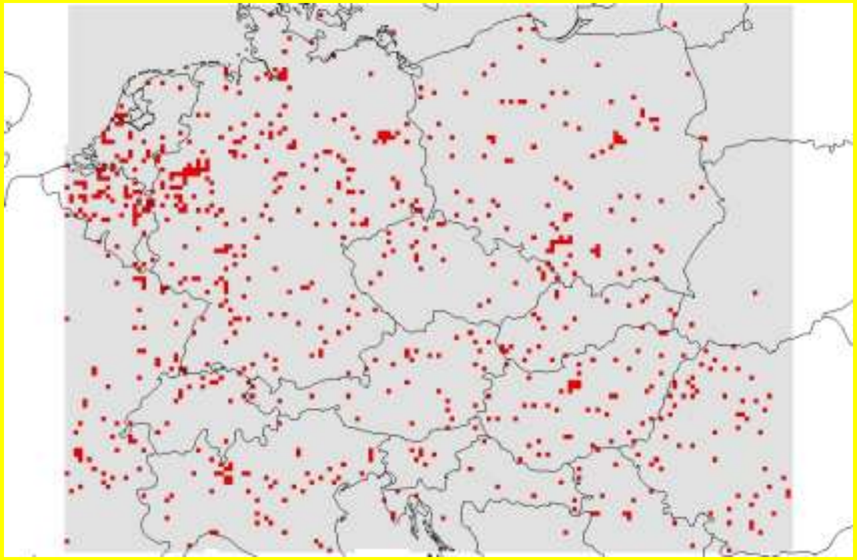
# RegCM4/SLUCM tests and selected results

- Eurpean domain – 10 km x 10 km (160 x 120), for BATS, 2 km x 2 km is used for SUB-BATS.
- Runs
  - NOURBAN – the run without urban canopy treatment (no urbane surface categories recognized)
  - SLUCM – run using the new SLUCM model.
- Summer impact on temperature and specific humidity at 2m, on PBL height and wind velocity studied
- 90% statistical significance in shaded areas

# Urban land use categories

**SUB-BATS, 2 km resolution** **BATS, 10 km resolution**





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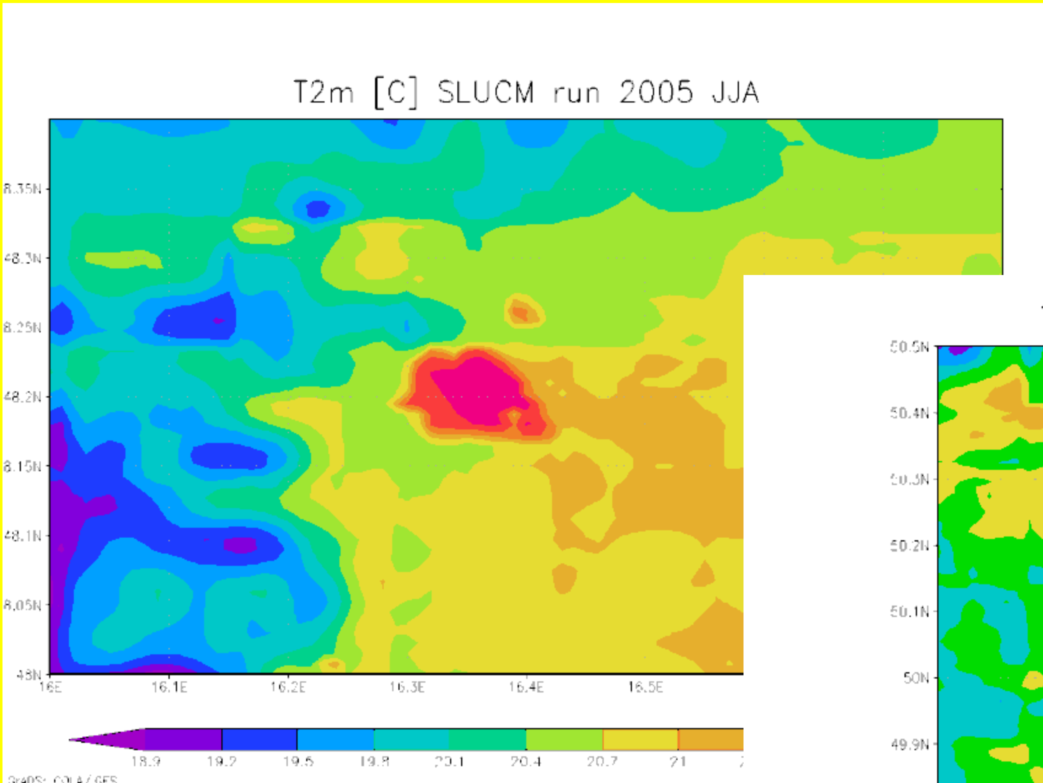
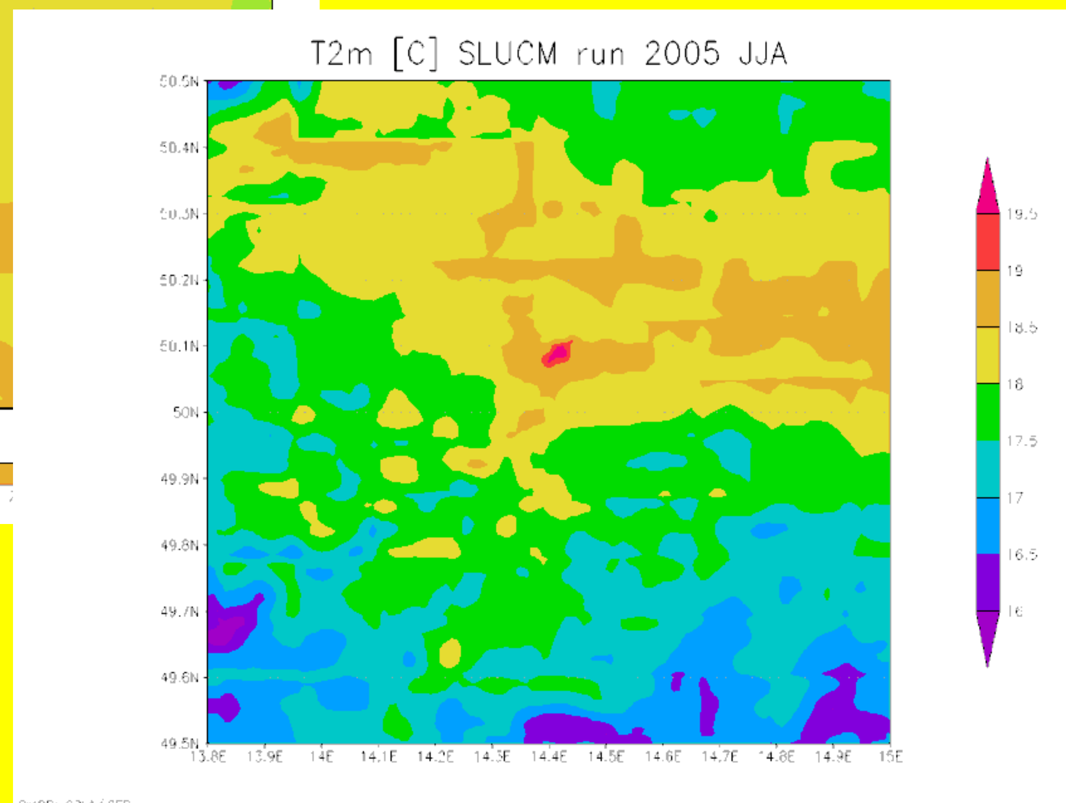
# Urban heat island

## Vienna

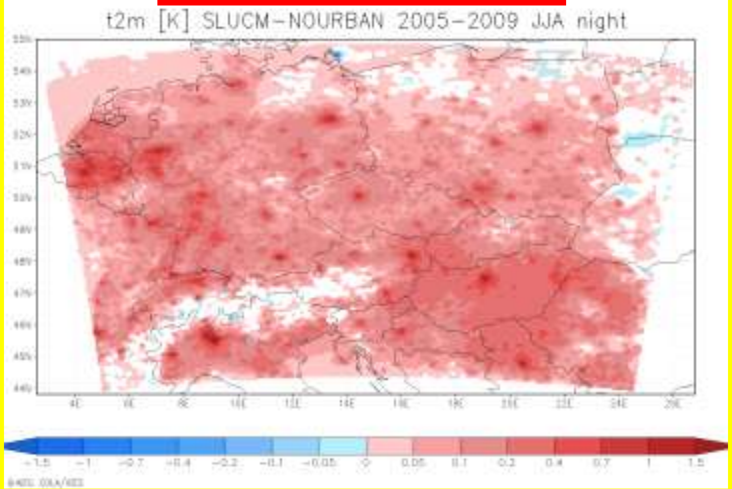



## Prague

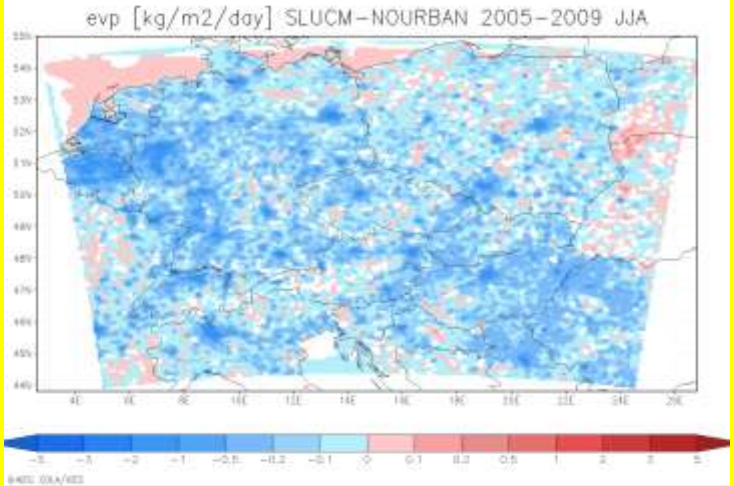


# SLUCM – NOURBAN 2005-2009, summer

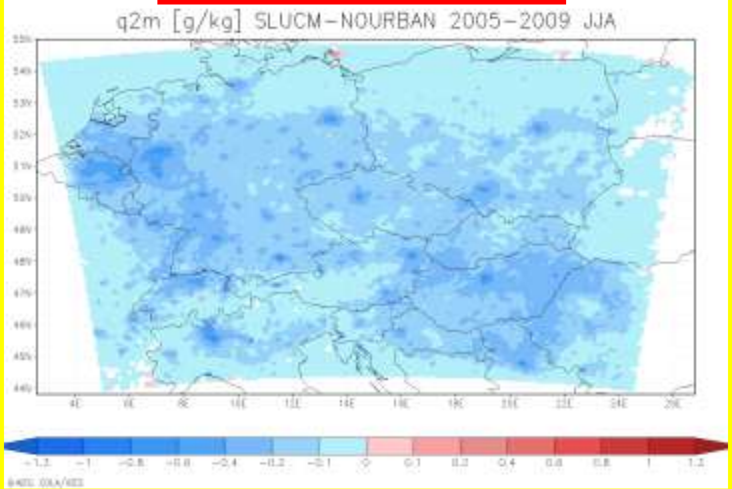
night temperature



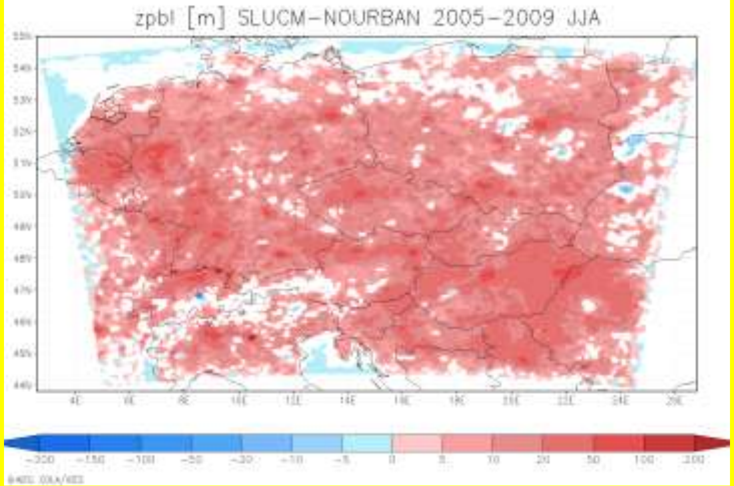

evaporation




humidity




PBL

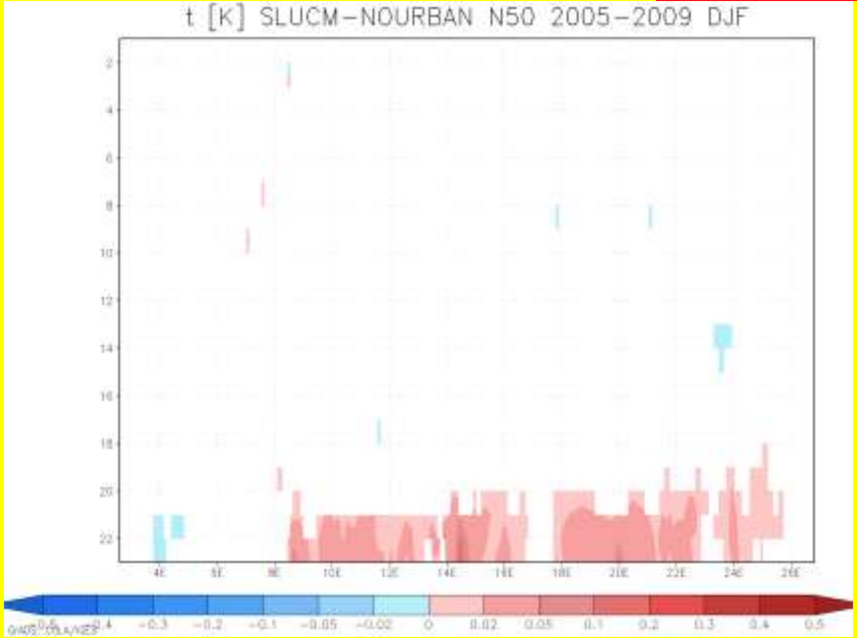


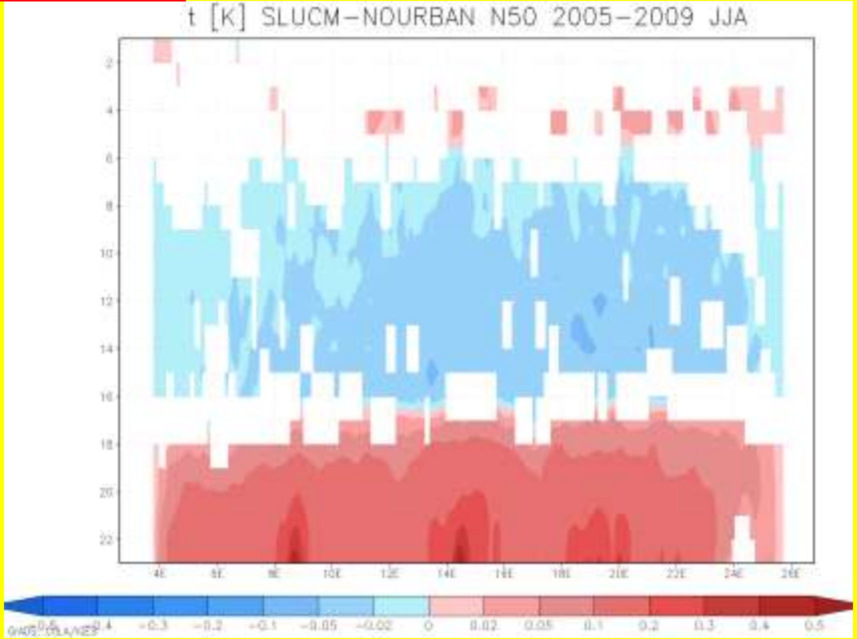
# SLUCM – NOURBAN 2005-2009 vertical cross-section at 50N

**winter**

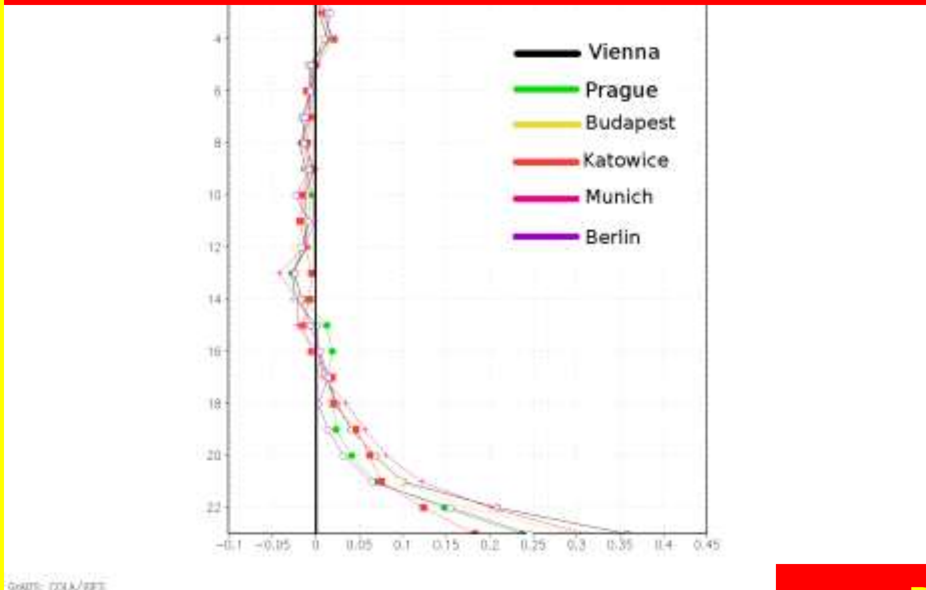
**summer**

temperature

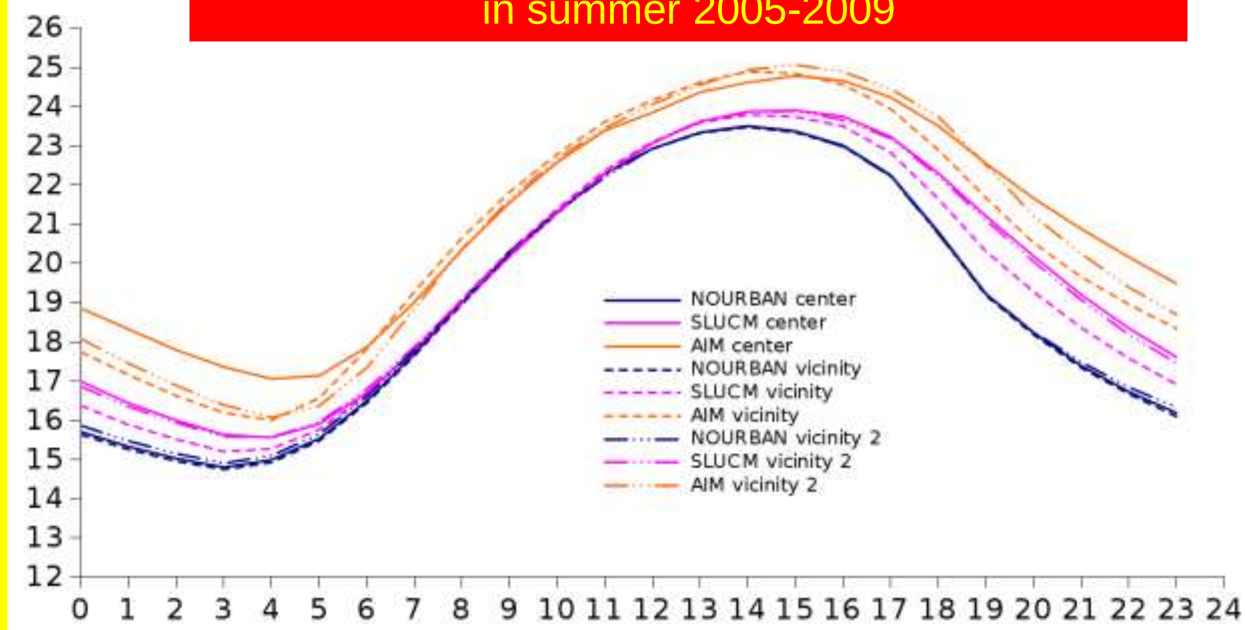


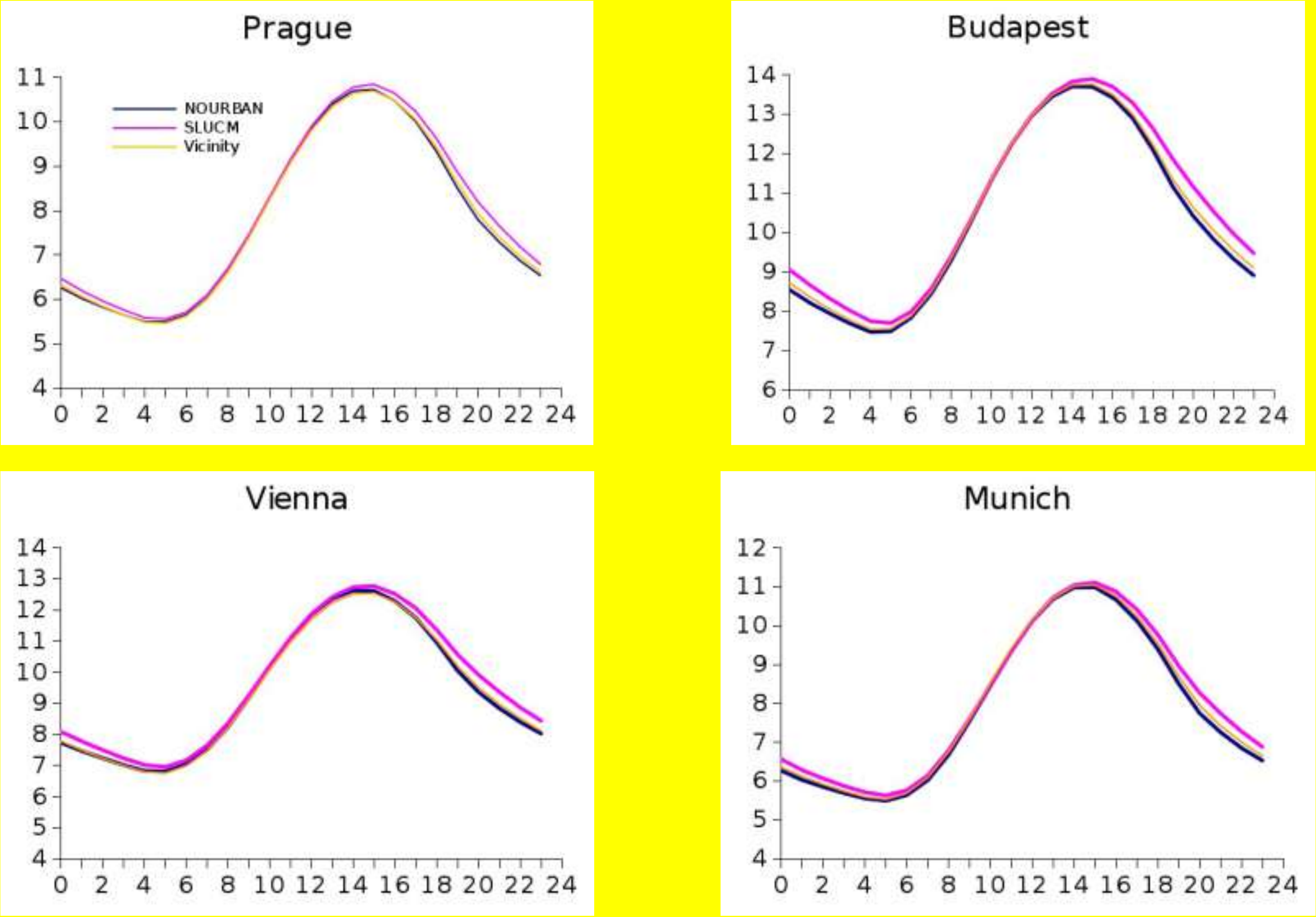
# Vertical profile of temperature changes over selected cities



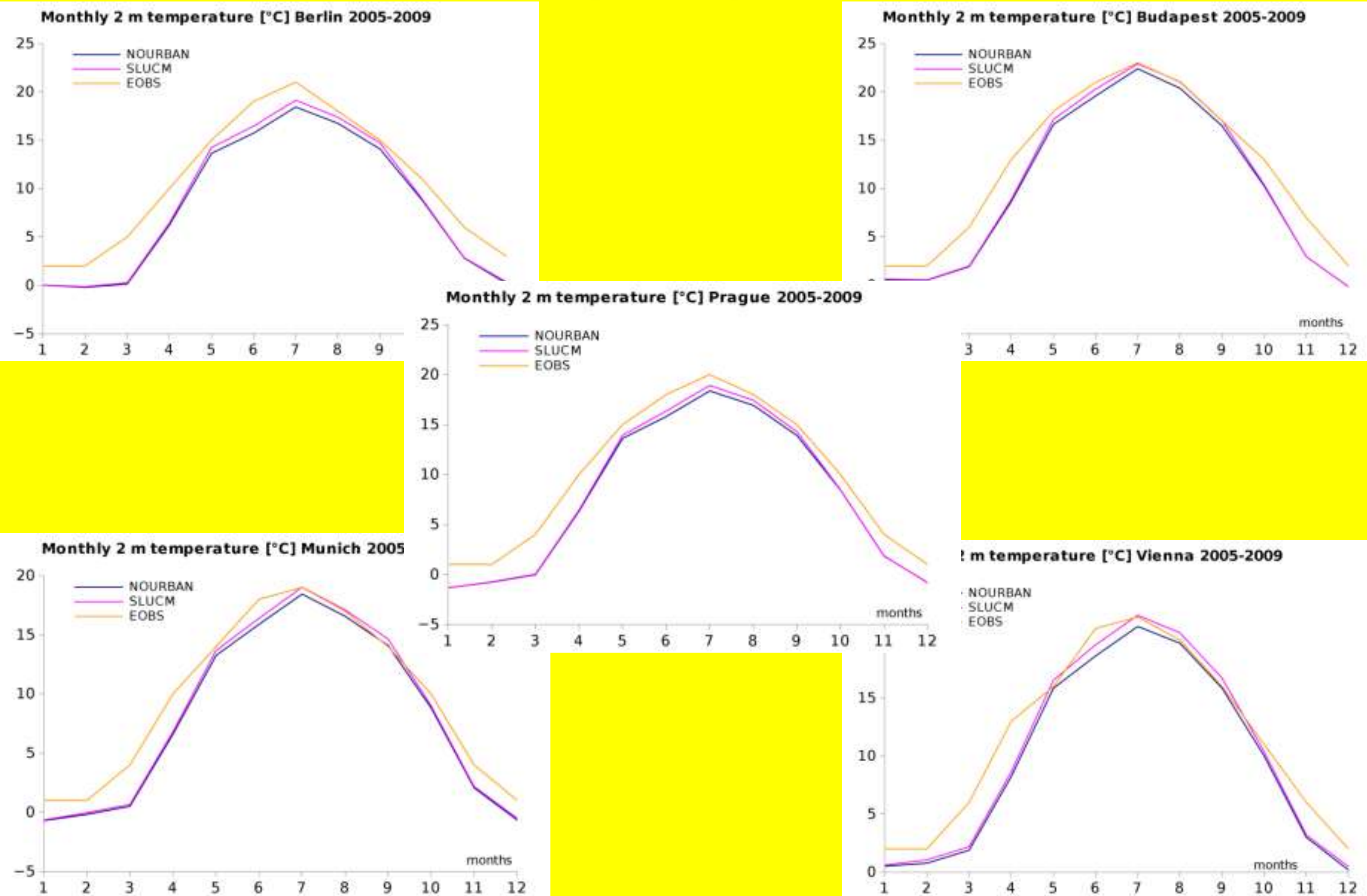

# Daily course of temperature for Prague in summer 2005-2009



# SLUCM – NOURBAN 2005-2009 and vicinity in diurnal variation



# SLUCM – NOURBAN 2005-2009 and observations in annual course

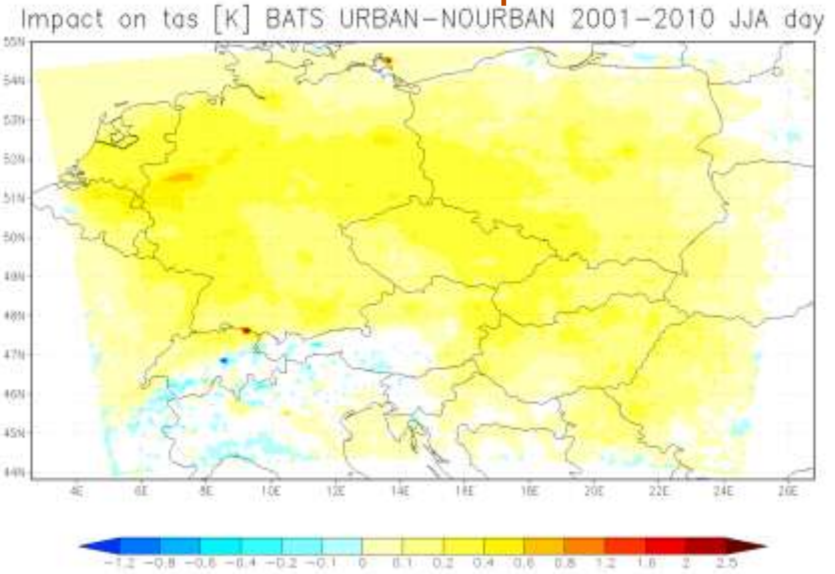


# BATS - SLUCM

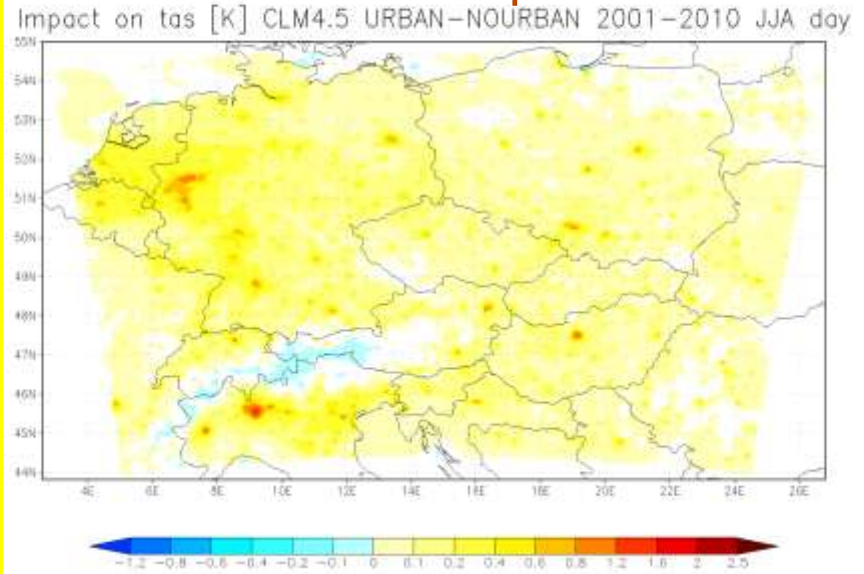
# CLM4.5 - CLMU

**Daytime**

**Near surface temperature**

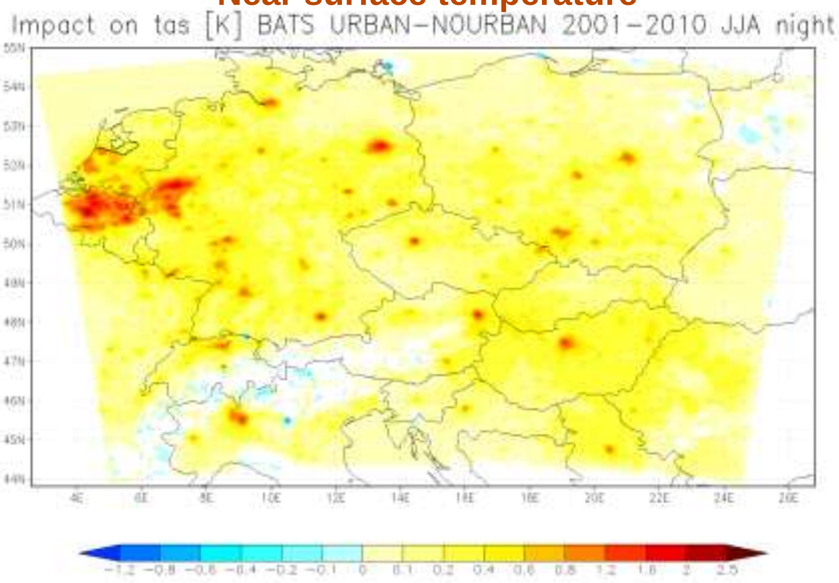



**Near surface temperature**

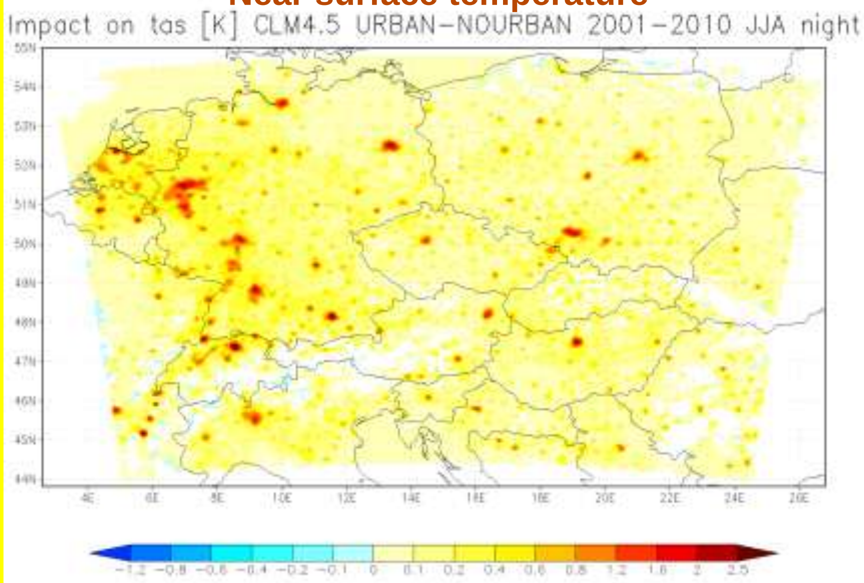



**Nighttime**

**Near surface temperature**




**Near surface temperature**



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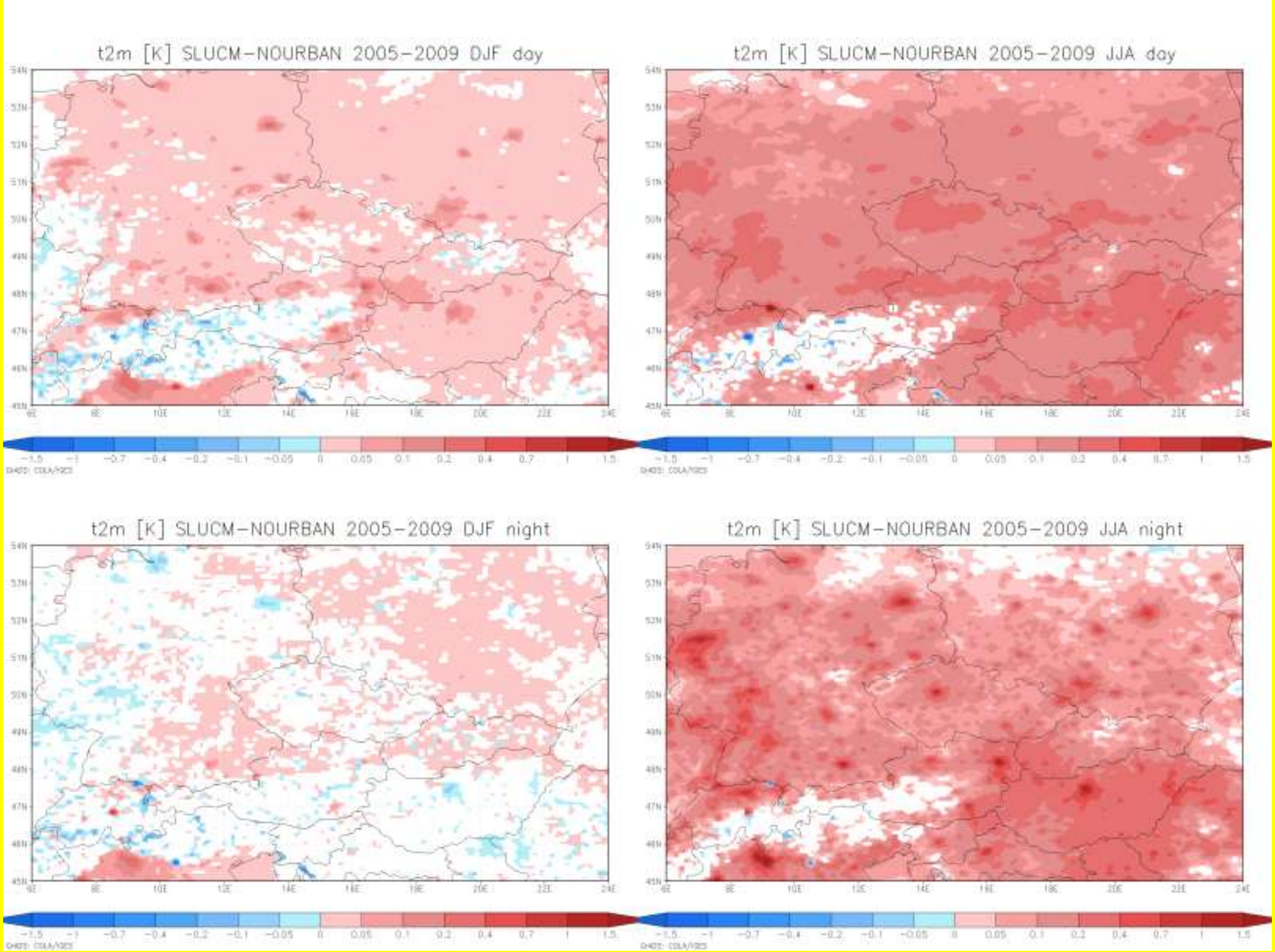
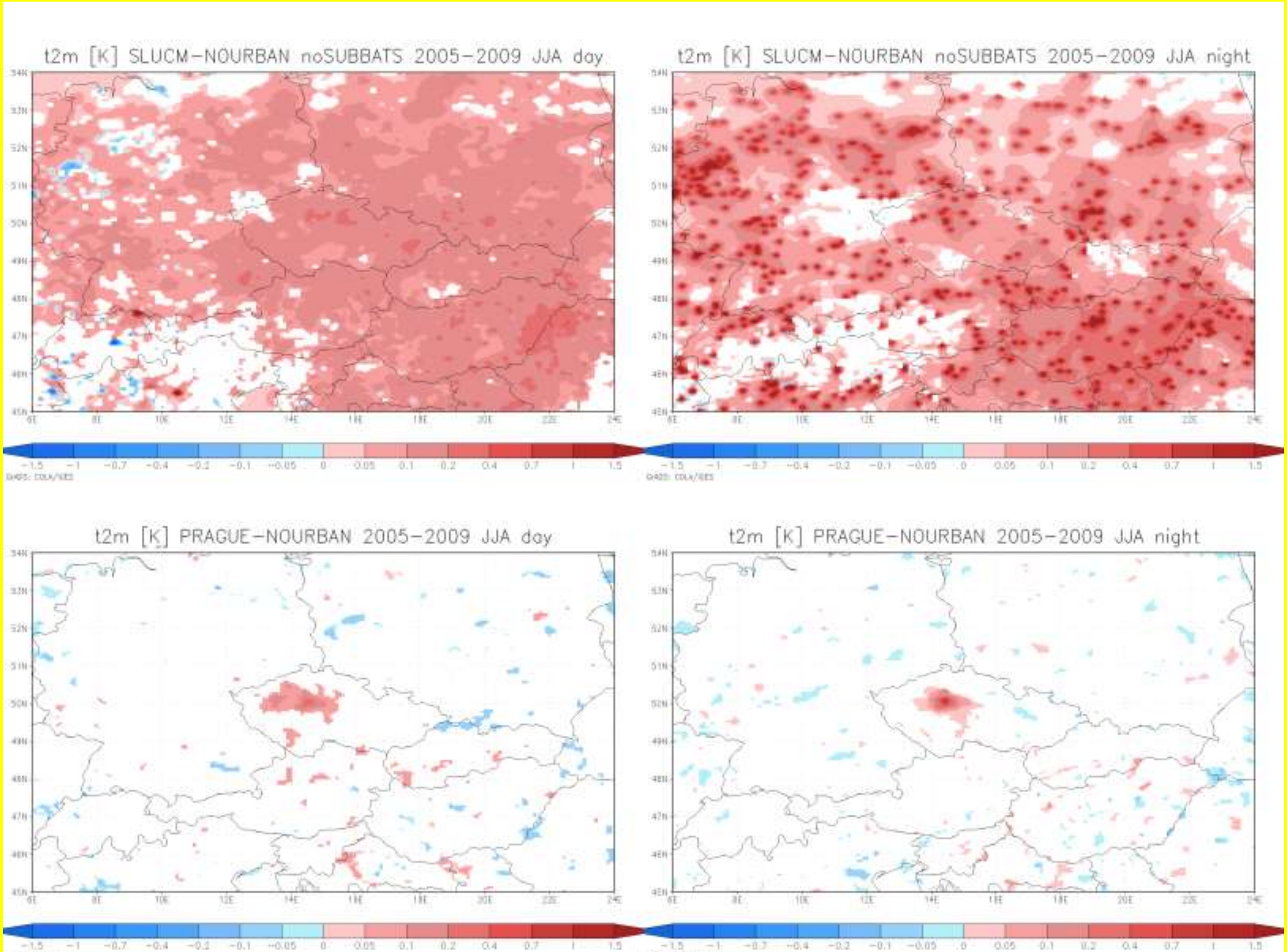
# Resolution effects tests



# Resolution effects tests



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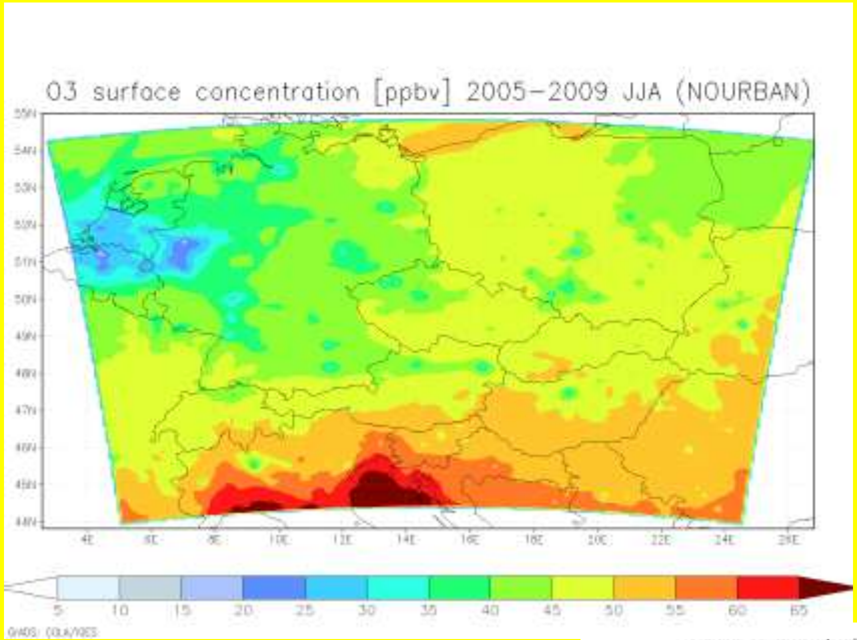
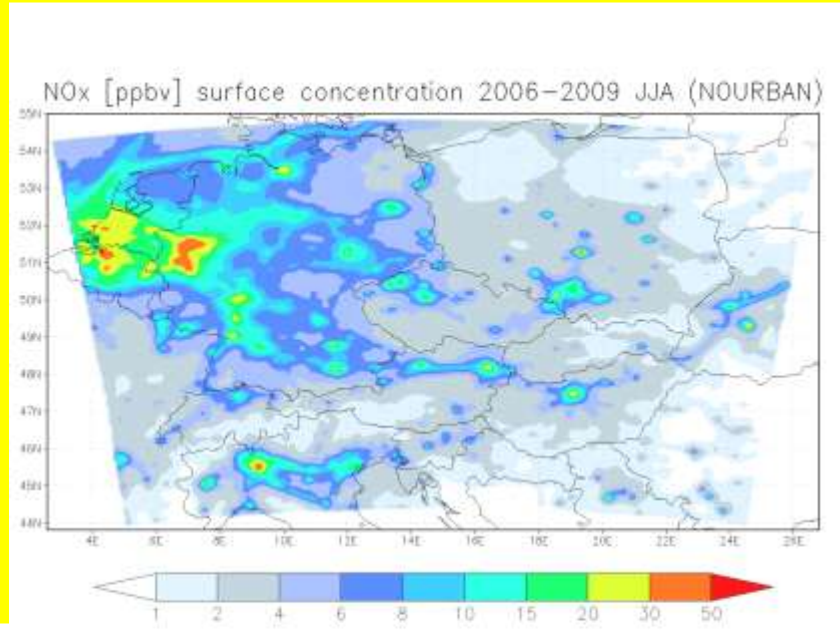
# Air quality, 2005-2009, summer
# NOURBAN

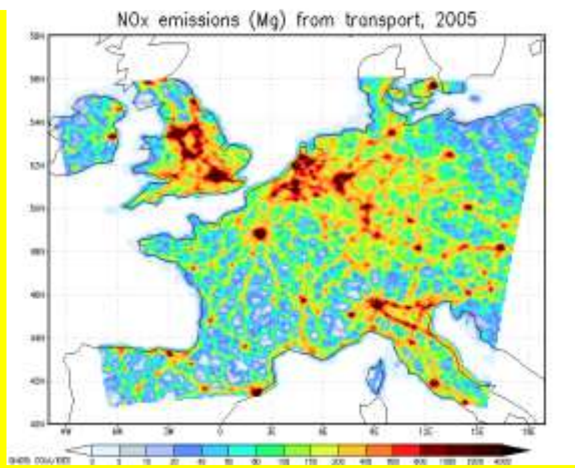
**$O_3$ surface concentration**



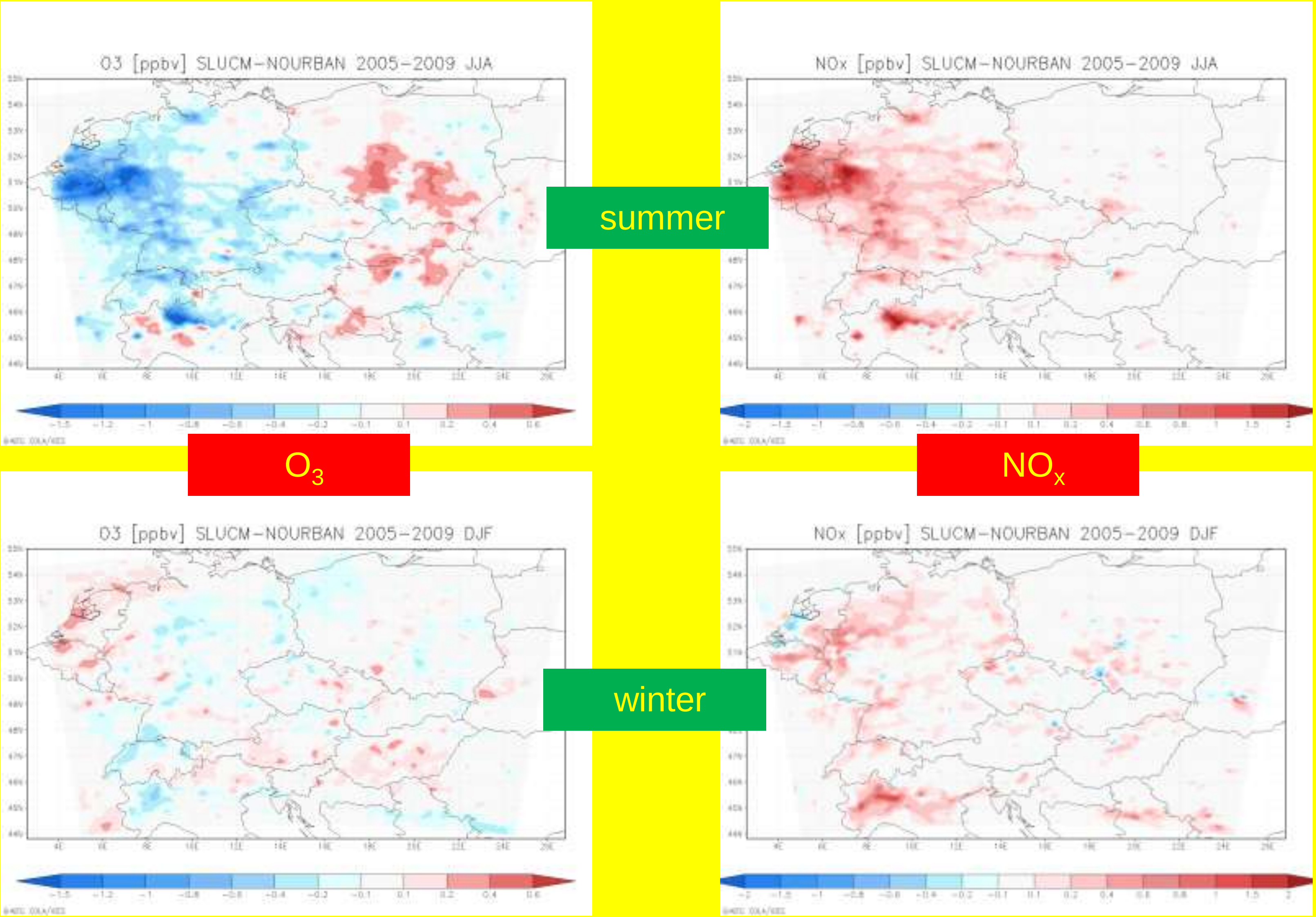

**$NO_x$ surface concentration**




**MEGAPOLI TNO**
**$NO_x$ emissions**

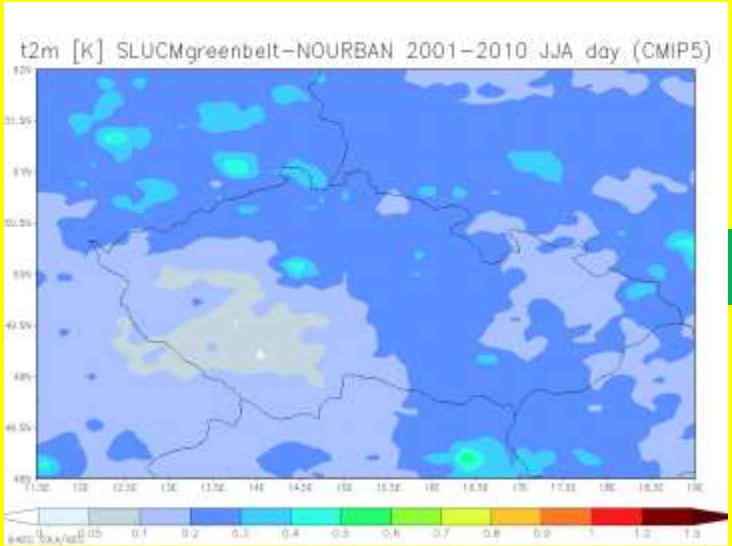


# Air quality, 2005-2009, urban effect

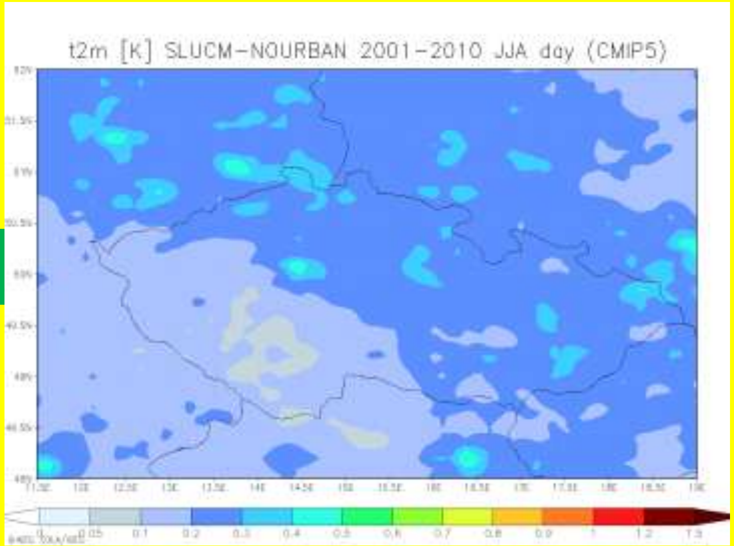



For more details and effect of urban emissions see P65 (Huszar et al.)

# Urban planning applications

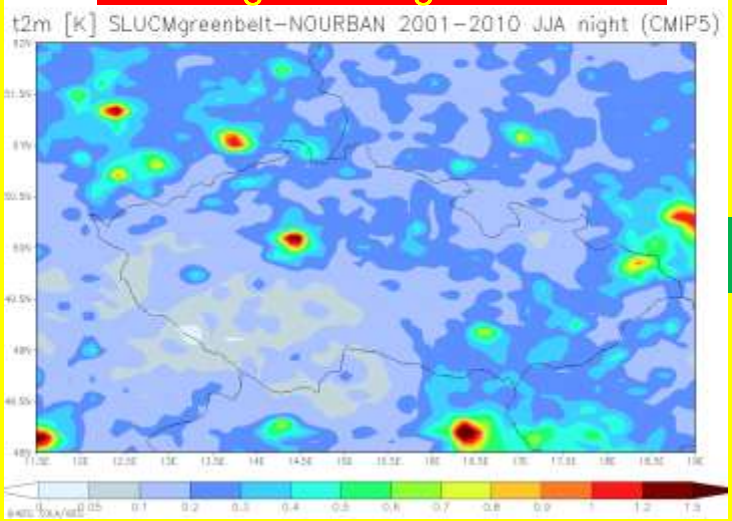



day

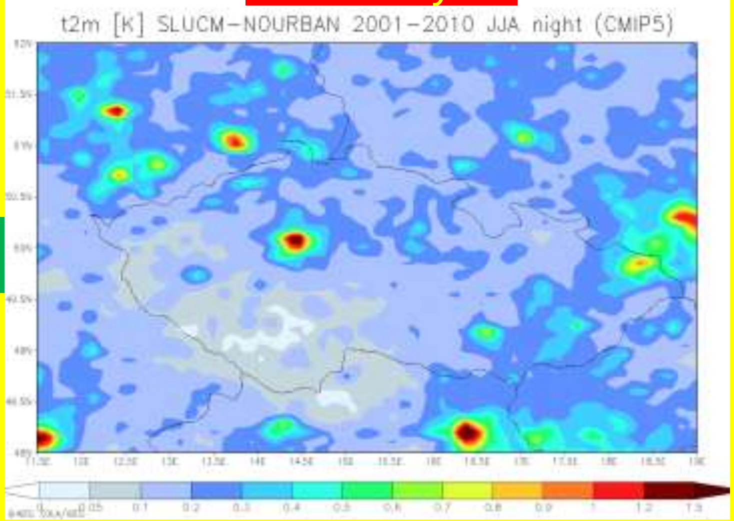



Prague with green belt

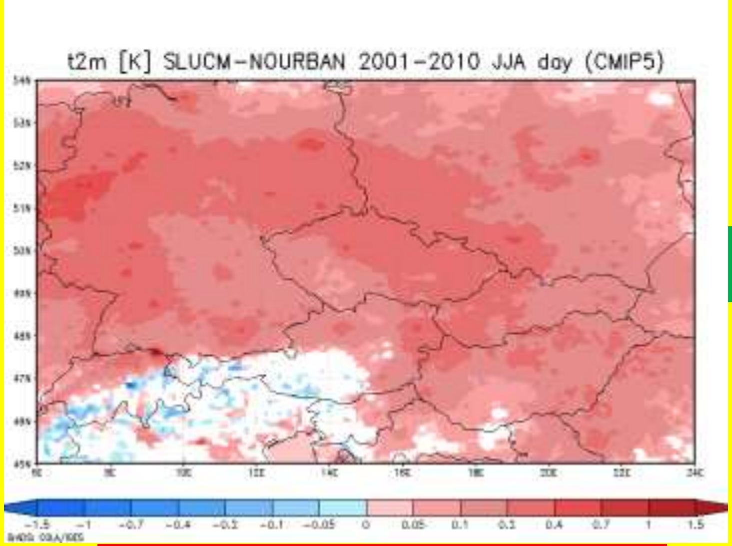
full city



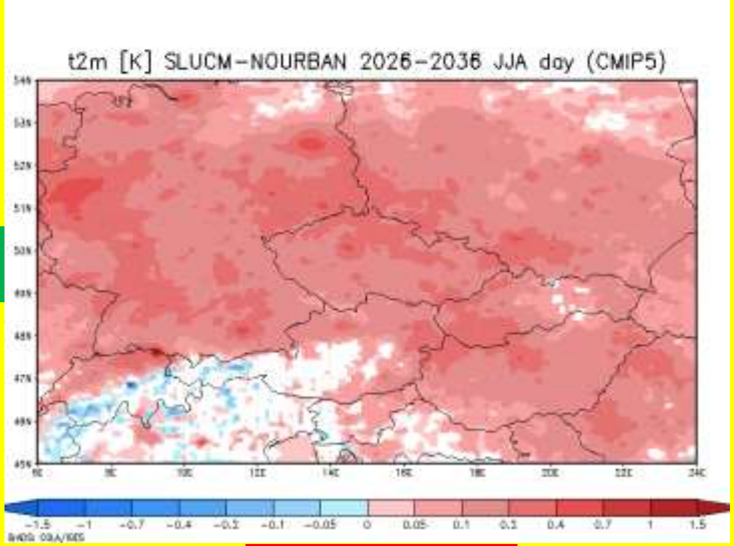

night



# Climate change study

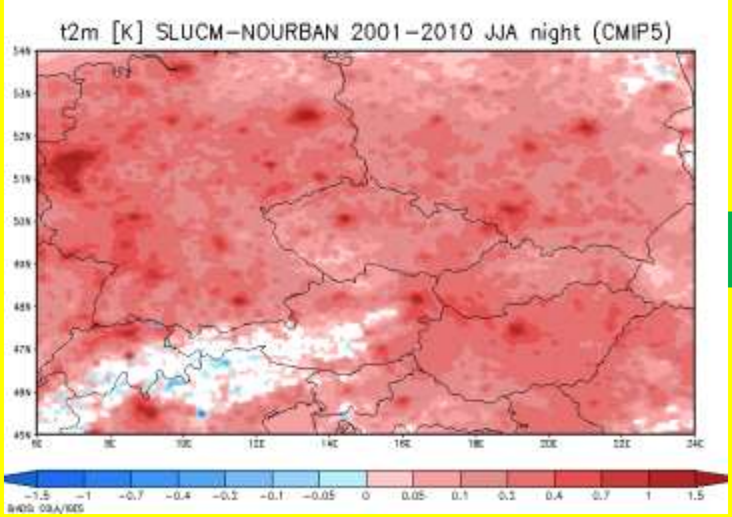



day

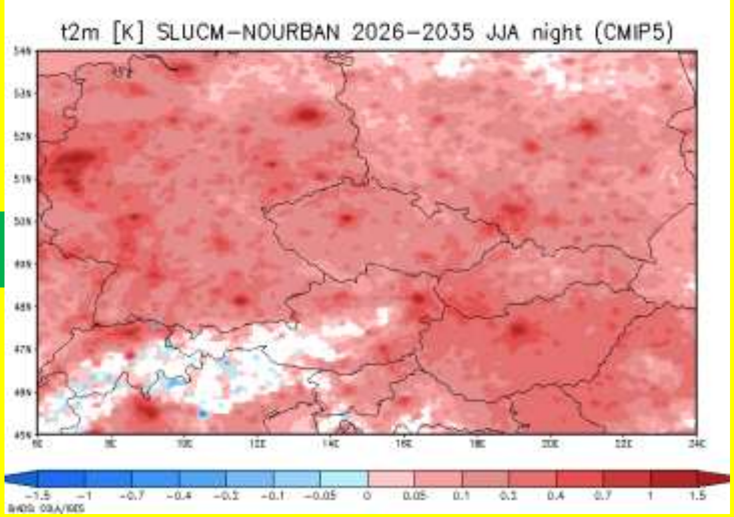



last decade

near future




night



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# 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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# Acknowledgement

The work performed under support by UHI project "Devel... ...d
Application of Mitigation and Adaptation Strategies a... ...for
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framework of EC Operation Programme C... ...e (3CE292P3),
using the previous development achi... ...EC FP6 STREP CECILIA
and EC FP6 IP QUANTIFY, late... ...ort by EC FP7 Project
MEGAPOLI (Megacities an... ...ot-spots air quality and climate),
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Soci... ...amework of Research Plan of MSMT under No. MSM
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THANKS FOR YOUR ATTENTION !

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