TEPELNÝ OSTROV MĚSTA A KLIMATICKÁ ZMĚNA

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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

Europe:
- 2008 - 73% of the population in cities
- mid 21st 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.

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)
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
## Prague heat island

<table>
<thead>
<tr>
<th>period</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
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<tbody>
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<td>1961-2009</td>
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<td>2.3</td>
<td>2.2</td>
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<td>2.4</td>
<td>2.3</td>
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<td>1961-1990</td>
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<td>2.2</td>
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<td>2.2</td>
<td>2.1</td>
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<tr>
<td>1991-2009</td>
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<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
<td>2.4</td>
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<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
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<td>Difference new vs. standard</td>
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<td>0.05</td>
<td>0.11</td>
<td>0.17</td>
<td>0.31</td>
<td>0.38</td>
<td>0.40</td>
<td>0.34</td>
<td>0.23</td>
<td>0.20</td>
<td>0.07</td>
<td>0.02</td>
<td>0.10</td>
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</tbody>
</table>

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](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](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 through 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
Daytime

Nighttime
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Resolution effects tests
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Air quality, 2005-2009, summer

NOURBAN

O₃ surface concentration

NOₓ surface concentration

MEGAPOLI TNO

NOₓ emissions
Air quality, 2005-2009, urban effect

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

Prague with green belt

full city

day

night
Climate change study

last decade

day

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 nighttime
• 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
Acknowledgement

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THANKS FOR YOUR ATTENTION!