Modeling of the Urban Heat Island using WRF comparing different urban parameterization schemes –
A preparation study for Air Chemistry Modeling

Joachim Fallmann, joachim.fallmann@kit.edu
Stefan Emeis, stefan.emeis@kit.edu
Peter Suppan, peter.suppan@kit.edu

1Institute of Meteorology and Climate Research (IMK-IFU) of the Karlsruhe Institute of Technology (KIT), Campus Alpine, Germany
Overview

- **CENTRAL Europe Project:**
  
  "Development and application of mitigation and adaptation strategies counteracting the Urban Heat Island (UHI)." (European Territorial Cooperation Objective CENTRAL EUROPE Programme - 3CE292P3)

- **Mesoscale numerical modeling** of the UHI for selected Region:
  - Urbanization of WRF → Selection of most suited urbanization scheme

- **Validation** of modeling results through measurement data

- **Simulation** of simple mitigation strategies
  - Change of land surface properties

- UHI triggers **secondary circulation**
  - Urban-Rural interaction
  - Air Quality assessment

- **Assistance to Urban Planning** (local stakeholders, City of Stuttgart)
Model approach

- Choosing the WRF/urban parameterization scheme suitable for the modeling approach (coupled with Noah LSM)
  - Single Layer Urban Canopy Model SLUCM (KUSAKA, 2001)
  - Building Energy Parameterization BEP (MARTILLI, 2002)

- Replace urban land use classes by natural vegetation
- Change albedo of urban surfaces
- Comparing temperature development under different scenarios

Fig. 1: Schematic of SLUCM (left) and multi-layer-BEP (right) (CHEN, 2011)
Fig. 2: Schematic of model domains (Source: EEA)

<table>
<thead>
<tr>
<th>Domain</th>
<th>D01</th>
<th>D02</th>
<th>D03</th>
</tr>
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<tbody>
<tr>
<td>Geographical input data</td>
<td>1km</td>
<td>1km</td>
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<tr>
<td>dx, dy</td>
<td>9</td>
<td>3</td>
<td>1</td>
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<tr>
<td>West-east [km]</td>
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<td>192</td>
<td>60</td>
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<tr>
<td>North-south [km]</td>
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<td>156</td>
<td>48</td>
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<tr>
<td>Total [km²]</td>
<td>118422</td>
<td>31680</td>
<td>2880</td>
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</table>
WRF Configuration

- WRF Single Moment 6-class scheme
- RRTM long wave radiation
- Dudhia short wave radiation
- Eta similarity surface layer
- NOAH Land Surface Model
- Mellor-Yamada-Janjic (MYJ) boundary layer scheme
- Kain-Fritsch scheme for cumulus parameterization (1st domain)
- Building-Energy parameterization (BEP)
Potential 2m-Temperature SLUCM vs. BEP

- test case Aug 11th – Aug 18th 2003, snapshot Aug 13th 2003 18:00
- urban parameterization applied for 3rd domain

Fig. 3: Modeled potential temperature 2m 18:00 using SLUCM (left) and BEP (right- anthropogenic heating (cooling) included)
Potential 2m-Temperature SLUCM vs. BEP

➤ test case Aug 11th – Aug 18th 2003, snapshot Aug 13th 2003 0:00

Fig. 4: Modeled potential temperature 2m 0:00 using SLUCM (left) and BEP (right- anthropogenic heating (cooling) included)
Validation against ground measurements

Fig. 5: Comparison of modeled 2m-temperature UCM (green) and BEP (blue) with measured value (red) for central urban location

Fig. 6: Scatter plot for BEP approach (left) and SLUCM (right)
Results

Fig. 7: Urban Heat Island Intensity for Urban and rural location
Land use change to test urban effects

Urban_On – Urban_Off = ‘Zero Case’

Fig. 8: Replacing ‘urban pixel’ by natural vegetation (deciduous forest, grassland)

→ 41% urban surface replaced by vegetation
Fig. 11: T2-development after changing surface properties over transect (right) in 3rd domain.
Fig. 10: T2-development after changing surface properties over transect (right) in 3rd domain.
Potential 2m-Temperature – W-E Transect; Aug 14th 2003 00:00 UTC

Anthropogenic heating 60-90 W/m²

Fig. 12: T2-development after changing surface properties over transect (right) in 3rd domain
Perspective – Air Quality Modeling

- biogenic emissions of surroundings getting mixed with urban pollutants
- additional air quality problems next to rising temperatures
- local circulation caused by UHI-formation – dispersions of aerosols
- Ozone formation correlates with temperature

Fig. 13: Cross Section through transect (right) for Aug 13th 2003 18:00

Fig. 14: Correlation between measured Ozone and modeled T2 m for period Aug 11th – 18th 2003
Thank you for your attention
Karlsruhe Institute of Technology (KIT) - Institute for Meteorology and Climate Research – Atmospheric Environmental Research (IMK-IFU) Garmisch- Partenkirchen (Germany)

Research Foci:

- Assessment of air quality and meteorological processes in **urban heat islands** + interaction with **surrounding regions**
- **Air quality** under **changing regional climate** conditions
- The role of **biogenic emissions** on the air quality in **urbanized and sensitive regions**
- **mitigation and adaptation strategies** to reduce air pollution and greenhouse gas emissions for **health impact** and **sociological assessment** studies in a changing global climate

Research Group: Regional Coupling of Ecosystem-Atmosphere-Processes

Methods:

- **measuring** methods and platforms (SODAR, Ceilometer, FTIR etc.)
- Measurement **campaigns**
- **numerical model systems** (WRF/chem, MM5, MCM)
- Regional scale **air quality modelling**
- Dynamical **downscaling** of global models
- Canopy scale **BVOC** measurements
- **Data fusion** from satellite, remote sensing, and in-situ data

Regions/ Projects:

- Santiago de Chile (“Risk Habitat Megacity”)  
- Mexico City  
- Alps (ALPNAP)  
- Augsburg (measurement site)  
- Beijing  
- Stuttgart (“CENTRAL EUROPE”)

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*Prof. Stefan Emeis*  
*stefan.emeis@kit.edu*  

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