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

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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)*

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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)

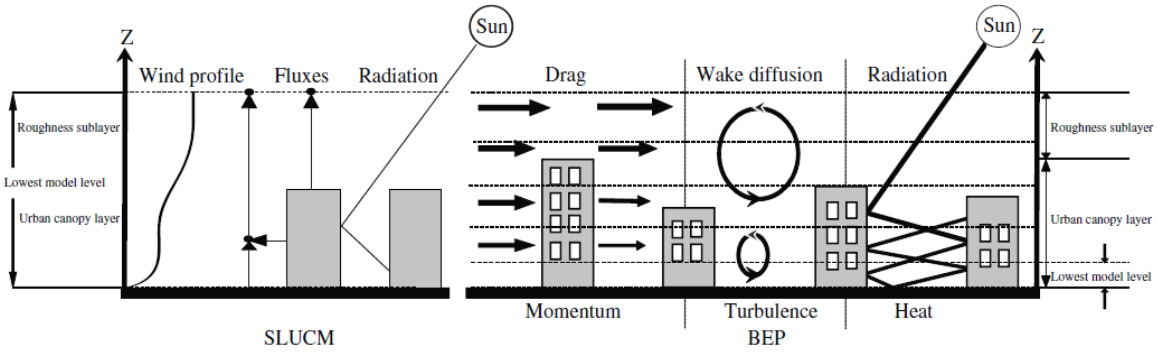

Fig. 1: Schematic of SLUCM (left) and multi-layer-BEP (right) (CHEN, 2011)

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

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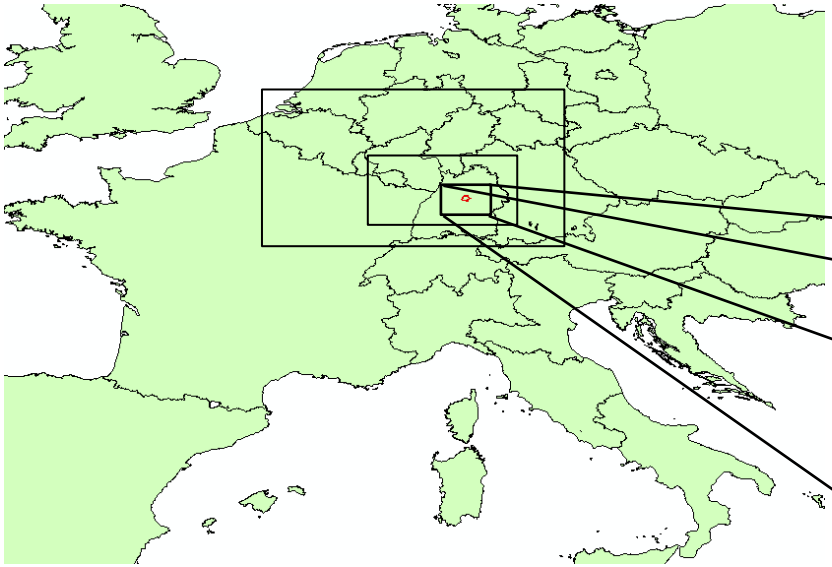
WRF Configuration



Meteorological driver:
ERA Interim 0.5° Reanalysis Data

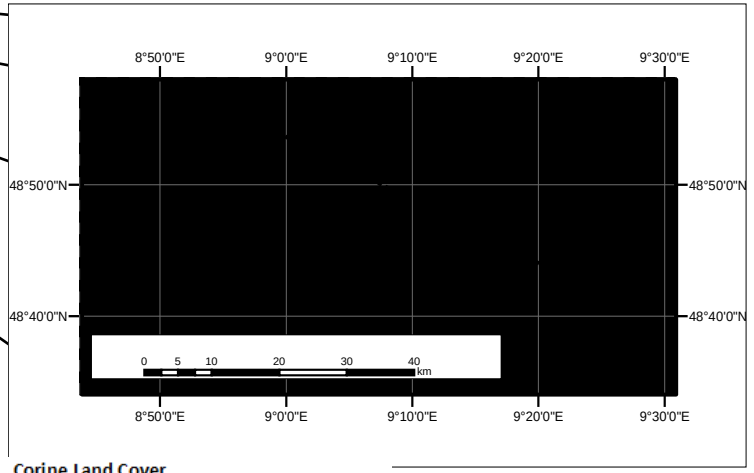
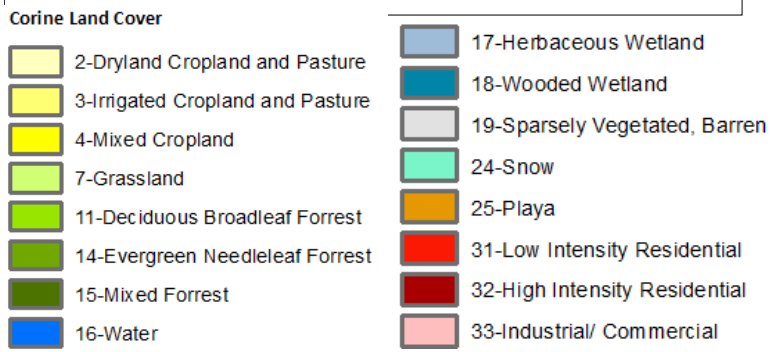


Fig. 2: Schematic of model domains (Source: EEA)

Domain	D01	D02	D03
Geographical input data	1km	1km	1km
dx, dy	9	3	1
West-east [km]	387	192	60
North-south [km]	306	156	48
Total [km²]	118422	31680	2880



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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)

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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

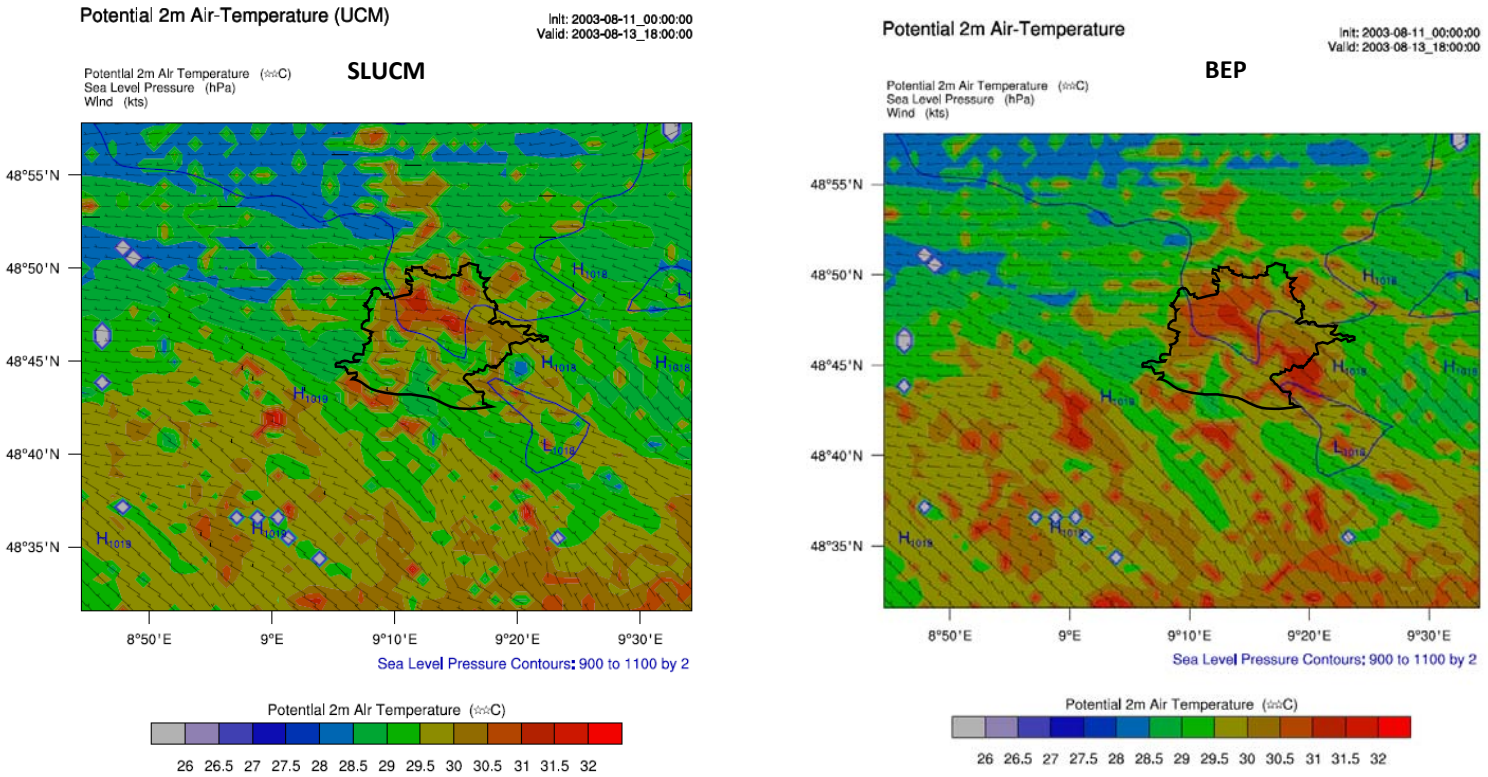

Fig. 3: Modeled potential temperature 2m 18:00 using SLUCM (left) and BEP (right- anthropogenic heating (cooling) included)

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Potential 2m-Temperature SLUCM vs. BEP

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

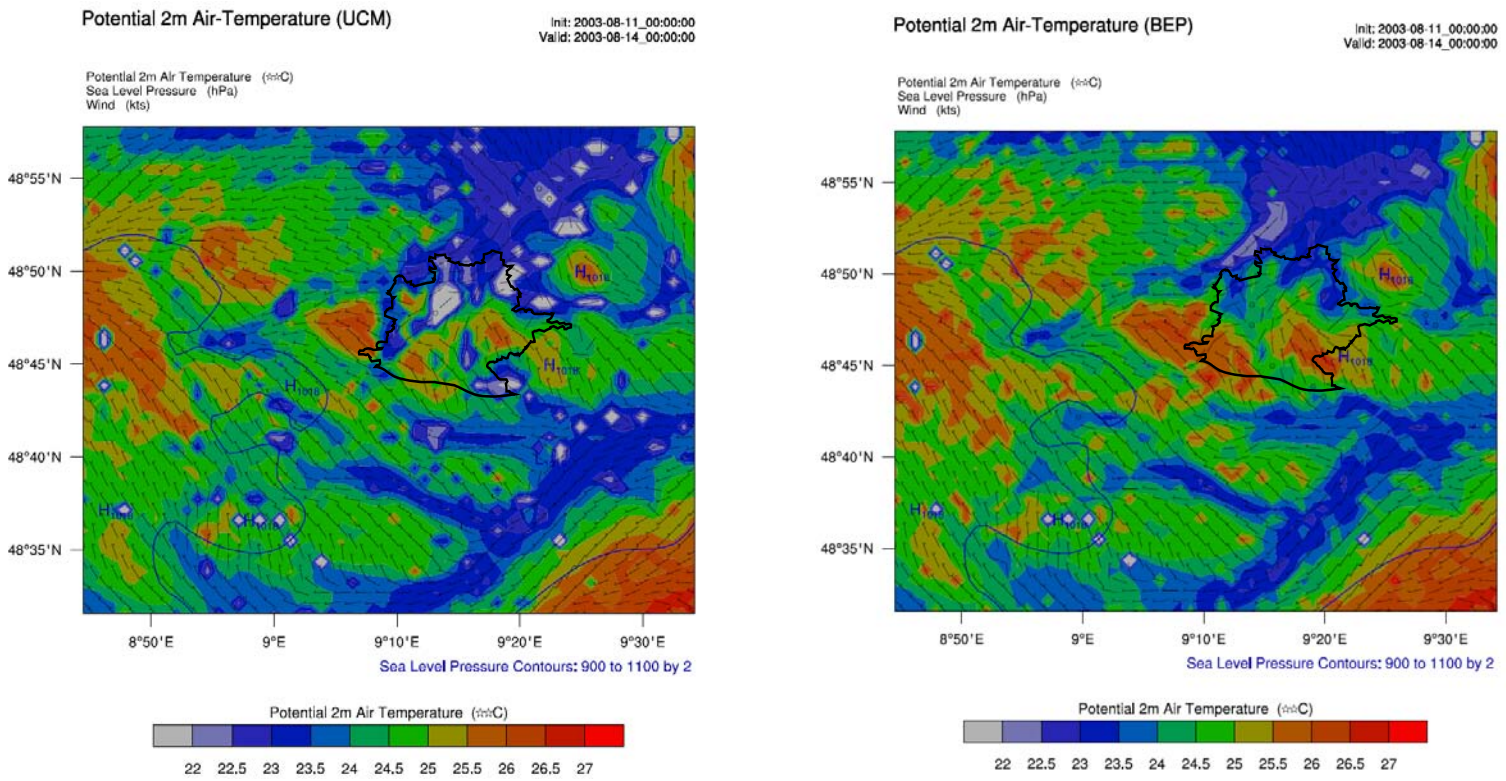

Fig. 4: Modeled potential temperature 2m 0:00 using SLUCM (left) and BEP (right- anthropogenic heating (cooling) included)

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Validation against ground measurements

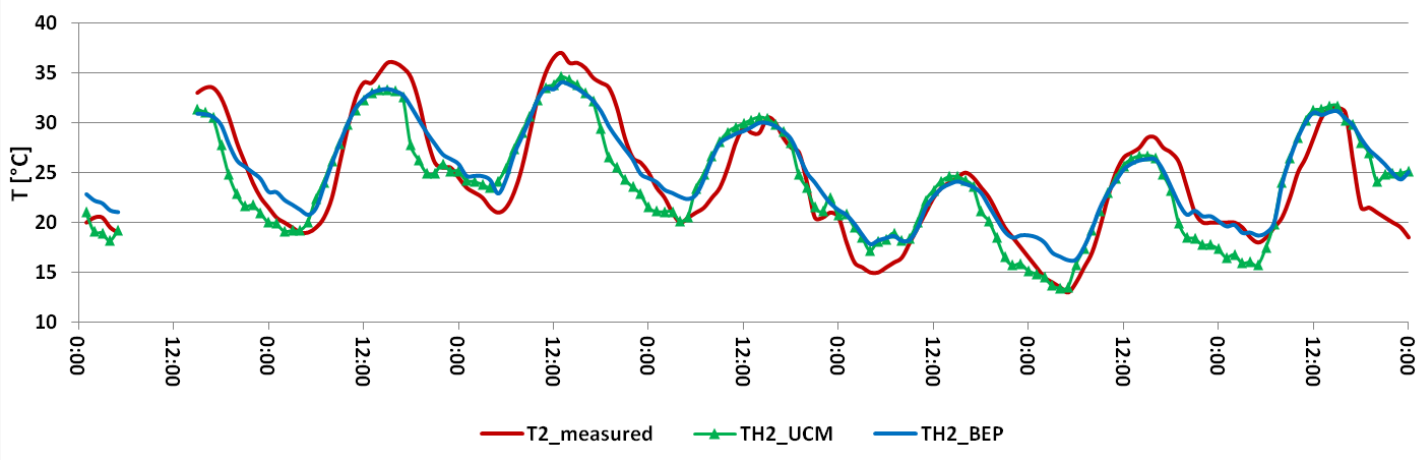

Fig. 5: Comparison of modeled 2m-temperature UCM (green) and BEP (blue) with measured value (red) for central urban location

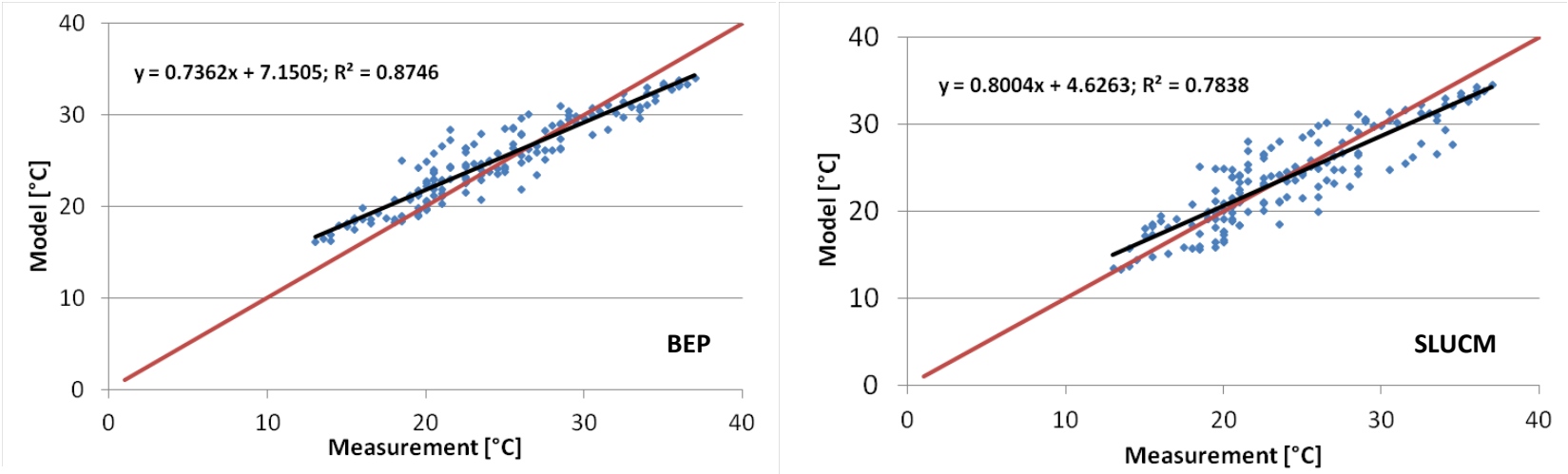

Fig. 6: Scatter plot for BEP approach (left) and SLUCM (right)

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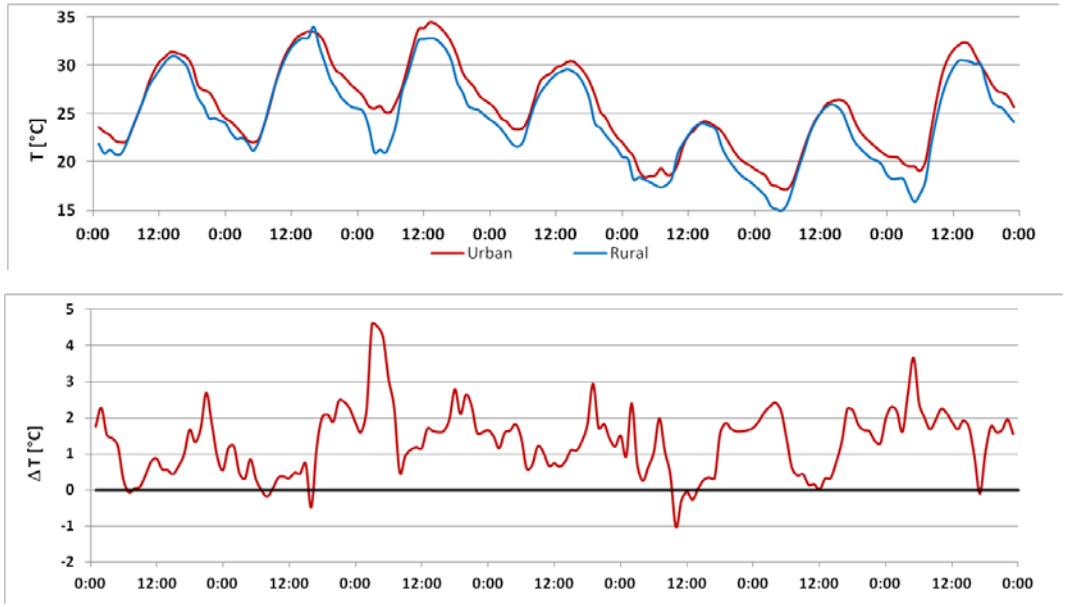
Results



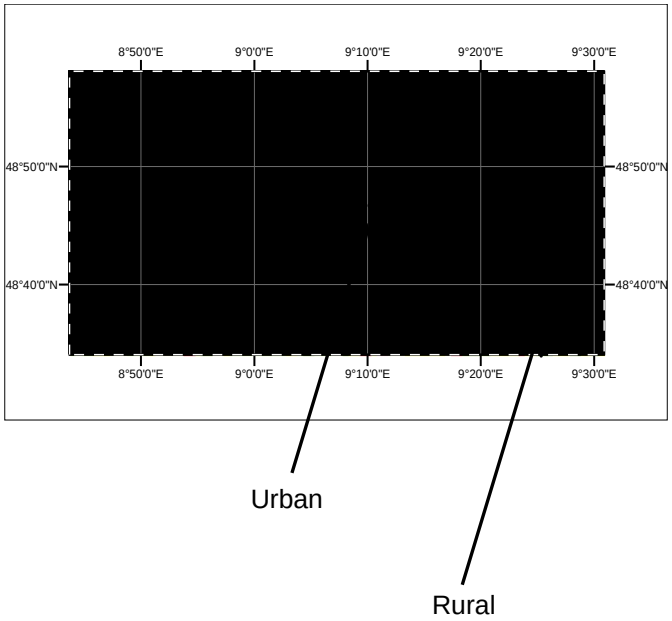


Fig. 7: Urban Heat Island Intensity for Urban and rural location

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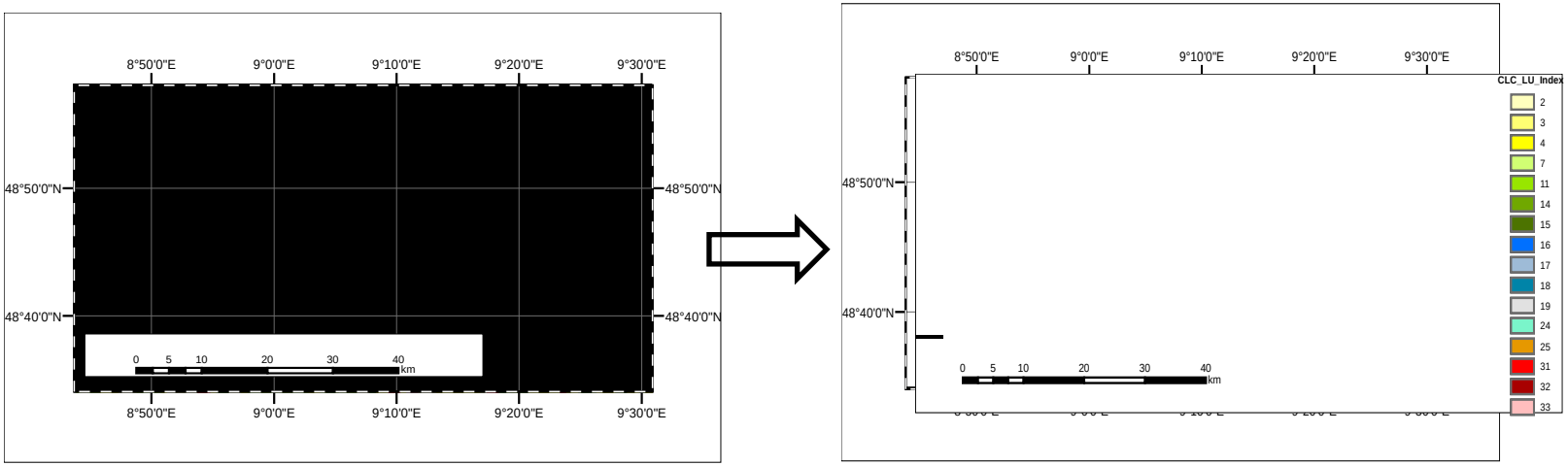
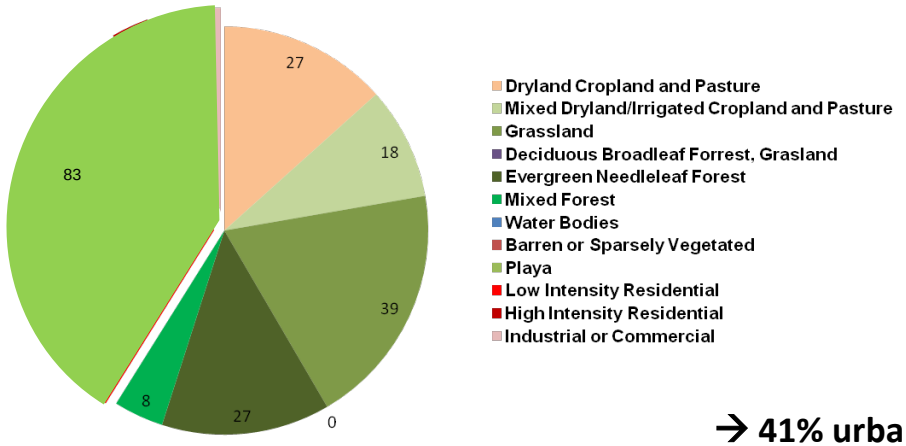
Land use change to test urban effects

Urban_On – Urban_Off = ‘Zero Case’





→ 41% urban surface replaced by vegetation

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

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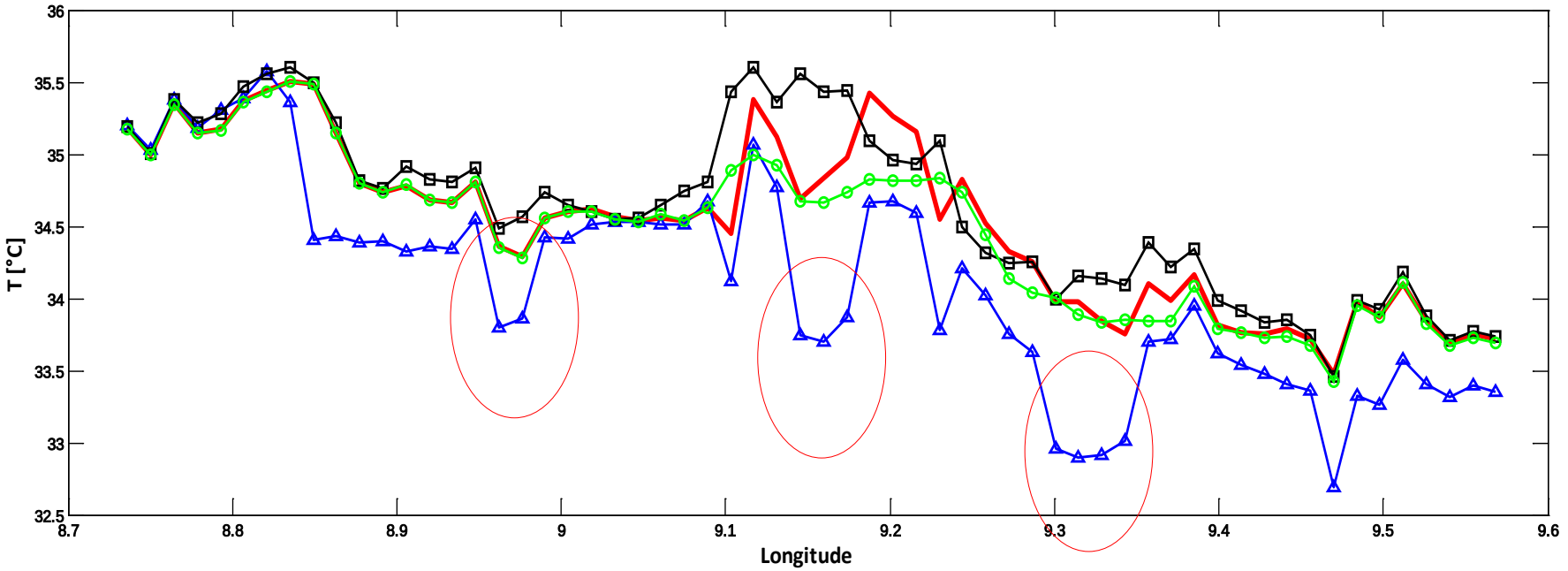
Potential 2m-Temperature – W-E Transect; Aug 13th 2003 12:00 UTC



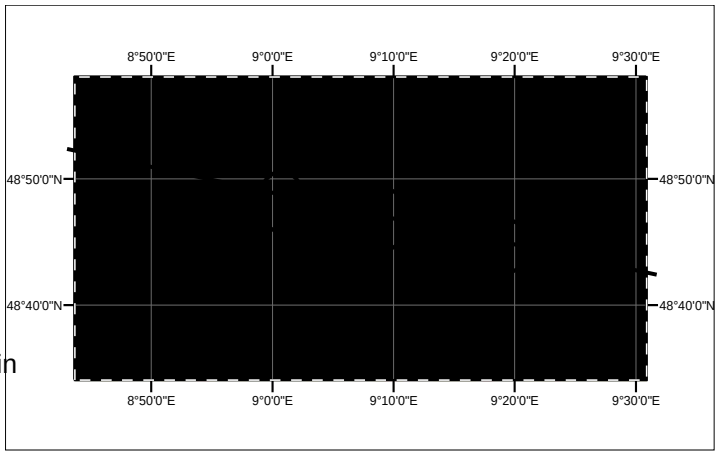


Fig. 11: T2-development after changing surface properties over transect (right) in 3rd domain

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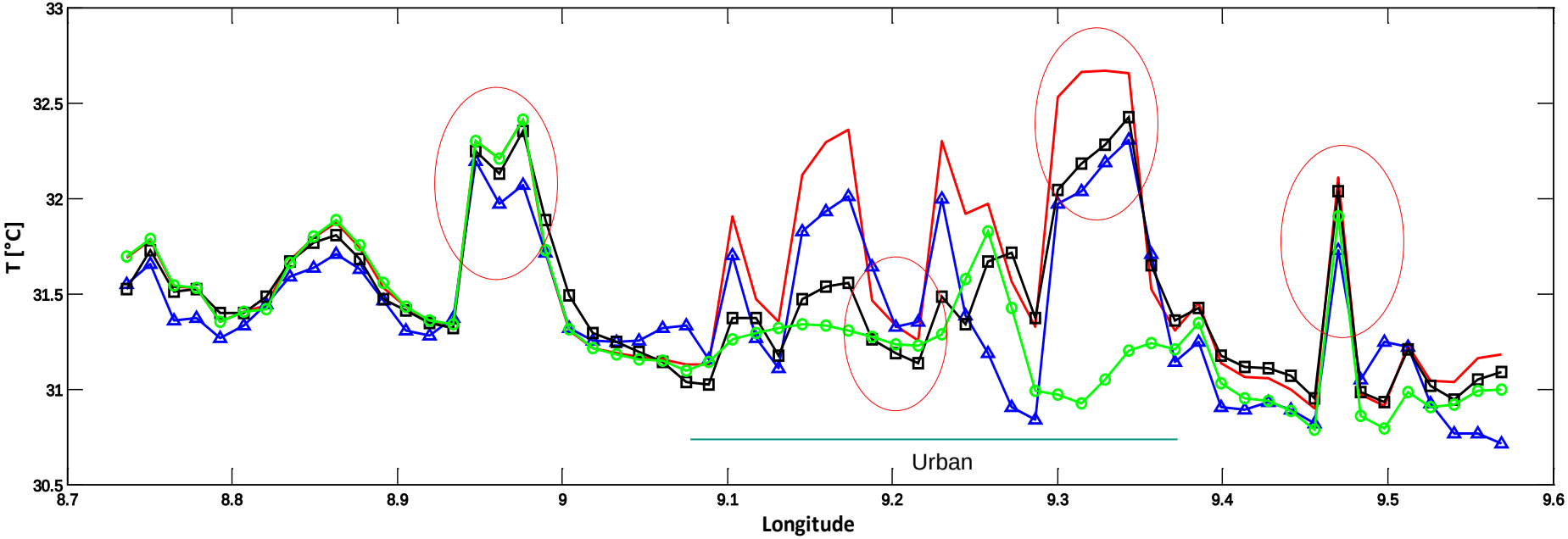
Potential 2m-Temperature – W-E Transect; Aug 13th 2003 18:00 UTC



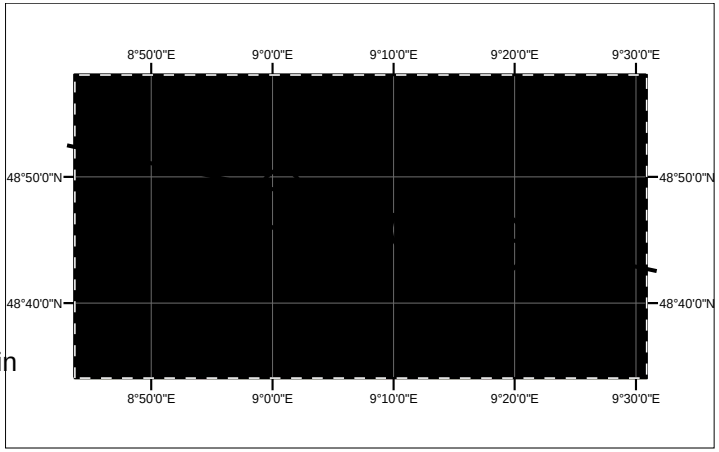


Fig. 10: T2-development after changing surface properties over transect (right) in 3rd domain

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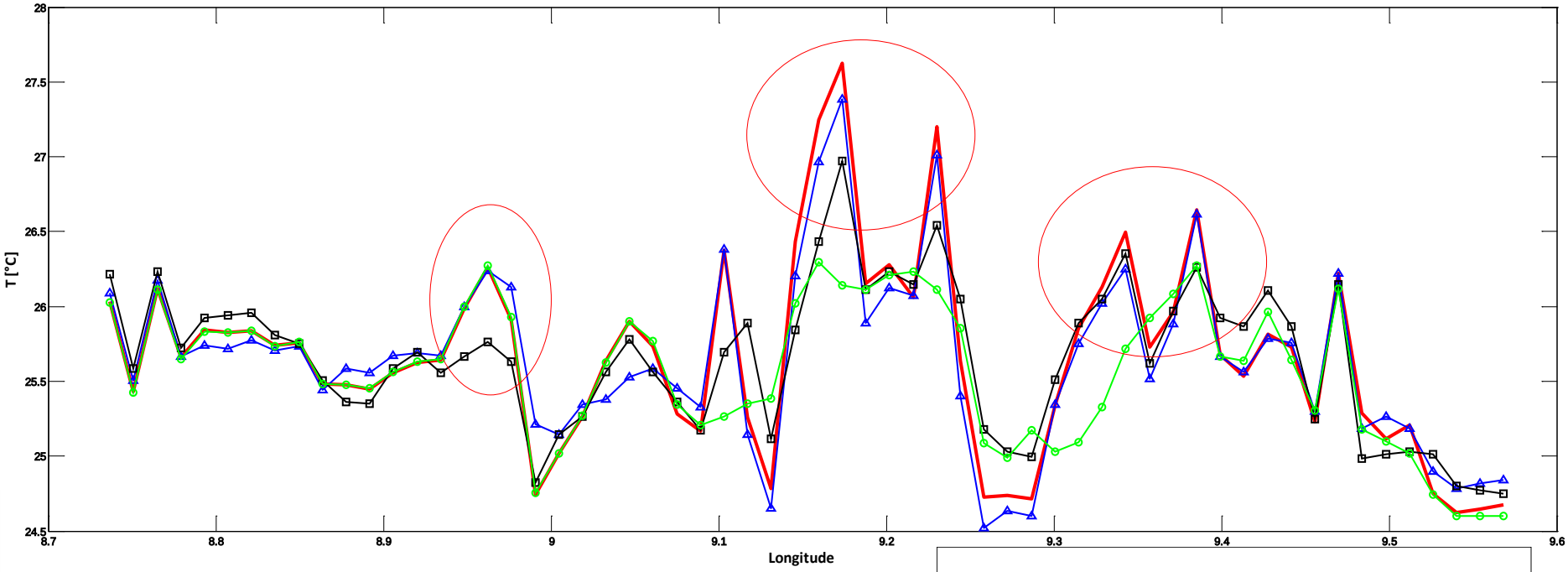
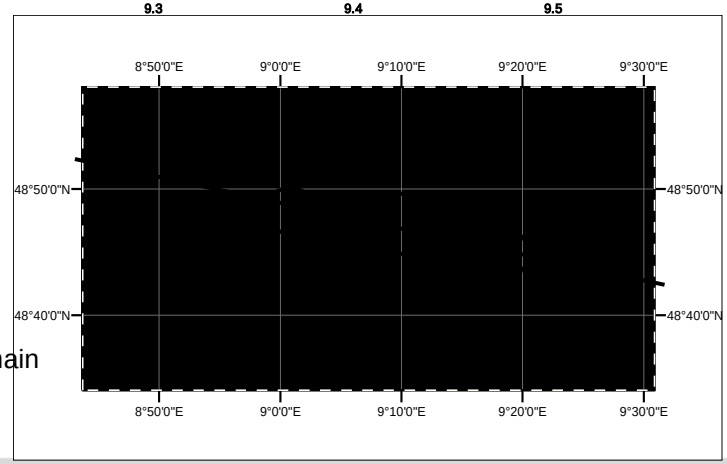
Potential 2m-Temperature – W-E Transect; Aug 14th 2003 00:00 UTC





Anthropogenic heating 60-90 W/m²

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

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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

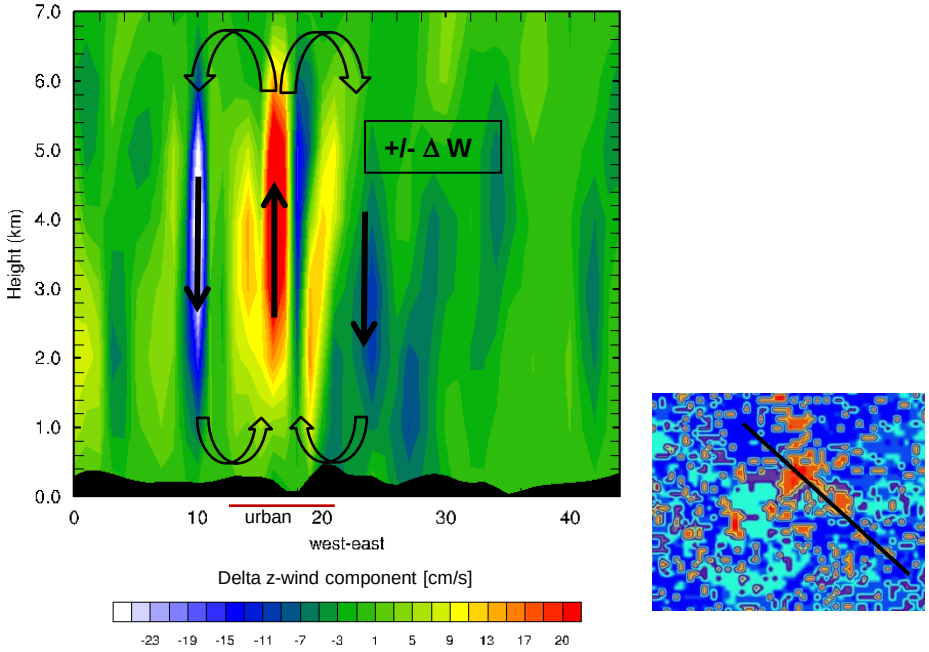

Fig. 13: Cross Section through transect (right) for **Aug 13th 2003 18:00**

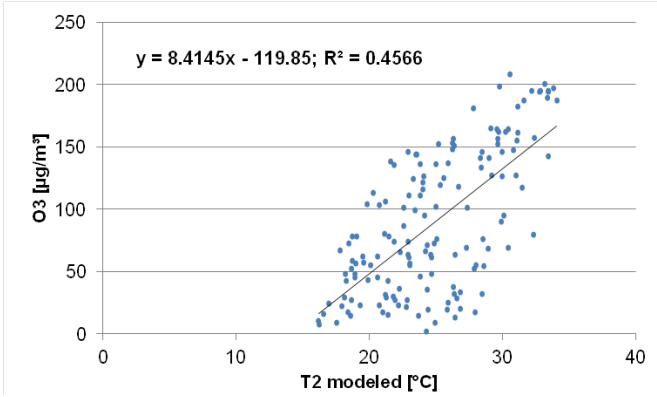

Fig. 14: Correlation between measured Ozone and modeled T 2m for period **Aug 11th – 18th 2003**

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Thank you for your attention

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Karlsruhe Institute of Technology

Campus-Alpin
IMK-IFU: Atmosphärische Umweltforschung

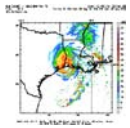
Research Foci:

- 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

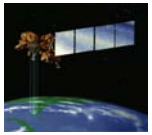
Research Group:
Regional Coupling of Ecosystem-Atmosphere-Processes

Methods:

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



http://www.mmm.ucar.edu/wrf/users/images/wrf_forecast.gif



http://upload.wikimedia.org/wikipedia/commons/thumb/1/19/Landsat7sat.gif/250px-Landsat7sat.gif

Regions/ Projects:

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

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