Karlsruhe Institute of Technology

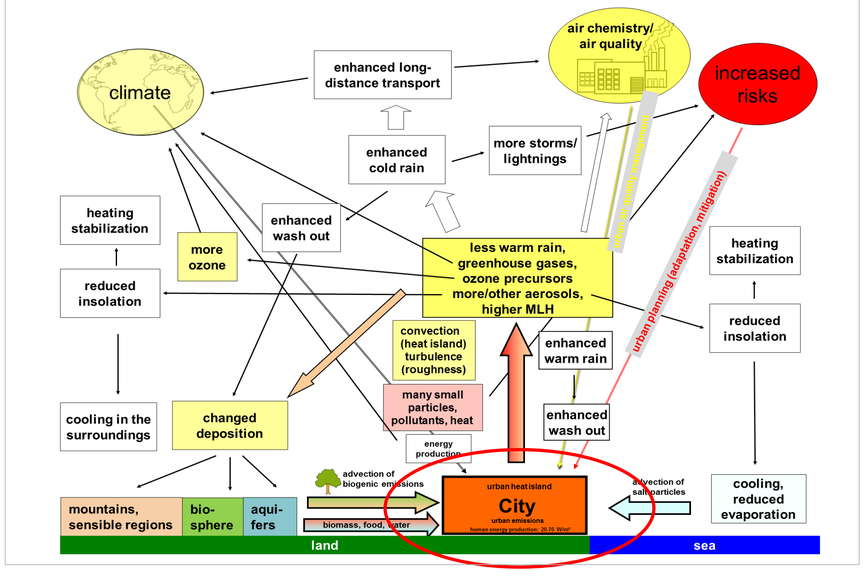
KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

# Modeling of the Urban Heat Island (UHI) – Assessment of mitigation Strategies using WRF

**Joachim Fallmann [1], Stefan Emeis[1], Peter Suppan[1], Renate Forkel[1], Georg Grell[2]**
**Contact:** joachim.fallmann@kit.edu

**1 Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research (IMK-IFU), 82467 Garmisch-Partenkirchen, Germany**
**2 NOAA Earth System Research Laboratory (ESRL), Global Systems Division (GSD), 325 Broadway Boulder, CO 80305-3328, USA**

DACH 2013




## 1. Motivation

- officially about **7 billion** people live on earth; growing rate: 78 million/year
- by **2030**, around **60%** living in cities, in 2000 nearly 2900 cities with more than 100000 inhabitants
- large urban areas impact **surface-atmosphere exchange processes**
- replacing natural landscape into impervious surfaces directly modifies sensible cycles in the earth system →urban environment/mankind embedded in a **complex system**
- **Climate change** will have specific urban expressions: altered urban heat island phenomena, impacts on regional circulation systems, air pollution levels, radiative feedback mechanisms of aerosols and **human health**
- analyzing state and chemical composition of the 'urbanized' atmosphere → need for measurement and modeling techniques on different scales to **bridge the gap** between meso- and microscale

## 2. Research Focus

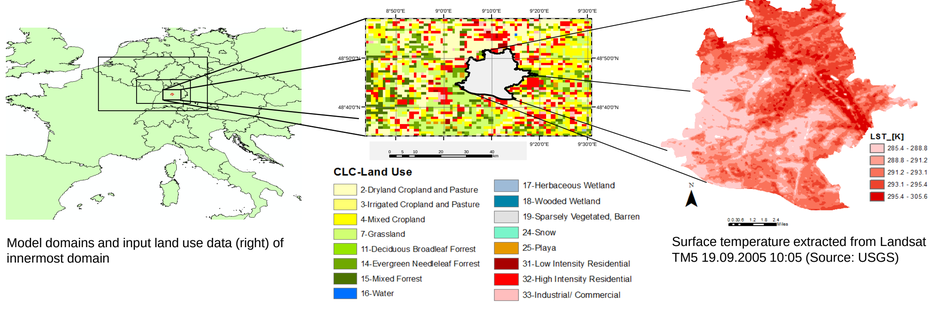
**The Urban Heat island**

- The tendency for an urbanized area to remain warmer than its surroundings → **urban- rural interactions**
- Additional heat sources, roughness effects and albedo of urban surfaces 'design' specific atmospheric dynamics
- Warmer environment and modified chemical reactions affect air quality and thus human health

**Challenging the complexity**

- downscaling mesoscale model WRF to city scale (1km)
- testing the effects of land use changes on meteorological conditions during summer heat waves using different urban parameterization approaches in WRF
- Simulate simple **mitigation strategies** : 1.effect of **white roofs** by increasing the albedo up to 0.70; 2.replace urban surface by natural **vegetation**; 3.decrease **building density**
- Conduct scenario-runs for different developments of the urban environment; area of interest: **Stuttgart** and rural surroundings

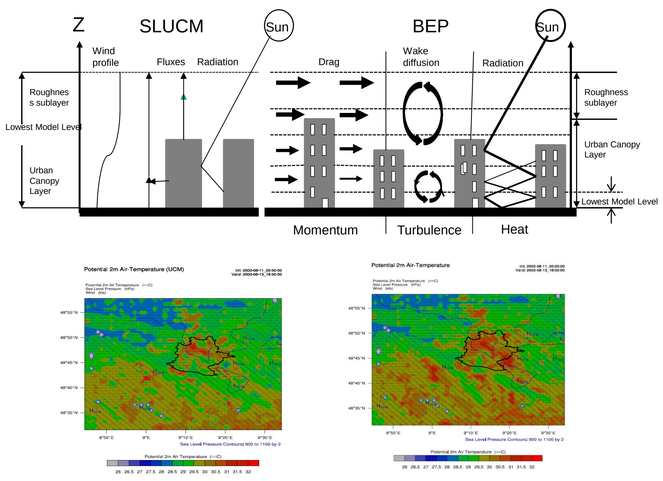
## 3. Strategies




Model domains and input land use data (right) of innermost domain

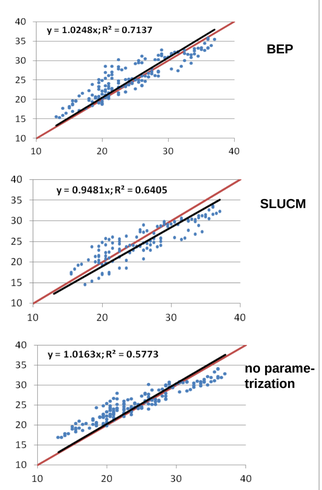
Surface temperature extracted from Landsat TM5 19.09.2005 10:05 (Source: USGS)

**Simplification by Parametrization**




Different parameterization strategies and modeled potential 2m-temperature with SLUCM approach (KUSAKA ,2001 - left) and BEP MARTILLI, 2002 – right)

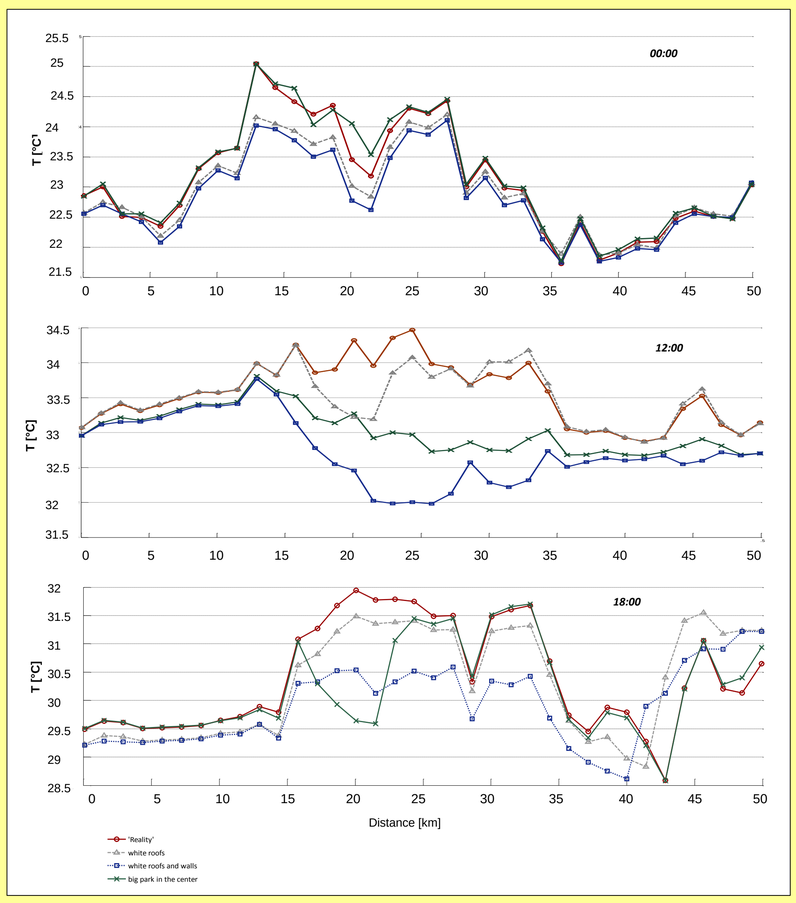
**Validation**




Correlation of modeled potential 2m temperature with measurement data of meteorological station in the city-centre of Stuttgart

## 4. Results: Mitigation scenarios

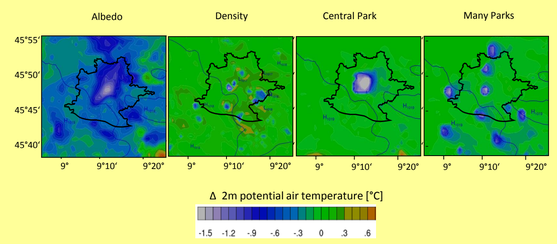
a) 2m Air Temperature Cross Section




Cross section through the central urban area of Stuttgart, showing 2m potential temperature for three different scenarios and the 'real' case. Photograph (Source: municipality of Stuttgart) of the area and USGS land cover map incl.transect line depicted on the upper right


Cross-Section shown for Photograph of Stuttgart Downtown seen from surrounded hill

b) 2m Air Temperature Surface Map




Difference in potential 2m temperature between scenario run and 'real case' for Aug 13th 2003

c) Urban Heat Island Intensity

Urban Heat Island Intensity expressed as difference between average 2m temperature of urban area and that of rural surrounding for the particular scenario and August 13th 2003

| Scenario | Albedo | Density | Many Parks | Big Park | Real Case |
|---|---|---|---|---|---|
| T mean urban [°C] | 32 | 32.4 | 32.46 | 32.34 | 33.1 |
| T max [°C] | 32.7 | 33 | 33.5 | 33.3 | 34.3 |
| Std dev. [°C] | 0.32 | 0.48 | 0.52 | 0.42 | 0.5 |
| UHI; ΔT [°C] | **0.84** | **1.32** | **1.47** | **1.19** | **2.52** |

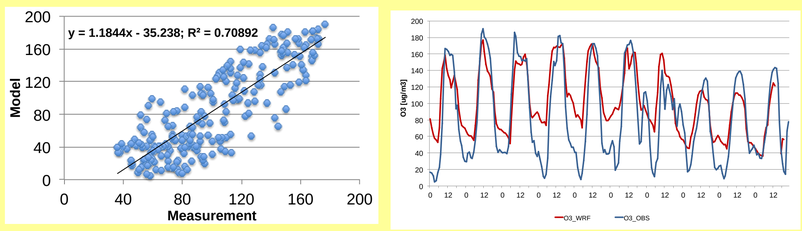
## 5. Outlook

- What is the effect of Urban Heat Island on Air Quality?
- How can the formation of Aerosols and other chemical reactions (O3,NOx,CO) be influenced by certain mitigation strategies?
- How big is the effect of increasing temperature on chemical reactions?
- Who are these effects aggravated by climate change?

*For this reason:*

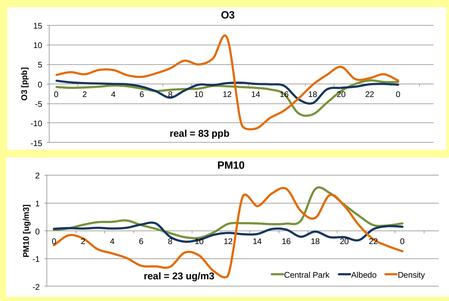
- Using meteorological results as well as anthropogenic-/biogenic emissions to drive regional air quality simulations (**WRF/chem**)

**First WRF-Chem results – Validation with O3**




Model validation by comparing 3x3km WRF-grid value of O3 with average value of 5 measurement stations in the area of the grid cell (left); Development of surface O3 for ten days in Summer (Aug 08 - Aug 18 2003) compared to measurements (right)

**Effect of land use change**




Effect of land use change on O3 and PM10 concentrations for Aug 13th 2003 in the course of a day; 'real' indicates effective modeled value (BEP)

This work is funded by the EU- Project "UHI - Development and application of mitigation and adaptation strategies and measures for counteracting the global UHI phenomenon" (3CE292P3) – CENTRAL Europe. (2011-2014).