

Cool Cities – Clean Cities ?

Secondary impacts of urban heat island mitigation strategies on urban air quality

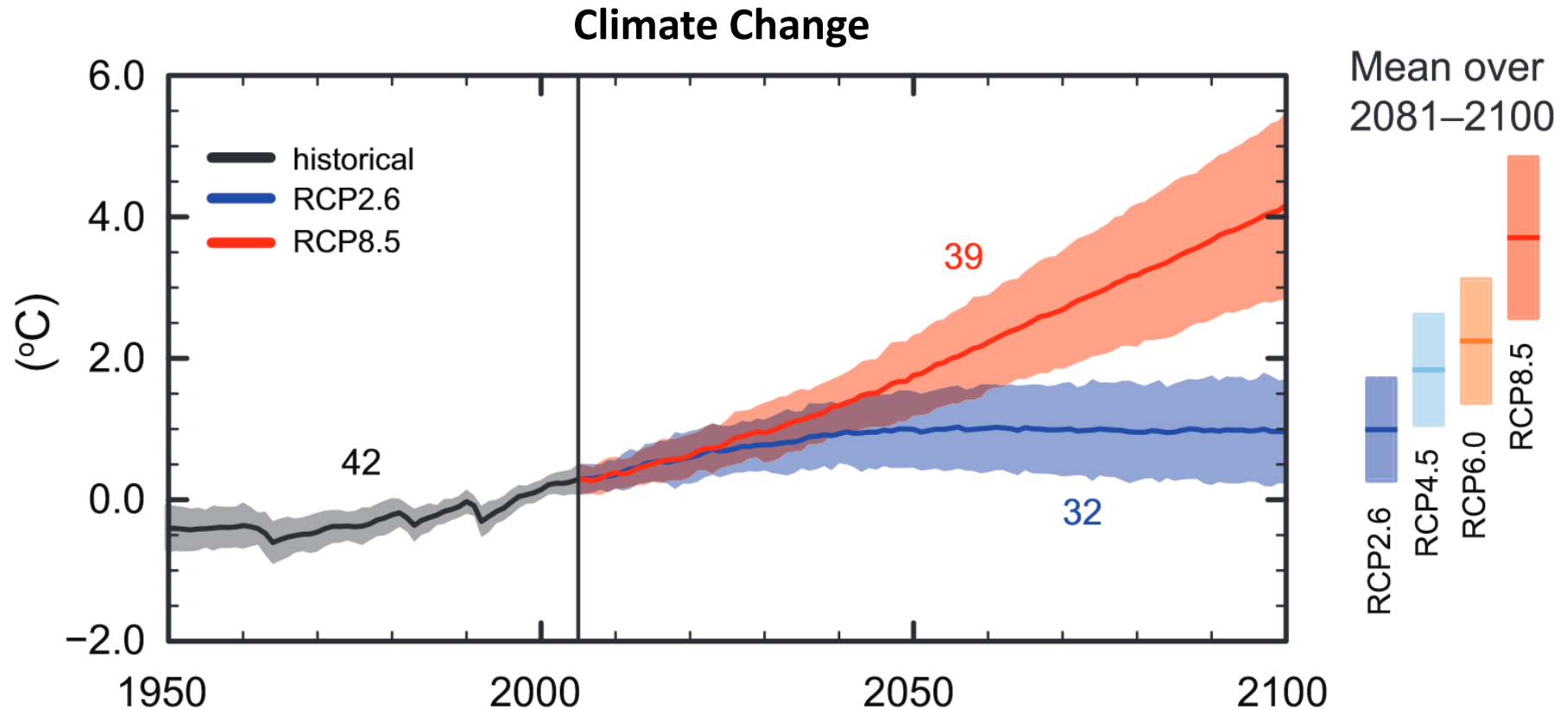
Dr. Joachim Fallmann

joachim.fallmann@kit.edu

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



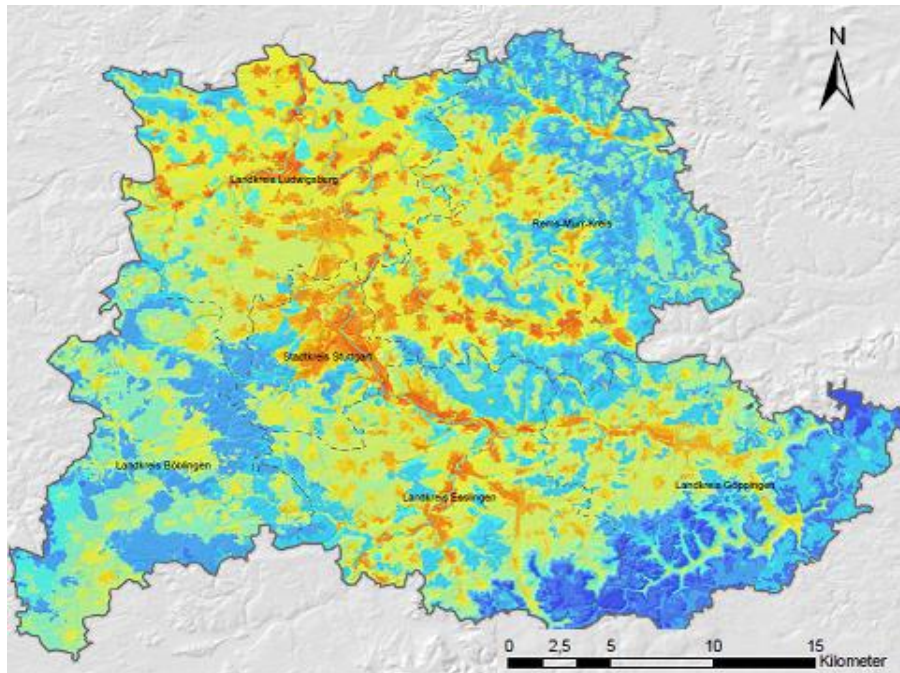
“2050: over 70% of people on earth will reside in cities [...]” (UN 2011)



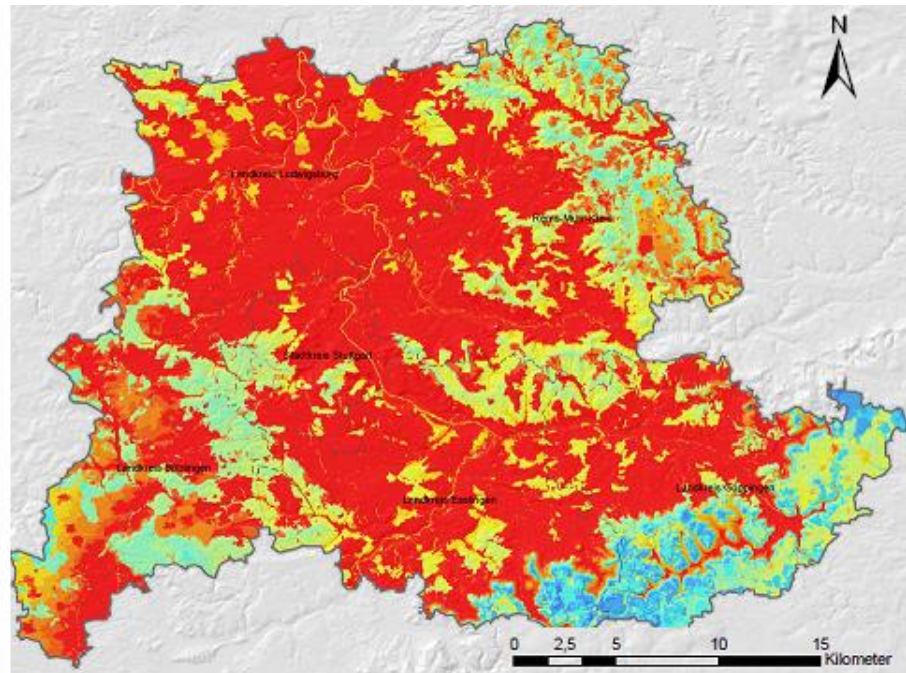
Source: IPCC AR5

„Heat stress days‘ per year (greater Stuttgart area)

1971-2000

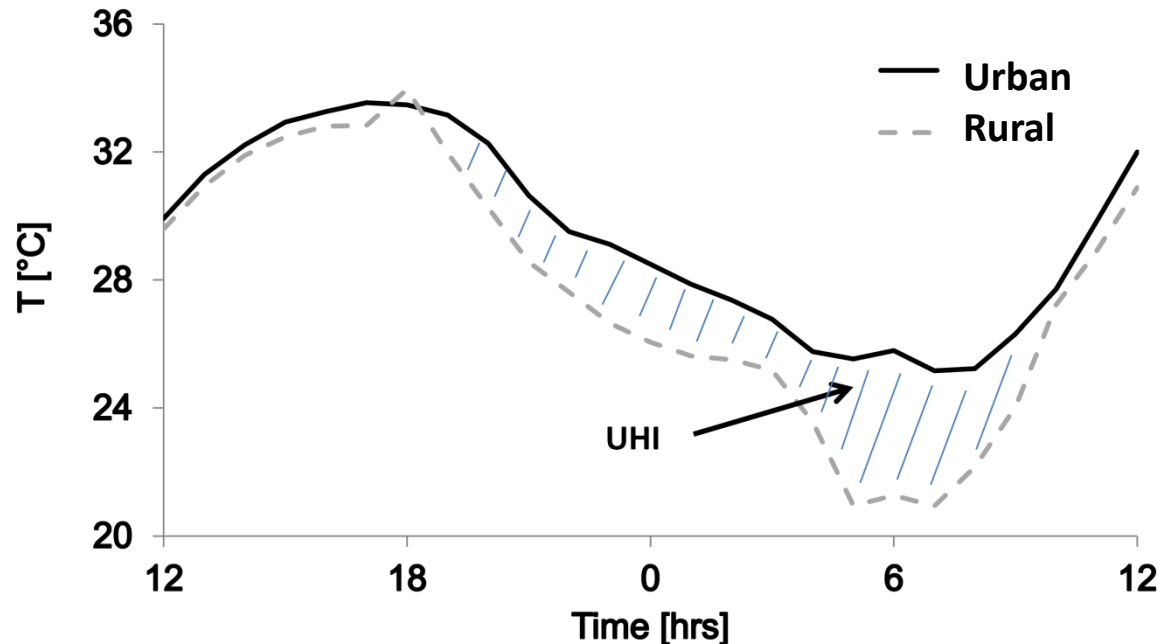


2071-2100



Source: Klimaatlas Region Stuttgart

Observations Stuttgart



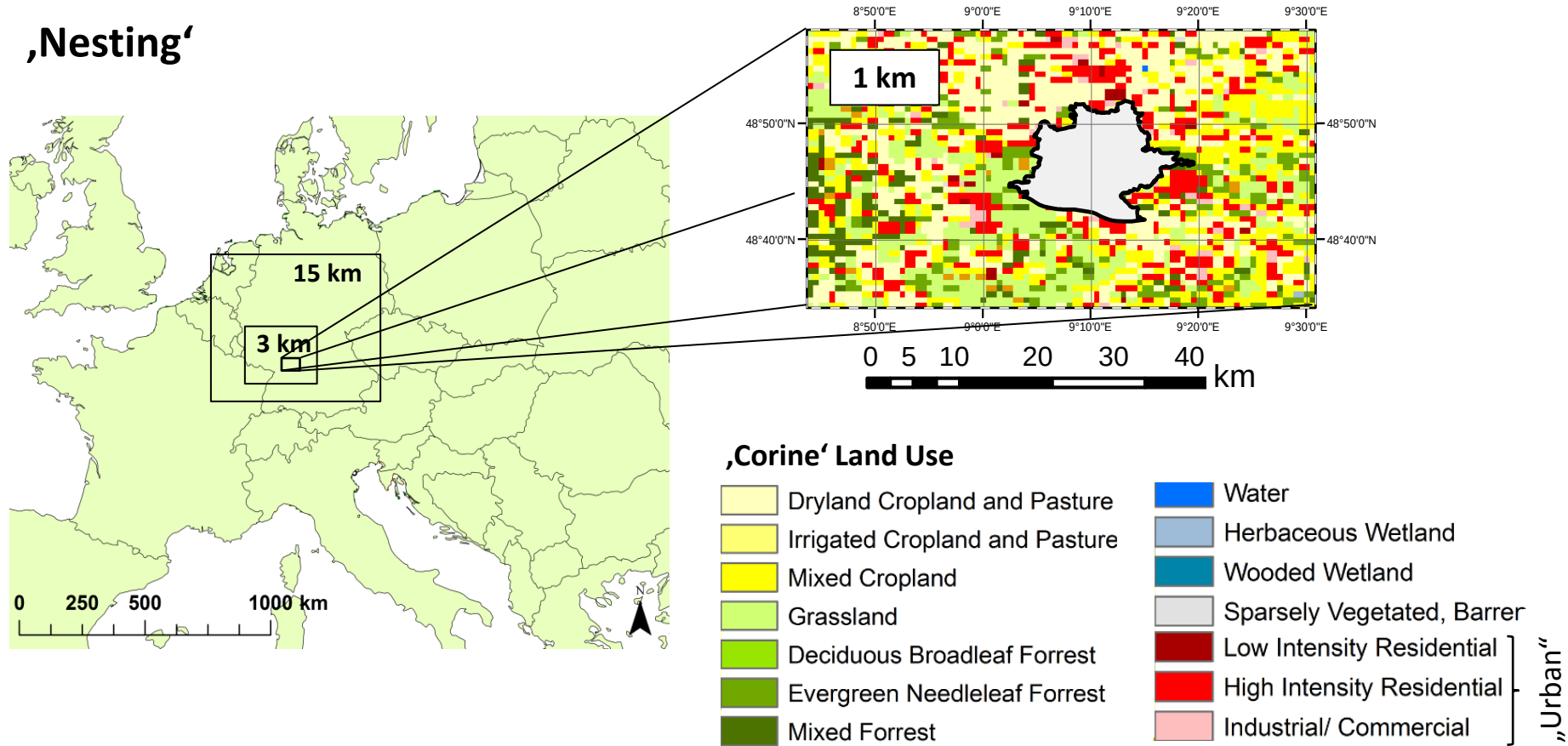
IPCC AR5: “[...] the relative warmth of a city compared with surrounding rural areas, [...] changes in runoff, effects on heat retention, and changes in surface albedo [...]”

➡ UHI mitigation strategies ?



www.stadtklima-stuttgart.de

„Nesting“



- Initial- und dynamical boundary conditions: **ERA-Interim 0.5°** Reanalysis
- Lower boundary conditions: **NOAH LSM**
- Modelling time frame: **Aug 8 – Aug 18 2003**

Classifying urban land use in the model

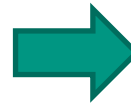
33:
**Industrial/
Commercial**



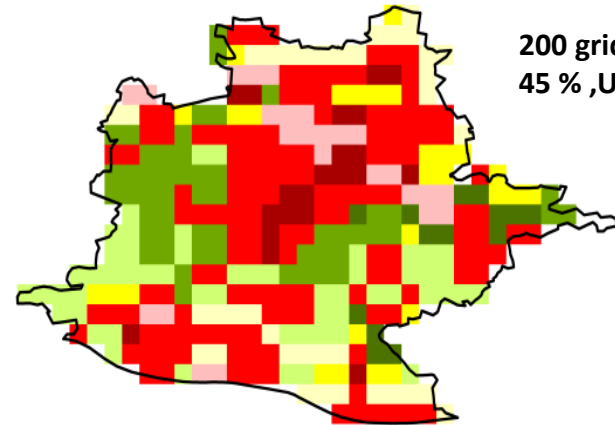
32:
**High Density
Residential**



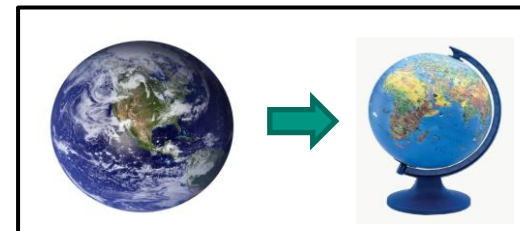
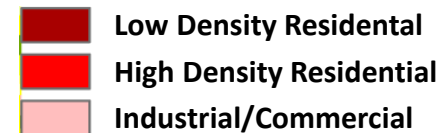
31:
**Low Density
Residential**



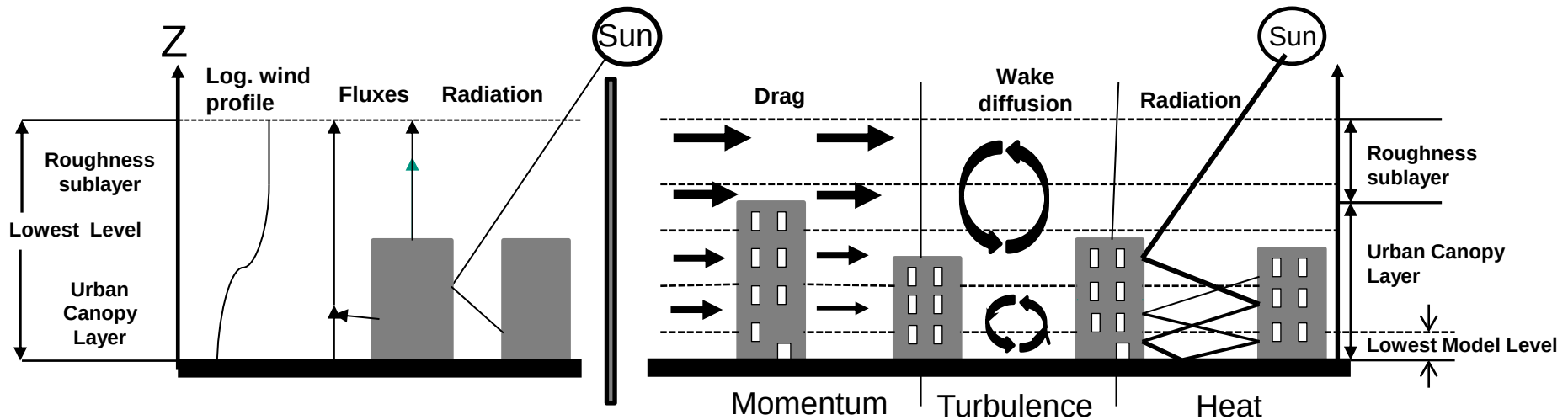
WRF Landuse



200 grid cells:
45 % 'Urban'



Urban Canopy Model



**Single Layer Urban
Canopy Model**
(Kusaka 2001)

Building Effect Parameterization
(Martilli 2002)

Changed from Chen (2011)

Urban Parameter Table

Urban Parameter

ZR: Roof level (building height) [m]
SIGMA_ZED: Standard Deviation of building height [m]
ROOF_WIDTH: Roof (i.e., building width) [m]
ROAD_WIDTH: road width [m]
AH: Anthropogenic heat [W m/m²]
FRC_URB: Fraction of the urban landscape which does not have natural vegetation [Fraction]
CAPR: Heat capacity of roof [J m³/ K]
CAPB: Heat capacity of building wall [J m³/ K]
CAPG: Heat capacity of ground (road) [J m³/ K]
AKSR: Thermal conductivity of roof [W m/K]
AKSB: Thermal conductivity of building wall [W m/K]
AKSG: Thermal conductivity of ground (road) [W m/K]
ALBR: Surface albedo of roof [fraction]
ALBB: Surface albedo of building wall [fraction]
ALBG: Surface albedo of ground (road) [fraction]
EPSR: Surface emissivity of roof [-]

‘Morphology’

‘Material characteristics’

33 **32** **31**

8.5 9.7 6.4
6.8 6.4 4.5
27.5 13.3 10

19 16.2 9.8

90 50 20

0.95 0.85 0.5

1.00E+06 1.00E+06 1.00E+06

1.00E+06 1.00E+06 1.00E+06

1.40E+06 1.40E+06 1.40E+06

0.67 0.67 0.67

0.67 0.67 0.67

0.4 0.4 0.4

0.2 0.2 0.2
0.2 0.2 0.2
0.2 0.2 0.2

0.8 0.9 0.92

Building Heights

Albedo

Street Parameters

Urban Category [index]	Direction [°]	street width [m]	building width [m]
33	0	19	25
33	90	19	25
32	0	13	13
32	90	13	13
31	0	18	10
31	90	18	10

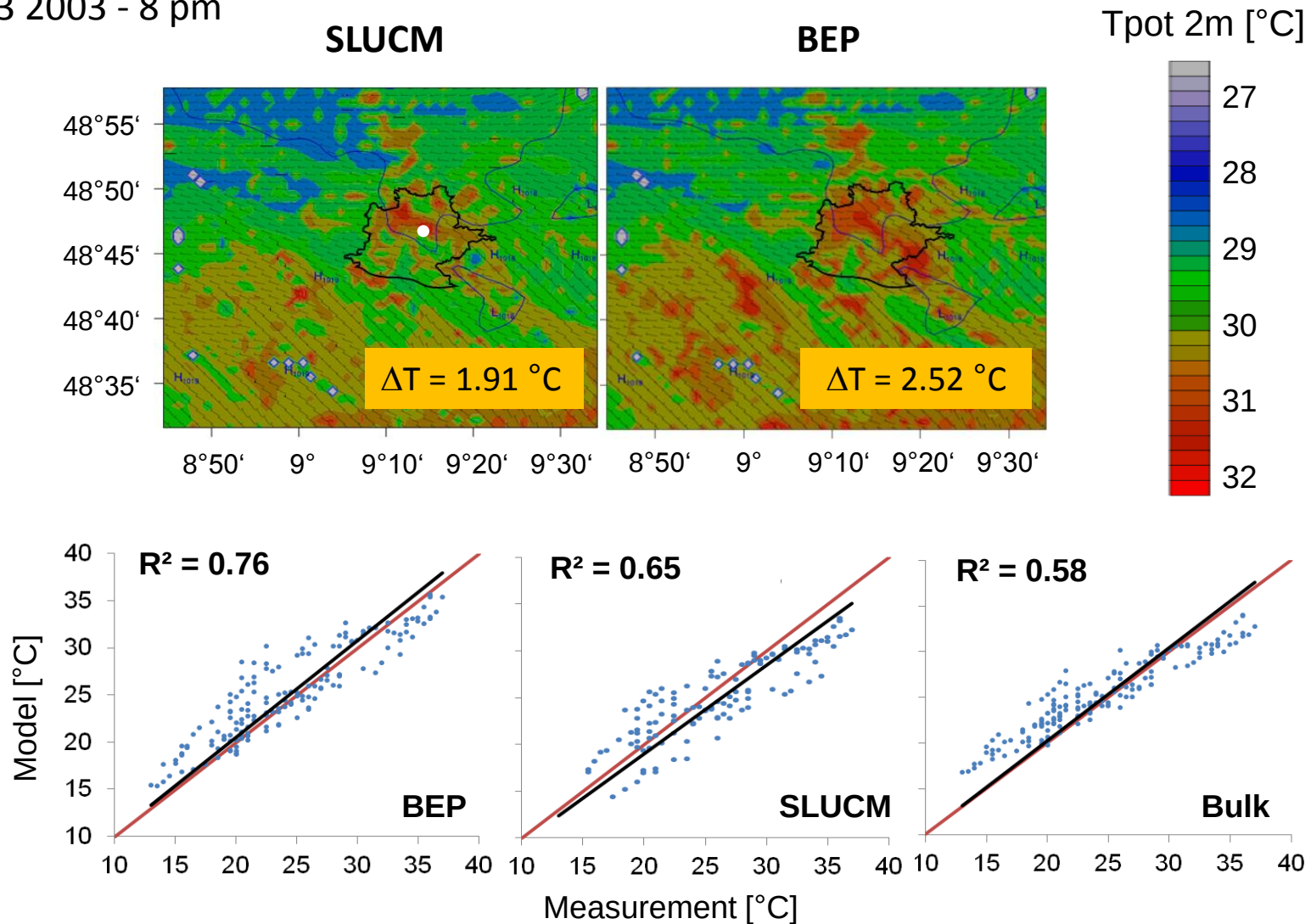
Road network

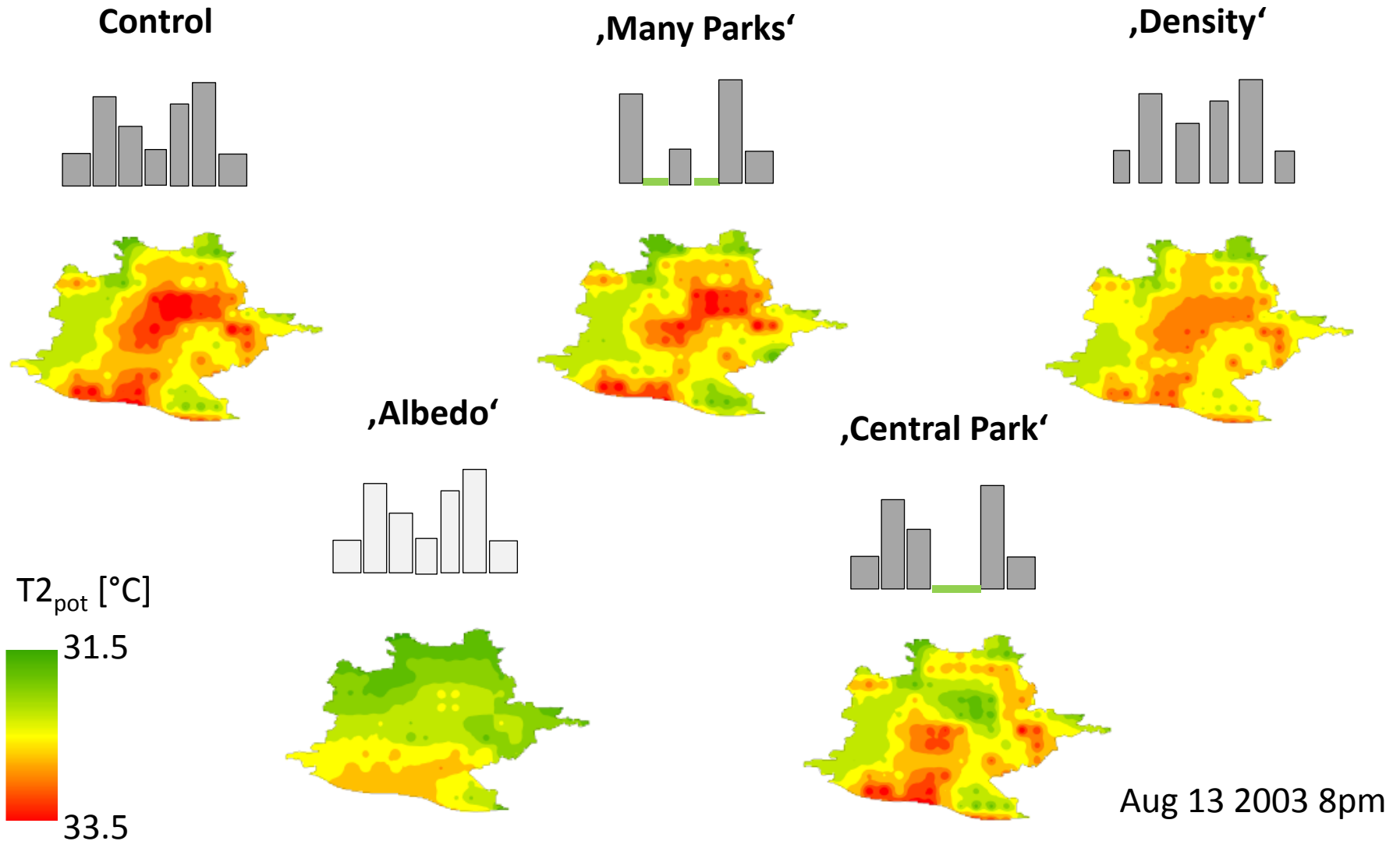
height [m]	33 Percentage [%]	32 Percentage [%]	31 Percentage [%]
5	33	33	48
10	28	20	37
15	14	13	11
20	8	3	3
25	4	1	1
30	2	2	
35	2		

Building properties

Model evaluation – Point vs. Pixel

Aug 13 2003 - 8 pm



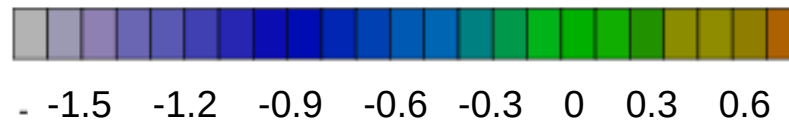
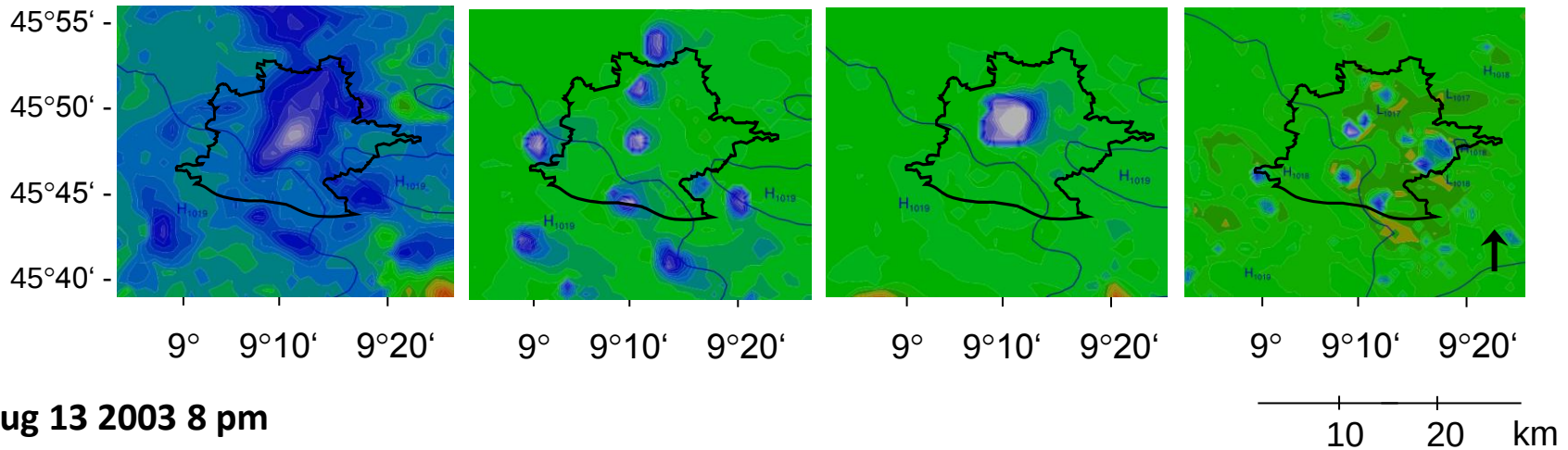


Albedo - Control

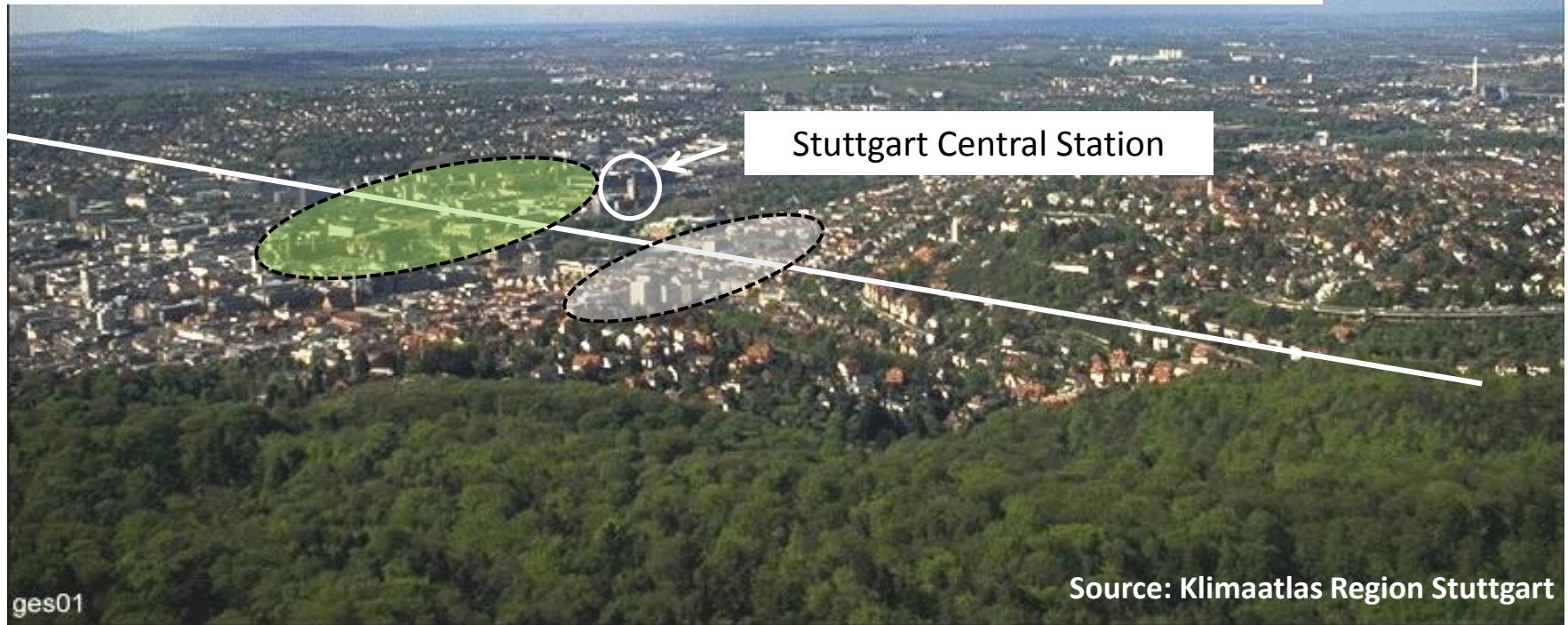
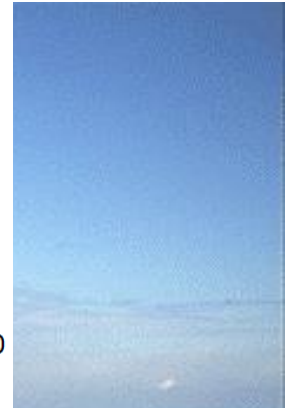
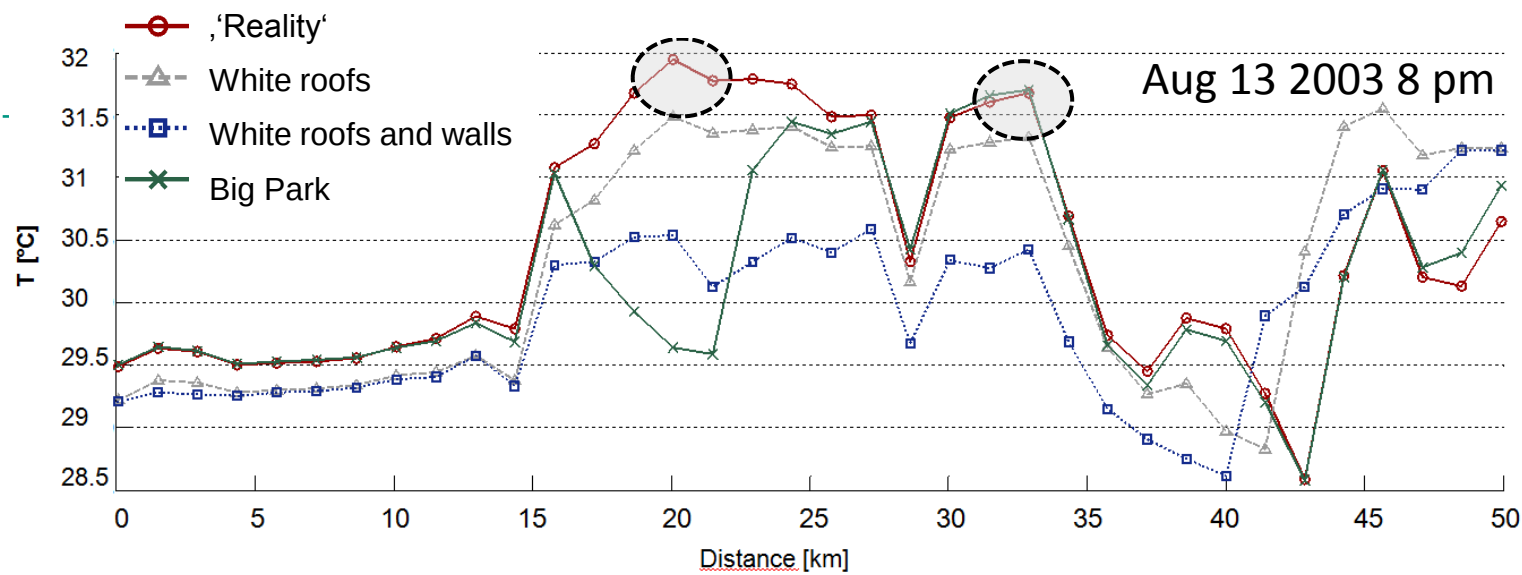
Many Parks - Control

Central Park - Control

Density - Control



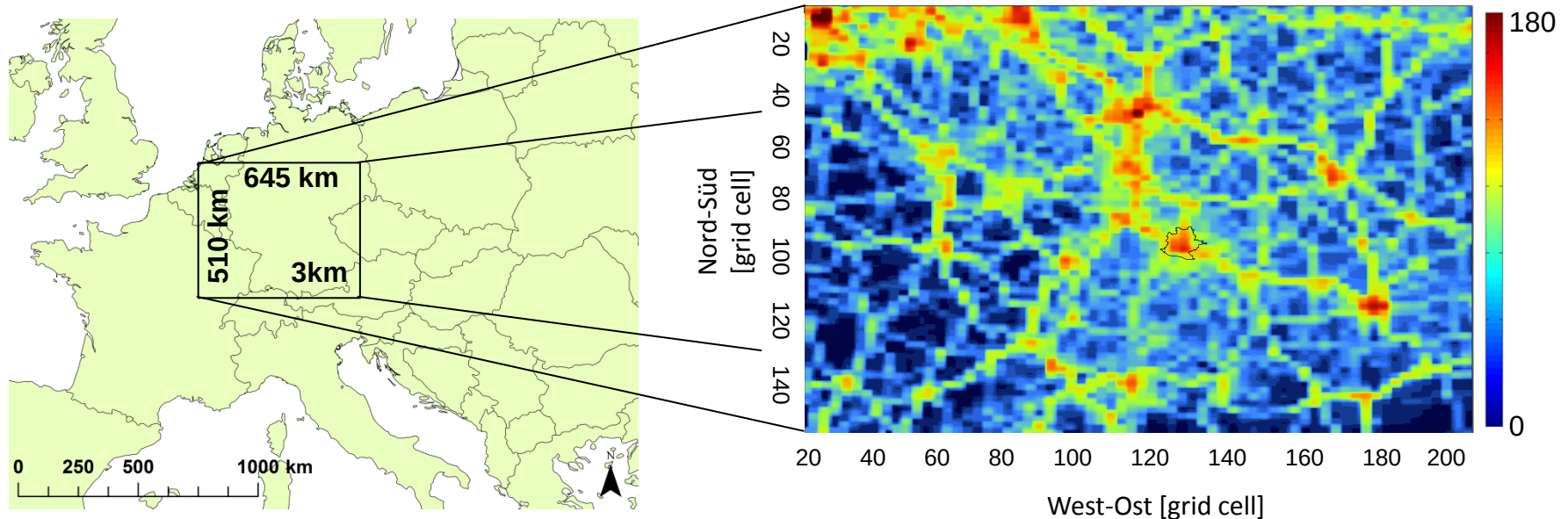
(Fallmann et al. 2014)



An aerial photograph of a landscape, possibly a coastal or rural area, with a clear blue sky and a hazy horizon. The foreground shows a mix of green fields and some buildings. A white rectangular box with a black border is centered in the middle of the image, containing the text "And now?".

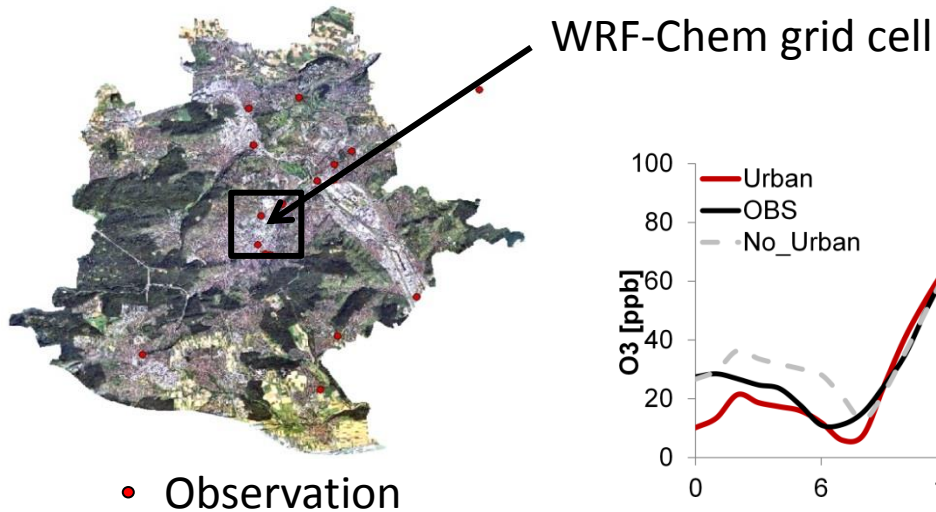
And now?

WRF-Chem Domain



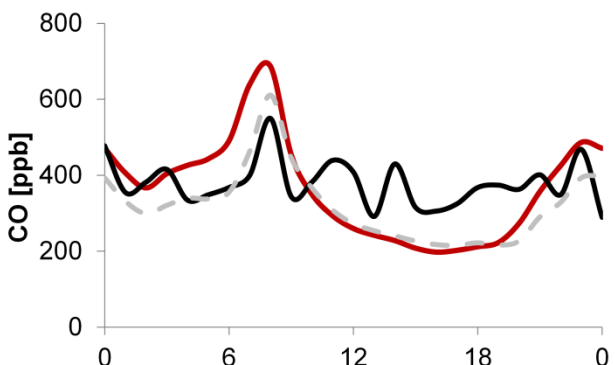
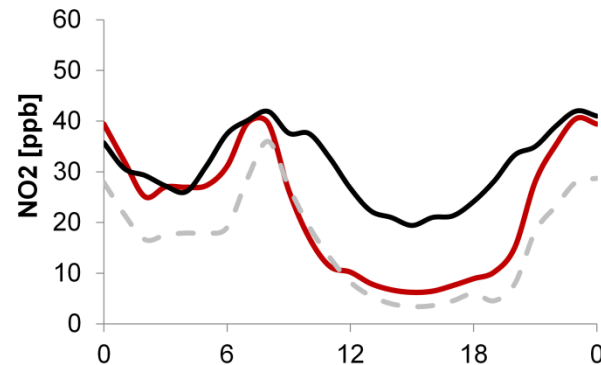
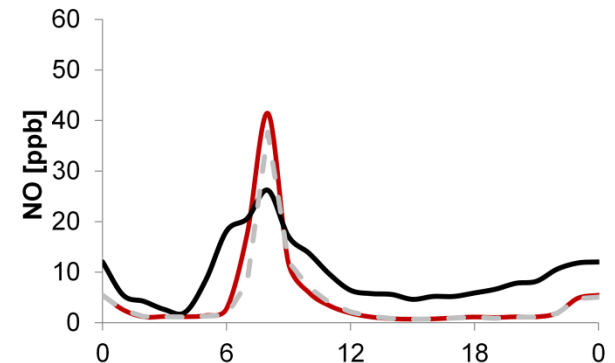
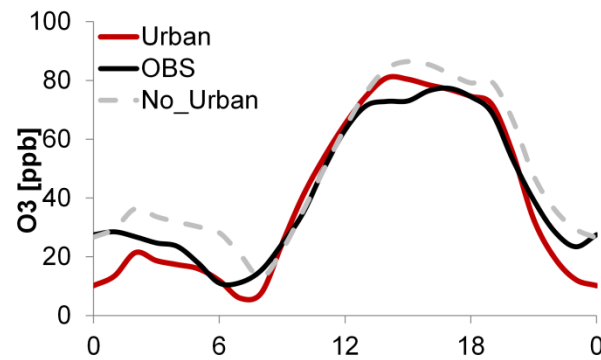
- Initial- and dynamical boundary conditions from global model **MOZART** (*anthropogenic*) und **MEGAN** (*biogenic*)
- Lower boundary conditions **MACC Emissions 2003-2007**
- Modelled time frame: Aug 9 – Aug 18 2003

Model evaluation – point vs. grid cell

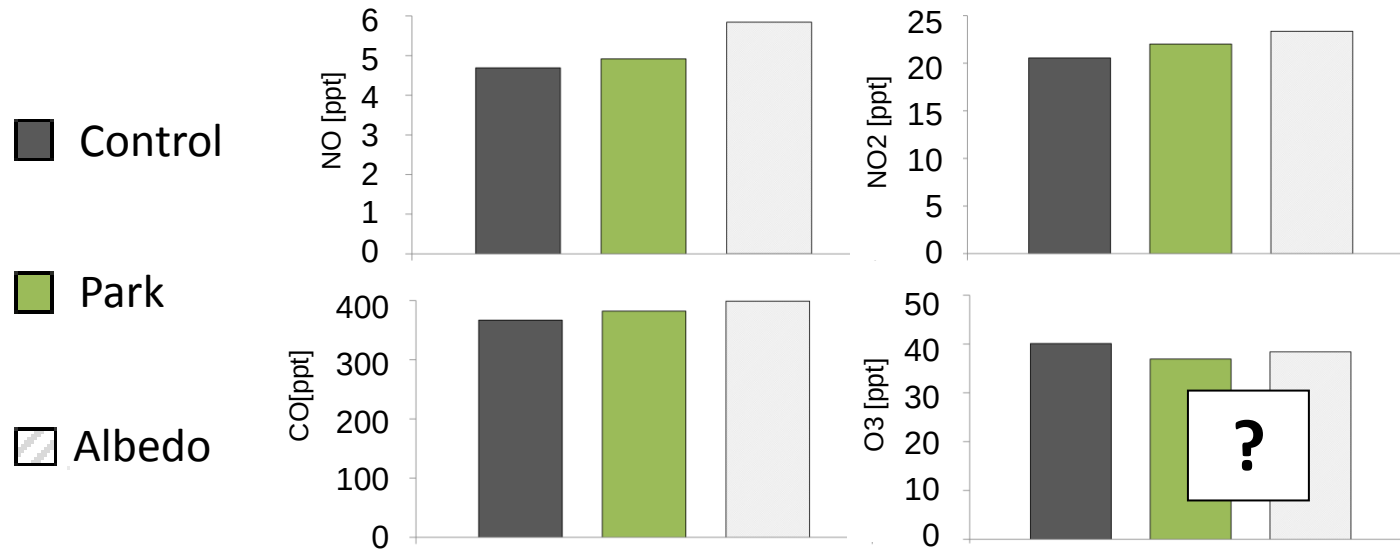


Mean over 3 Stations:

- Bad Cannstadt
- Schwabenzentrum
- Mitte – Arnulf-Klett Platz



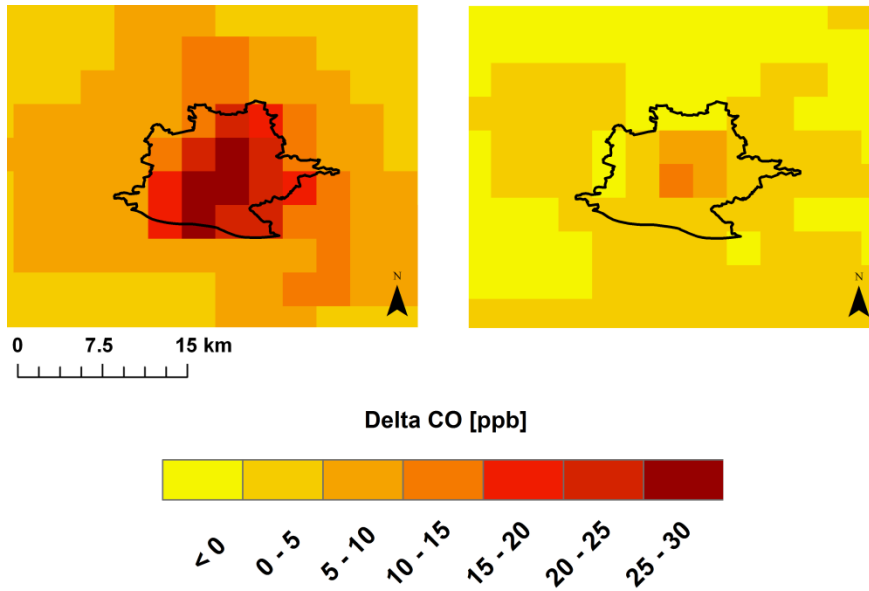
Mean concentration for modelling period



Primary pollutants (e.g. CO)

„Albedo-Control“

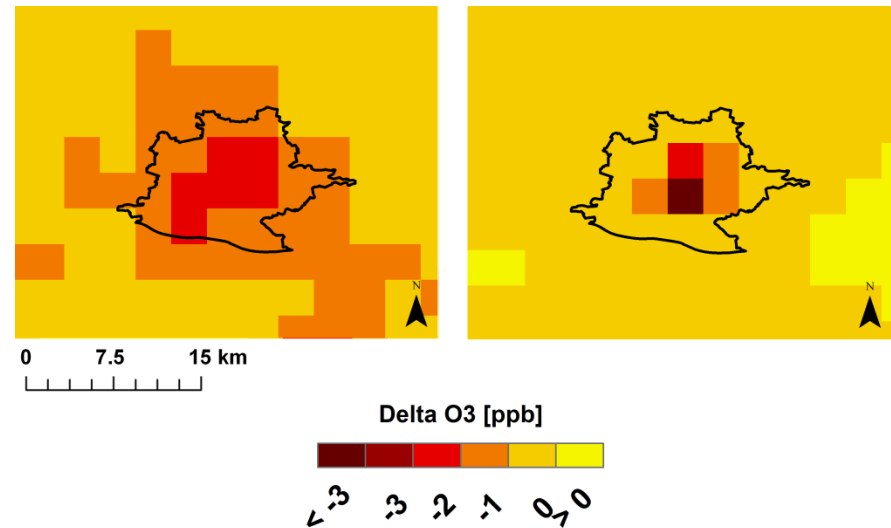
„Park-Control“

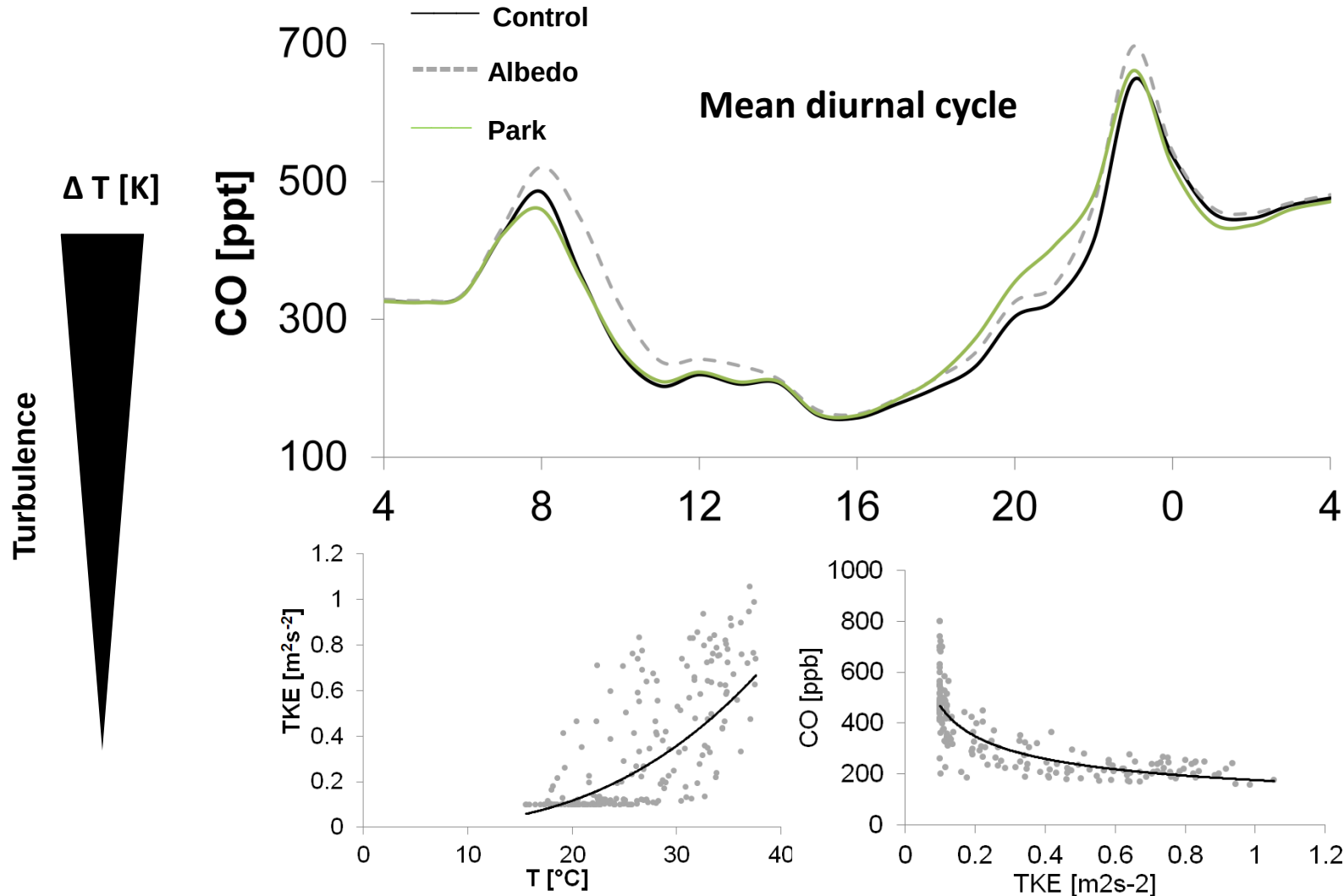


Secondary pollutants (e.g. O3)

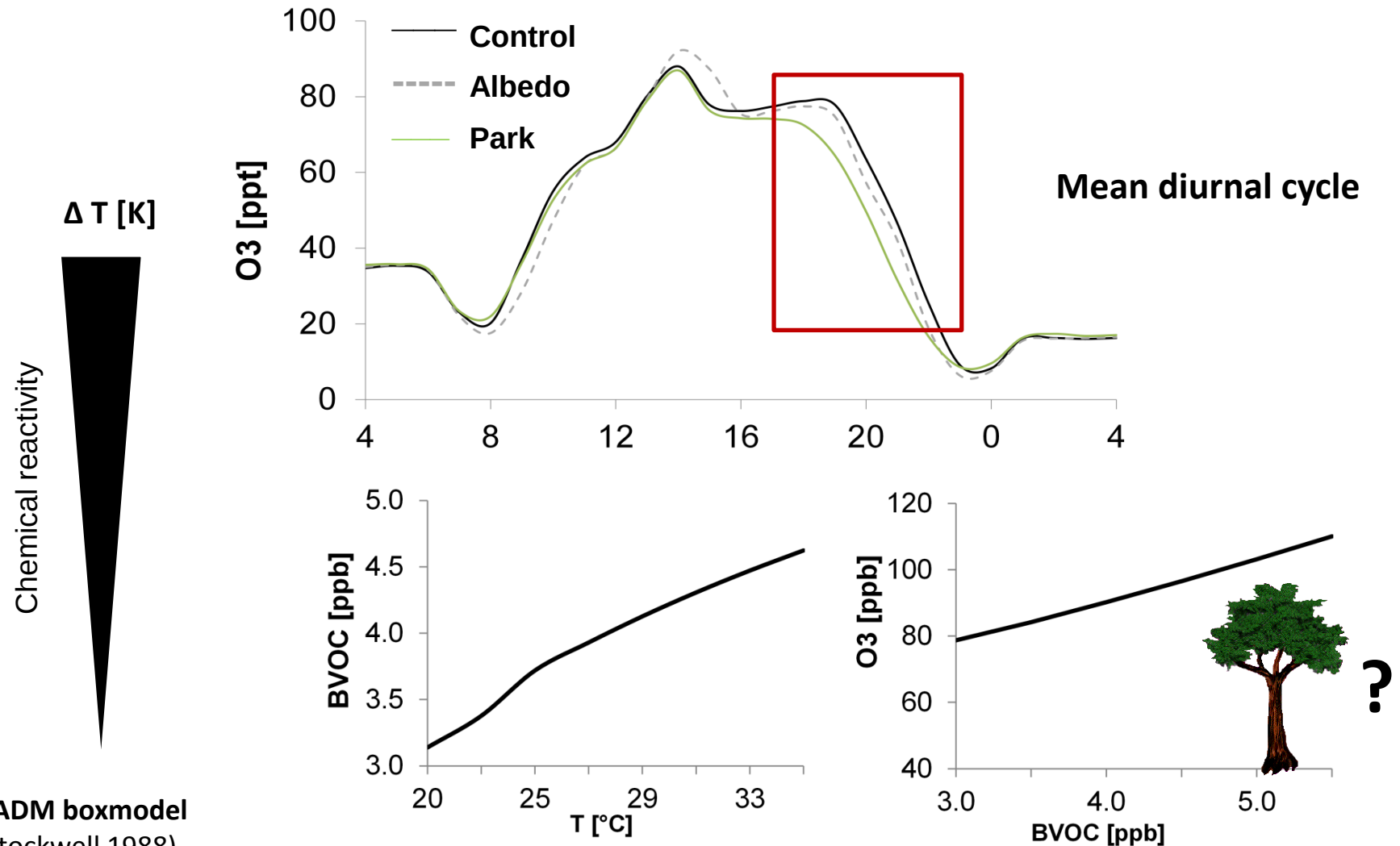
„Albedo-Control“

„Park-Control“





Secondary pollutants (Ozone) – Chemical reactivity

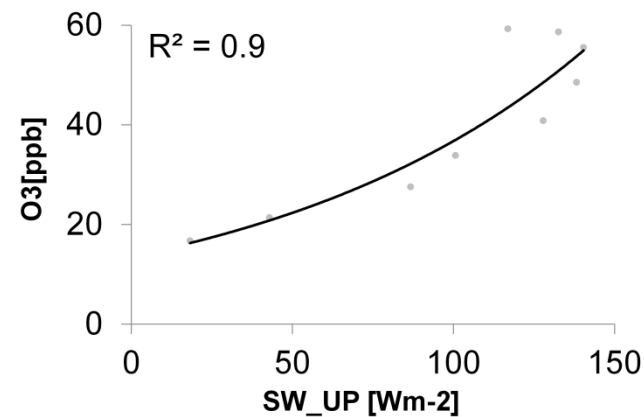
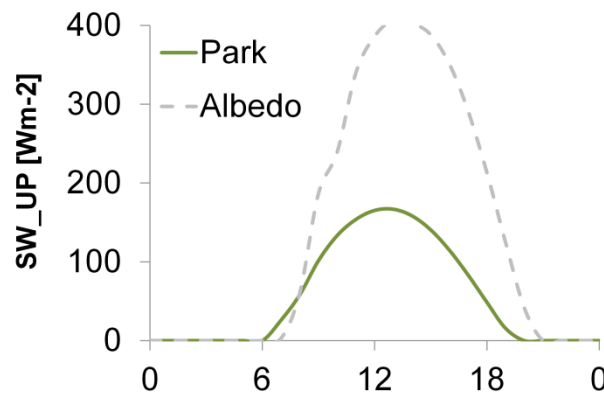
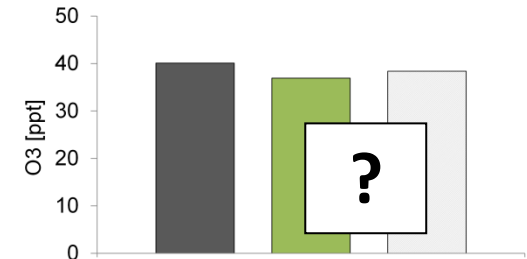
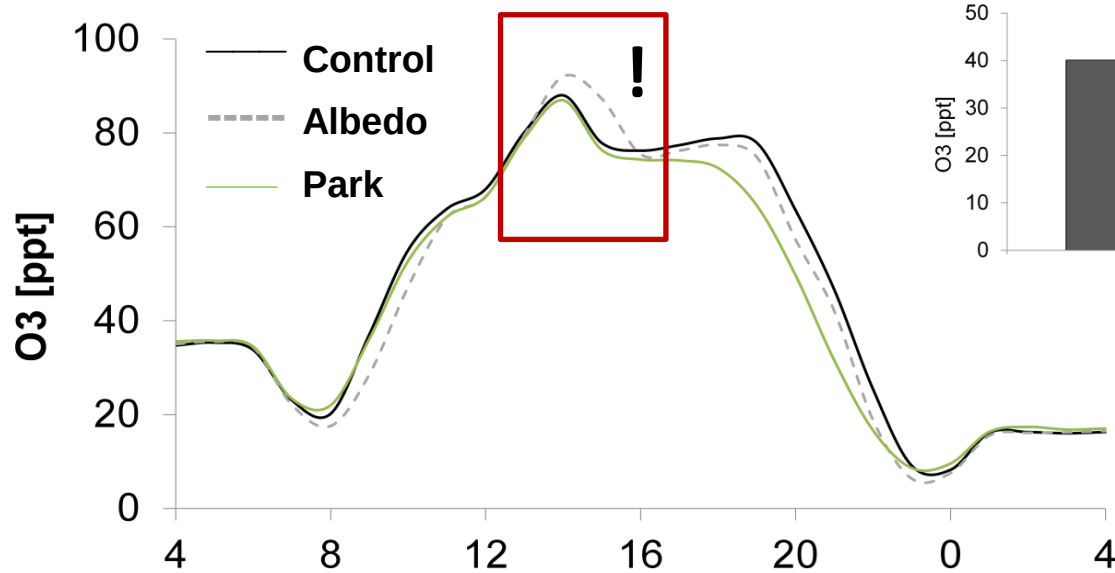


RADM boxmodel
(Stockwell 1988)

Secondary pollutants (Ozone) - Photolysis

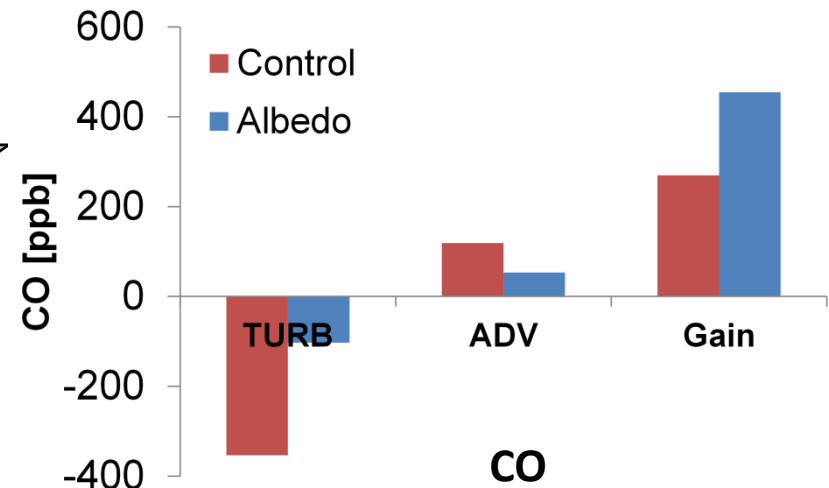
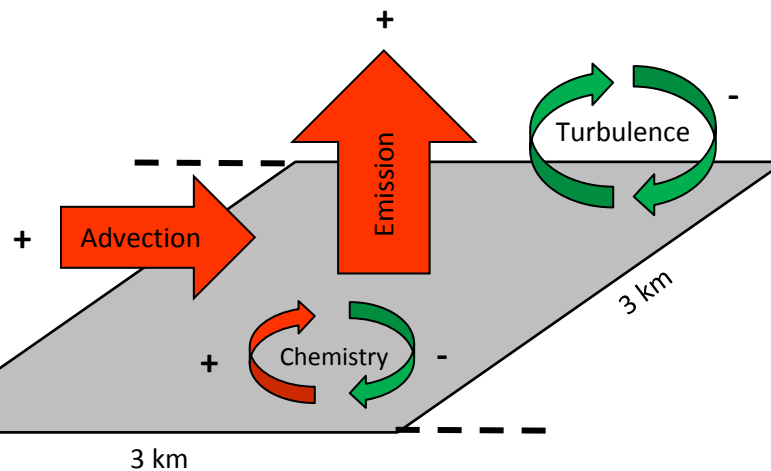
SW_UP [Wm⁻²]

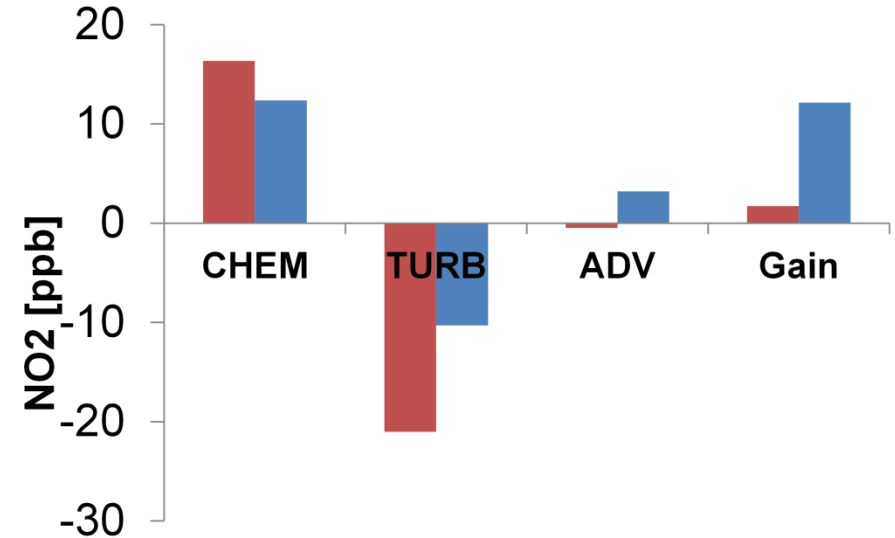
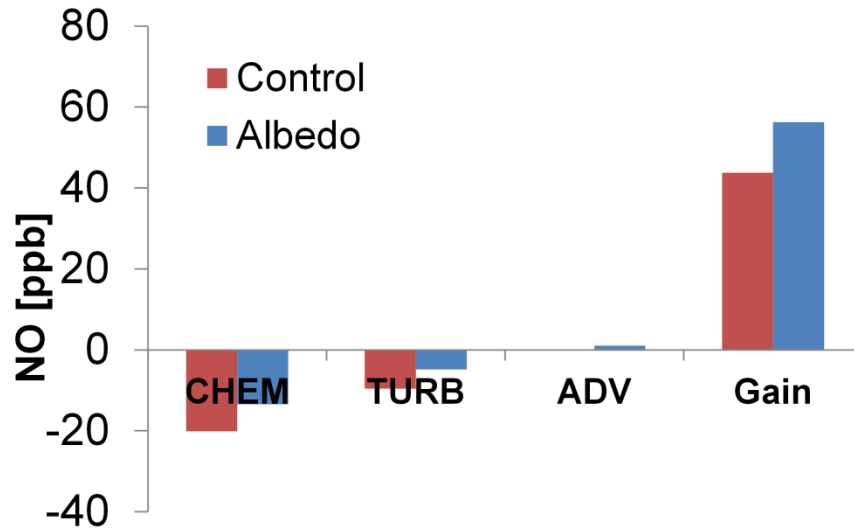
Photolysis rate



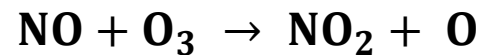
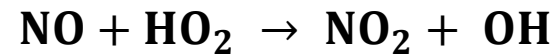
- Impact of chemistry and dynamics on concentration of pollutants on the basis of hourly budgets (7 - 8 am) [ppb h⁻¹]
- **'Tendency terms':**
 - chemical production/loss tendency (CHEM)
 - Turbulent vertical mixing (TURB)
 - Advection (ADV)
 - Emission (EMIS)

Balance:
Gain/Loss = EMIS + CHEM + TURB + ADV



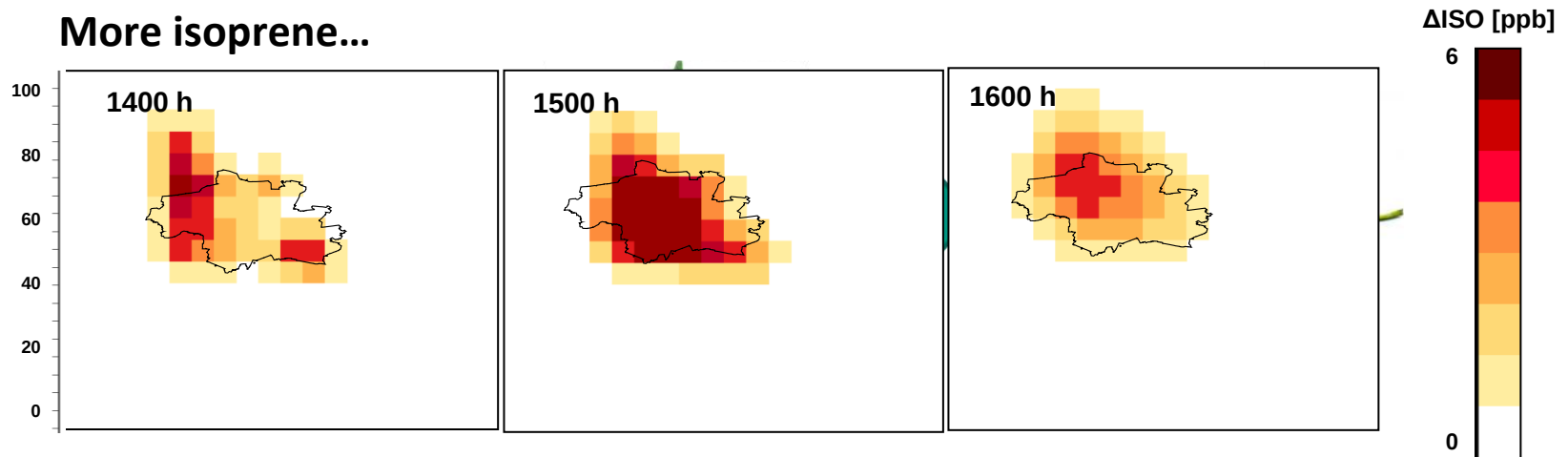


NOx-Cycle

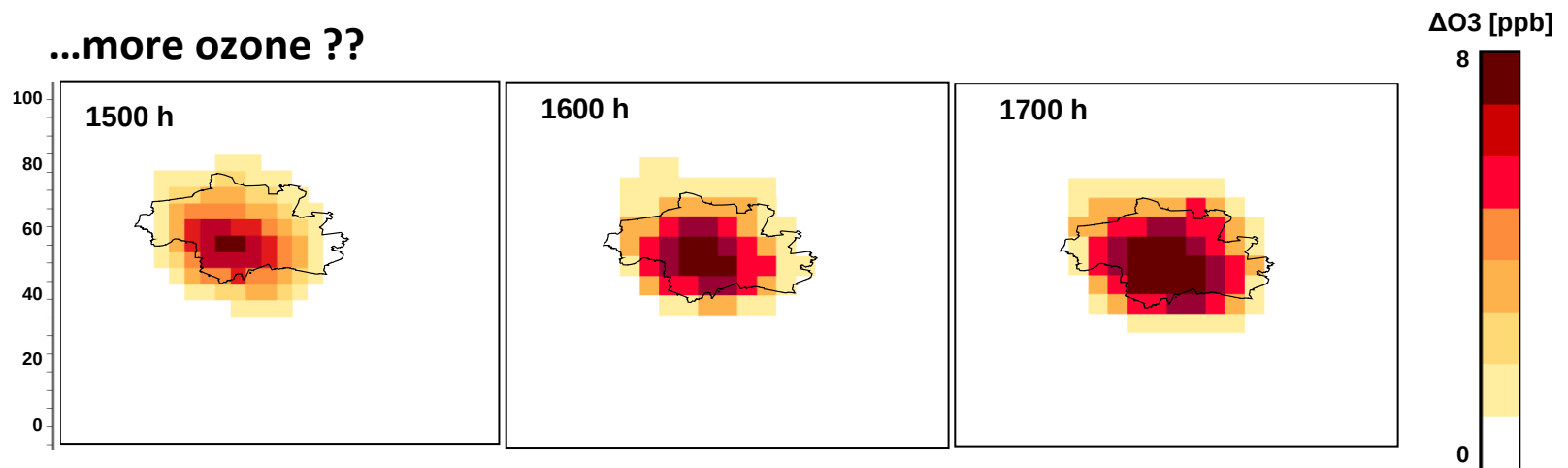


Case Study: The wrong trees for Munich ?!

More isoprene...

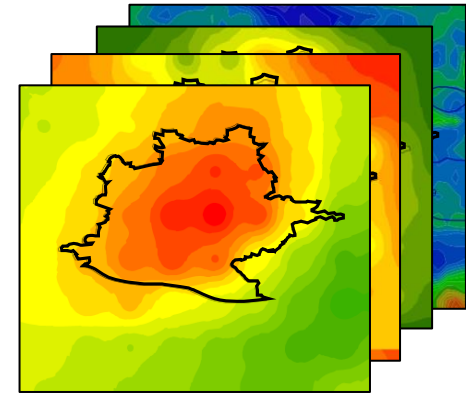


...more ozone ??



➤ Urban Heat Island mitigation strategies?

- Surface reflectivity
- Urban greening
- Reduction of building density



➤ **Feedback** on urban air quality?

➤ Primary vs. Secondary pollutants

Primary: Increase of CO and NO_x

→ Reduction of the temperature dependent turbulent mixing

→ **Dynamics dominate**

Secondary I: Reduction of ozone levels

→ temperature dependency

Secondary II: Increase of peak ozone concentrations for ‚white roofs‘

→ increased photolysis rates due to reflected UV

Thank you



PHD-Thesis: <http://kups.ub.uni-koeln.de/view/creators/Fallmann=3AJoachim=3A=3A.html>