Cool Cities – Clean Cities ?

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

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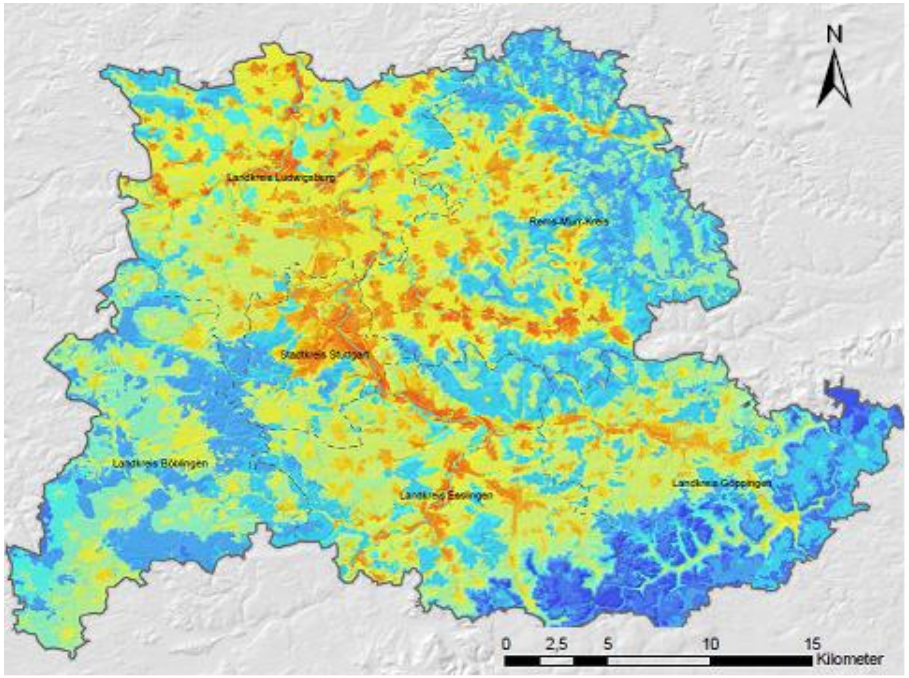
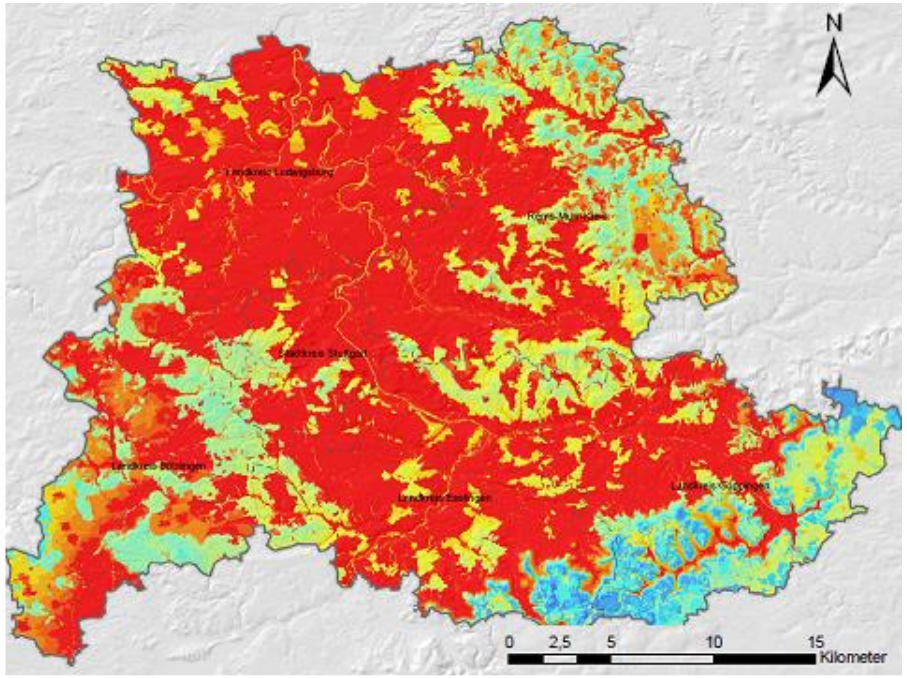
Heat stress in urban areas

‚Heat stress days' per year (greater Stuttgart area)

1971-2000



2071-2100



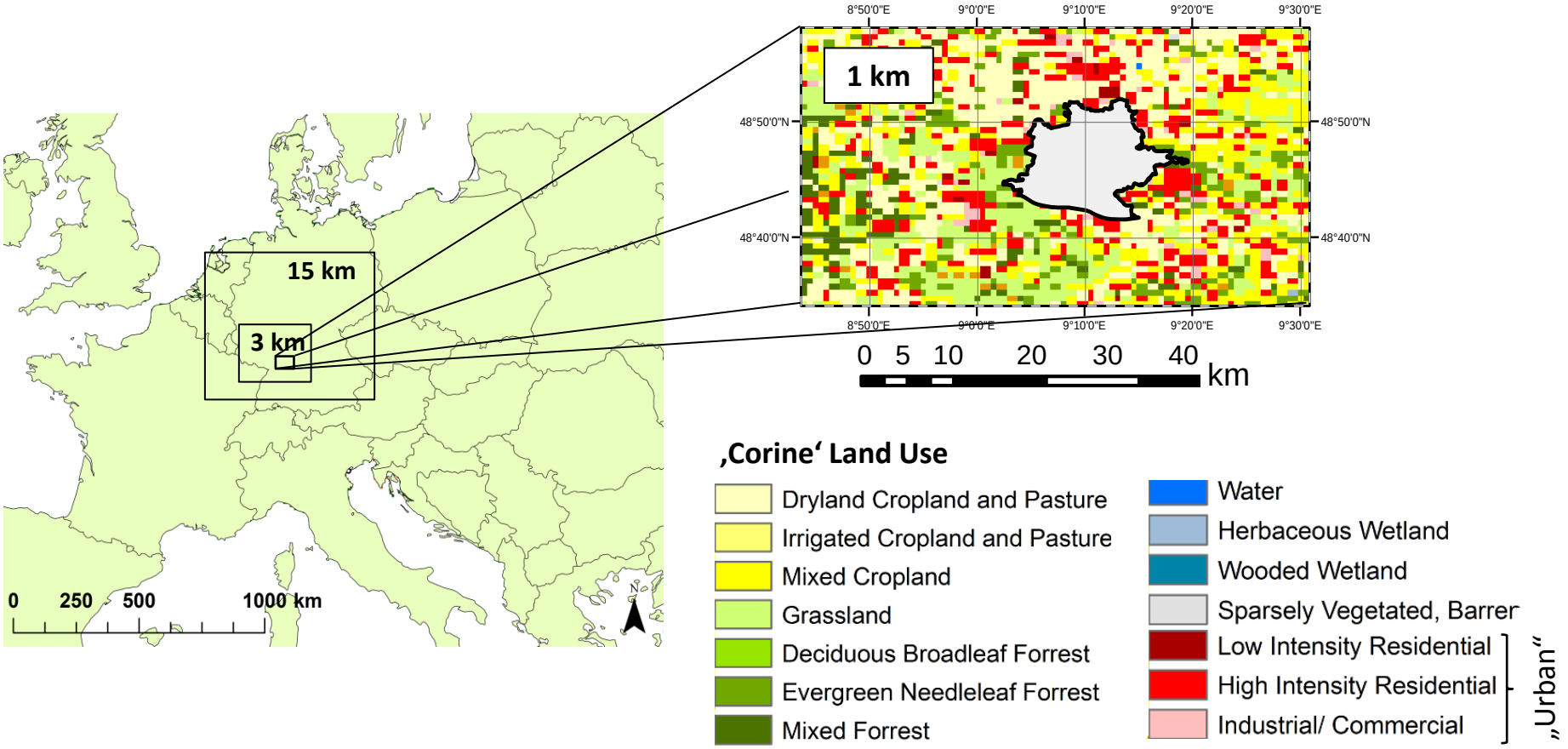
< 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 | 22.5 | 25 | 27.5 | 30 | 32.5 | 35 | >35

Source: Klimaatlas Region Stuttgart

The Urban Heat Island

UHI mitigation strategies ?

1. Step: Modelling of the Urban Heat Island (WRF)



- Initial- und dynamical boundary conditions: ***ERA-Interim 0.5°*** Reanalysis
- Land surface processes: ***NOAH LSM***
- Parametrization of sub-grid scale processes: ***BEP Urban Canopy Model***
- Modelling time frame**: Aug 8 – Aug 18 2003**

Evaluation: Fallmann et al. 2014

Urban areas in mesoscale models

Urban Parameter	33	32	31
ZR: Roof level (building height) [m]	8.5	9.7	6.4
SIGMA_ZED: Standard Deviation	6.8	6.4	4.5
ROOF_WIDTH: Roof (i.e., building	27.5	13.3	10
ROAD_WIDTH: road width [m]	19	16.2	9.8
AH: Anthropogenic heat [W m/m²]	90	50	20
FRC_URB: Fraction of the urban landscape which does not have natural vegetation [Fraction]	0.95	0.85	0.5
CAPR: Heat capacity of r	1.00E+06	1.00E+06	1.00E+06
CAPB: Heat capacity of	1.00E+06	1.00E+06	1.00E+06
CAPG: Heat capacity of grou	1.40E+06	1.40E+06	1.40E+06
AKSR: Thermal conductivity of roof [	0.67	0.67	0.67
AKSB: Thermal conductivity of building wa	0.67	0.67	0.67
AKSG: Thermal conductivity of ground (road) [J /	0.4	0.4	0.4
ALBR: Surface albedo of roof [fraction]	0.2	0.2	0.2
ALBB: Surface albedo of building wall [fraction]	0.2	0.2	0.2
ALBG: Surface albedo of ground (road) [fraction]	0.2	0.2	0.2
EPSR: Surface emissivity of roof [-]	0.8	0.9	0.93

‚Morphology'

‚Material characteristics'

Albedo

Street Parameters

Urban Categ… [index]	…irection …]	street width [m]	building width [m]
33		19	25
33	90	19	25
32	0		13
32	90		13
31	0	18	10
31	90	18	10

Road network

Building Heights

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

Building properties

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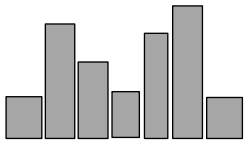
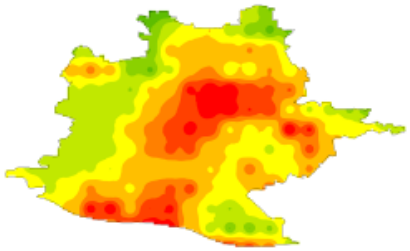
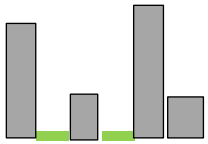
Simulation of UHI mitigation scenarios

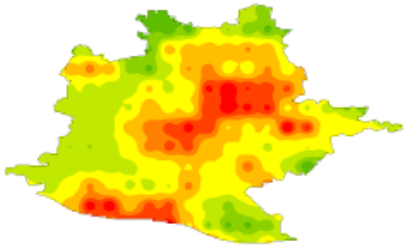
Control



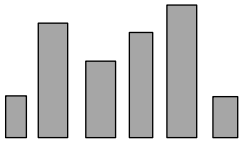


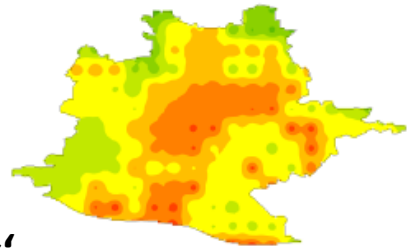
‚Many Parks'



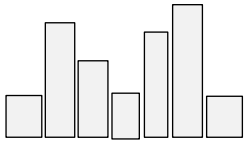


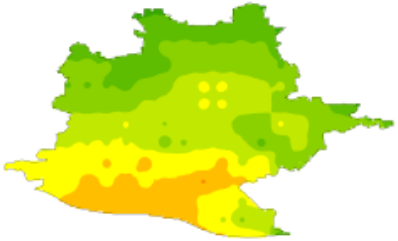
‚Density'



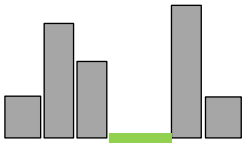


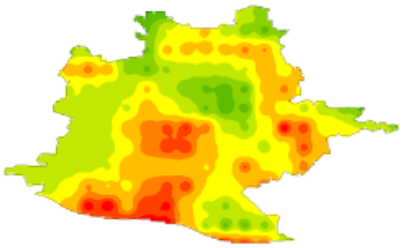
‚Albedo'





‚Central Park'





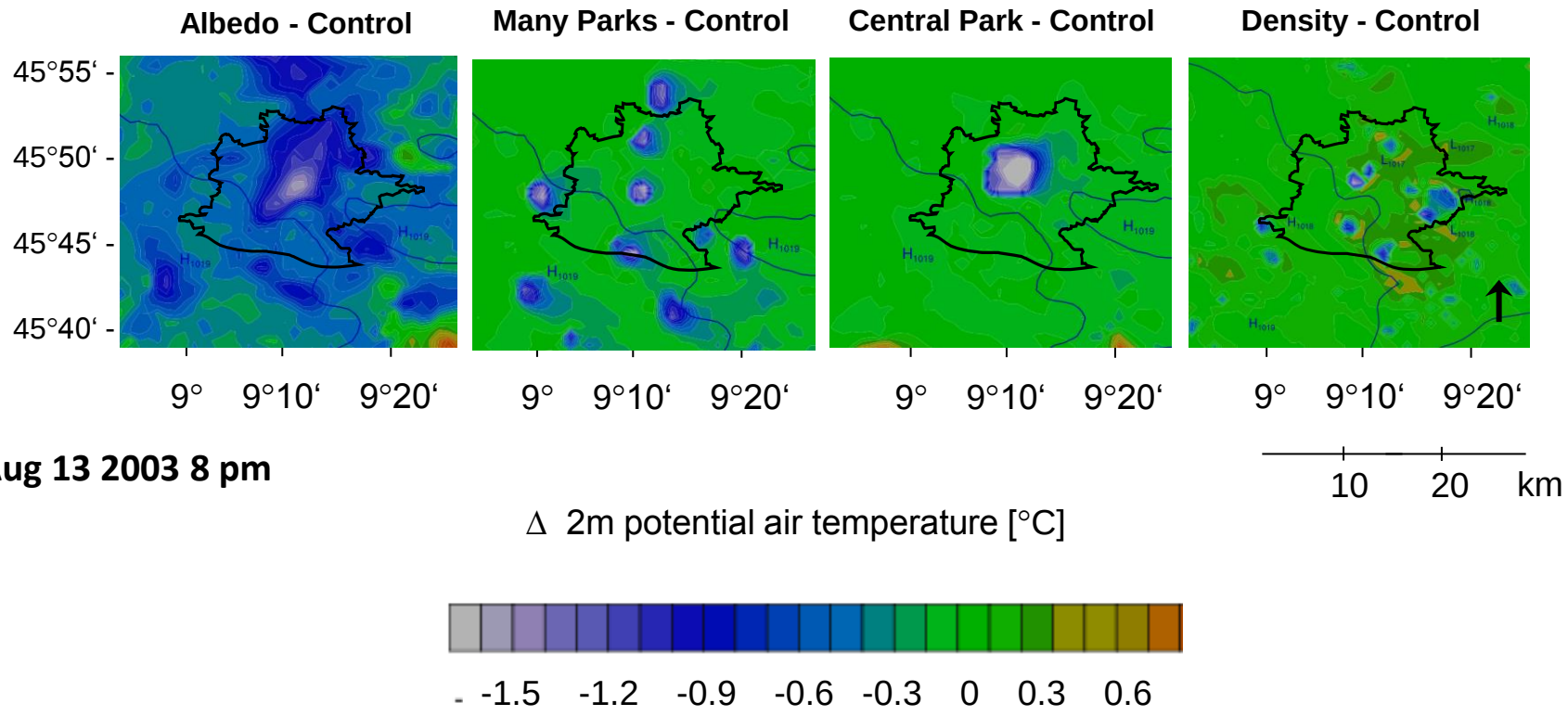
$T2_{pot}$ [°C]

31.5

33.5

Aug 13 2003 8pm

‚Efficiency‘



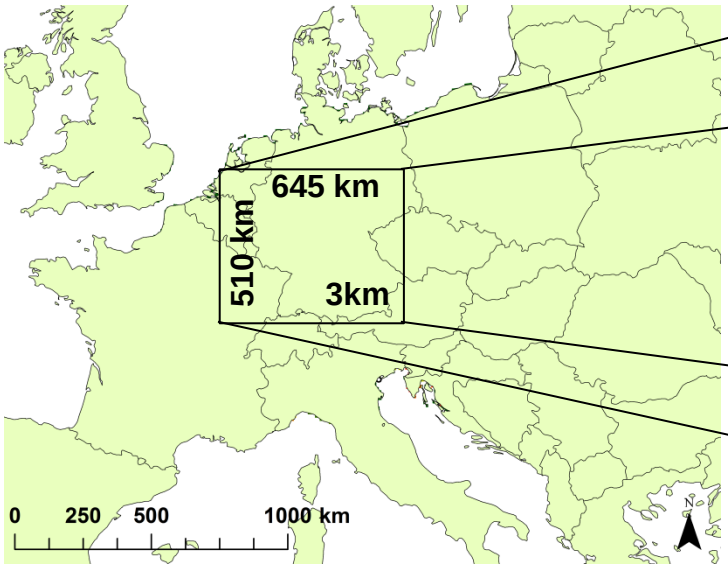
Aug 13 2003 8 pm

(Fallmann et al. 2014)

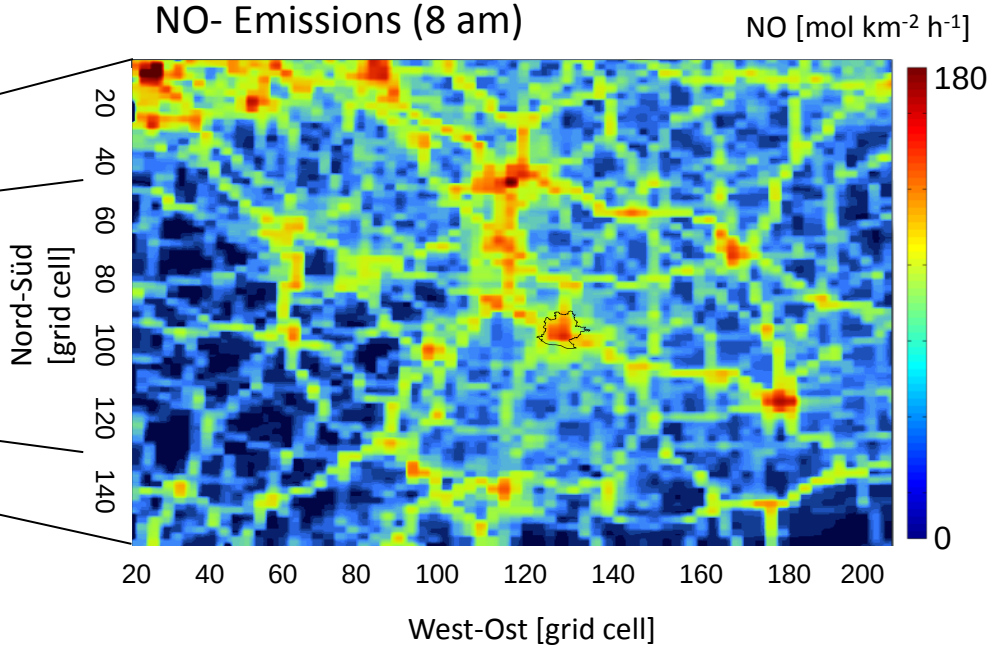

And now?

2. Step: Air Quality modelling (WRF-Chem)

WRF-Chem Domain



NO- Emissions (8 am)



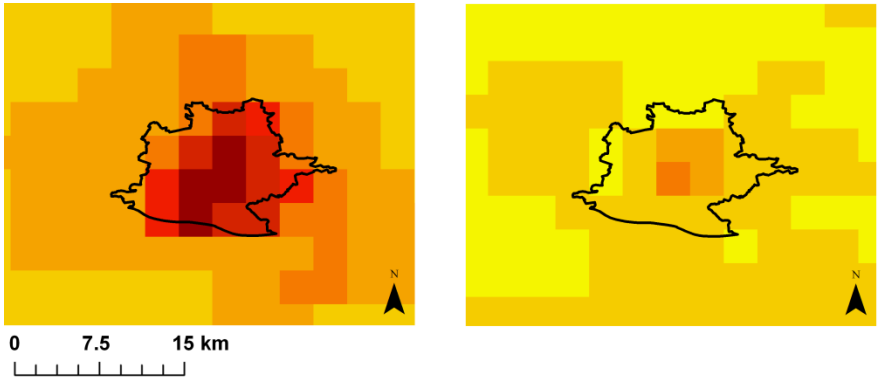
- Initial- and dynamical boundary conditions from global model ***MOZART*** *(anthropogenic)* **und *MEGAN*** *(biogenic)*
- Lower boundary conditions ***MACC Emissions 2003-2007***
- Modelled time frame: Aug **9 – Aug 18 2003**

Evaluation: Fallmann et al. 2015

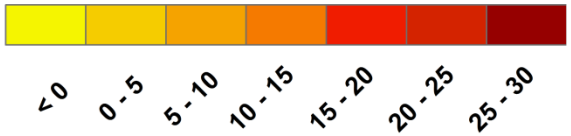
Effect of decreased Temperature

Primary pollutants (e.g. CO)

‚Albedo-Control‘ ‚Park-Control‘



Delta CO [ppb]

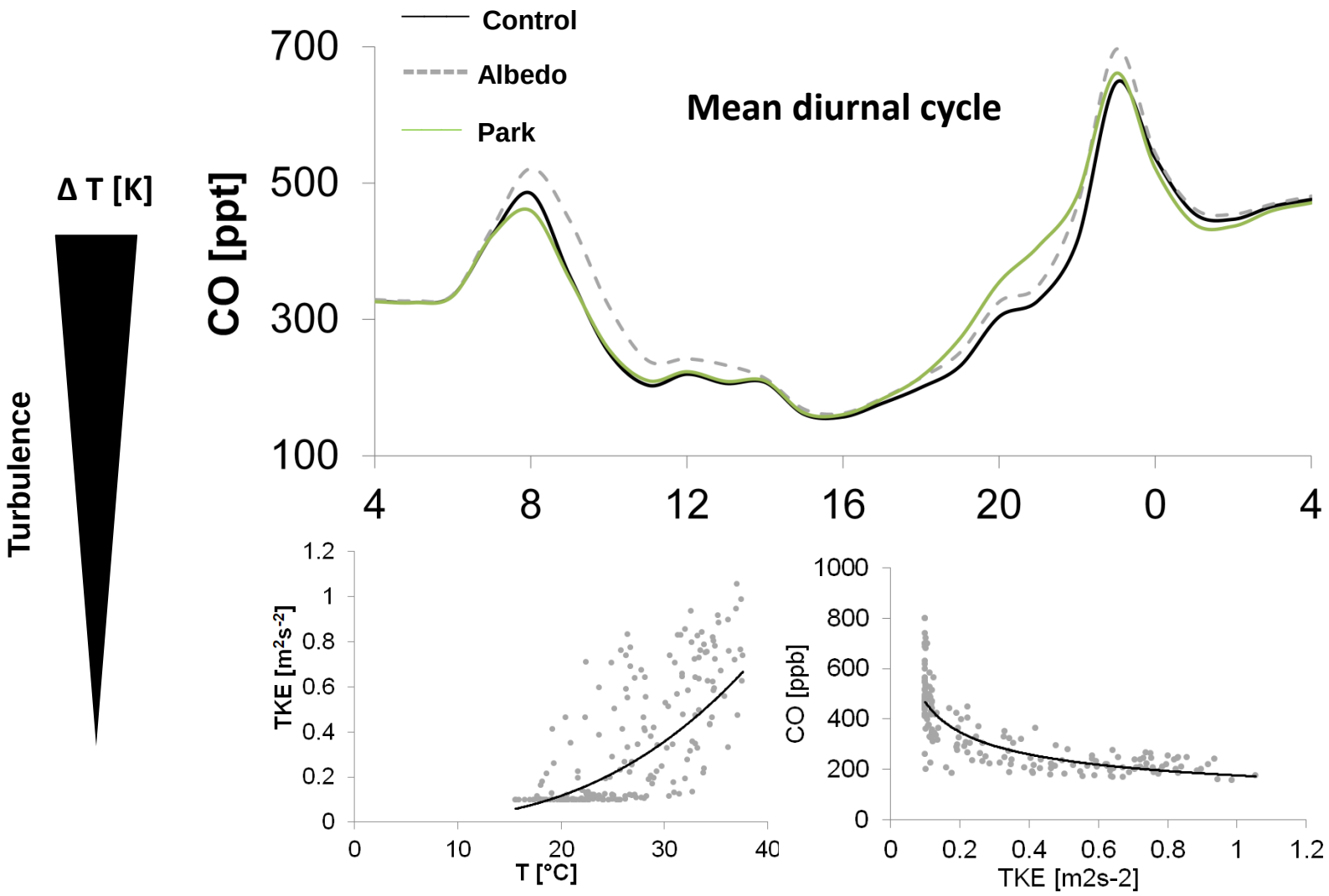


Secondary pollutants (e.g. O3)

‚Albedo-Control‘ ‚Park-Control‘

Delta O3 [ppb]

Primary pollutants(CO, NO) – Atmospheric dynamics



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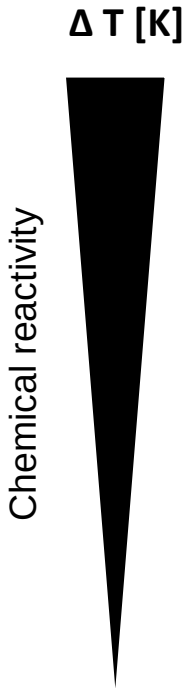
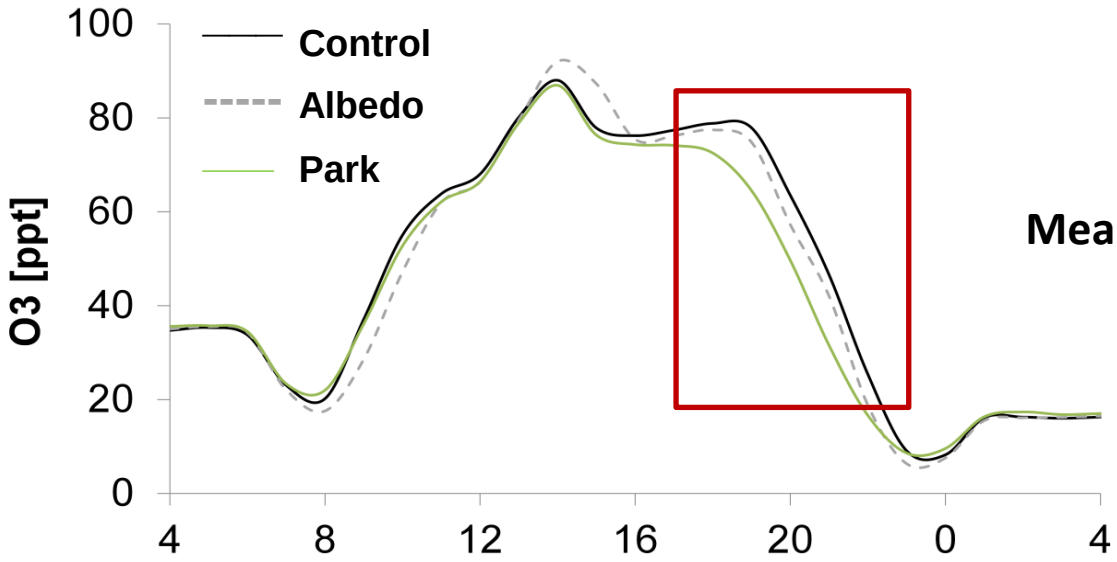
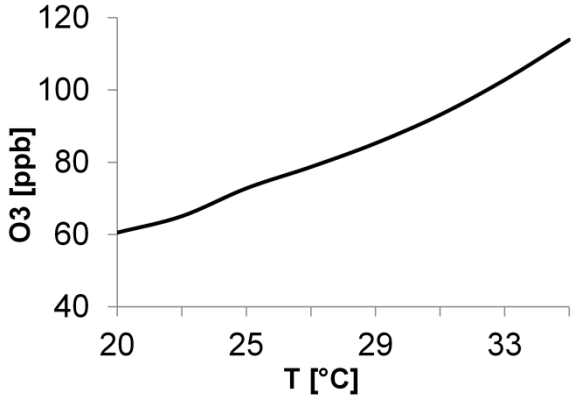
Secondary pollutants (Ozone) – Chemical reactivity

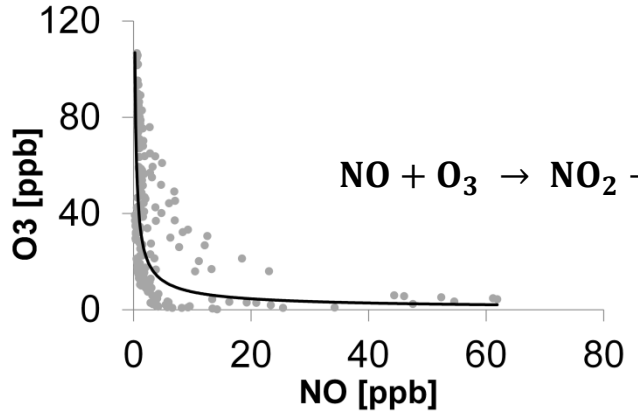


RADM boxmodel
(Stockwell 1988)



Mean diurnal cycle



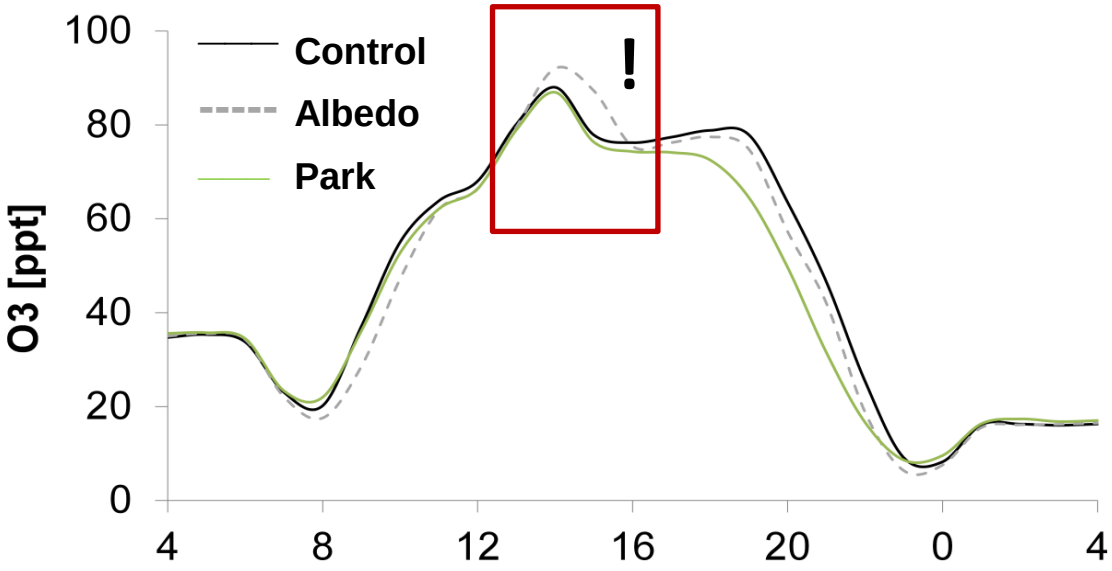


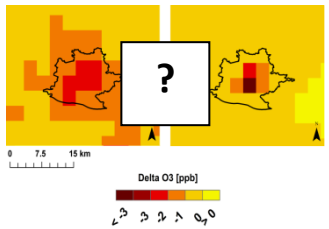
$$NO + O_3 \rightarrow NO_2 + O$$

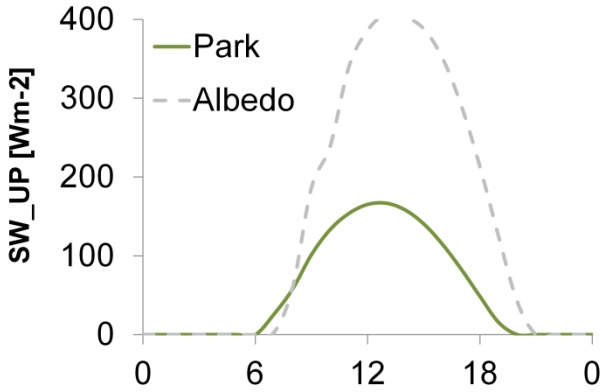
Secundary pollutants (Ozone) - Photolysis

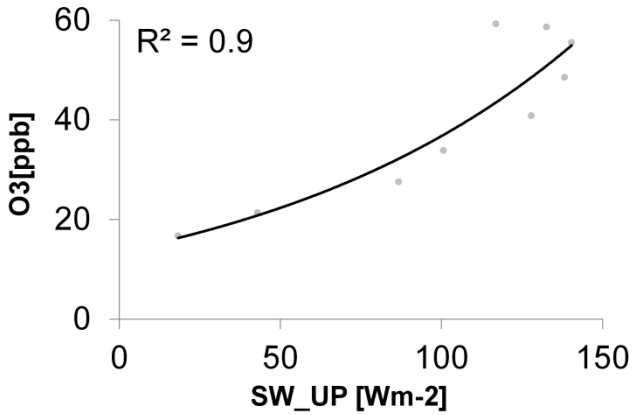
SW_UP [Wm-2]

Photolysis rate







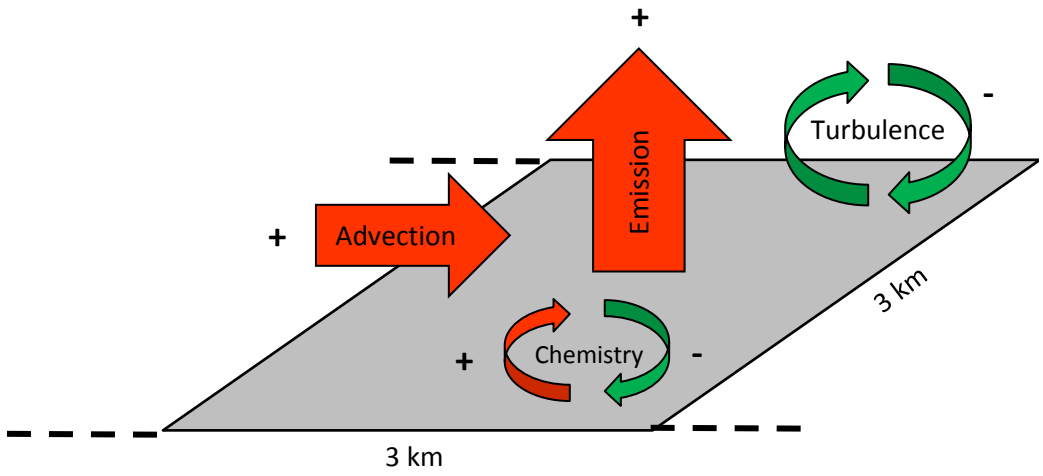


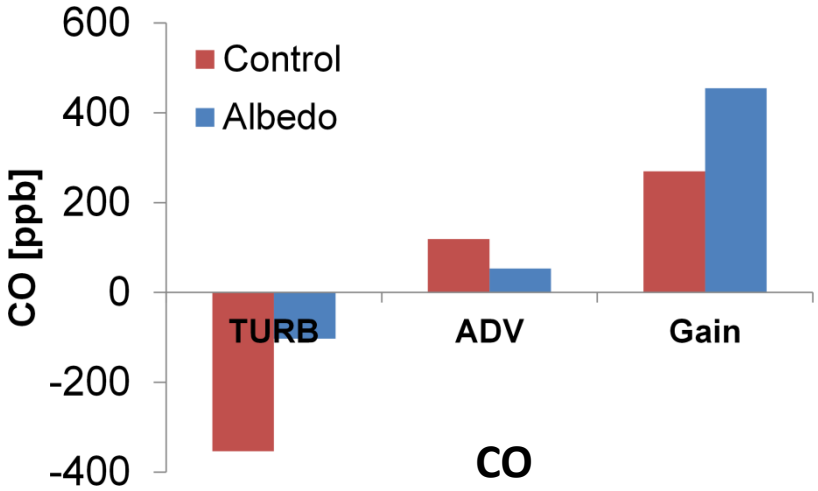
Quantification via tendency terms

- 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)

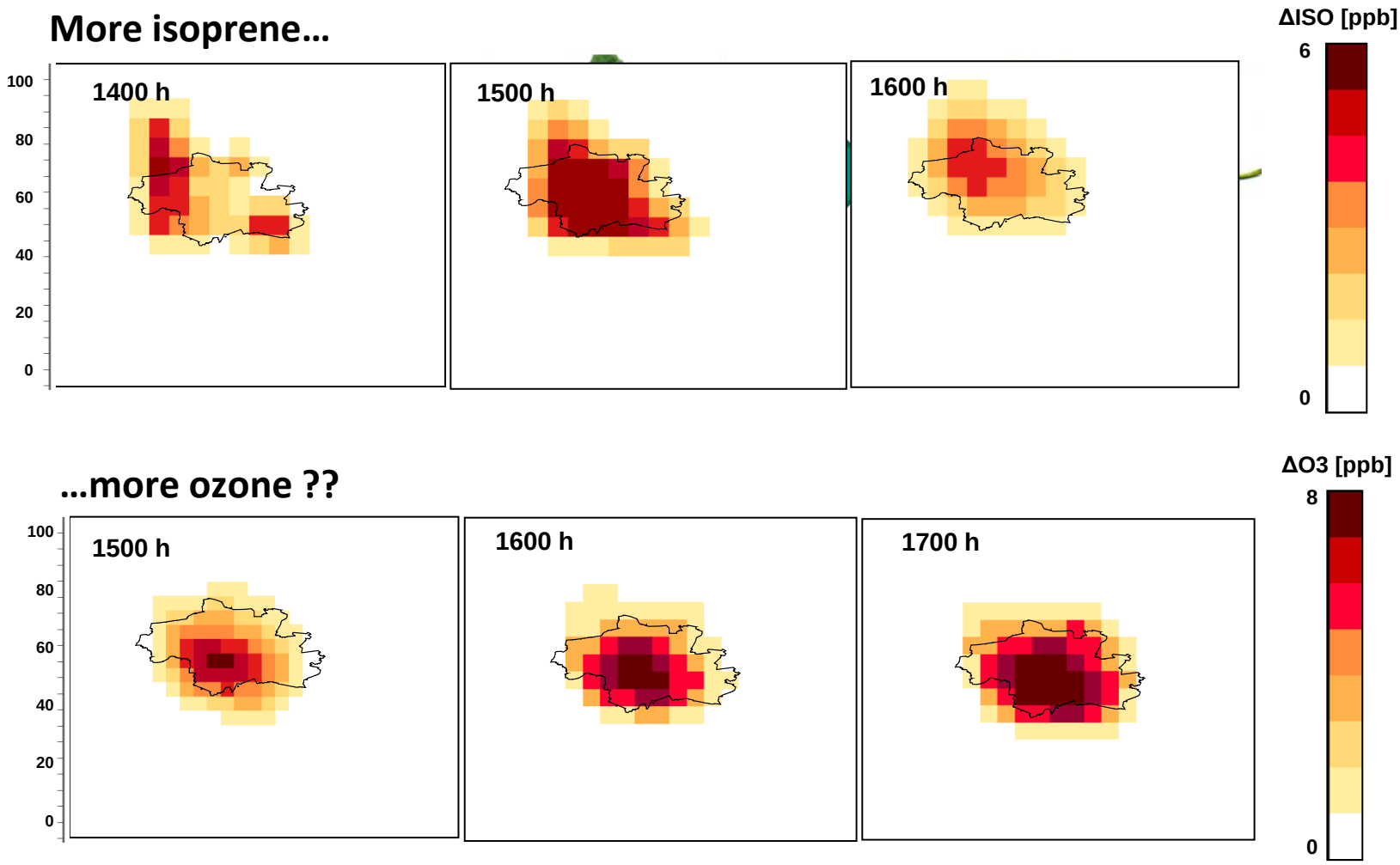
Balance:

Gain/Loss = EMIS + CHEM + TURB + ADV





Case Study: The wrong trees for Munich ?!



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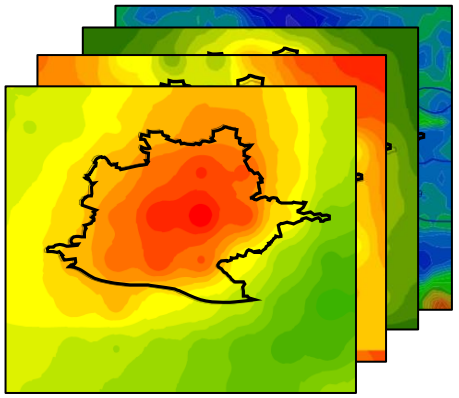
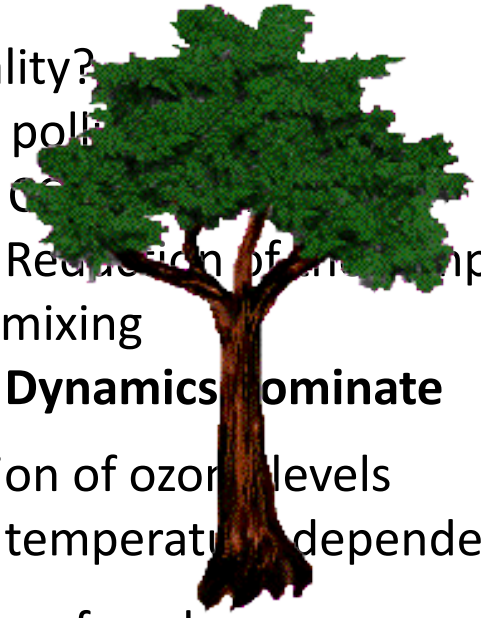
Summary



- Urban Heat Island mitigation strategies?
  - Surface reflectivity
  - Urban greening
  - Reduction of building density



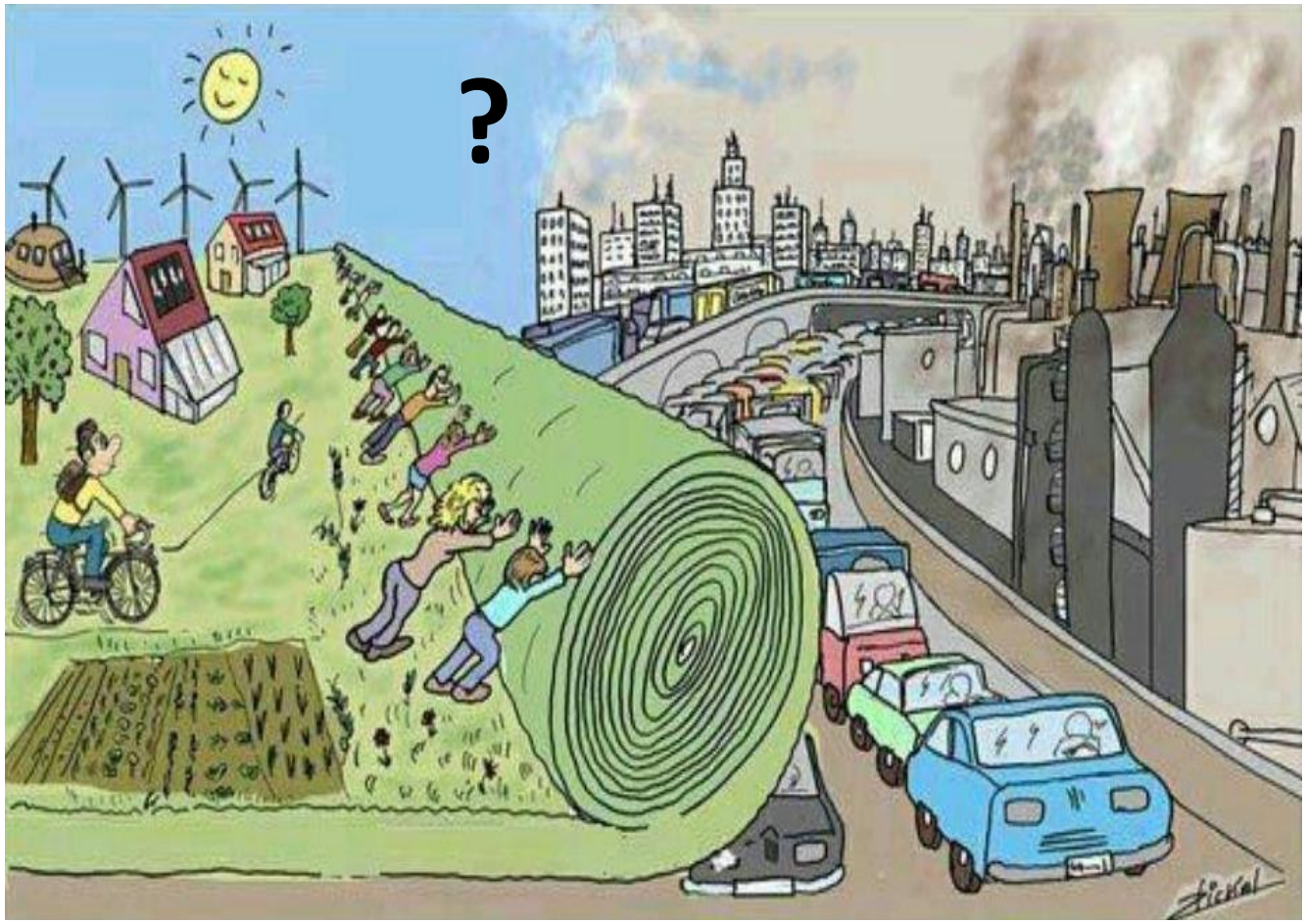
?

- **Feedback** on urban air quality?
  - Primary vs. Secondary pol
    Primary: Increase of O
    → Red ion of the temperature dependent turbulent mixing
    → **Dynamics dominate**

    Secondary I: Reduction of ozon levels
    → temperat dependency

    Secondary II: Increase of peak ozone concentrations for ‚white roofs'
    → increased photolysis rates due to reflected UV

Merci Beaucoup



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