Cooler City – Cleaner City?

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

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The Urban Heat island

- The tendency for an urbanized area to remain significantly warmer than its rural surroundings (Oke 1982)
- Additional heat sources, roughness effects and albedo of urban surfaces 'design' specific atmospheric dynamics → urban-rural circulation patterns
- Regional secondary circulation patterns → transport of rural air pollutants (e.g. BVOCs) into city → reaction with urban pollutants
- Specific urban planning strategies can reduce negative effects (Taha 1997)

UHI mitigation scenarios

- Urban planning strategies:
  - effect of white roofs by increasing the albedo from 0.2 to 0.7 (Albedo)
  - replace urban surface by natural vegetation (grass) one park of 20 km² (Central Park) and several parks of the same accumulated size (many parks)
  - decrease building density by 20%

Effect on Air Quality ?

Urbanization of a mesoscale model

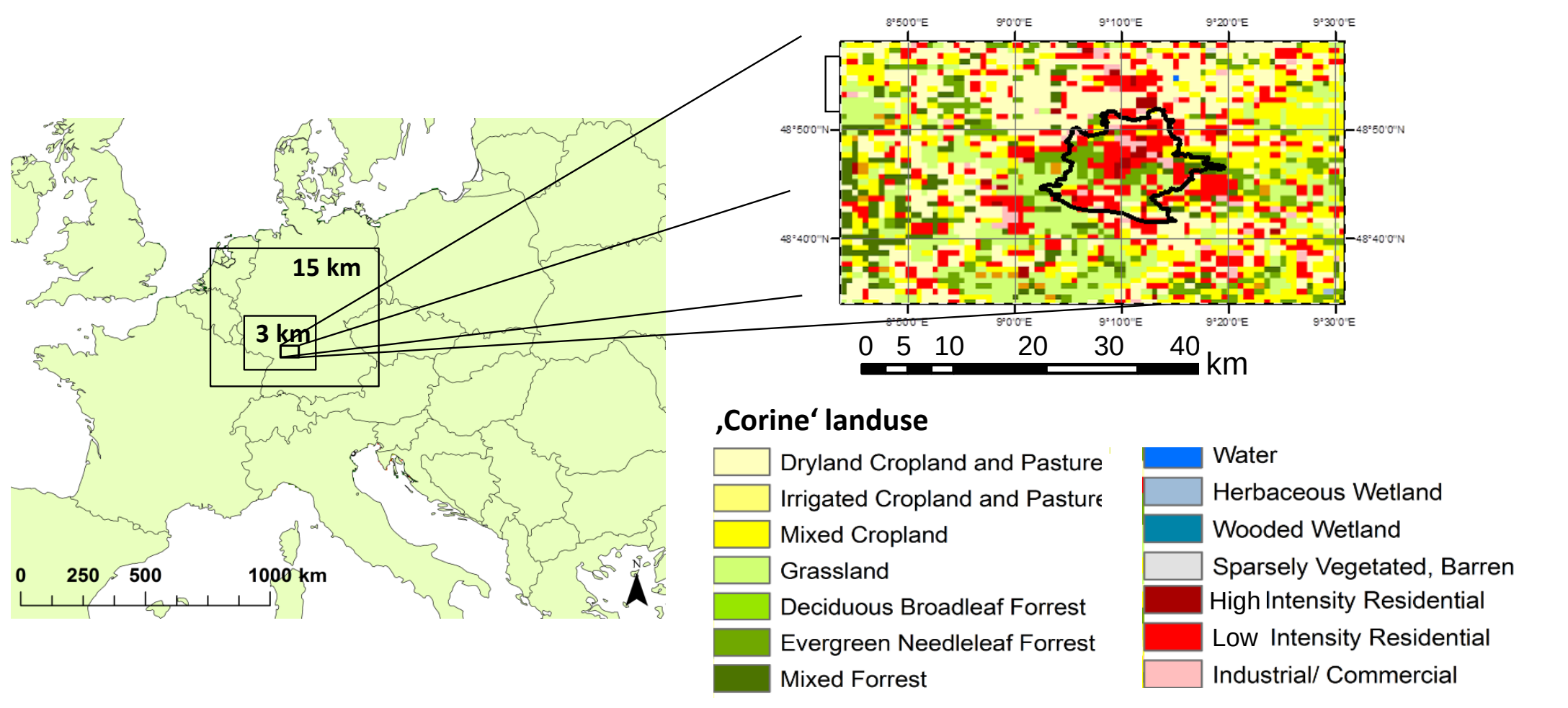


Fig. 1: WRF-Chem domain and map of land cover (left); schematic image of two WRF urban canopy models and evaluation of temperature (right)

Reduction of the urban temperature

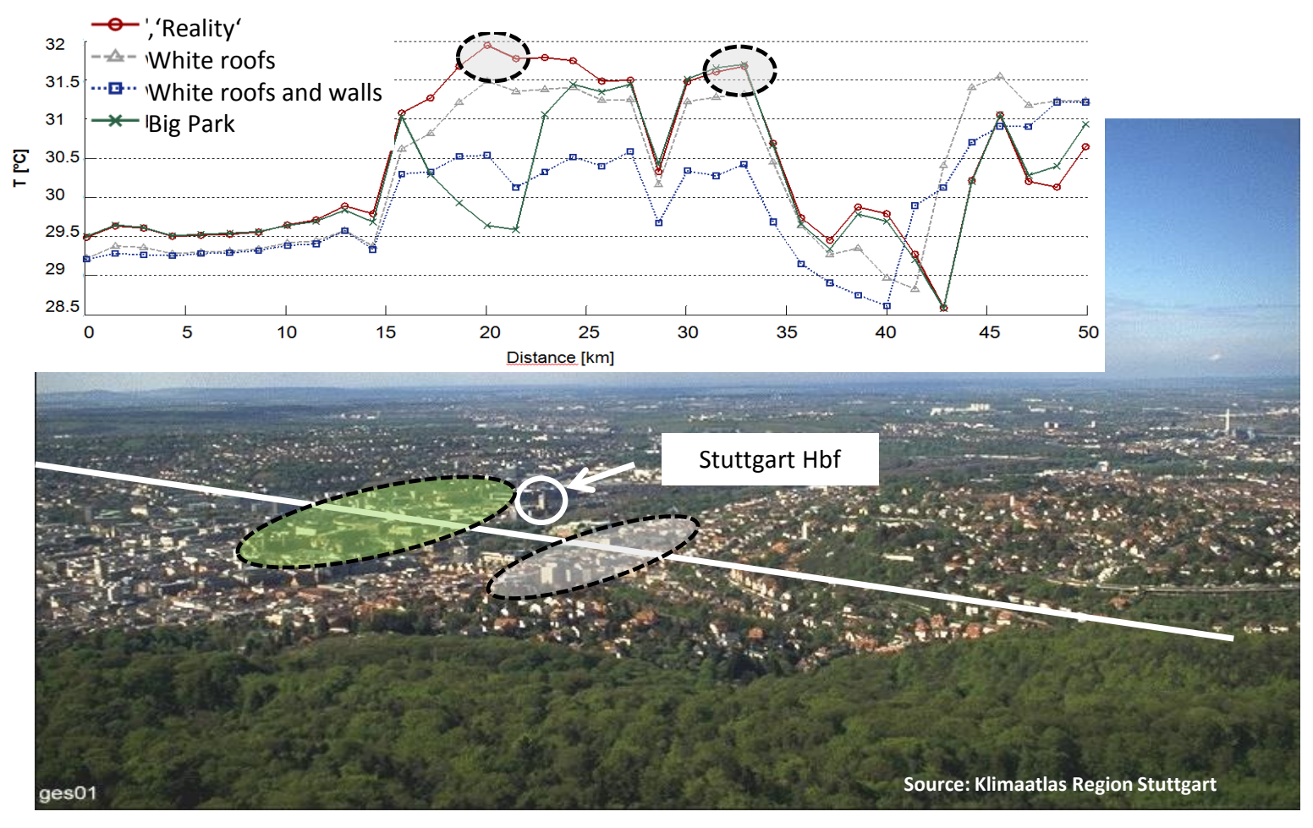


Fig. 2: Development of 2m potential temperature over cross section (left) and for the urban area of Stuttgart (right) **August 13th 2003 8 pm**

Reduction of the UHI

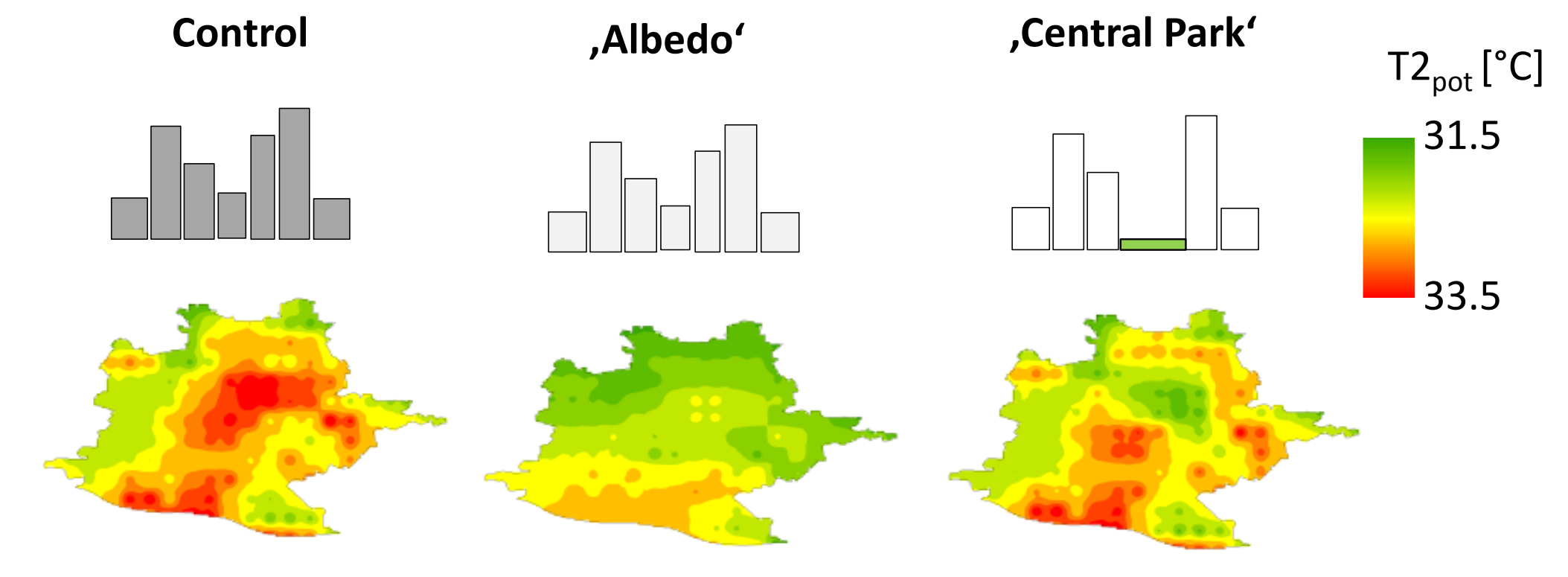


Fig. 3: Development of 2m potential temperature over urban area of Stuttgart **August 13th 2003 8 pm**

UHI

Scenario	Control	Albedo	Central Park
UHI [K]	2.5	0.8	1.2

Chemical modelling (WRF-Chem)

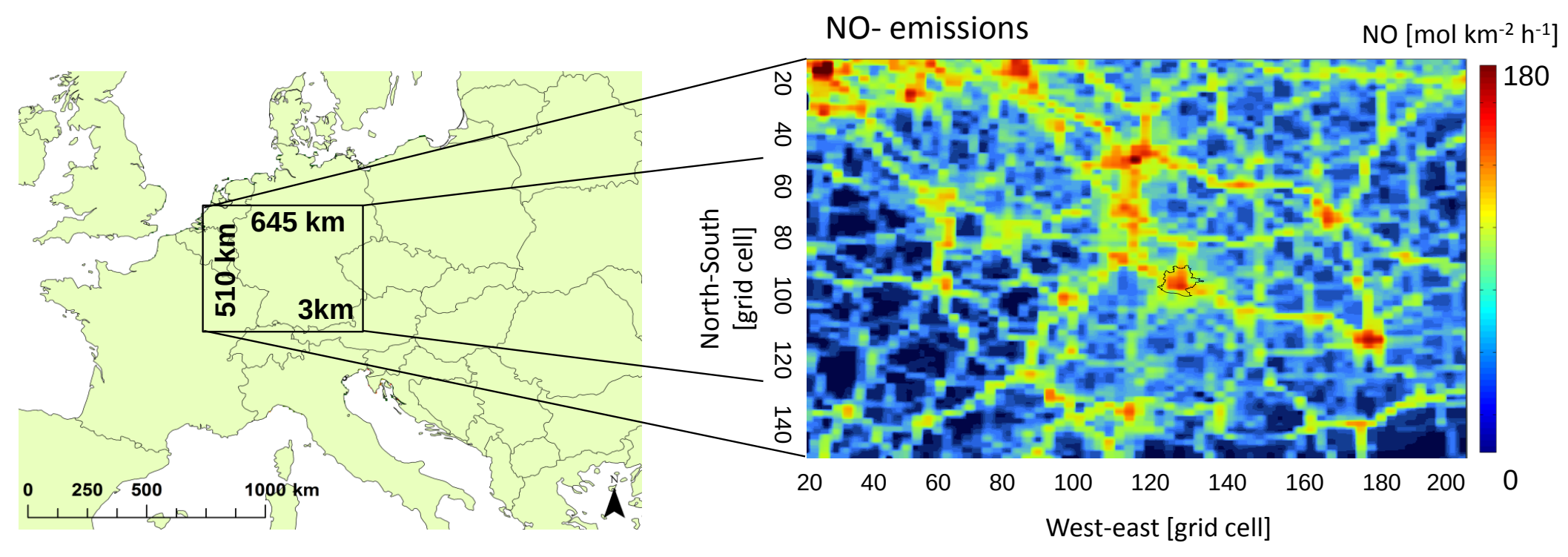


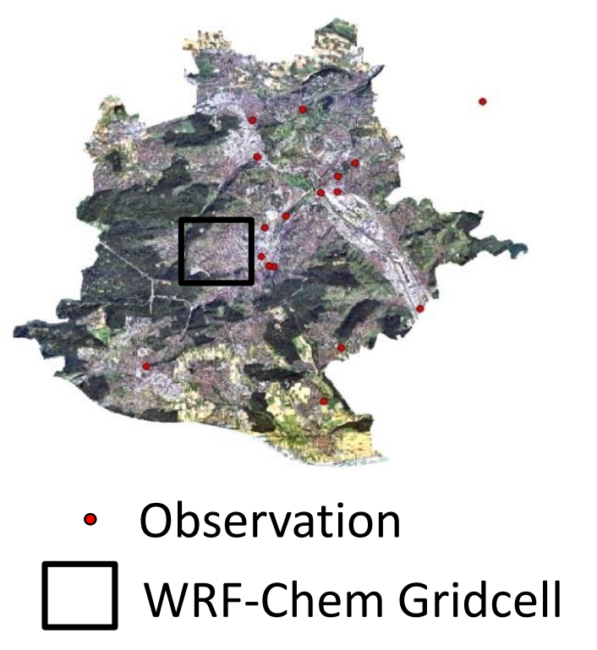
Fig. 4: WRF-Chem domain and map of NO emissions

Tab. 1: WRF-Chem setting

Parameter/Scheme	Specification	Parameter/Scheme	Specification	Parameter/Scheme	Specification
geographical input data	1km USGS land use	vertical layers	36	urbanization scheme	BEP (Martilli 2002)
dx, dy	3km	time frame	8/9 - 8/18/03	land surface model	Noah LSM
west-east [grid cells]	200	lowest model level	11m	chemical option	RADM2, MADE/SORGAM
south-north [grid cells]	150	meteorological BC	0.5 Deg ERA-Interim		

Parameter/Scheme	Specification	Parameter/Scheme	Specification	Parameter/Scheme	Specification
longwave	RRTMG	microphysics	Lin et al.	biochemistry	MEGAN global data
shortwave	RRTMG	emission inventory	7km MACC 2006	photolysis scheme	FastJ
cumulus	Grell Devenyi	chemical boundary	MOZART global data		

Evaluation



Mean:

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

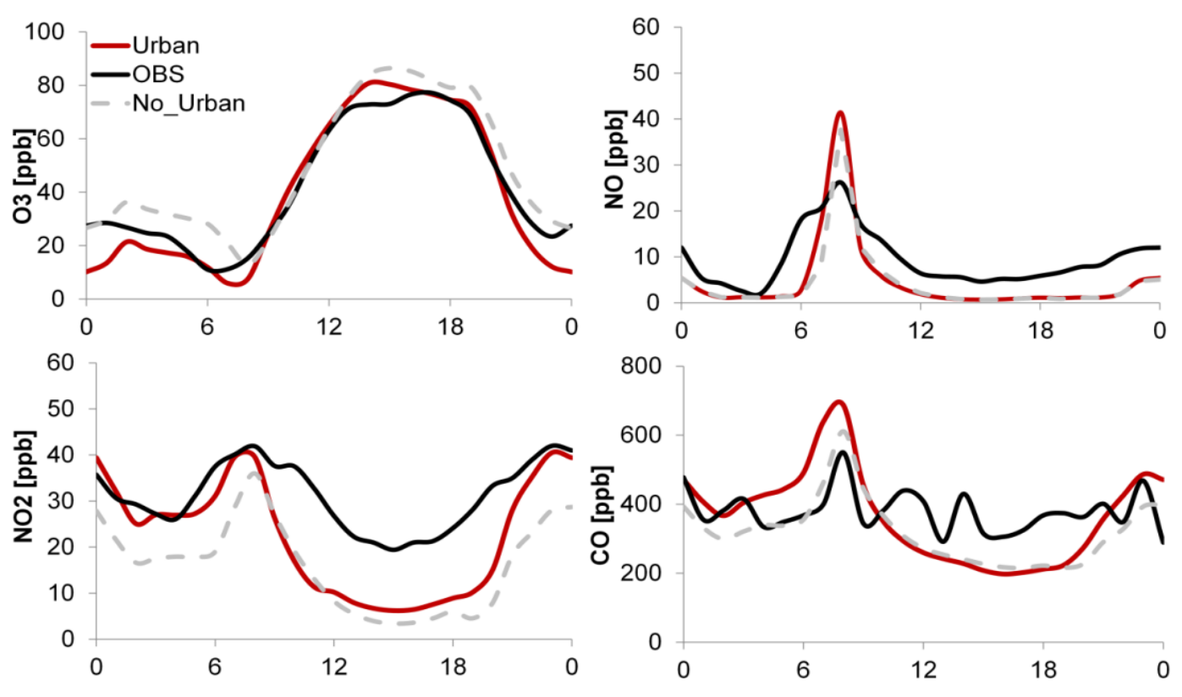


Fig. 5: Comparison between simulated WRF-Chem variable at a central urban grid point and average value of 4 observations within that 3x3 km cell for an average daily cycle. From up left to right: O3, NO2, NO and CO

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Primary pollutants **Secondary Pollutants** **Ozone – 1500 h**

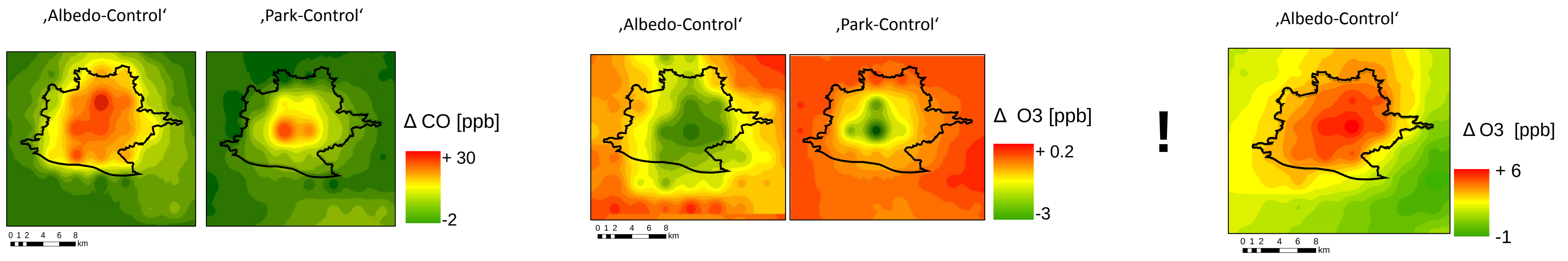

Fig. 6: Mean Difference between control- and scenario run [ppb] for modelling period for carbon monoxide (left), ozone (middle) and difference in peak ozone concentration at 1500 h (right)

Turbulence

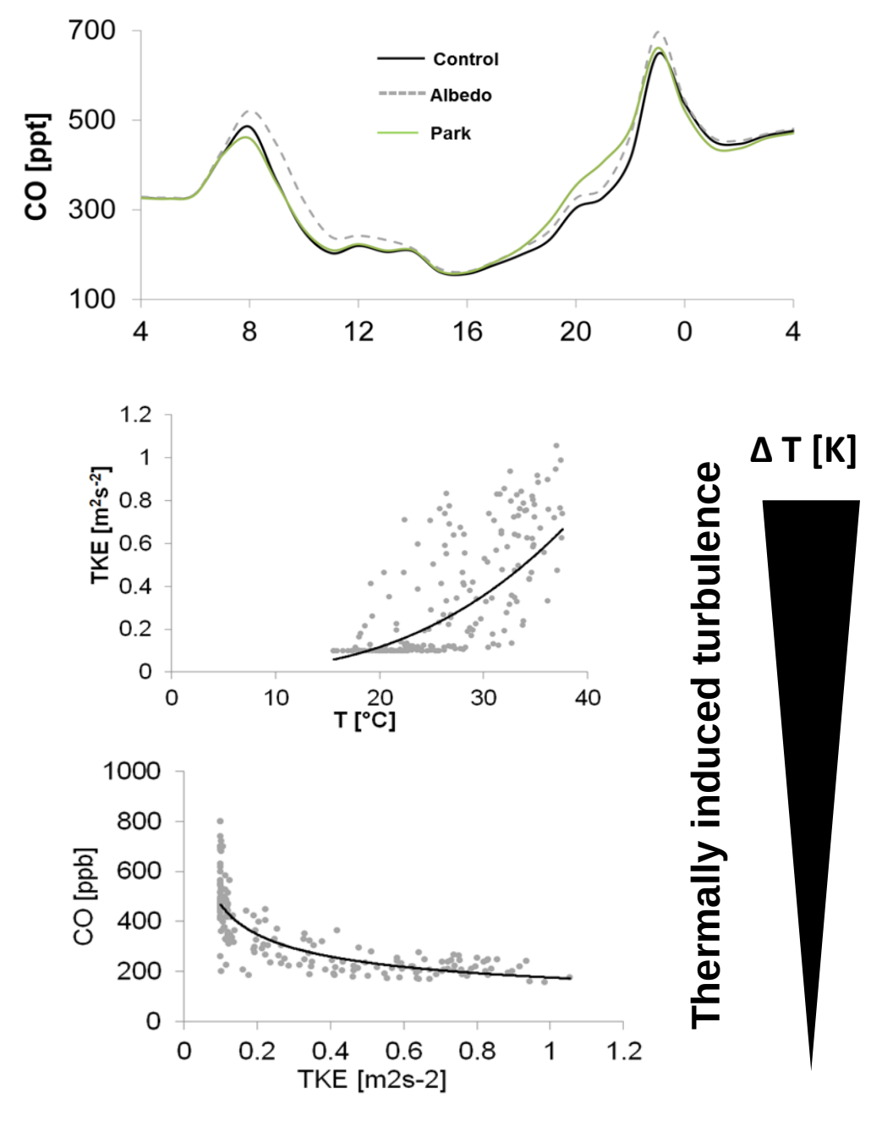

Fig. 7: Diurnal cycle of CO concentration for 3 scenarios and correlation between TKE and temperature/CO concentration at the lowest model level

Temperature

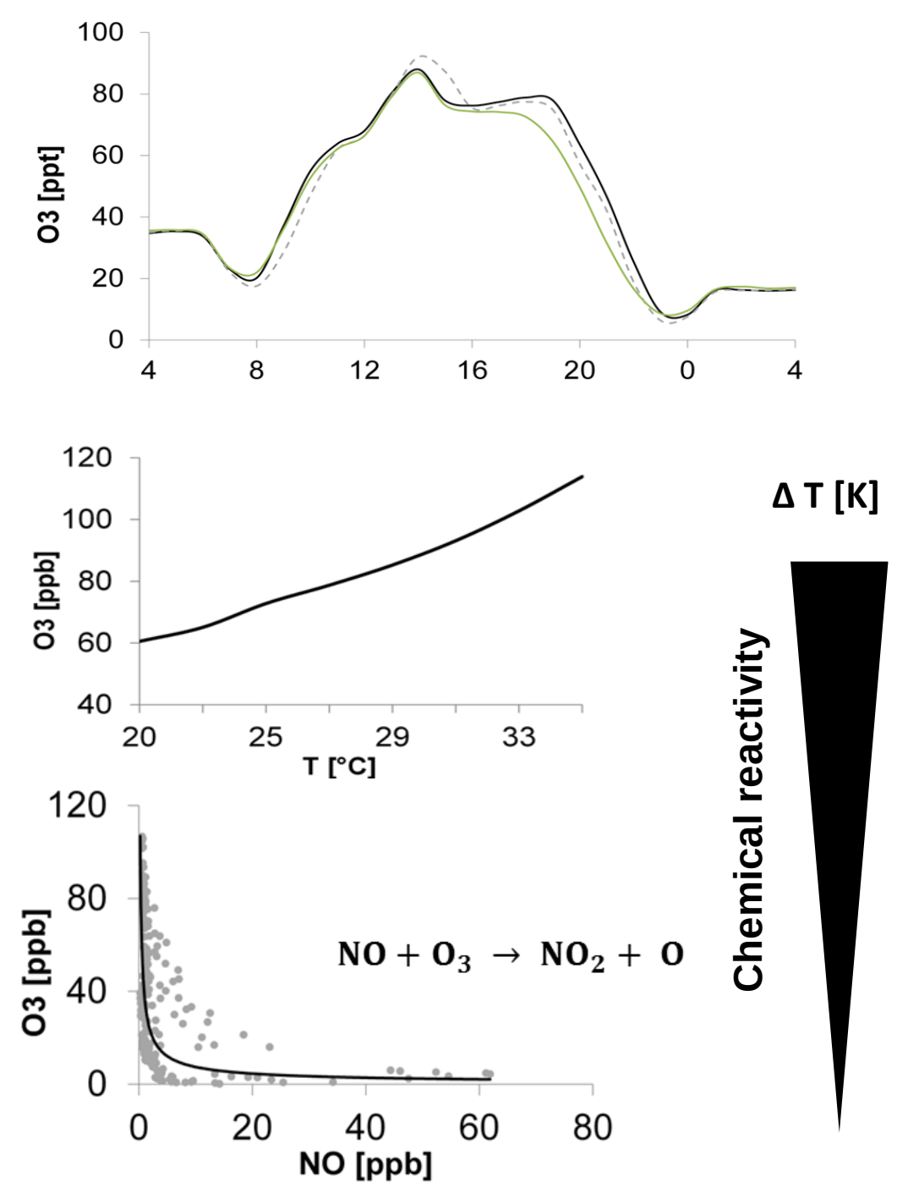

Fig. 8: Diurnal cycle of O3 for 3 scenarios (top), correlation of temperature and O3 (middle), correlation between NO and O3 in the lowest model level (bottom)

Photolysis

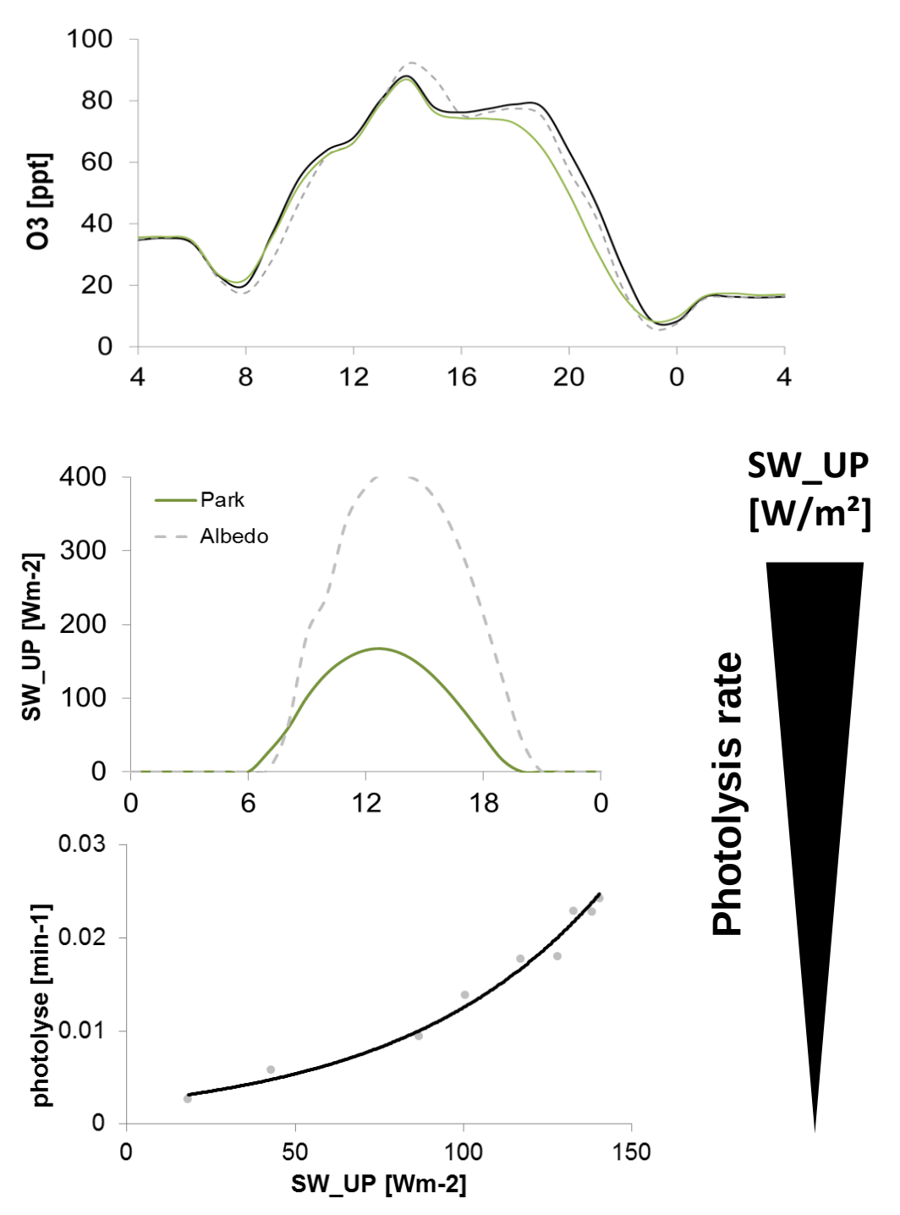

Fig. 9: Diurnal cycle of O3 for 3 scenarios (top), diurnal cycle of reflected SW radiation (middle), correlation between reflected SW and photolysis rate in the lowest model level (bottom)

5. Conclusion

- UHI mitigation strategies generate **negative effects** on primary and some secondary pollutants
- Reduced temperature leads to a reduction of turbulence → **increase of primary pollutants**
- Reduced temperature leads to a reduction of chemical reactivity → **decrease of ozone**
- Higher **albedo** leads to an increased amount of reflected SW radiation → **increase of peak ozone**

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Funded by the EU- Project "UHI - Development and application of mitigation and adaptation strategies and measures for counteracting the global UHI phenomenon" (3CE292P3) (2011-2014).