Mapping of micro-meteorological conditions using statistical approaches – The example of Stuttgart

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Introduction

- maps are fundamental for decision-making for city planers and architects
- quantification of recent and future conditions
- quantification of adaptation measures facing climate change

Data and methods

① Intra-urban temperature differences

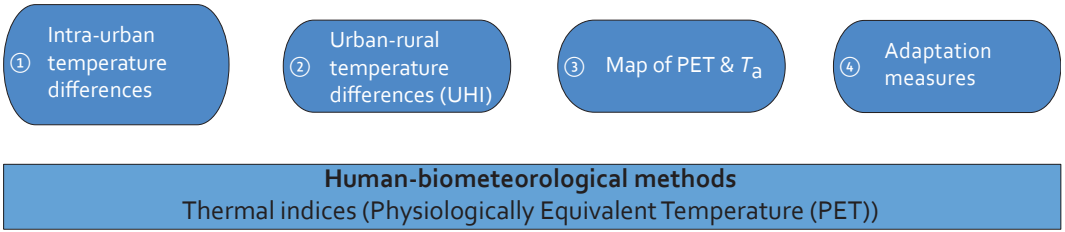
② Urban-rural temperature differences (UHI)

③ Map of PET & T_a

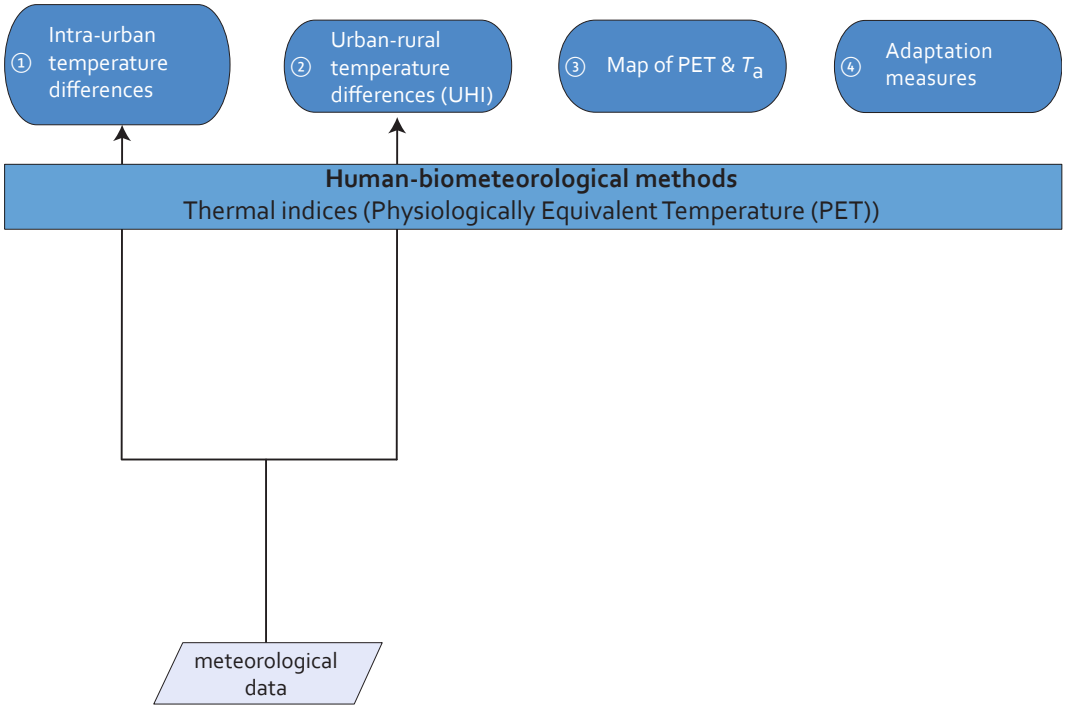
④ Adaptation measures

PET: Physiologically Equivalent Temperature (Mayer & Höppe 1987, Höppe 1999)

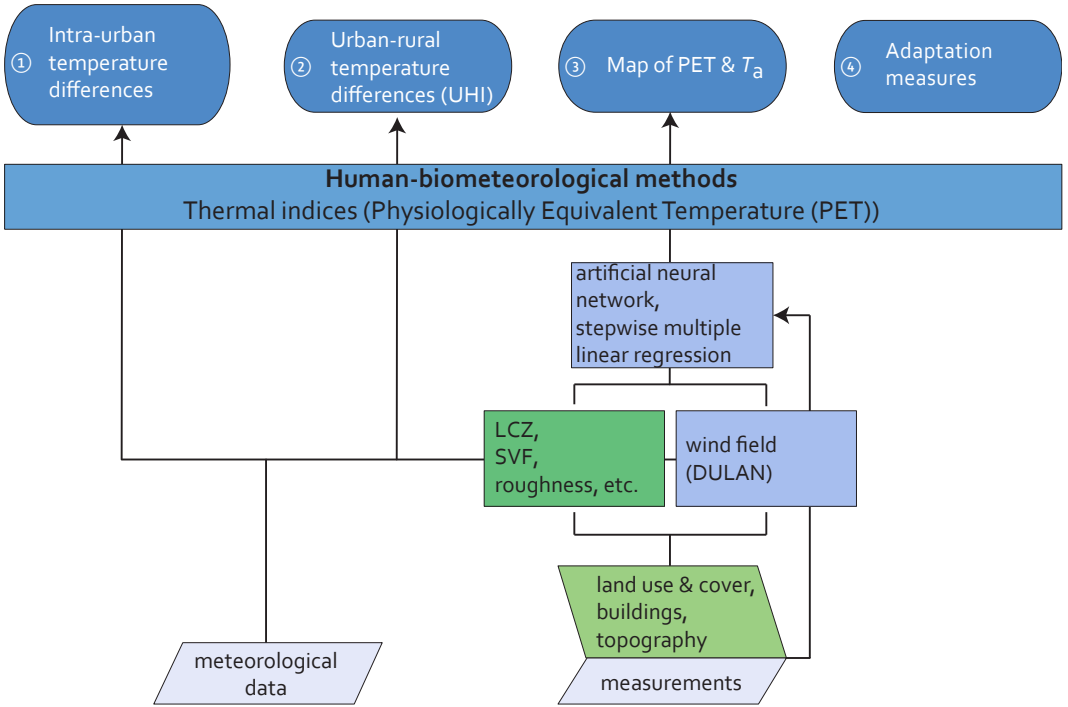
Data and methods



Data and methods

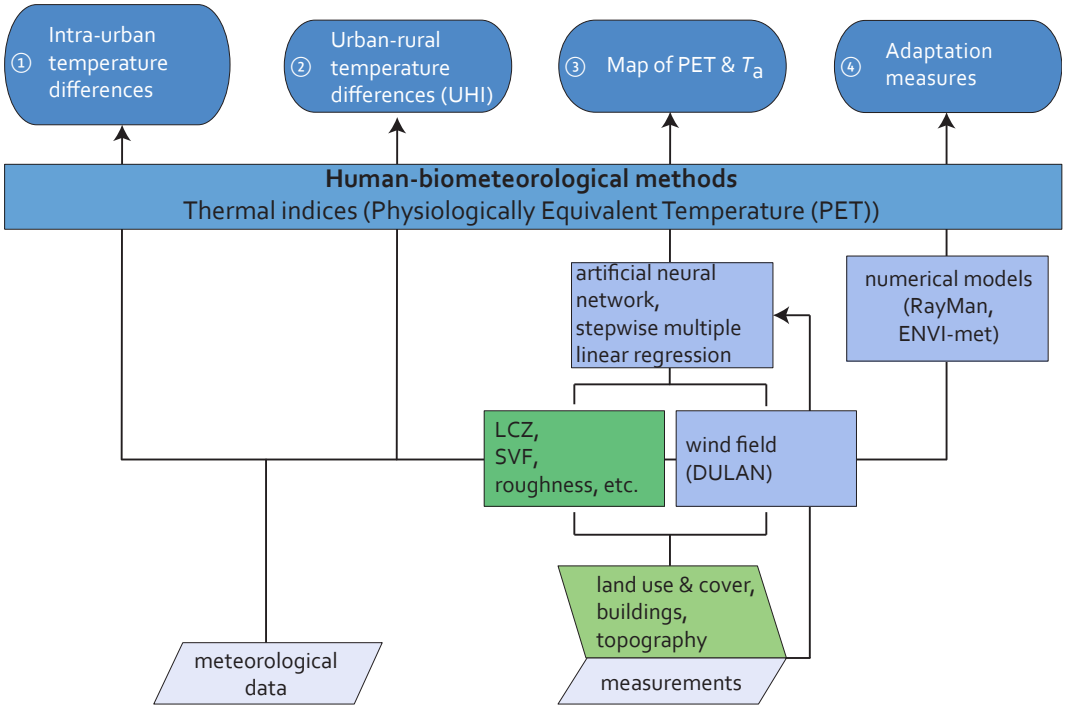


Data and methods



LCZ: Local Climate Zone (Stewart & Oke 2012), SVF: Sky View Factor

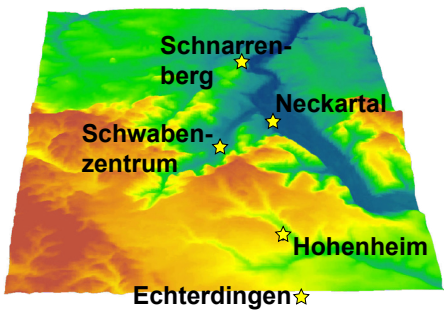
Data and methods



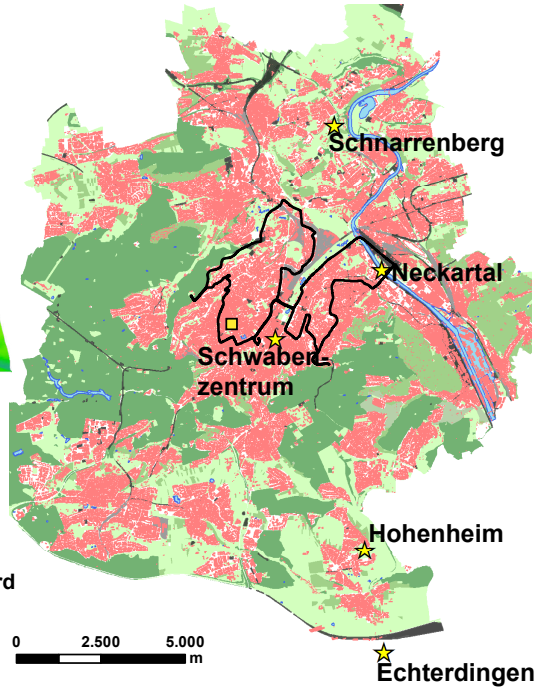
ENVI-met (Bruse & Fleer 1998), RayMan (Matzarakis et al. 2007, 2010)

Study area: Stuttgart

Topography



Land use and land cover



Data © Stuttgart 2012

Results and discussion

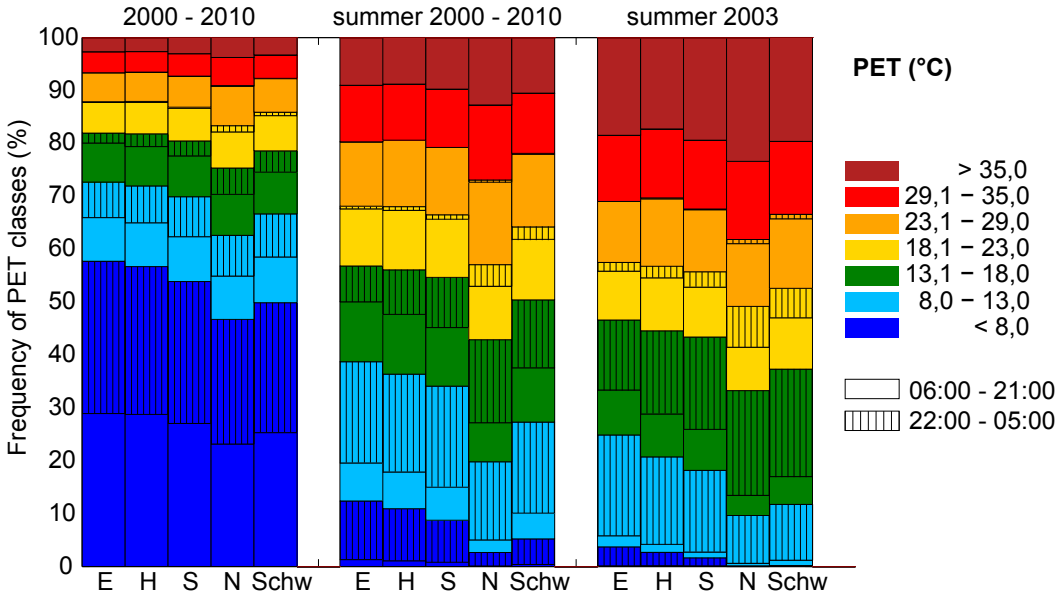
① Intra-urban temperature differences

② Urban-rural temperature differences

③ Maps (PET, Ta, UHI)

④ Adaptation measures

① Intra-urban PET-differences



Echterdingen, **H**ohenheim, **S**chnarrenberg, **N**eckartal, **Schw**abenzentrum

Data: 2000 – 2010, hourly values

② Urban-rural PET-differences

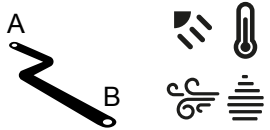
- strong heat stress (PET > 35 °C) only in daytime
- 12 - 115 h weak heat stress between 22:00-6:00 CET

frequency (in %)/ Δ_{u-r} PET (K)	Stuttgart - city center (Schwabenzentrum) winter	spring	summer	autumn
< -2.0	0.1	0.1	0.1	0.1
-2.0 - 0.0	7.0	4.1	3.6	6.1
0.1 - 2.0	63.5	54.4	45.5	57.2
2.1 - 4.0	25.6	30.6	35.7	28.3
> 4.0	3.9	10.7	15.2	8.3

Data: 2000 – 2010, houly values, rural reference station: Echterdingen

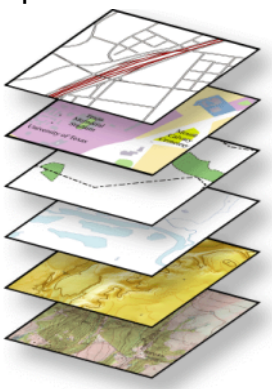
③ Mapping PET

Meteorological data



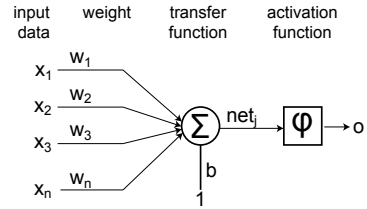
prepare data
detrending
calculation of
- wind field
- Tmrt
→ PET

Spatial data



slope,
aspect,
roughness,
wind speed,
cold air flow,
SVF,
morphological
parameters

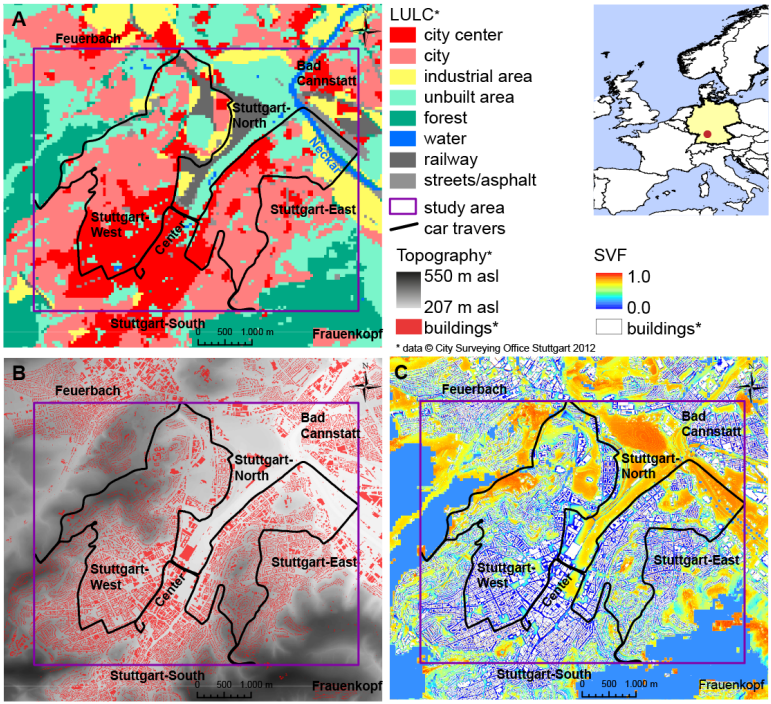
Artificial neural networks



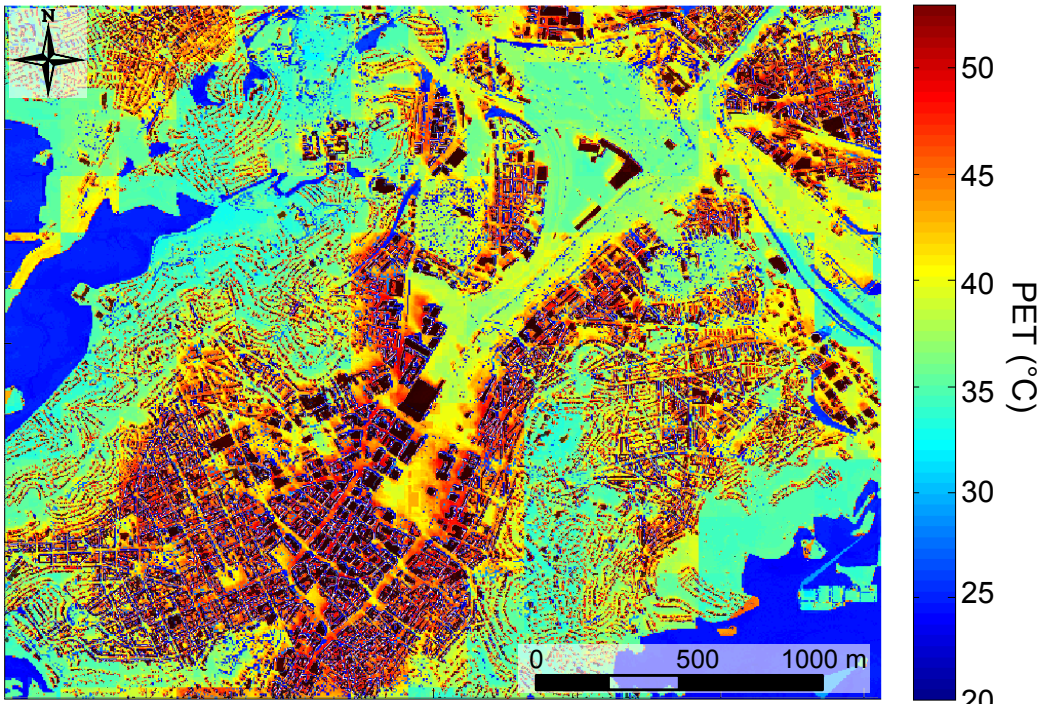
net_j netto input
b bias
o output of the neuron

Stepwise multiple linear regression

③ Land use and land cover, SVF, topography

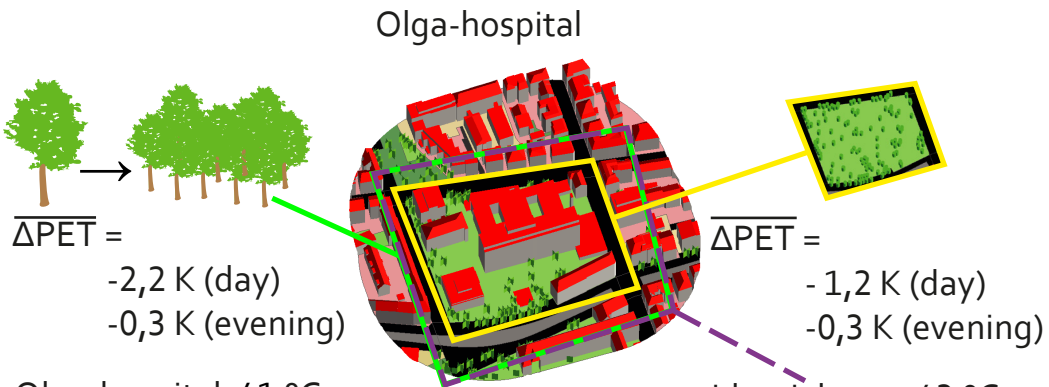


③ Map: PET

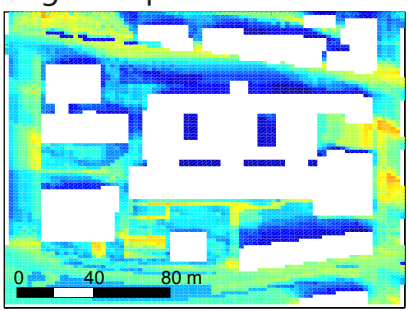


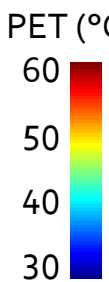
Data: 3 July 2014 13:00 CET; method: artificial neural network

④ Quantification of adaptation measures

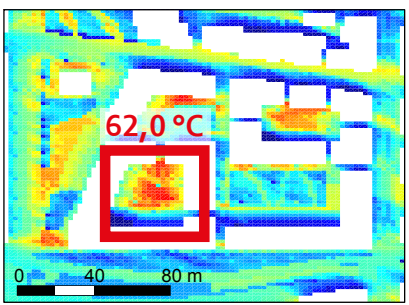


Olga-hospital: 41 °C





residential area: 43 °C



ENVI-met 3.5 simulations, average value 10:00-17:00

④ Quantification of adaptation measures

Height-/ width ratio	Frequency (in %)	Orientation N-S 0°	15°	NW-SE 30°	45°	60°	75°	W-E 90°	105°	SW-NE 120°	135°	150°	165°
0,5	heat stress	26,5	26,6	26,8	27,0	27,1	27,2	27,2	27,1	26,9	26,7	26,5	26,4
	th. comfort	50,2	50,1	49,8	49,6	49,0	48,5	48,5	49,0	49,3	49,9	50,1	50,2
	cold stress	23,4	23,4	23,4	23,4	23,9	24,3	24,3	24,0	23,7	23,4	23,4	23,3
1	heat stress	24,3	24,4	24,5	24,7	24,8	24,9	25,0	24,8	24,6	24,4	24,3	24,2
	th. comfort	54,1	54,1	54,2	54,3	54,3	54,1	53,6	53,6	54,0	54,2	54,2	54,4
	cold stress	21,6	21,5	21,3	20,9	20,9	20,9	21,4	21,6	21,4	21,4	21,5	21,4
1,5	heat stress	23,4	23,4	23,6	23,7	23,9	23,9	23,9	23,8	23,8	23,6	23,6	23,4
	th. comfort	56,1	55,9	56,2	56,1	56,0	56,3	56,2	55,7	55,6	55,8	56,1	55,8
	cold stress	20,5	20,6	20,2	20,2	20,1	19,8	19,9	20,5	20,6	20,5	20,3	20,8
2	heat stress	22,9	23,0	23,1	23,2	23,3	23,4	23,3	23,2	23,2	23,2	23,1	23,0
	th. comfort	56,8	57,0	56,9	56,9	57,0	57,1	57,1	56,8	56,6	56,5	56,7	56,8
	cold stress	20,3	19,9	20,0	19,9	19,7	19,6	19,6	20,0	20,1	20,3	20,3	20,3
2,5	heat stress	22,7	22,7	22,8	22,9	23,0	23,1	23,1	22,9	23,0	22,9	22,8	22,7
	th. comfort	57,2	57,7	57,4	57,5	57,5	57,4	57,7	57,3	57,2	57,3	57,4	57,7
	cold stress	20,1	19,5	19,8	19,6	19,5	19,5	19,3	19,8	19,8	19,8	19,8	19,6
3	heat stress	22,5	22,4	22,5	22,6	22,7	22,8	22,8	22,6	22,7	22,6	22,5	22,4
	th. comfort	57,9	58,1	57,8	58,0	58,0	57,8	58,0	57,9	58,0	57,7	57,7	58,1
	cold stress	19,6	19,4	19,7	19,4	19,3	19,4	19,2	19,5	19,4	19,7	19,7	19,5
3,5	heat stress	22,3	22,3	22,4	22,5	22,6	22,6	22,7	22,5	22,5	22,4	22,4	22,2
	th. comfort	58,3	58,3	58,1	58,2	58,2	58,0	58,1	58,1	58,2	58,1	58,0	58,3
	cold stress	19,4	19,4	19,5	19,4	19,2	19,3	19,2	19,4	19,3	19,5	19,6	19,4

cold stress PET < 13 °C, th. comfort: 13°C < PET < 28 °C, heat stress: PET > 28 °C

RayMan simulation, data: Schwabenzentrum 2000 – 2010, hourly values

④ Quantification of adaptation measures

Height-/ width ratio	Frequency (in %)	Orientation N-S 0°	15°	NW-SE 30°	45°	60°	75°	W-E 90°	105°	SW-NE 120°	135°	150°	165°
0,5	heat stress					26,9 ± 0,3							
	th. comfort					49,7 ± 0,6							
	cold stress					23,4 ± 0,3							
1	heat stress												
	th. comfort												
	cold stress												
1,5	heat stress					23,6 ± 0,2							
	th. comfort					56,1 ± 0,2							
	cold stress					20,4 ± 0,3							
2	heat stress												
	th. comfort												
	cold stress												
2,5	heat stress												
	th. comfort												
	cold stress												
3	heat stress												
	th. comfort												
	cold stress												
3,5	heat stress					22,5 ± 0,1							
	th. comfort					58,2 ± 0,1							
	cold stress					19,4 ± 0,1							

cold stress PET < 13 °C, th. comfort: 13°C < PET < 28 °C, heat stress: PET > 28 °C

RayMan simulation, data: Schwabenzentrum 2000 – 2010, hourly values

Conclusions

- heat stress occurs mainly in daytime

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    - thermal indices

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    - reduction of heat stress in daytime

Conclusions

- heat stress occurs mainly in daytime
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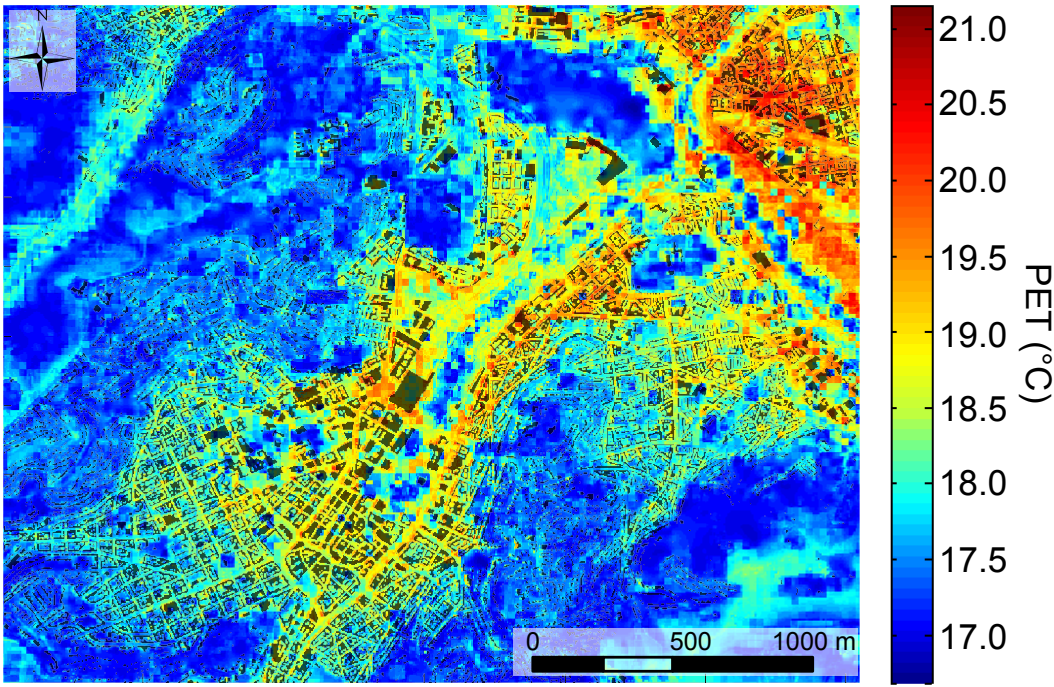
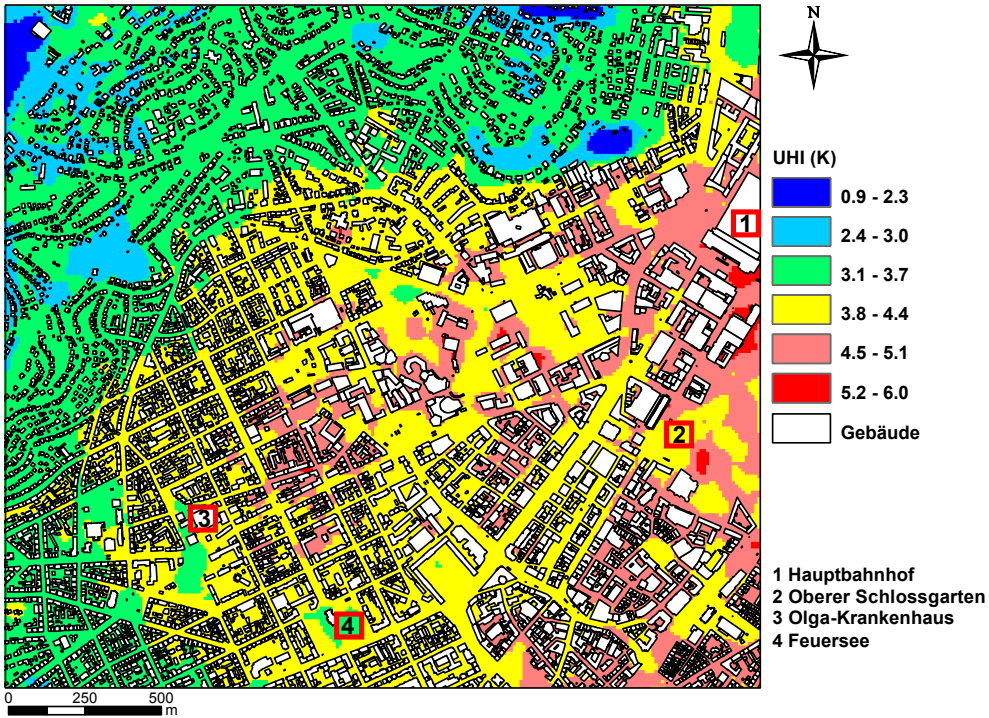
- artificial neural networks
- quantification of adaptation measures
    - thermal indices
    - consideration of all seasons
    - reduction of heat stress in daytime
    - nocturnal air temperature is defined by the background conditions

Thank you very much for your attention!

PET - 21:00 CET

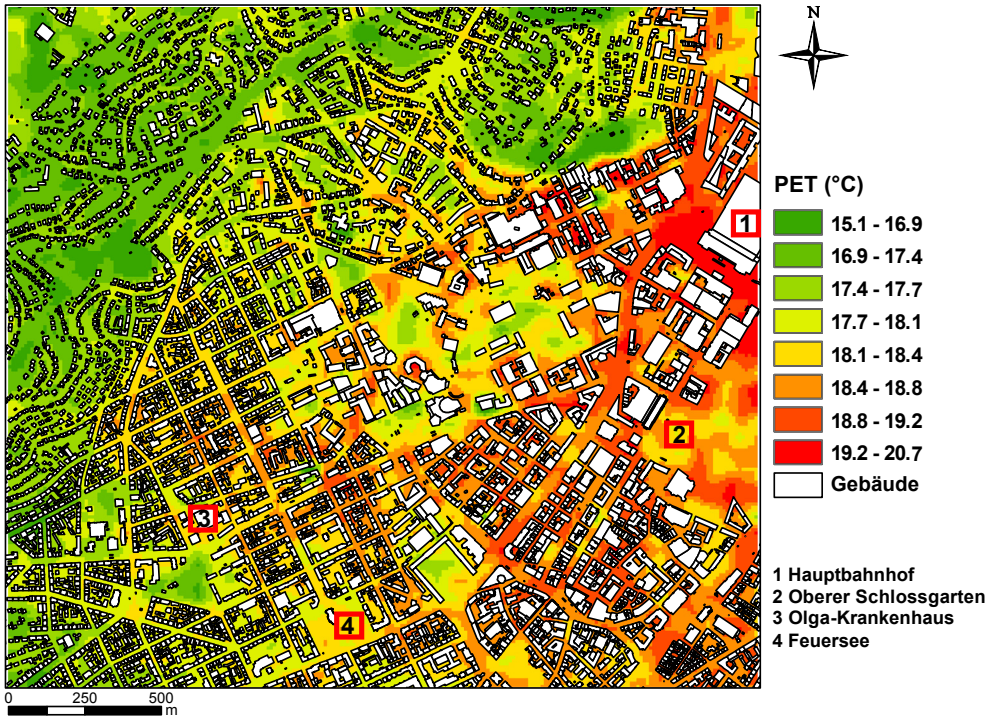


Urban heat island (Ta)



measurements: 3 July 21:00 MEZ; methode: SMLR

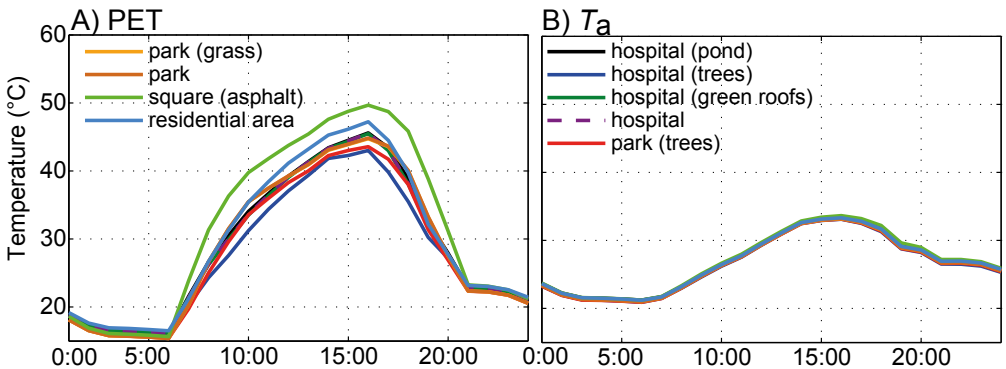
PET 21:00



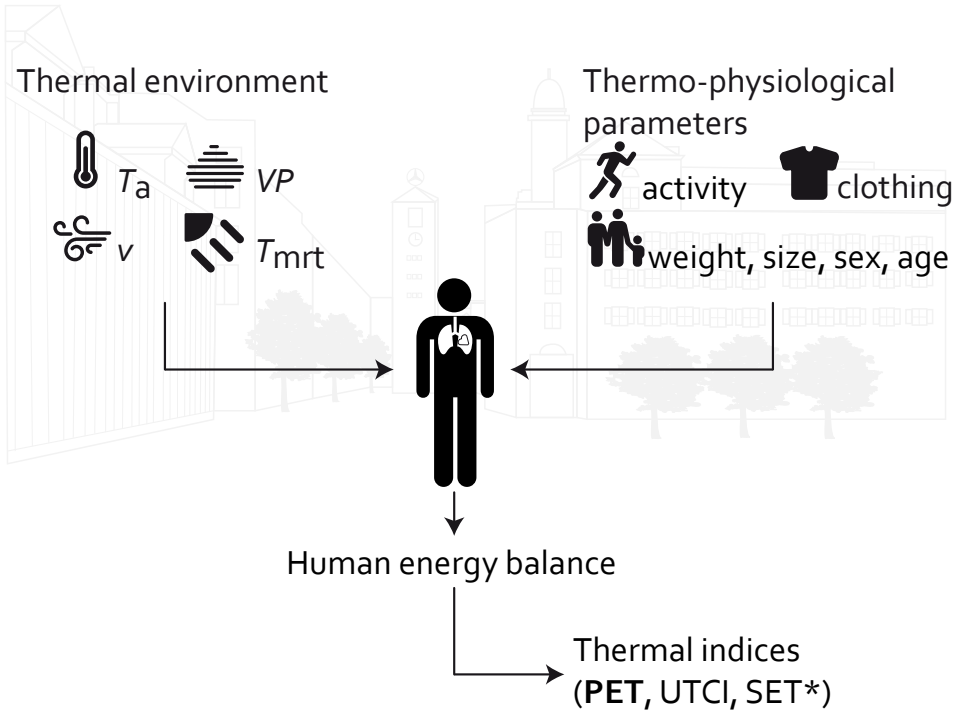
measurements: 3 July 2014 21:00 CET; methode: SMLR

Quantification of adaptation measures

	sealed (%)	un-sealed (%)	build./ area (%)	av. building-height (m)	trees	scrubs	grass
hospital	0,4	0,3	0,3	24,7	55	51	1087
hospital (pond)	0,4	0,3	0,2	25,2	55	51	1087
hospital (green roofs)	0,4	0,3	0,3	24,7	55	51	1087
hospital (trees)	0,4	0,3	0,3	24,7	656	39	848
residential area	0,3	0,2	0,2	15,4	86	20	1067
Square (asphalt)	0,8	0,1	0,1	16,3	38	20	311
Park (grass)	0,3	0,6	0,1	16,3	175	234	3667
Park (trees)	0,3	0,6	0,1	16,3	961	200	2946
Park	0,3	0,6	0,1	16,3	175	234	3667

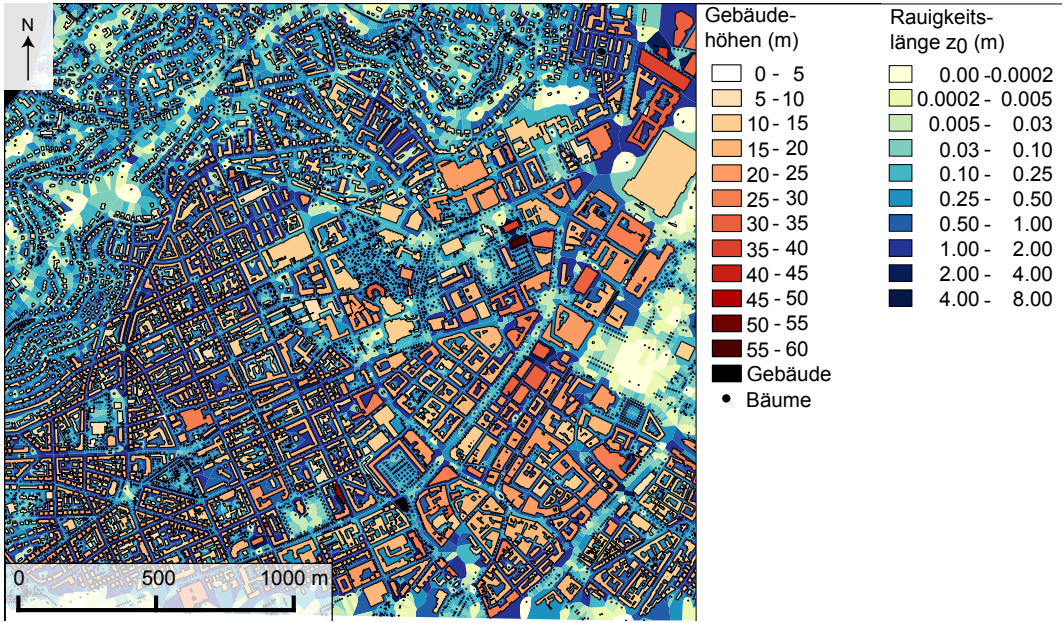


Introduction - Human–Biometeorology



PET: Physiological Equivalent Temperature (Mayer & Höppe 1987 , Höppe 1999, Matzarakis et al. 1999)

③ Calculation of roughness



Calculation of roughness based on Bottema & Mestayer (1998)