

# Assessment of human-biometeorological conditions in urban areas embedded in complex topographies

- The example of Stuttgart -

Christine Ketterer, [Letizia Martinelli](#), Andreas Matzarakis

Albert-Ludwigs-Universität Freiburg

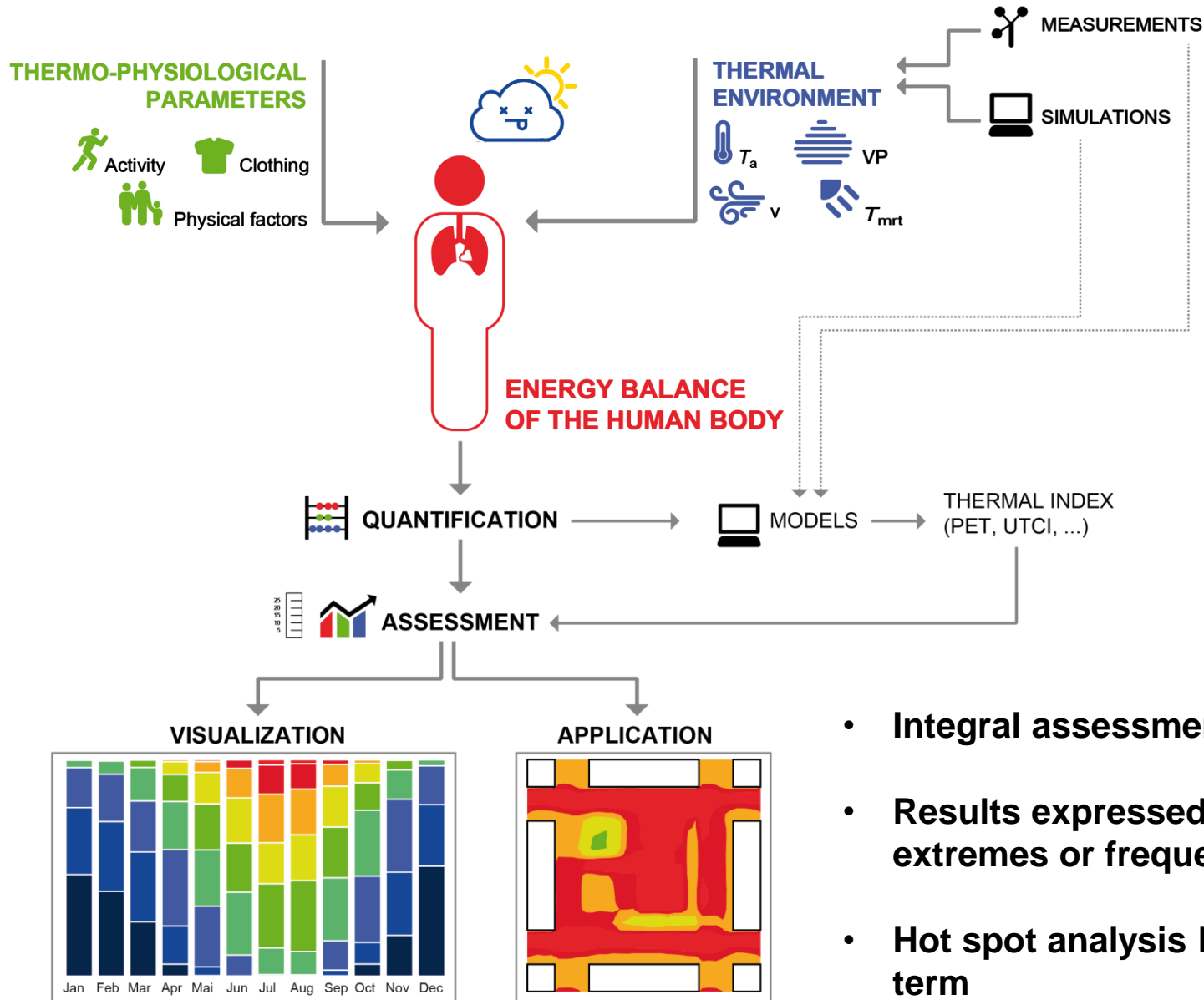
Chair of Meteorology and Climatology



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# Introduction

## Focus of city planners: human-biometeorology in the urban environment



- Integral assessment of comfort
- Results expressed by means, extremes or frequencies
- Hot spot analysis linked with long term



## Data

4 measuring/climate stations in Stuttgart

1 reference station at airport (rural reference station)

REgional climate MOdel REMO, A1B scenario

## Thermal indices

Physiologically Equivalent Temperature PET

(Mayer and Höppe 1987, Höppe 1999, Matzarakis et al. 1999)

## Micro-scale models

ENVI-met (Bruse & Fleer 1998)

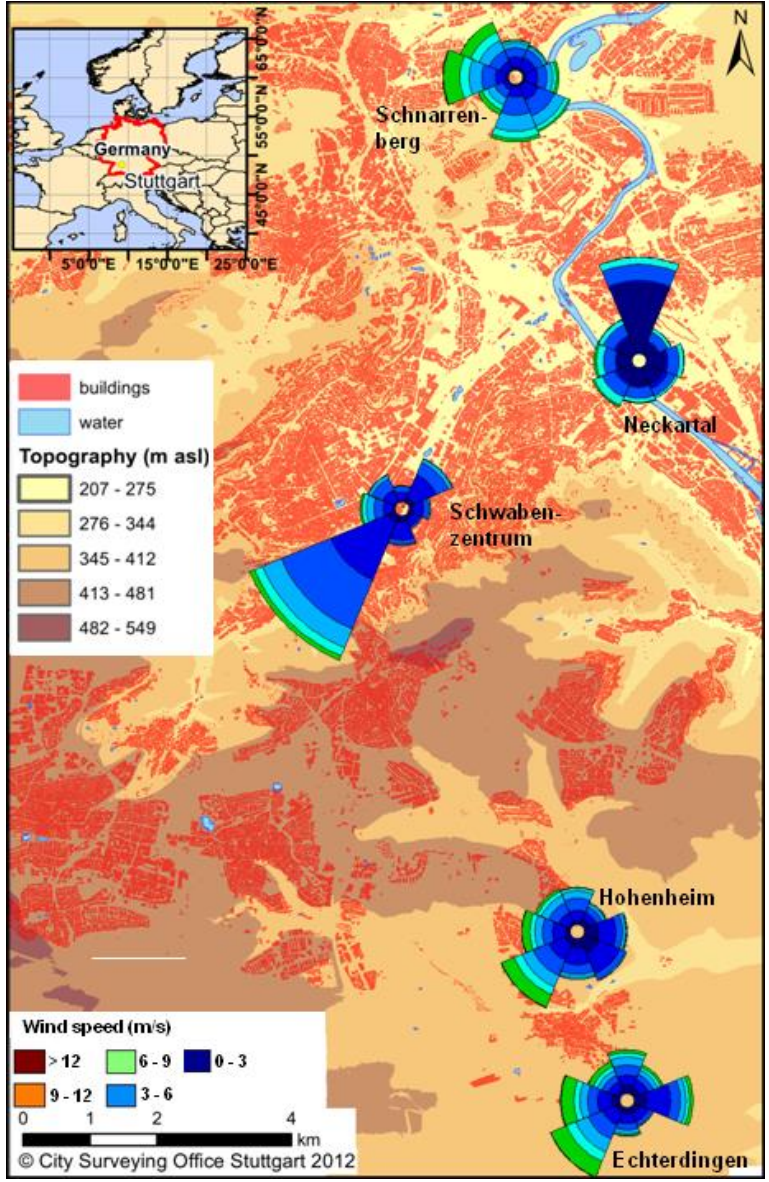
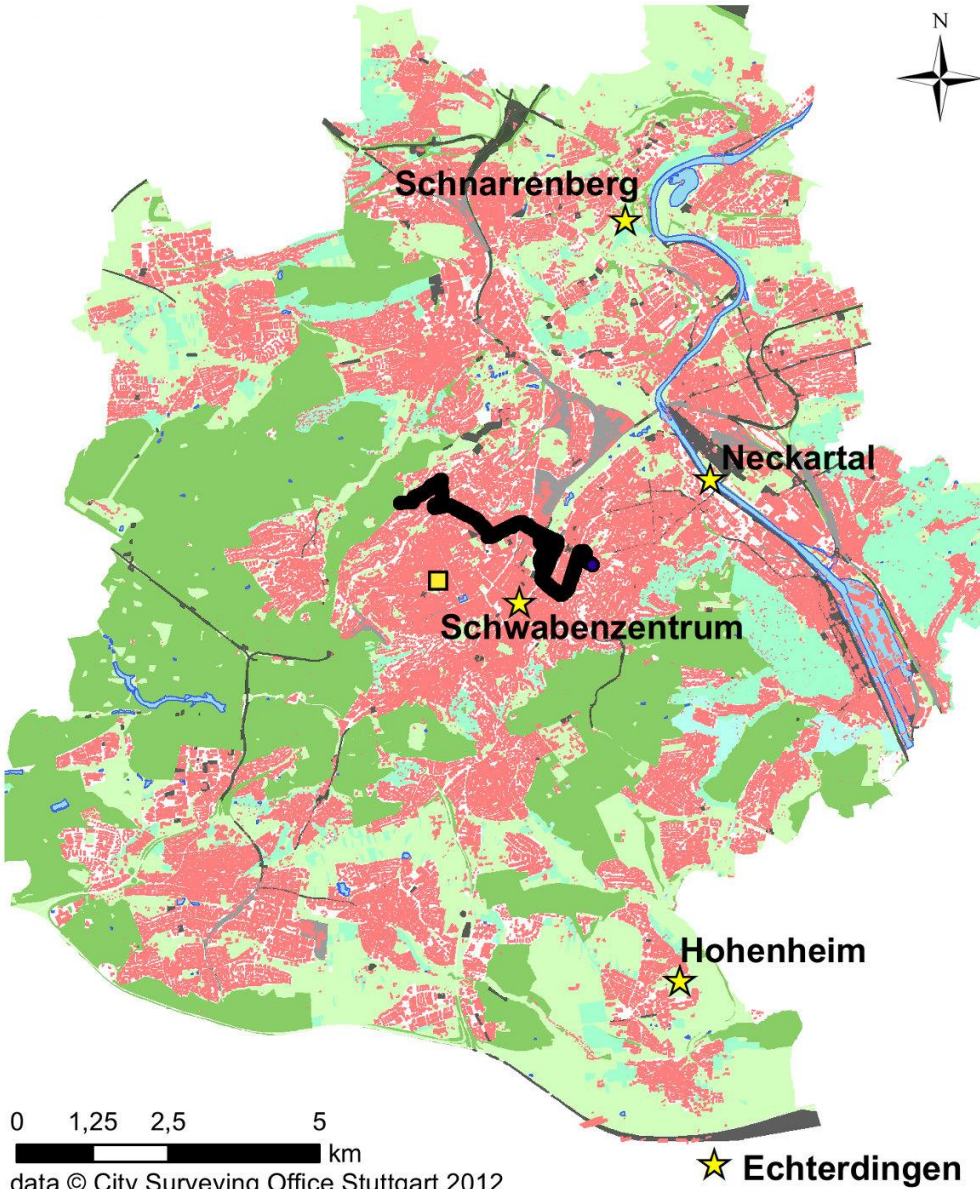
TIC-ENVI-met (Ketterer & Matzarakis 2014)

RayMan (Matzarakis et al. 2007, 2010)

# Study area - Stuttgart



## Land use types



# Study area - Stuttgart



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- **Frequencies of urban-rural differences (UHI)**
- **“Hot Spot” simulations: Olga hospital**
- **Systematic analysis of aspect ratio and orientation of streets**
- **Climate change and sensitivity analysis**



# The urban heat island (UHI)

## Percentage of PET difference between the city stations and the rural station

$\Delta$ PET (K)	Winter				Spring			
	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim
< -2	0.4	1.3	0.1	3.7	0.2	0.8	0.1	2.3
-2 - 0	9.4	51.8	7.0	64.8	8.8	47.2	4.1	56.9
0 - 2	70.9	40.8	63.5	26.7	70.7	42.2	54.4	33.0
2 - 4	18.2	5.6	25.6	4.5	17.1	8.9	30.6	7.3
> 4	1.1	0.5	3.9	0.3	3.2	0.9	<b>10.7</b>	0.4

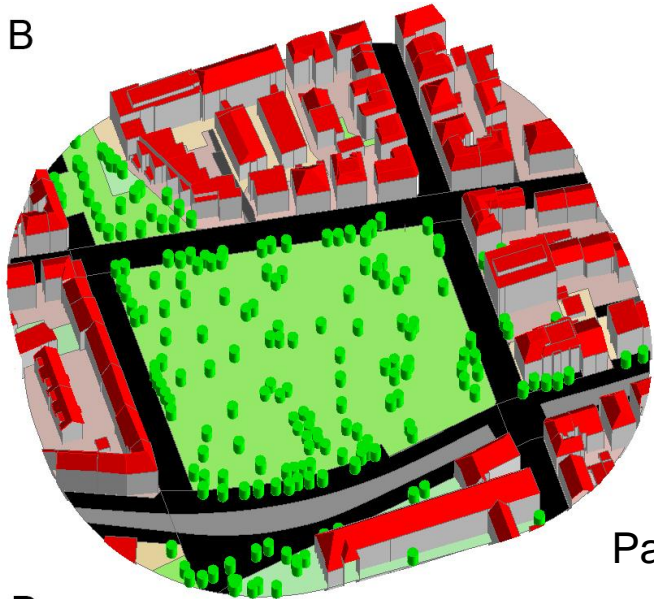
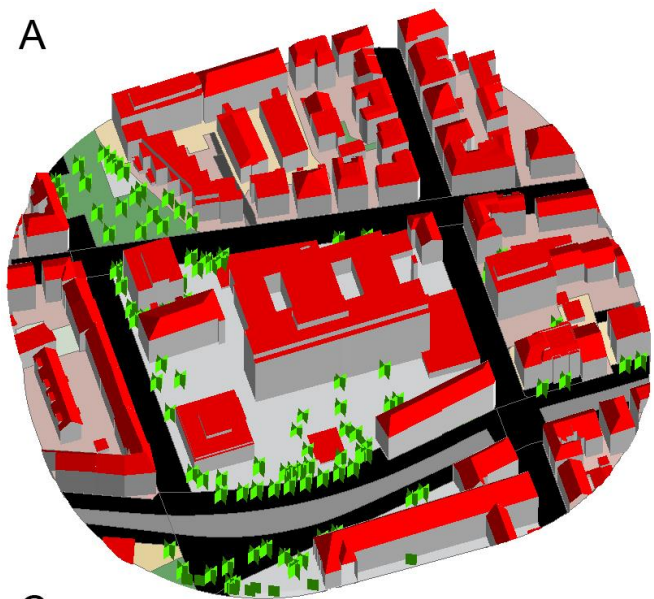
$\Delta$ PET (K)	Summer				Autumn			
	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim
< -2	0.0	0.7	0.1	2.5	0.3	1.5	0.1	2.9
-2 - 0	5.1	38.6	3.6	59.7	11.3	48.4	6.1	61.7
0 - 2	64.6	51.4	45.5	34.6	66.1	42.5	57.2	31.2
2 - 4	26.4	8.3	35.7	3.2	19.0	6.9	28.3	4.0
> 4	3.8	1.0	<b>15.2</b>	0.1	3.2	0.6	<b>8.3</b>	0.2

Data: 2000-2010      $\Delta$ PET = PET<sub>urban</sub> - PET<sub>rural</sub>

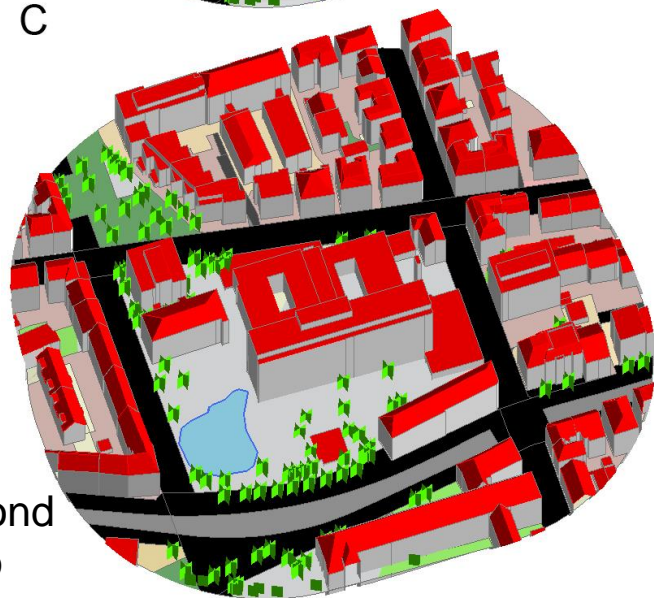
# Adaptation and Mitigation measures



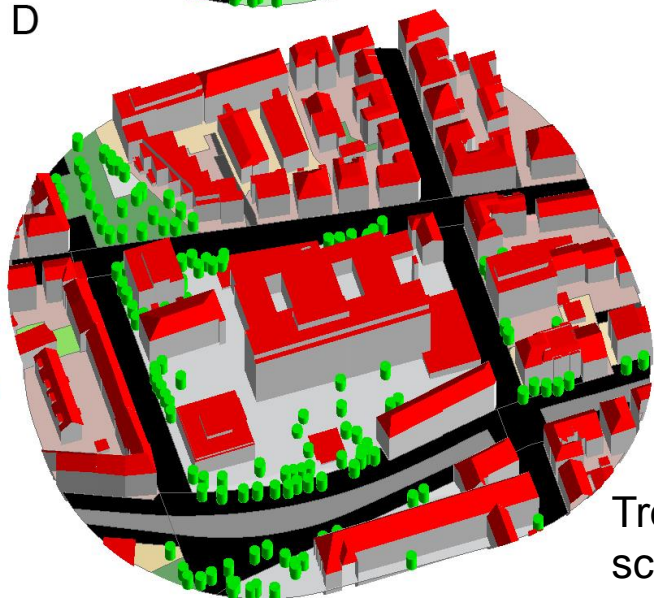
## Olga Hospital area redevelopment



Park scenario



Small pond scenario



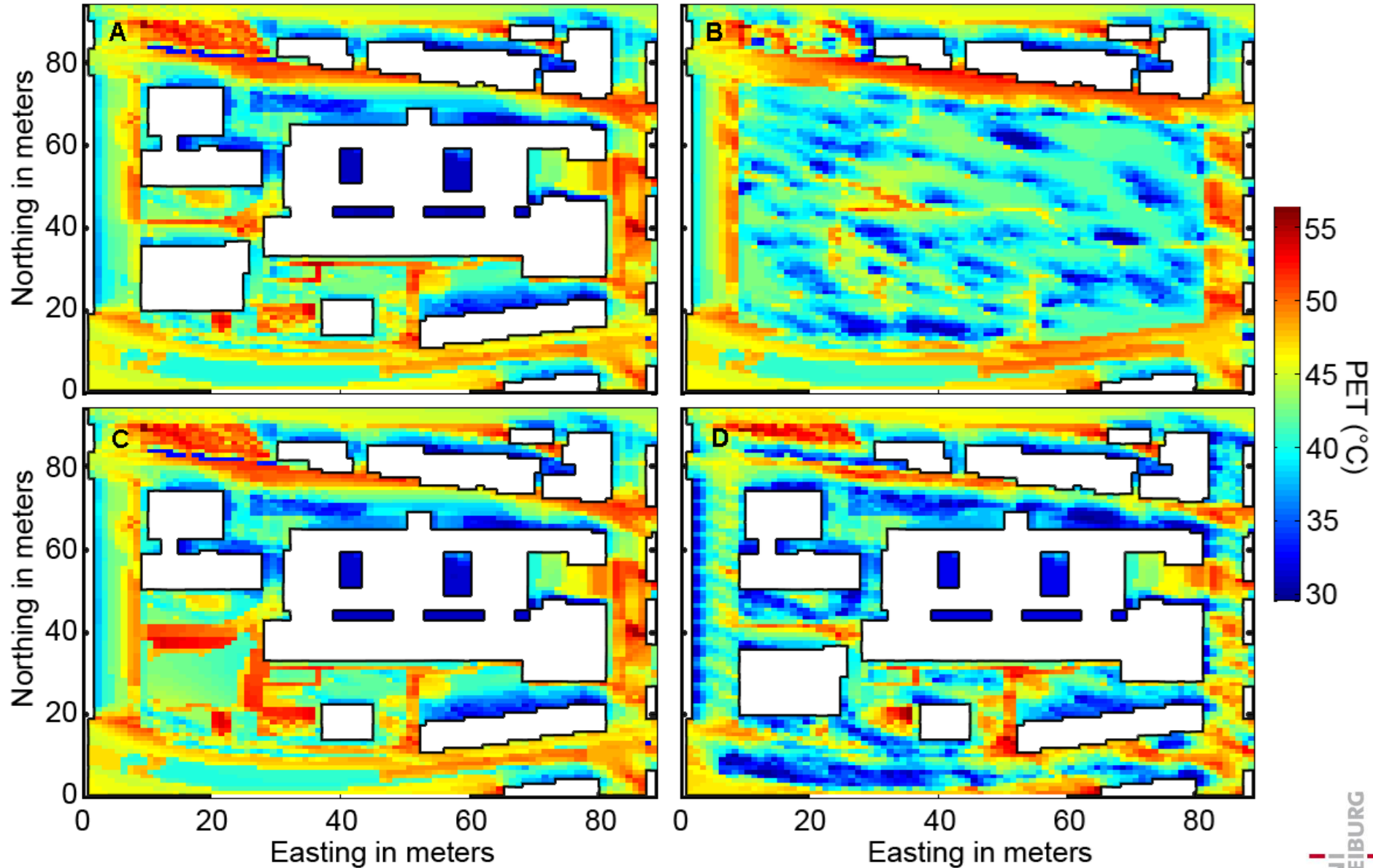
Trees' increment scenario





# Adaptation and Mitigation measures

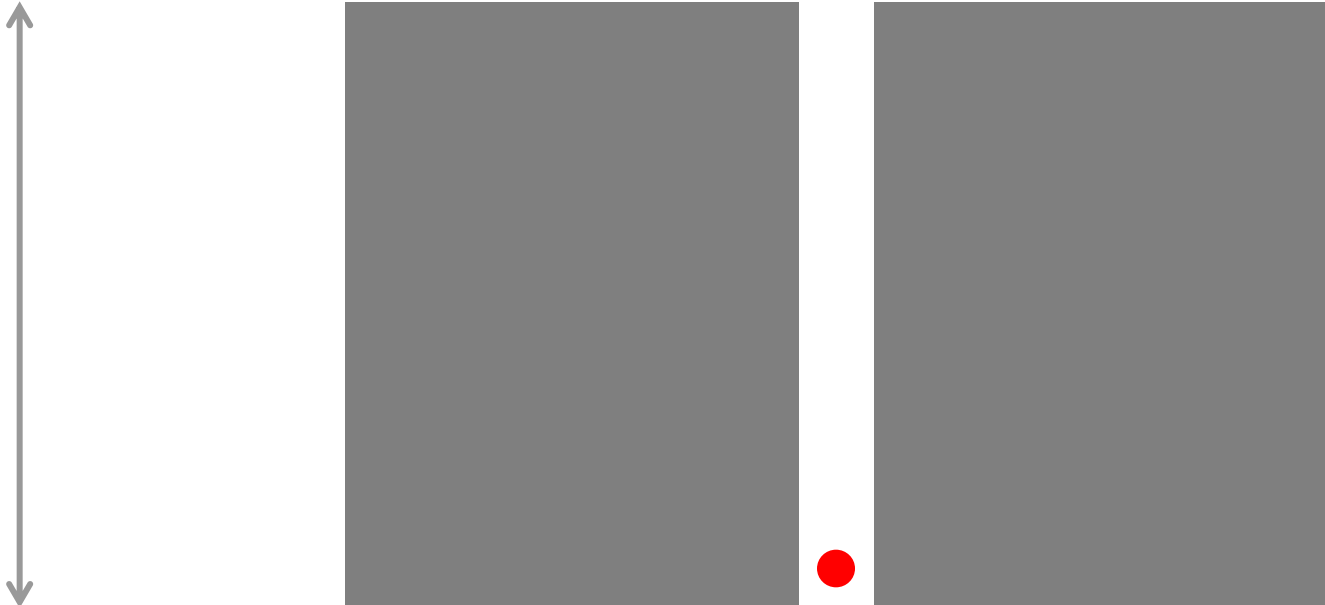
PET analysis for 25 June 2003 14:00 LT





# Adaptation measures – Street canyon

Systematic analysis of aspect ratio

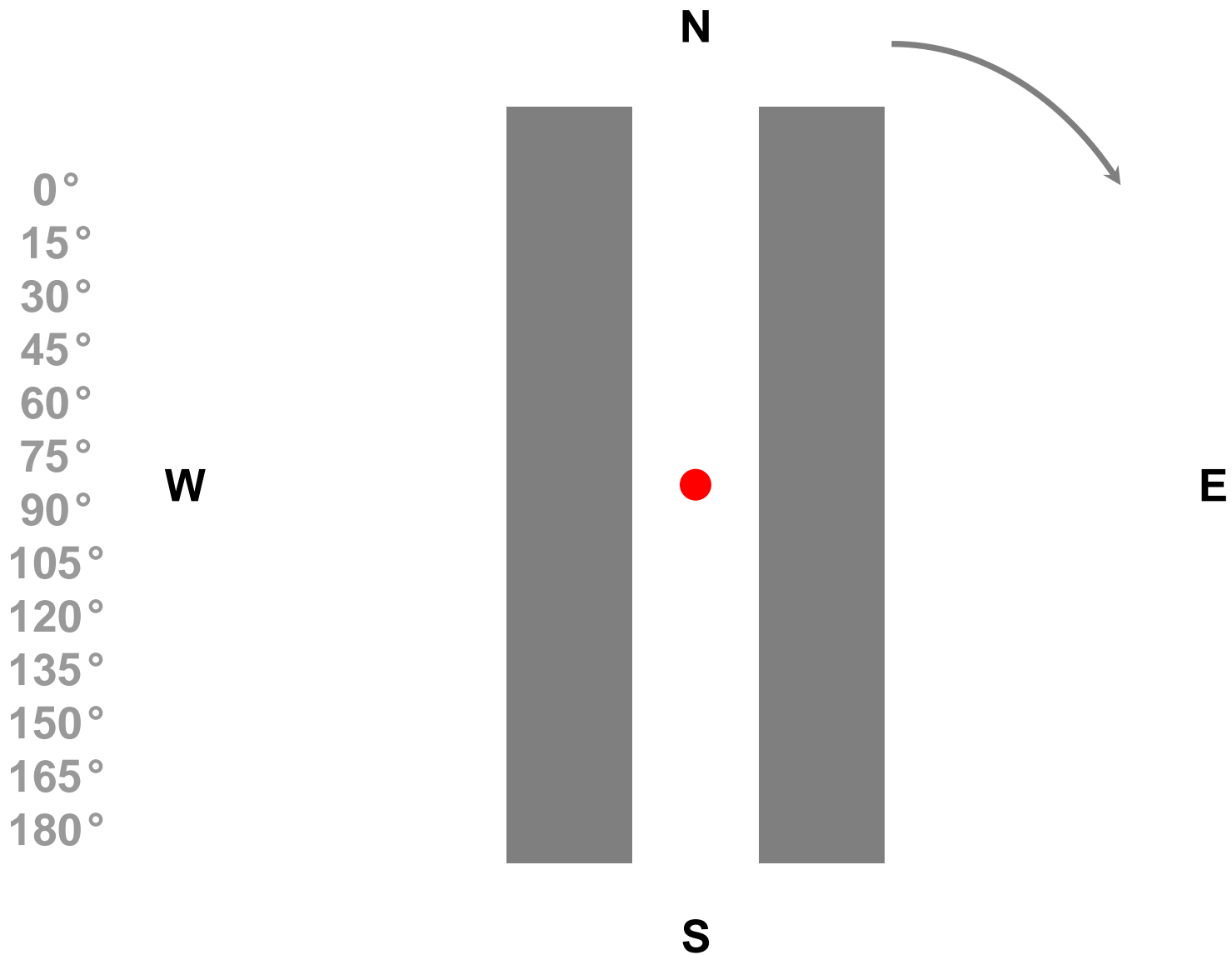


- H/W= 0.5
- H/W= 1.0
- H/W= 1.5
- H/W= 2.0
- H/W= 2.5
- H/W= 3.0
- H/W= 3.5

# Adaptation measures – Street canyon

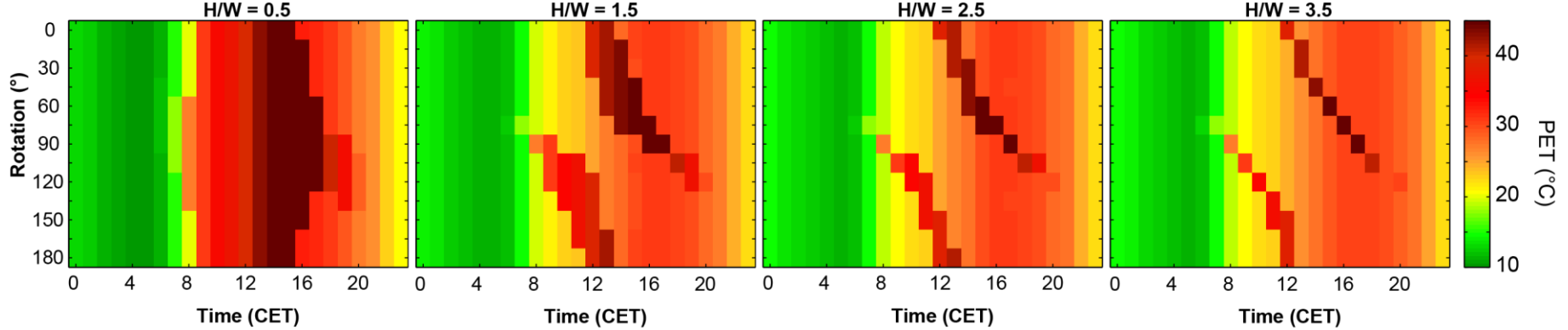


Systematic analysis of orientation

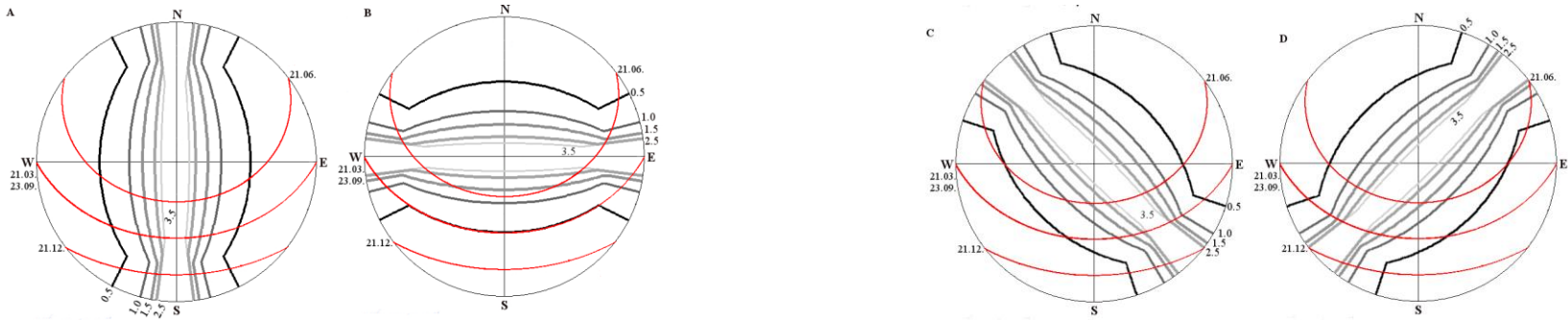


# Adaptation measures – Street canyon

## PET analysis for 25 June 2003 at the center of the street canyon



## Relation between sun path and street canyon morphology



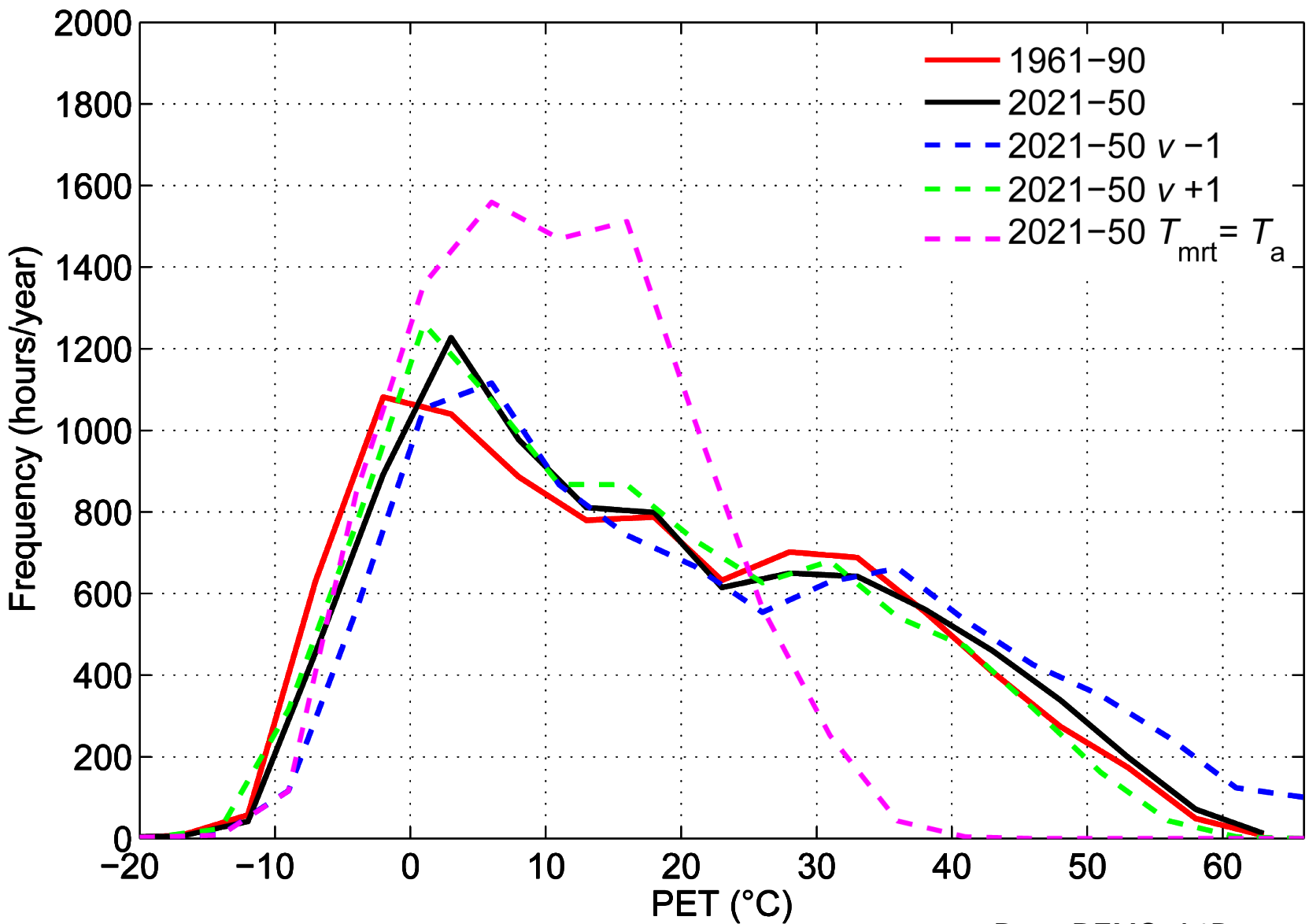
## Frequency of cold, heat and comfortable thermal conditions (extract)

Aspect ratio	Thermal comfort/ street orientation	Street orientation											
		0°	15°	30°	45°	60°	75°	90°	105°	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
	comfortable (%)	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
	comfortable (%)	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

(Ketterer and Matzarakis, 2014, Landscape and Urban Planning)



## PET sensitivity analysis

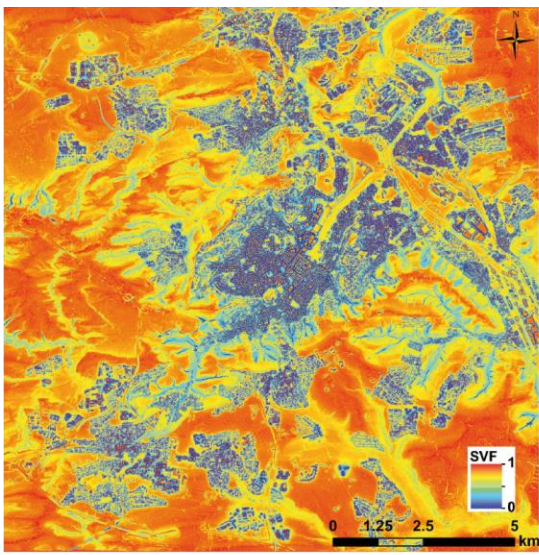


Data: REMO, A1B scenario

# Outlook – Map of PET for Stuttgart



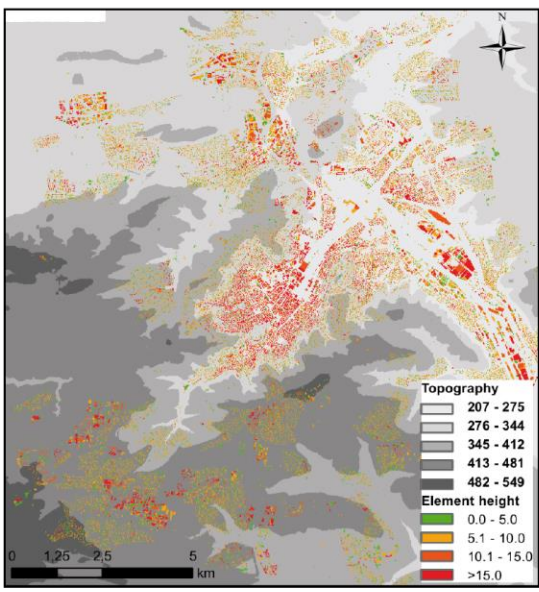
## Meteorological data



## Urban built environment data



- Buildings
- Topography
- Land use & land cover
- Trees & green areas
- Street canyons



## Maps UHI & PET



Topography and land use allow the formation of many local microclimates in Stuttgart: there is a high variability of UHI

It is necessary to develop, quantify and implement adaptation and mitigation measures for Urban Heat Island

Air temperature alone is not an appropriate measure for human thermal comfort

→ Thermal indices based on the human energy balance (PET, UTCI, etc.)

Long term and hotspot analysis should be combined to provide a broader understanding of cities' meteorological and climatic conditions