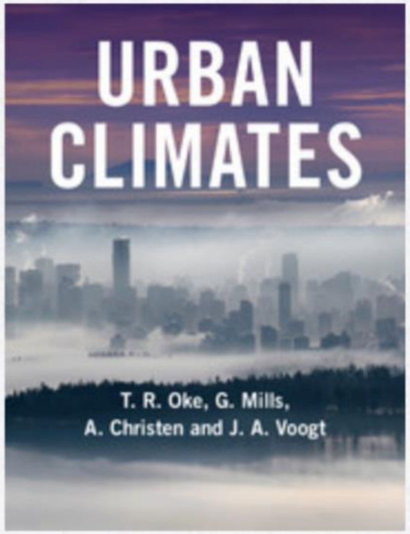
Urban Climate
Urban Heat Island (UHI)
Urban Deign

THE IMPACT OF MORPHOLOGICAL FEATURES ON SUMMER TEMPERATURE VARIATIONS ON THE EXAMPLE OF TWO RESIDENTIAL NEIGHBOURHOODS IN LJUBLJANA, SLOVENIA

Doc. Dr. JANEZ PETER GROM

Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). Reviews. In *Urban Climates* (p. Ii). Cambridge: Cambridge University Press.



Urban Climates

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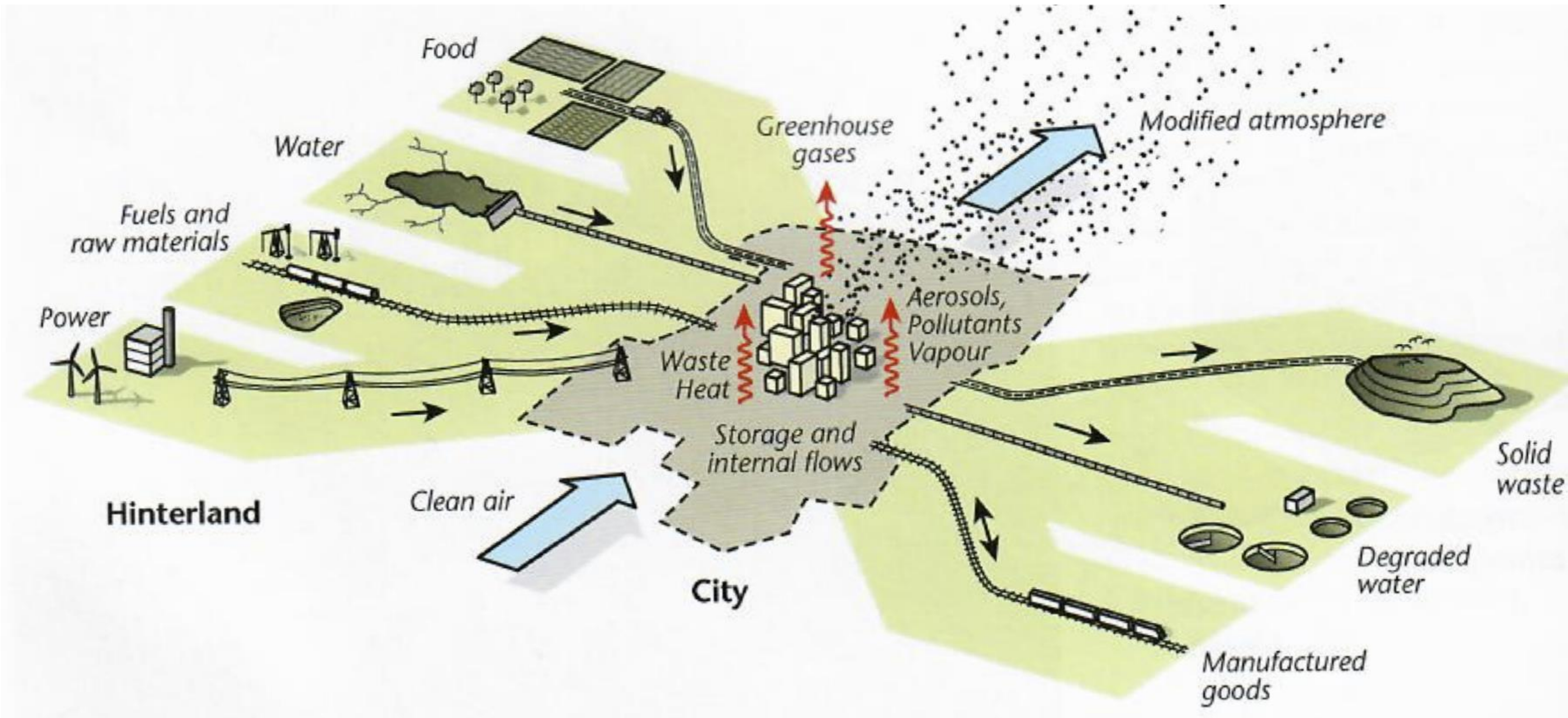
Oke, T.R. Initial guidance to obtain representative meteorological observations at urban sites. In Instruments and Observing Methods; World Meteorological Organization: Geneva, Switzerland, 2006; Available online: http://weather.gladstonefamily.net/UrbanMetOps.pdf

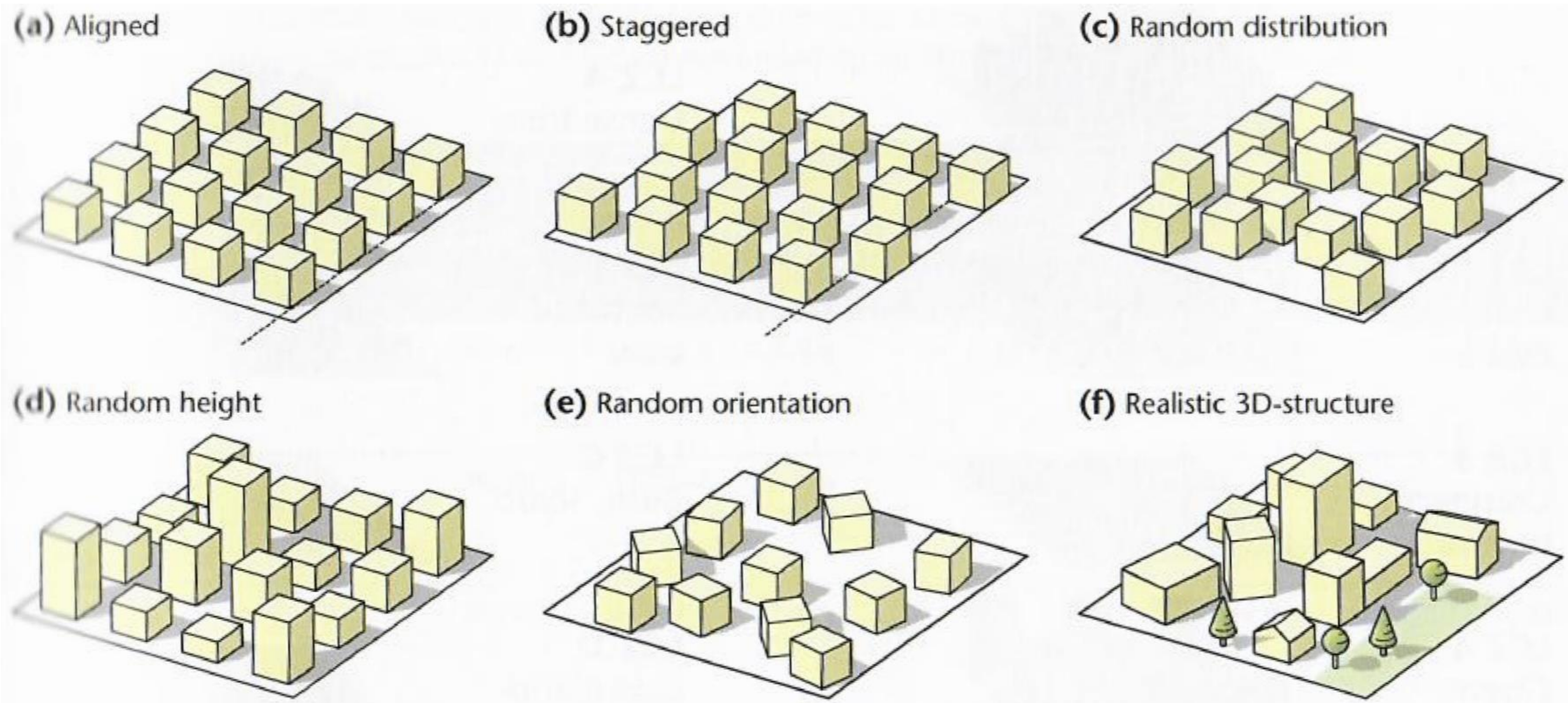
Pogačar, T.; Zalar, M.; Crepinšek, Z.; Kajfež Bogataj, L. Vročinski valovi v Sloveniji. In Proceedings of ˇ the Conference VIVUS—On Agriculture, Environmentalism, Horticulture and Floristics, Food Production and Processing and Nutrition, with Knowledge and Experience to New Entrepreneurial Opportunities, Naklo, Slovenia, 20–21 April 2016; Biotechnical Centre Naklo: Naklo, Slovenia, 2016; pp. 58–64. Kajfež Bogataj Lučka in 2007, together with Albert Arnold (Al) Gore Jr, was awarded the Nobel Peace Prize

Landsat Project Description. Available online: http://landsat.usgs.gov/about_project_descriptions.php (accessed on 10 July 2016). Landsat shows us Earth from space. Since the first Landsat satellite launched in 1972, the mission has collected data on the forests, farms, urban areas and freshwater of our home planet, generating the longest continuous record of its kind; understand environmental change; launch of Landsat 9 scheduled for mid-2021, managed by NASA's Goddard Space Flight Center.



Inputs and outputs from an ecosystem (modified by Christen, 2014).

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

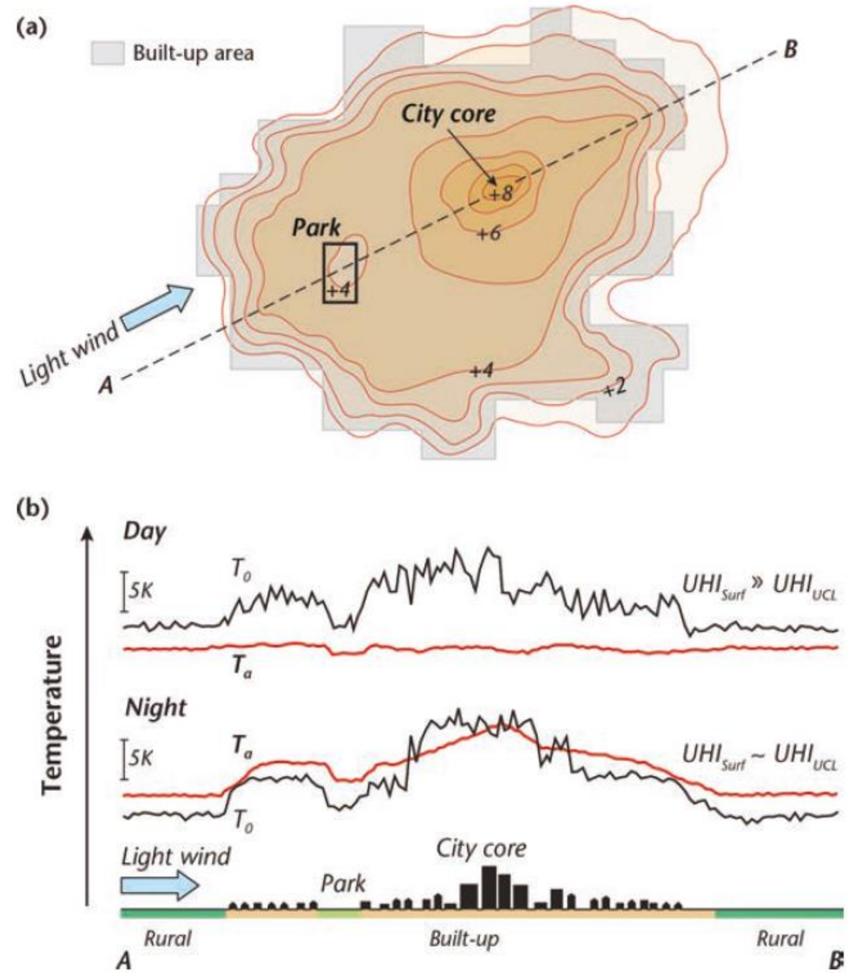


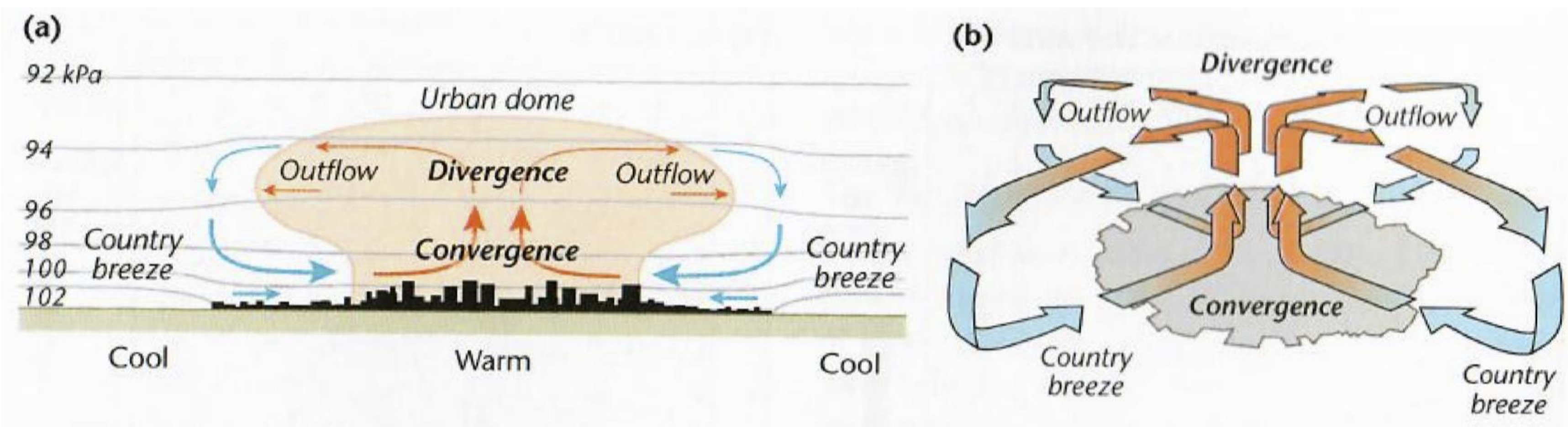
Ilustrations of common elements arrays used to represent the buildings distribution in urban areas.

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

Schematic depiction of a typical UHI (in the urban canopy layer) at night in calm and clear conditions in a city on relatively level terrain.

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.





Schematic of the Urban Heat Island Circulation (UHIC).

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

PMV	PET	Thermal perception	Grade of physiological stress	Universal Thermal Climate Index (UTCI) (°C) range	Physiological responses
		Very cold	Extreme cold stress	< 40	Decrease in core temperature
−3.5	4			−27 to −40	Shivering, average skin temperature will fall below 0°C if exposure is sustained
−2.5	8	Cold	Strong cold stress	−13 to −27	Face temperature < 7°C (numbness), core to skin temperature gradient increases
		Cool	Moderate cold stress	0 to −13	Vasoconstriction, exposed skin temperature < 15°C
−1.5	13	Slightly cool	Slight cold stress	+9 to 0	Localized cooling, need for gloves
−0.5	18				
		Comfortable	No thermal stress	+9 to +26	Comfortable, sweat rate < 100 g h^{-1}
0.5	23				
1.5	29	Slightly warm	Slight heat stress	+26 to +32	Slight heat stress
		Warm	Moderate heat stress	+32 to +38	Positive change in rate of sweating, and of skin temperature
2.5	35	Hot	Strong heat stress	+32 to +38	Sweat rate > 200 g h^{-1}
3.5	41			+38 to +46	Small core to skin temperature gradient (< 1 K). Sweat rate increase (> 650 g h^{-1} at limit)
		Very hot	Extreme heat stress	> 46	Increase in core temperature

Schematic of the Urban Heat Island Circulation (UHIC).

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

Section	UHI type	Scale	Processes	Models	Direct measurement	Remote sensing
7.2	**Surface heat island** (UHI_{Surf})	Micro	Surface EB	Surface EB and equilibrium surface temperature	Temperature sensors attached to surface	Satellite/ aircraft sensors
7.3	**Canopy layer heat island** (UHI_{UCL})	Local	Surface EB and EB of UCL air volume	Canopy and RSL scheme incl. interactions with subsurface and overlying BL	Temperature sensors at fixed points, arrays and mobile in UCL and rural SL	Mini-sodar(1), mini-lidar
7.4	**Boundary layer heat island** (UHI_{UBL})	Local and meso	EB at top of RSL and BL EB	BL scheme incl. interaction with RSL/surface and free atmosphere	Temperature sensors mounted on aircraft, balloons and tall towers	Sodar, lidar, RASS profiler
7.5	**Subsurface heat island** (UHI_{Sub})	Local	Subsurface Energy Balance (EB)	Heat (water) diffusion in solid	Temperature sensors within substrate	-

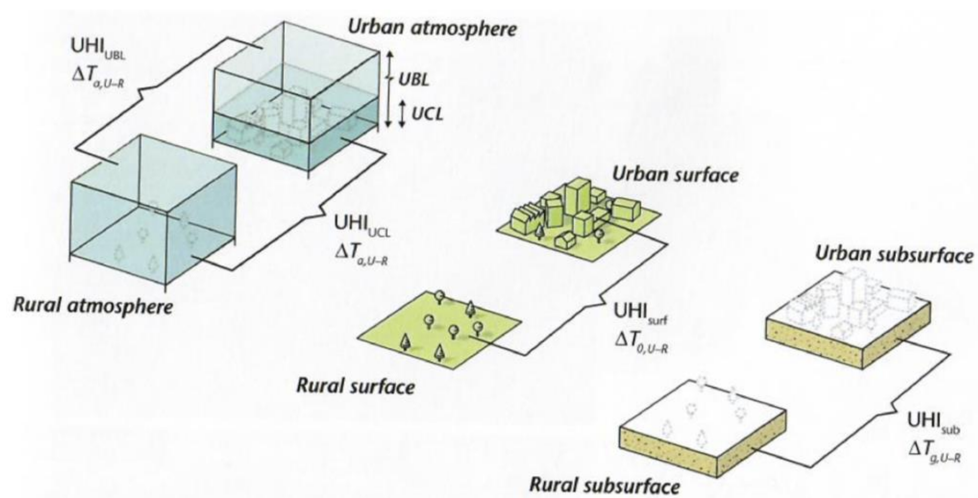
(1) Sodar does not measure T, but can sense temperature structure.

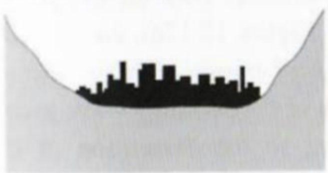
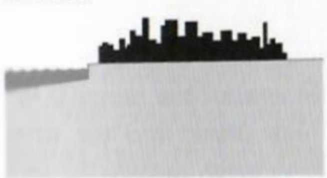
Summary of UHI types, their scales, causative thermal processes ect.

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

Illustations of the temperature differences forming the four types of UHI:
UBL – air layer from the ground up to the entrainment zone
UCL – air ground to about roof level
Surface – complete surface including ground and all exposed facets of urban elements
Subsurface – ground surface to depth of active temperature change over period of interest

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.



Orographic setting	Mechanical	Thermal	Air quality
Mountain top or ridge 	Wind speed increased due to elevation; cloud and precipitation enhanced due to uplift.	Under clear conditions higher solar irradiance and longwave radiation loss. Higher diurnal and seasonal temperature range.	Good air quality when windy but potential for photochemical smog on clear and calm days.
Slope or slope terrace 	On lee (windward) side shelter (exposure) from (to) ambient winds. Affected by strong downslope winds in certain circumstances.	If the aspect is toward (away) from the Sun, the surface and adjacent air is warmed (cooled) causing upslope (downslope) winds. At night, higher slopes cool fastest and downslope winds result.	Generally good air quality unless located in recirculation zone or close to the inversion level.
Basin or valley 	Effect depends on geometry of valley in relation to ambient wind direction. If perpendicular (aligned) to the valley axis, the valley may be sheltered (exposed).	Cross-valley winds develop during daytime (nighttime) owing to anabatic (katabatic) flows on valley sides. Katabatic system is stronger in shallow nighttime surface layer.	Potential for very poor air quality due to pooling of cool air on valley floor at night.
Base of slope 	On the leeward side foehn winds may occur depending on local topography. On windward side, flow may be blocked against barrier.	Daytime (nighttime) anabatic and katabatic flows.	On the windward side cool air become blocked; on leeward side some conditions can create a recirculation eddy and poor air quality.
Coastal 	On-shore winds generated by storms are much stronger than those off land for the same conditions.	Under calm and clear regional conditions, a coastal breeze circulation is established that brings air on-shore (off-shore) during daytime (nighttime).	Daytime air pollution possible when sea breeze conditions dominate and cause a strong, near-surface inversion.

Common topographic settings of cities (modified after Wanner and Fillinger, 1989).

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.

Does the urban heat island effect impact all parts of the city of Rotterdam equally, or are distinct districts more affected than others, which areas are these?

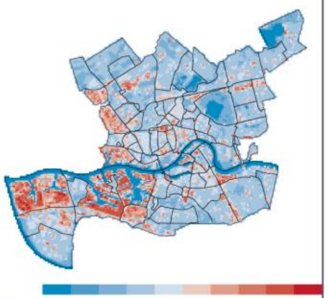
Does a link exist between the **urban heat island** in the city of Rotterdam and **the mortality among senior citizens** during heatwaves?

Can the differences in the urban heat island effect between districts be **explained by the morphology** and land-use of the city of Rotterdam?

Do the **social, morphological and land-use dimensions** of the urban heat island effect represent coherent spatial patterns that allow an area-oriented approach in the urban planning and management of the city?

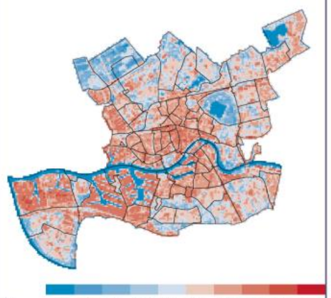
Q*	Net solar radiation received by the earth's surface
QE	Energy consumed through evaporation (by water and greenery)
QH	Sensible heat (conversion of heat from surface to air)
QS	Energy absorbed by the ground, buildings and surface water

Sensible heat



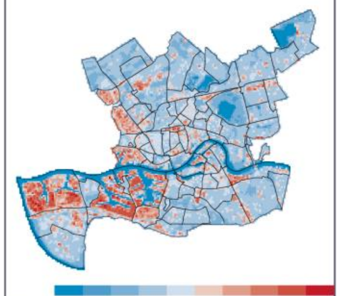
Key	
Contents	Sensible heat is the convection heat that heats the air. This heating process takes place primarily above surfaces with a high temperature. In the conversion of surface temperatures to air temperatures, (small) pockets of turbulence – known as eddies – play an important role.
Values	W/m2
Method	Surface energy balance
Software	BEAM-VISAT, ATCOR2, ArcGIS
Data	NASA, Landsat 8, 22 July 2014, 12:40

Ground heat flux



Key	
Contents	Ground heat flux is the heat absorbed by the ground, buildings, and surface water. The stored heat is released at night and affects the nightly heat island.
Values	W/m2
Method	Surface energy balance
Software	BEAM-VISAT, ATCOR2, ArcGIS
Data	NASA, Landsat 8, 22 July 2014, 12:40

Sensible heat



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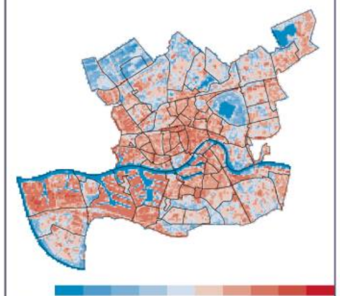
Ground heat flux



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sustainability

Article

The Impact of Morphological Features on Summer Temperature Variations on the Example of Two Residential Neighborhoods in Ljubljana, Slovenia

Alenka Fikfak [1,*], Saja Kosanović [2], Miha Konjar [1], Janez P. Grom [1] and Martina Zbašnik-Senegačnik [1]

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2 Department for Architecture, Faculty of Technical Sciences, University of Priština in Kosovska Mitrovica, Kneza Miloša Street 7, 38220 Kosovska Mitrovica, Kosovo; saja.kosanovic@pr.ac.rs
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The study is focused on two levels at the micro-scale, including the correlation between urban morphology and climate change in open spaces or voids:

1. Interconnection of urban morphology and climate impacts through mapping and spatial analysis; 2. Observation of detailed climate parameters with an emphasis on temperature variability.

Oke [2006] defined four **significant controls** on urban climate including urban structure, urban cover, urban fabric, and urban metabolism (anthropogenic heat, water, and pollution). These four controls, playing important roles in creating certain urban climatic environments, are all related to urban morphology:

urban structure: urban density, dimensions of buildings and in-between spaces, street widths and spacing, building typology, programme (housing, mixed use), and the weighted density;

urban cover: fractions of built-up/paved/vegetated surfaces, vegetation type (tall vegetation impacts shadowing), bare soil and water;

urban fabric: type of materials, colors, materialized surface properties in terms of heat conduction, heat storage, and other;

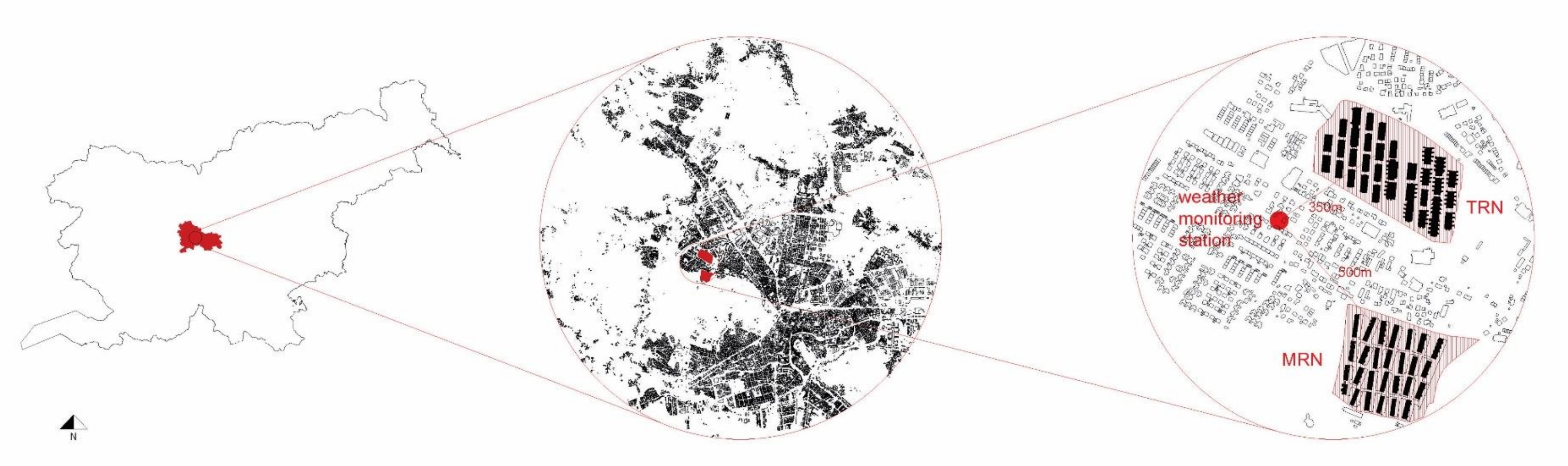
urban metabolism: heat, water, and pollutants due to human activity on the micro scale (recording elements as: density of inhabitants in open space, air conditioning, rubbish bins, cars, open fires, and other).

[1] Oke, T.R. Initial guidance to obtain representative meteorological observations at urban sites. In Instruments and Observing Methods; Report No. 81; WTO/TD-No. 1250; World Meteorological Organization: Geneva, Switzerland, 2006. Available online: http://weather.gladstonefamily.net/UrbanMetOps.pdf (accessed on 15 May 2016).

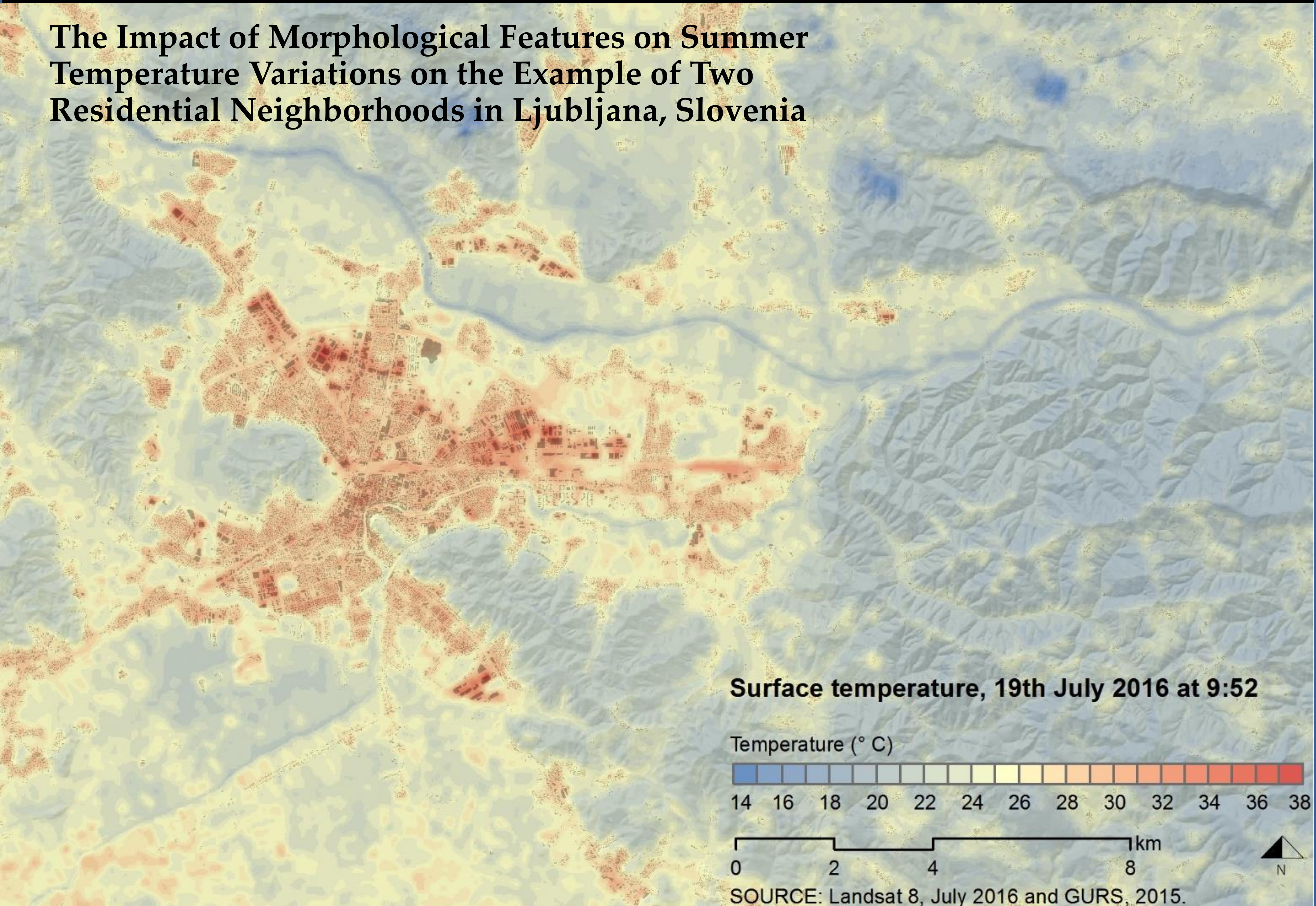
City of Ljubljana, the largest urban area in Slovenia - 13.87% of total country's population reside (in 2016 Slovenia had a population of 2,064,188).

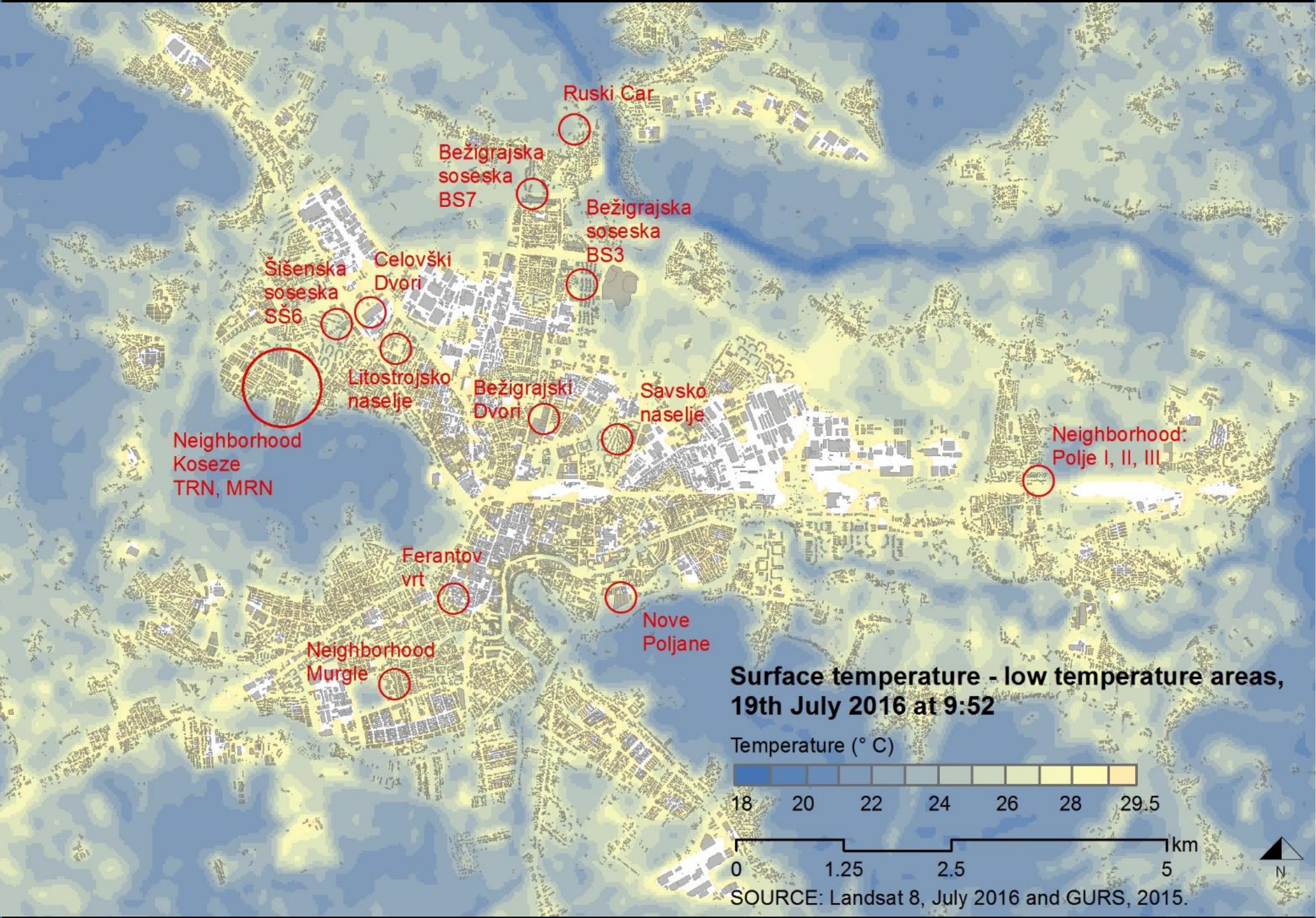
the population density is **1044.4** inhabit./km^{2},

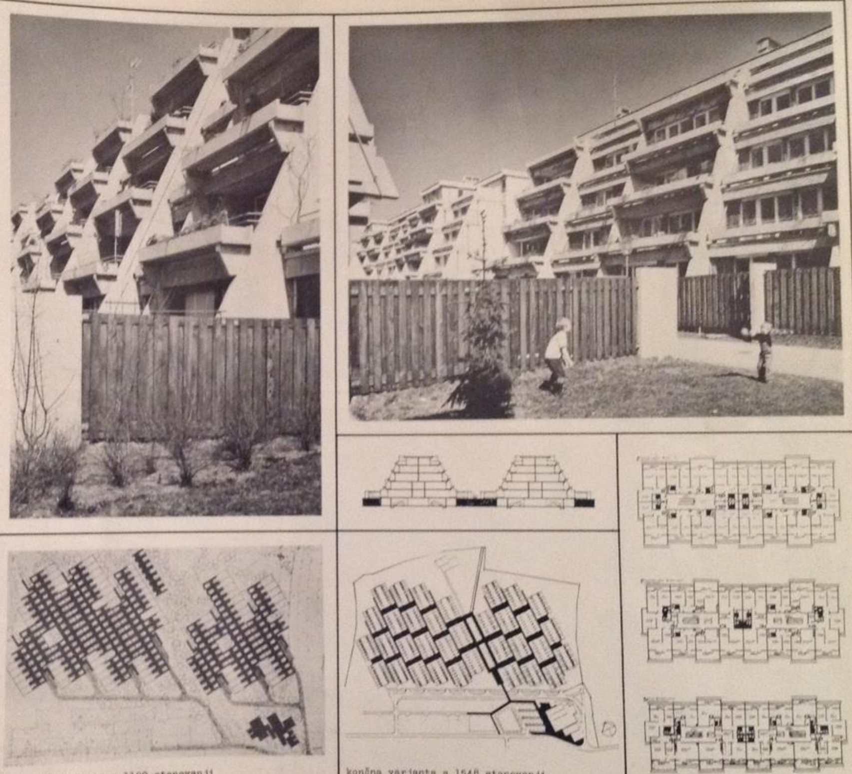
the climate is characterized by the transition between Mediterranean and Continental climates, with moderately cold winters (with temperatures below 3.9 °C) and warm summers (with temperature up to 25 °C).



The Impact of Morphological Features on Summer Temperature Variations on the Example of Two Residential Neighborhoods in Ljubljana, Slovenia




Ruski Car
Bežigrajska soseska BS7
Bežigrajska soseska BS3
Šišenska soseska SŠ6
Celovški Dvori
Litostrojsko naselje
Bežigrajski Dvori
Savsko naselje
Neighborhood Koseze TRN, MRN
Neighborhood: Polje I, II, III
Ferantov vrt
Nove Poljane
Neighborhood Murgle
Surface temperature - low temperature areas, 19th July 2016 at 9:52
Temperature (° C)
18
20
22
24
26
28
29.5
km
0
1.25
2.5
5
N
SOURCE: Landsat 8, July 2016 and GURS, 2015.



The **terraced residential neighborhood** (arch. dr. Viktor Pust; 1968-1978): neighborhood of long, linear, and low residential buildings with terraces, in total 1564 apartments.

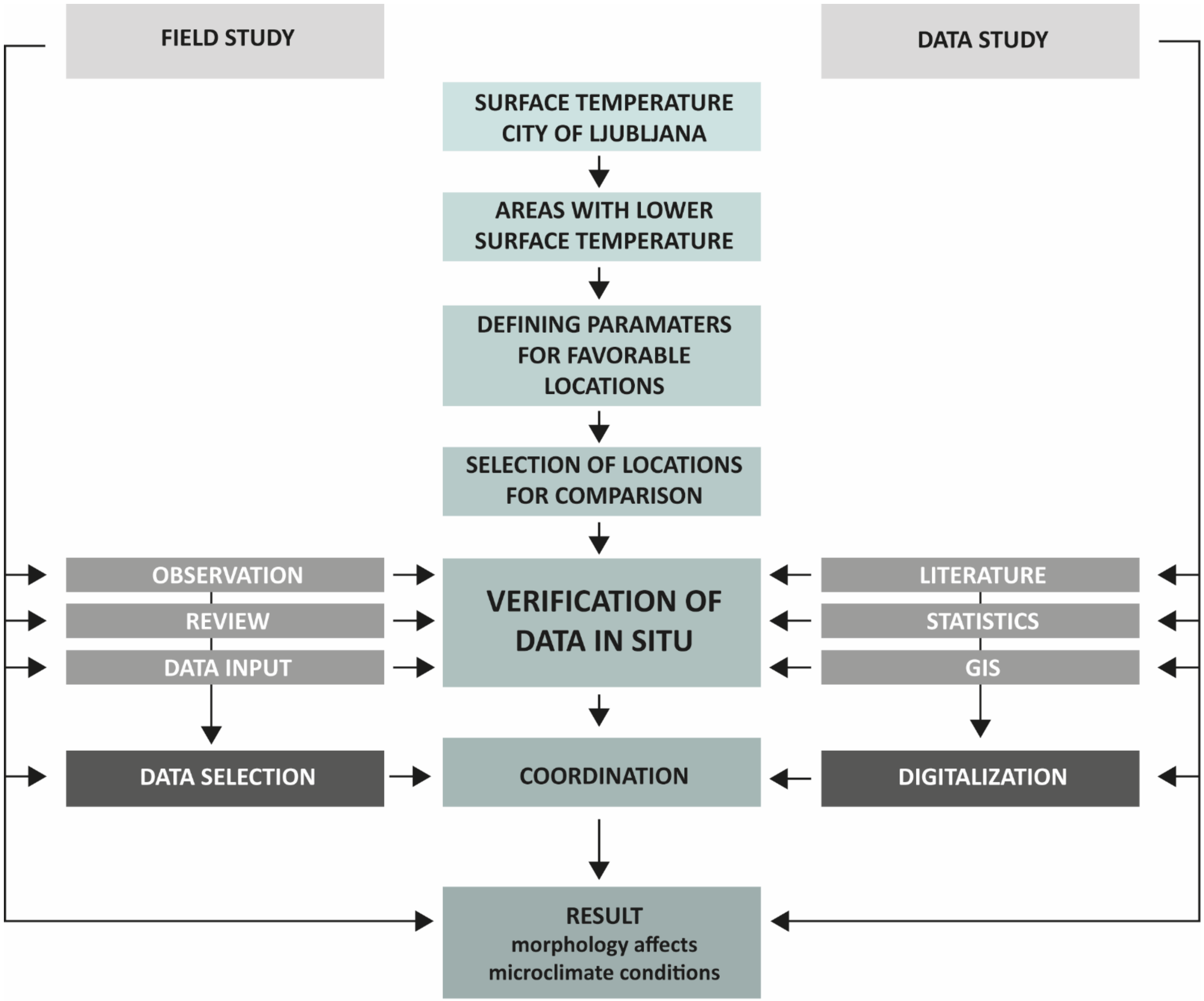
- high-quality living conditions, excluding car traffic from the pedestrian level;

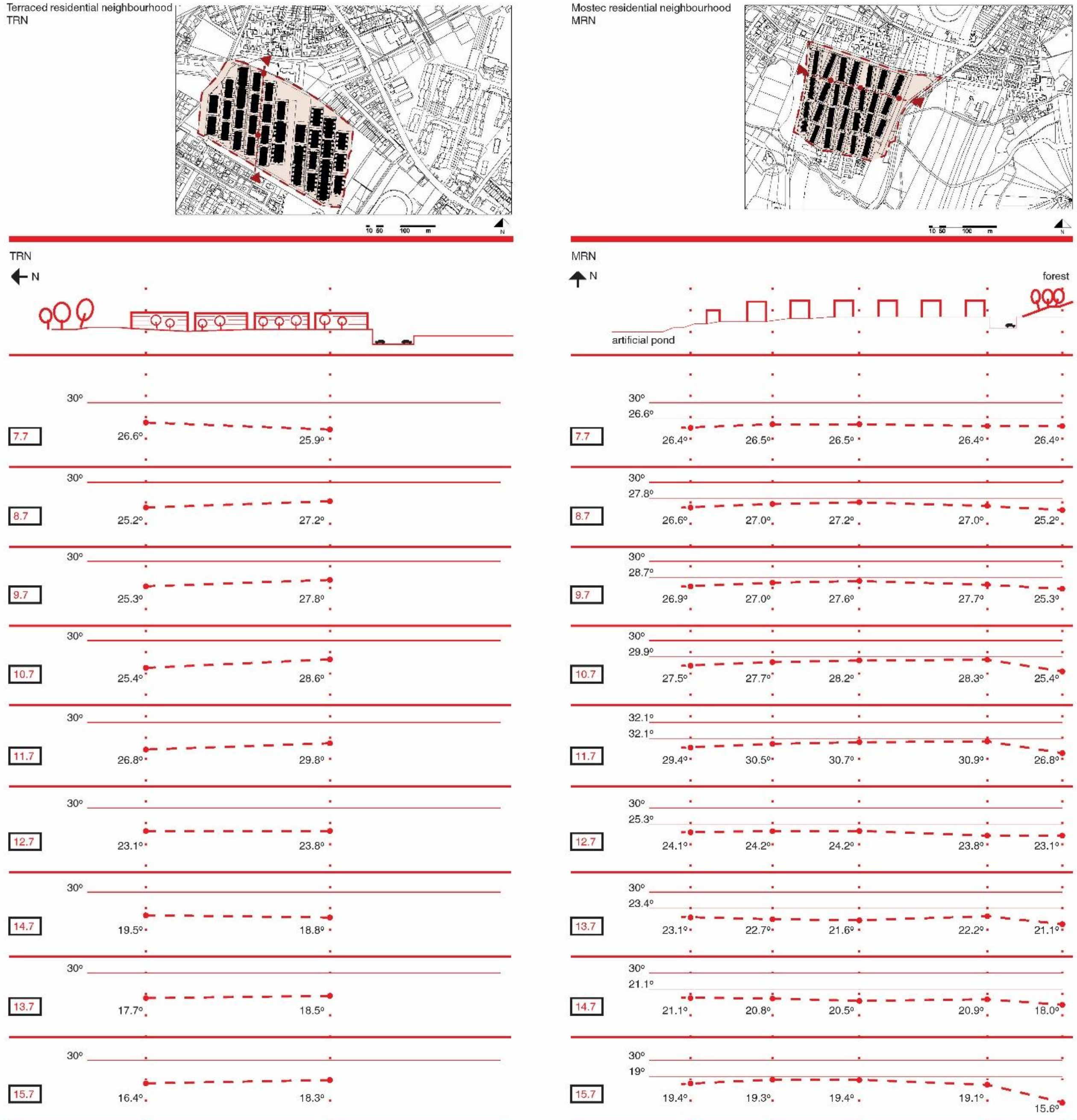
- terraced shape G+3 buildings, inclined profile and atrium apartments;
- the neighborhood is a composition of terraced blocks of the same design;
- each apartment has its own outdoor space, a terrace;
- parallel apartment blocks inclined at an angle of 5° (in NE–SW direction)
- Koseze terraced neighborhood was selected among 100 nationally significant architectural and urban design works of Slovenian Modernism of the 20th century, i.e., as part of the Slovenian cultural heritage;
- in 2010, its population was 3251.

Mostec residential area, 1997-2000 Urbanizem: Janez Vrhunc, Urška Vrhunc, Tomaž Maechtig Arhitektura: Bevk Perović arhitekti, Janez Koželj, Ofis, Aleš Vodopivec, Janez Vrhunc, Urška Vrhunc, Tomaž Maechtig

- 540 apartments organised in different housing blocks or houses;
- underground parking area;
- Green ground floor without cars;
- Walking paths, part of the PST system path;
- playgrounds, fitness in open air, small lake etc.


N
N


FIELD STUDY
DATA STUDY
SURFACE TEMPERATURE CITY OF LJUBLJANA
AREAS WITH LOWER SURFACE TEMPERATURE
DEFINING PARAMATERS FOR FAVORABLE LOCATIONS
SELECTION OF LOCATIONS FOR COMPARISON
OBSERVATION
REVIEW
DATA INPUT
VERIFICATION OF DATA IN SITU
LITERATURE
STATISTICS
GIS
DATA SELECTION
COORDINATION
DIGITALIZATION
RESULT
morphology affects microclimate conditions


Terraced residential neighbourhood
TRN
Mostec residential neighbourhood
MRN
TRN
N
MRN
N
forest
artificial pond
7.7
30º
26.6º
25.9º
8.7
30º
25.2º
27.2º
9.7
30º
25.3º
27.8º
10.7
30º
25.4º
28.6º
11.7
30º
26.8º
29.8º
12.7
30º
23.1º
23.8º
14.7
30º
19.5º
18.8º
13.7
30º
17.7º
18.5º
15.7
30º
16.4º
18.3º
7.7
30º
26.6º
26.4º
26.5º
26.5º
26.4º
26.4º
8.7
30º
27.8º
26.6º
27.0º
27.2º
27.0º
25.2º
9.7
30º
28.7º
26.9º
27.0º
27.6º
27.7º
25.3º
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30º
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11.7
32.1º
32.1º
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30º
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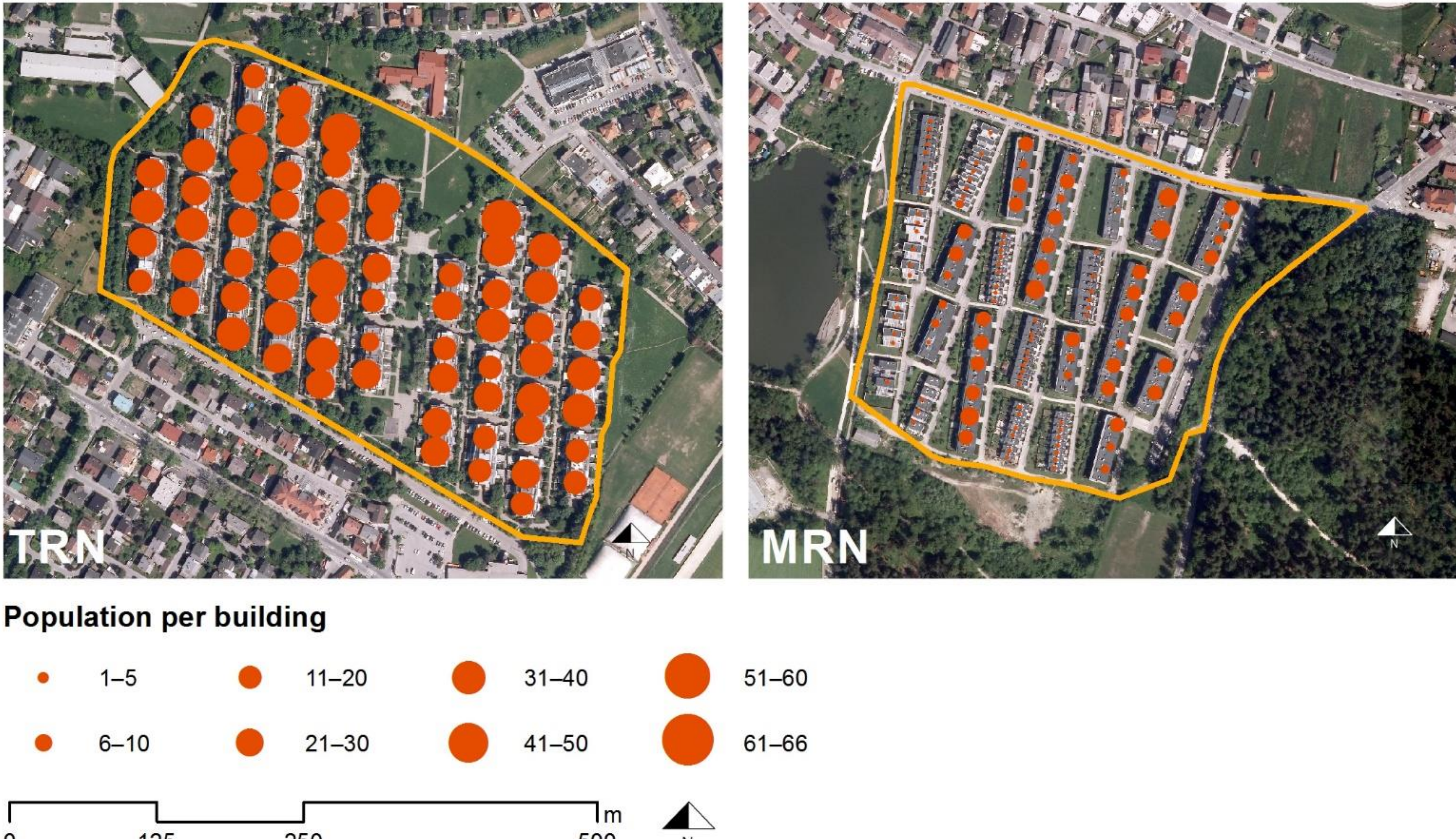
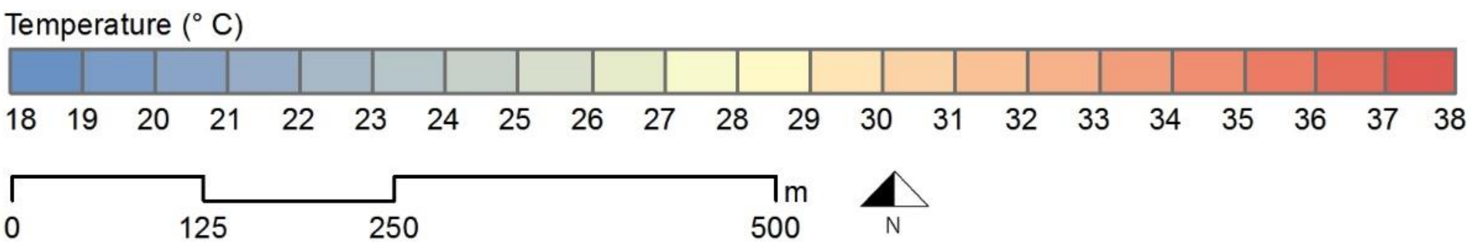
24.1º
24.2º
24.2º
23.8º
23.1º
13.7
30º
23.4º
23.1º
22.7º
21.6º
22.2º
21.1º
14.7
30º
21.1º
21.1º
20.8º
20.5º
20.9º
18.0º
15.7
30º
19º
19.4º
19.3º
19.4º
19.1º
15.6º

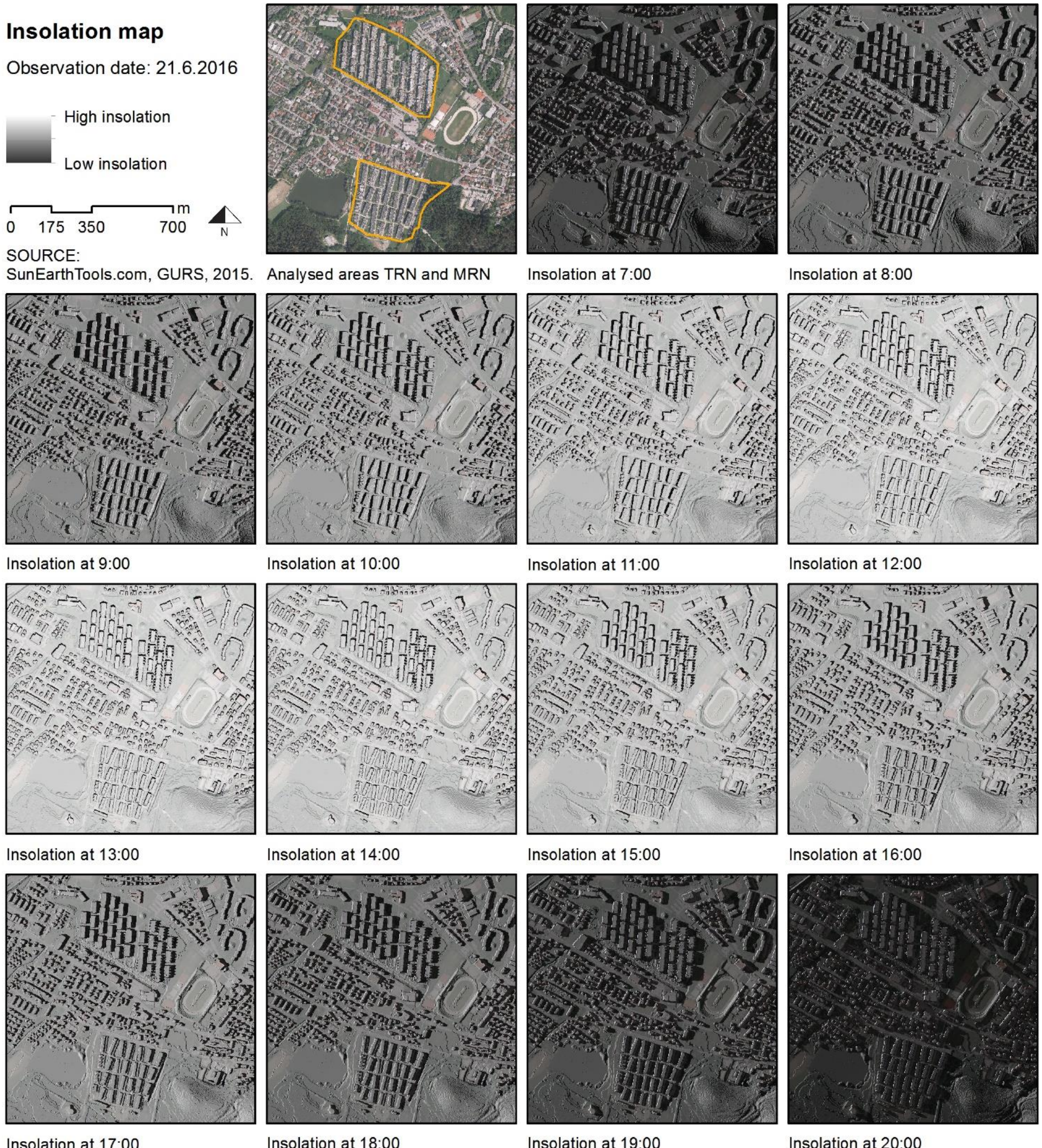


SOURCE: GURS, 2015, SURS, 2010.

Surface temperature, 19th July 2016 at 9:52

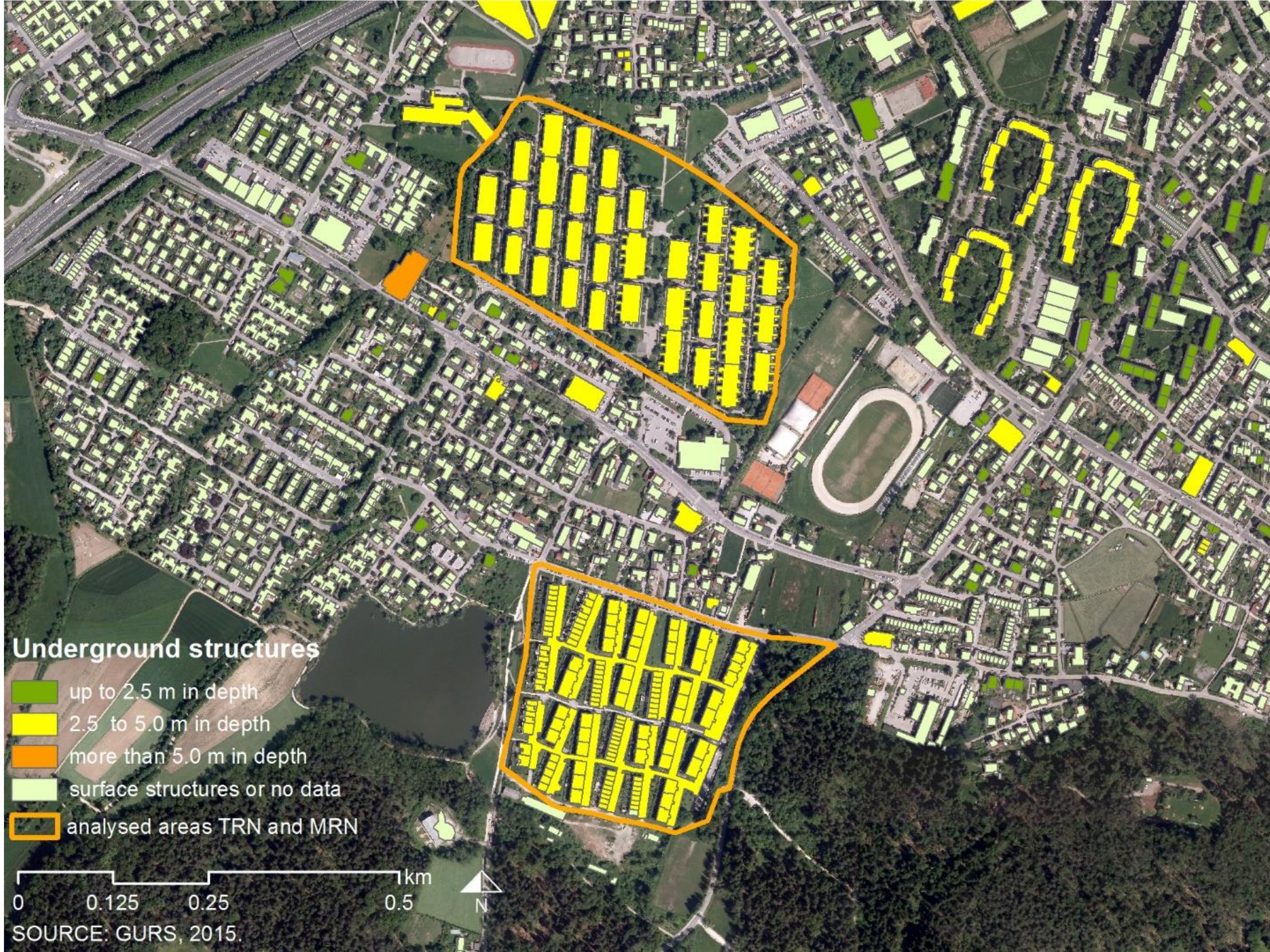


SOURCE: Landsat 8, July 2016 and GURS, 2015.



Insolation map
Observation date: 21.6.2016
High insolation
Low insolation
0 175 350 700 m
N
SOURCE:
SunEarthTools.com, GURS, 2015.
Analysed areas TRN and MRN
Insolation at 7:00
Insolation at 8:00
Insolation at 9:00
Insolation at 10:00
Insolation at 11:00
Insolation at 12:00
Insolation at 13:00
Insolation at 14:00
Insolation at 15:00
Insolation at 16:00
Insolation at 17:00
Insolation at 18:00
Insolation at 19:00
Insolation at 20:00


Building height [m]
lower then 2.5
2.6–5.0
5.1–7.5
7.6–10.0
10.1–12.5
12.6–15.0
15.1–17.5
17.6–20.0
20.1–22.5
more than 22.5
analysed areas TRN and MRN
0
0.125
0.25
0.5
km
N
SOURCE: GURS, 2015.



Underground structures
up to 2.5 m in depth
2.5 to 5.0 m in depth
more than 5.0 m in depth
surface structures or no data
analysed areas TRN and MRN
0
0.125
0.25
0.5
km
N
SOURCE: GURS, 2015.


0
50
100
200 m
N
paved surface
green remains
parks, grass fields
denser tree growth
private atrium / green area
individual trees
building e.n.
building outline
TRN


0
50
100
200 m
N
paved surface
green remains
parks, grass fields
denser tree growth
private atrium / green area
individual trees
building e.n.
building outline
MRN

What can we do about it?

A1. Make green areas greener

A2. Make streets greener

A3. Add urban water elements

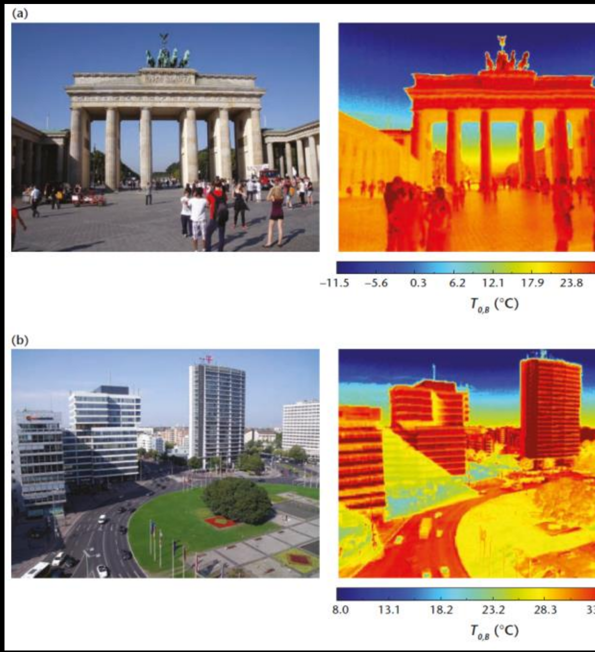
A4. Cool street surfaces

A5. Add shade to public places

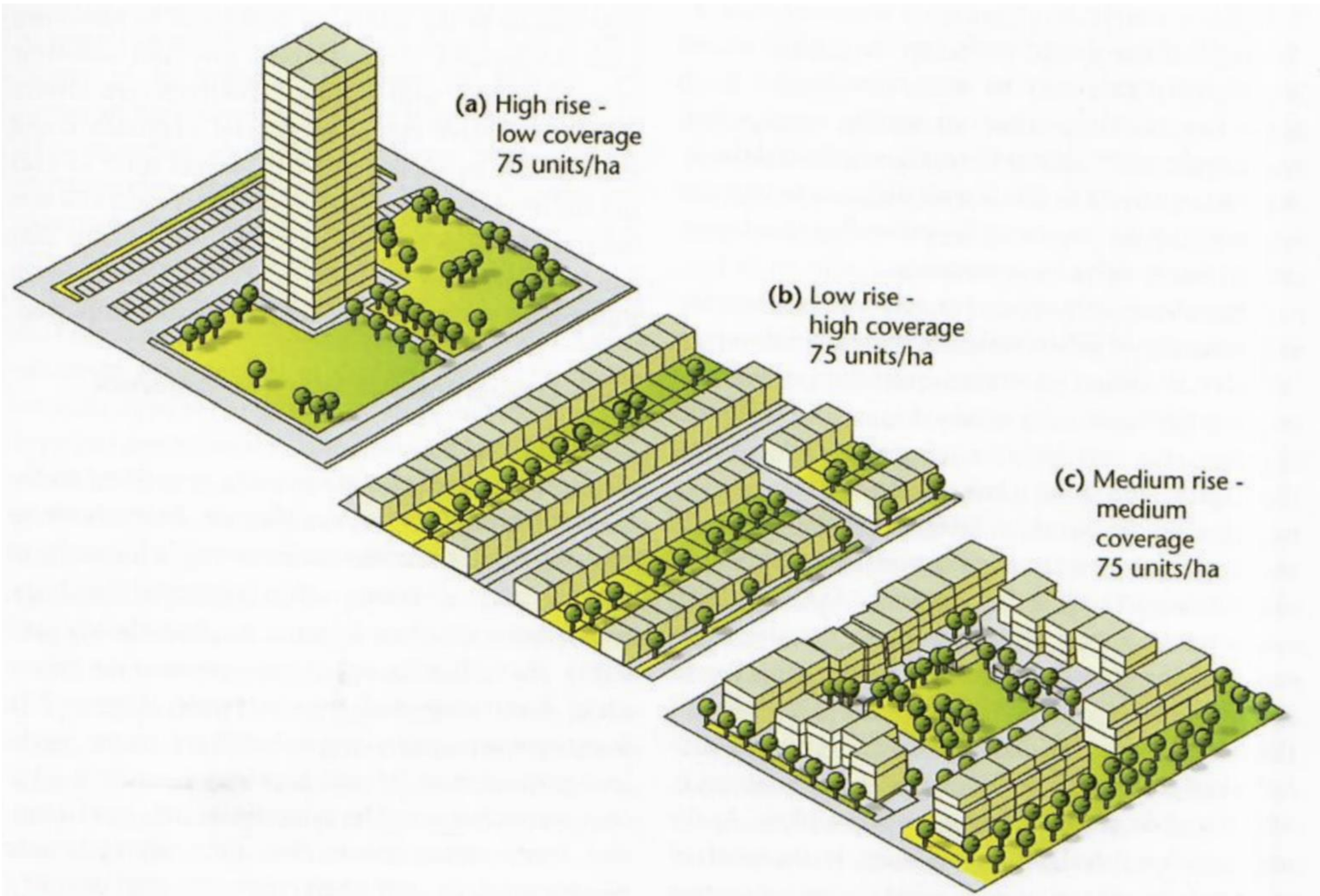
A6. Increase energy efficiency

A7. Capacitate district cooling

A8. Keep roofs cool



van der Hoeven, F., & Wandl, A. (2015). *Hotterdam*. TU Delft.



The same building density can result in radically different buildings and neighborhood outcomes (modified after: Urban Task Force, 1999).

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HVALA ZA POZORNOST

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