Revisiting the urban block in the light of climate change, a case study of Budapest

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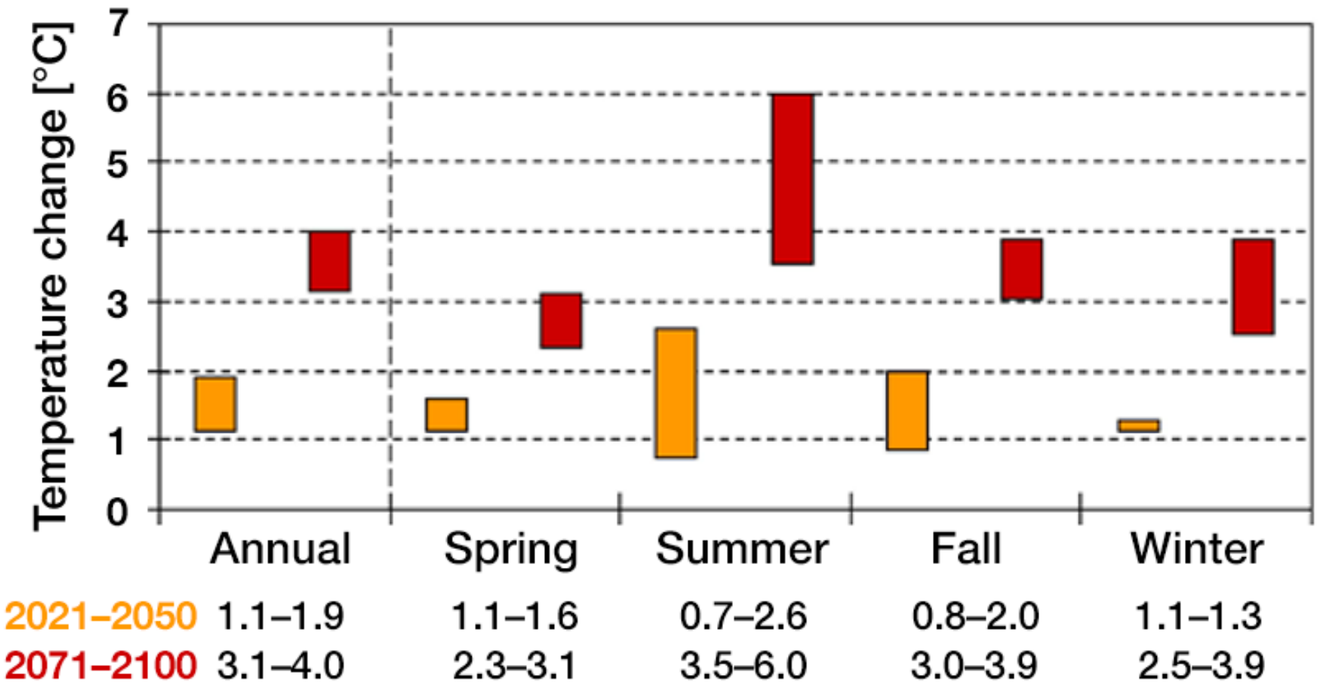
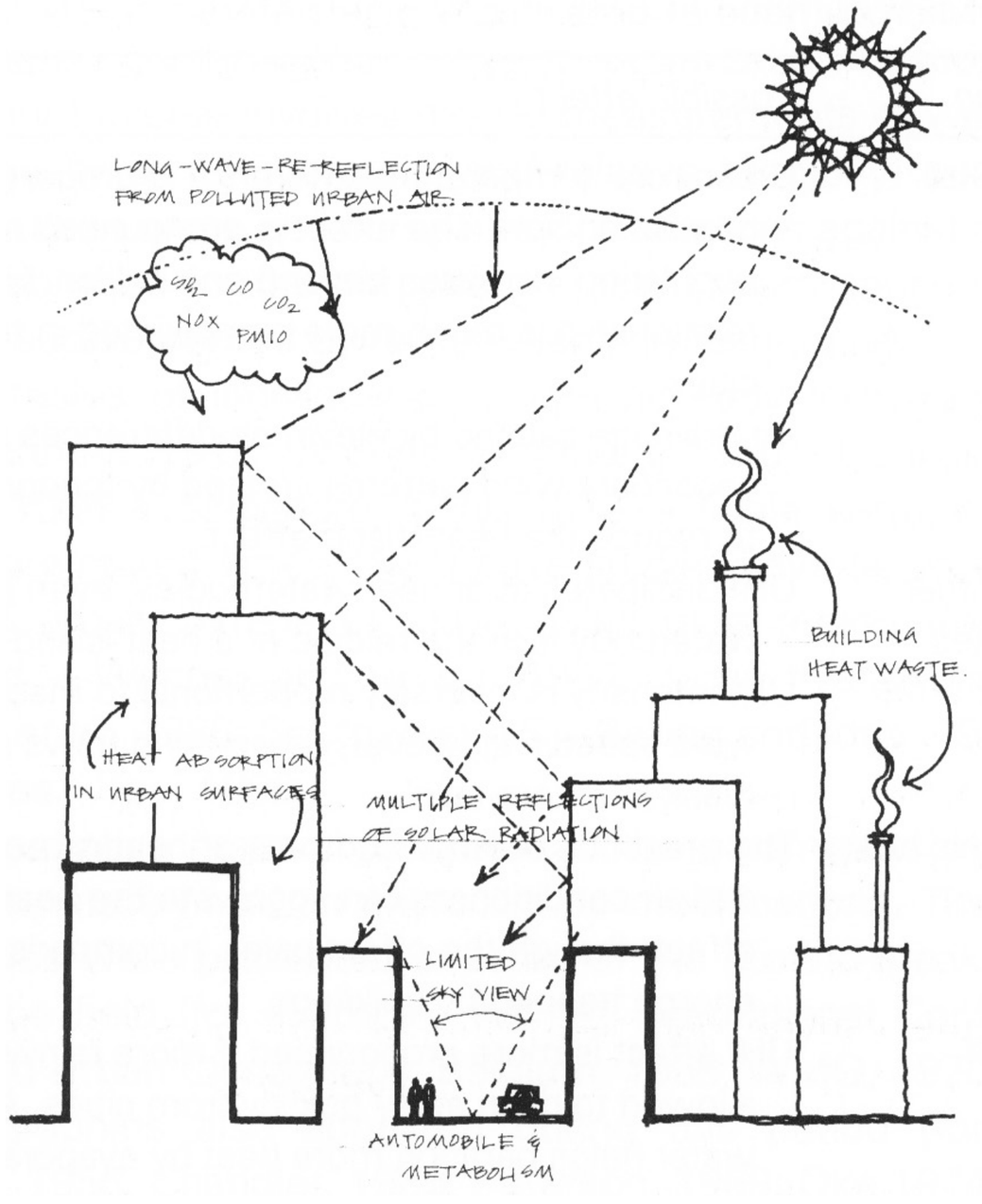
Projected seasonal temperature changes



Horányi, A. (2011b). In J. Bartholy, L. Bozó, & L. Haszpra (Eds.), *Klímaváltozás - 2011: Klímaszcenáriók a Kárpát-medence térségére.* Budapest, Hungary: MTA-ELTE Meteorológia Tanszék, p. 198.

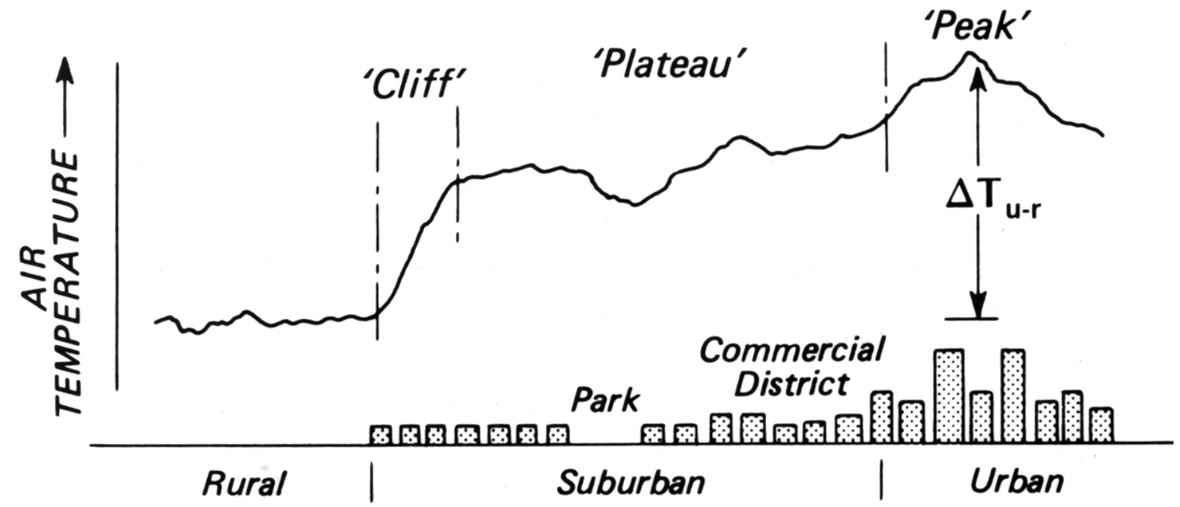
Causes of the urban heat island

- decreased wind speed,
- increased radiative trapping,
- increased heat absorption in urban surfaces,
- decreased evapotranspiration (reduction in green spaces and pervious surfaces),
- added anthropogenic heat,
- increased long-wave radiation due to polluted urban air.



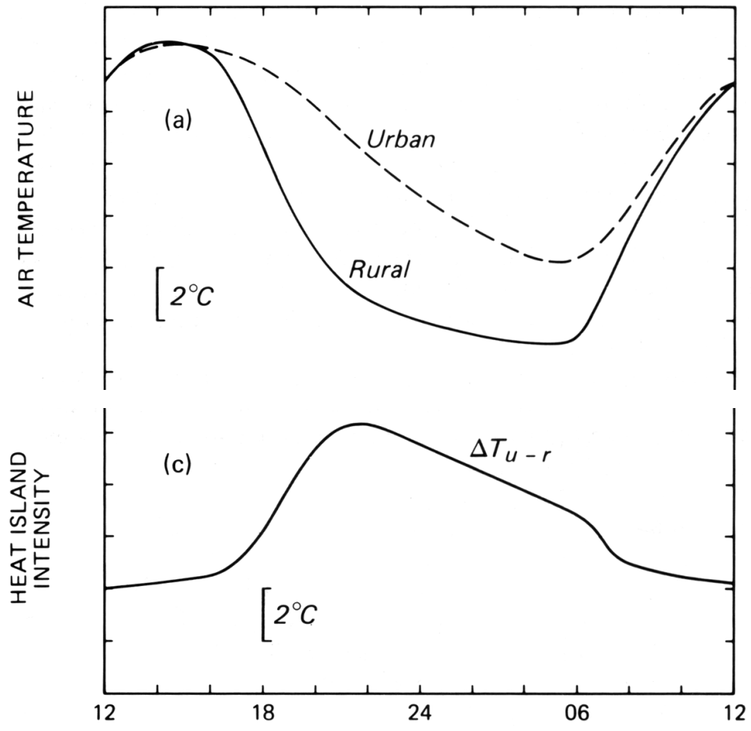
Emmanuel, M. R. (2005). *An urban approach to Climate-Sensitive design: strategies for the tropics*. New York: Spon Press, p. 25.

Generalized cross-section of a typical urban heat island



Oke, T. R. (1995). *Boundary layer climates*. 2nd ed. London & New York: Routledge, p. 288.

Urban heat island intensity

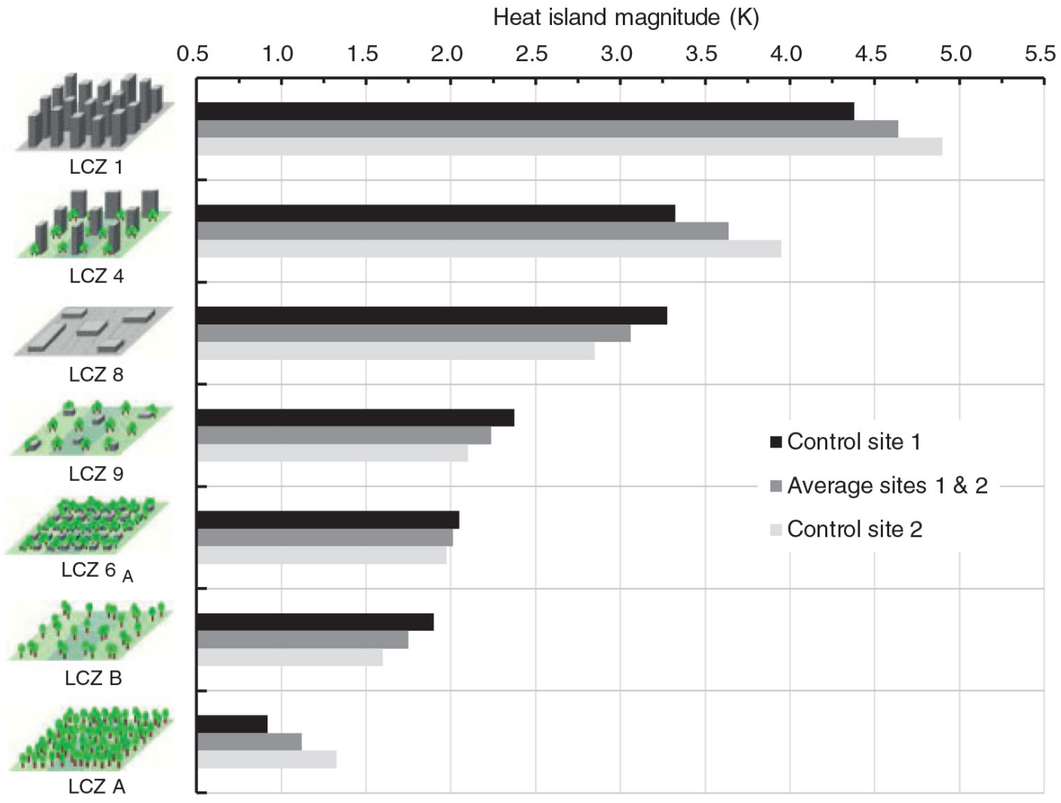


Oke, T. R. (1995). *Boundary layer climates*. 2nd ed. London & New York: Routledge, p. 290.

UHI magnitudes for Vancouver during a nighttime traverses (4 November 1999)

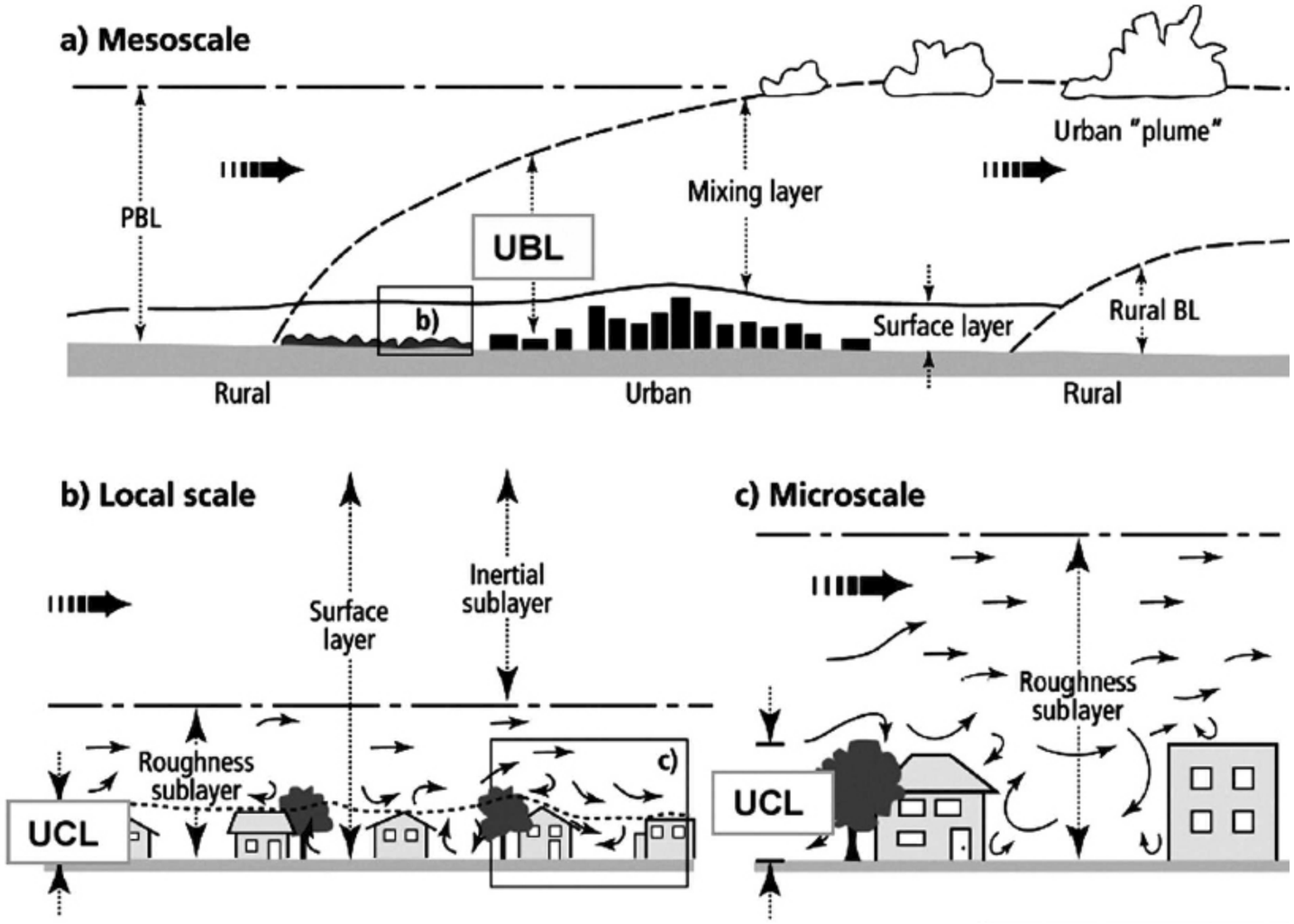
Stewart, I.D., Oke, T.R., and E.S. Krayenhoff. 2014. Evaluation of the 'local climate zone' scheme using temperature observations and model simulations. *International Journal of Climatology*, 34, p. 1070.

UHI magnitudes for Vancouver during a nighttime traverses (March 2008 and 2010)



Stewart, I.D., Oke, T.R., and E.S. Krayenhoff. 2014. Evaluation of the 'local climate zone' scheme using temperature observations and model simulations. *International Journal of Climatology*, 34, p. 1072.

The vertical structure of the urban boundary layer



Oke, T. R. (2006). *Initial guidance to obtain representative meteorological observations at urban sites*. Geneva, Switzerland, p. 105.

The objectives of the study are:

1) to compare the summertime microclimatic performance of typical, high density urban block typologies of Budapest,

2) to evaluate the effectiveness of common heat mitigation strategies,

3) to assess the microclimatic differences within the urban blocks experimentally

Google Maps. 2010. [Urban blocks from Budapest, Hungary]. Retrieved March 15, 2010, from http://maps.google.com

Numerical simulation study

T1

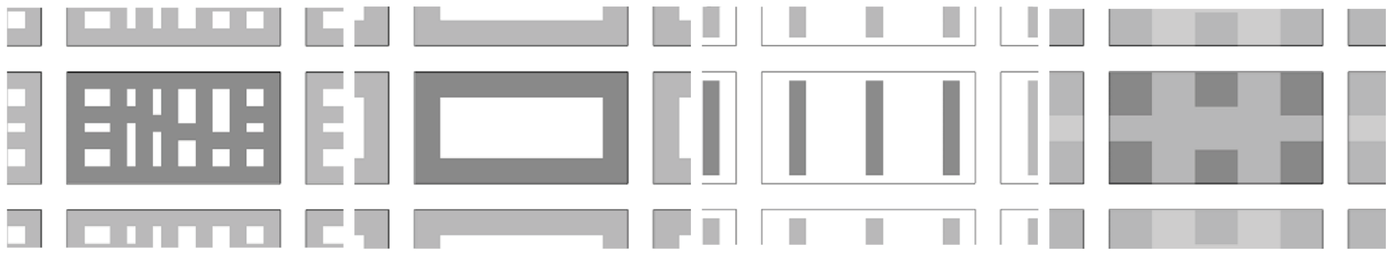
T2

T3

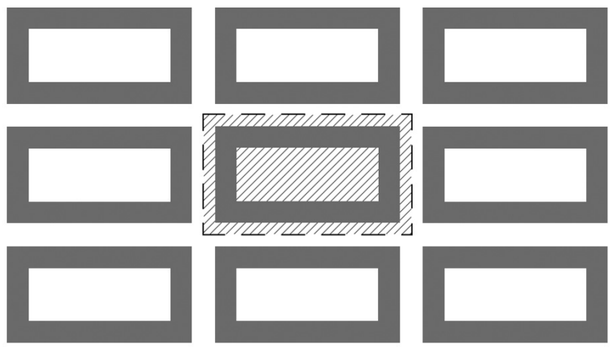

Vác út
Bessenyei utca
Bessenyei utca
Bessenyei utca
Vörösmarty utca
Bessenyei
Ceodák Palotája
interaktív múzeum
Túrái utca
Túrái utca

T4

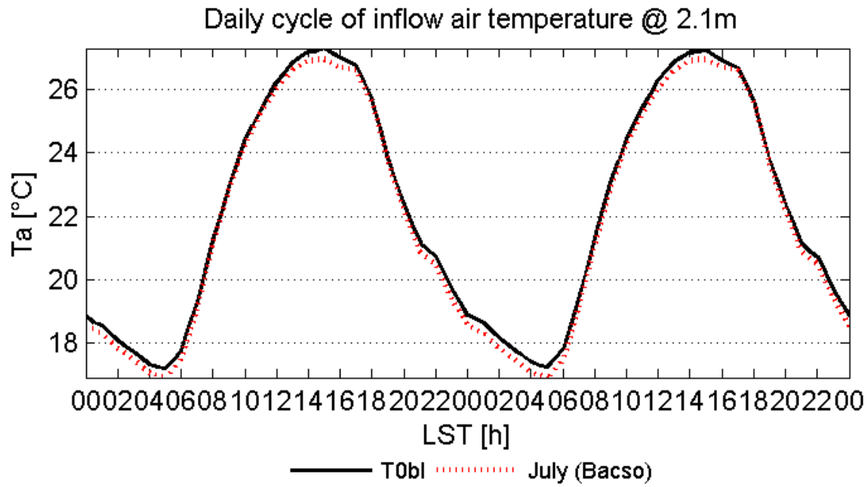
Budapest's metropolitan blocks

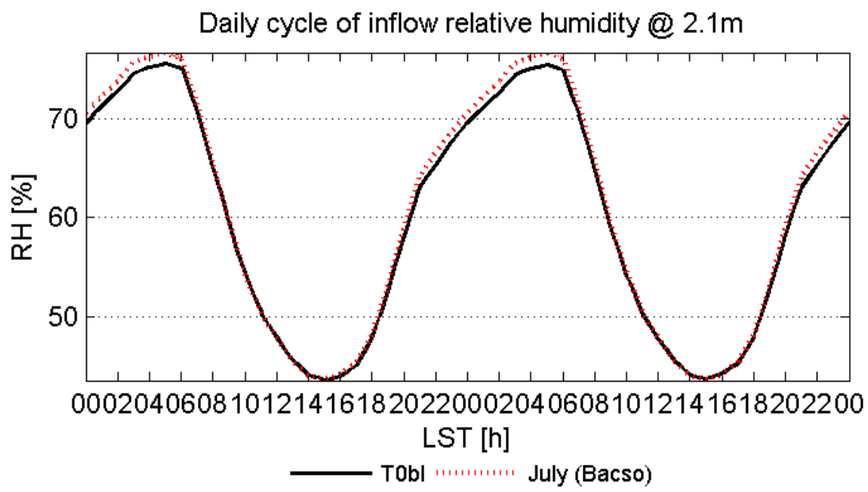


The idealized models



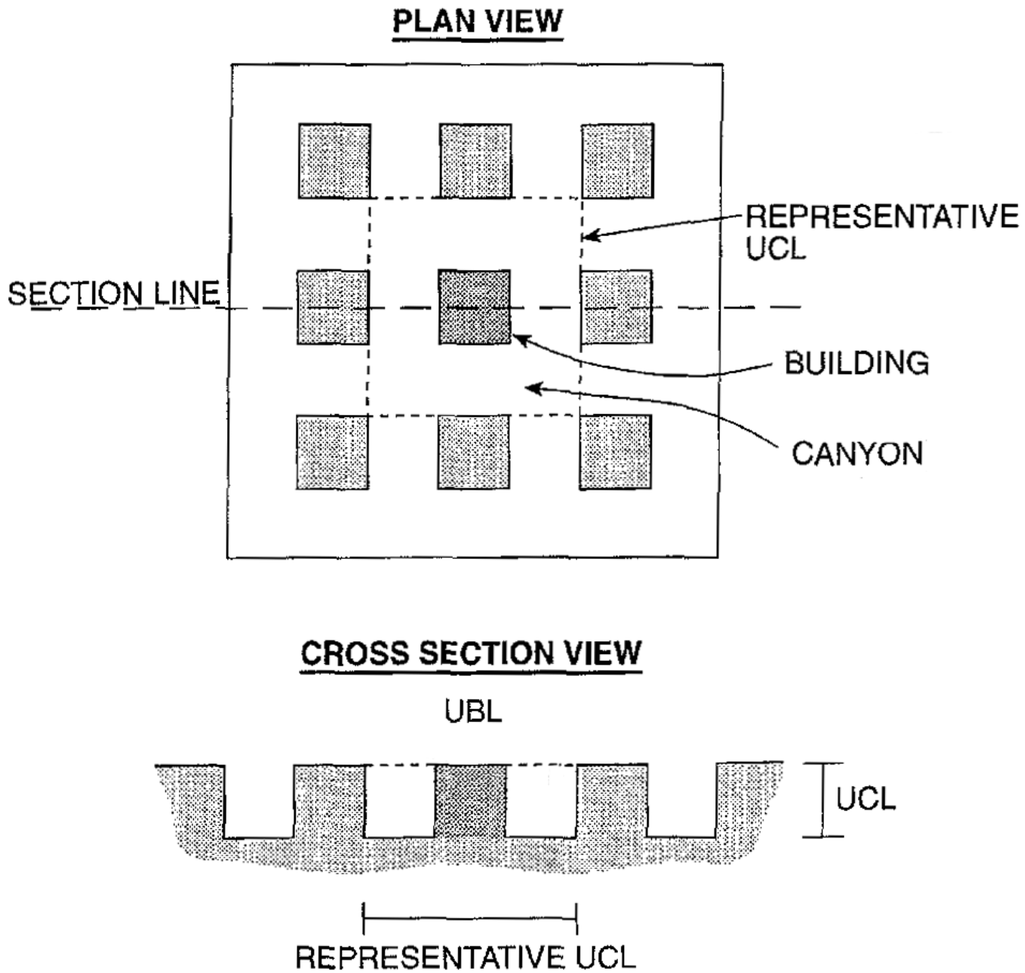
The 3-by-3 model layout with the analyzed area (indicated by hatching)





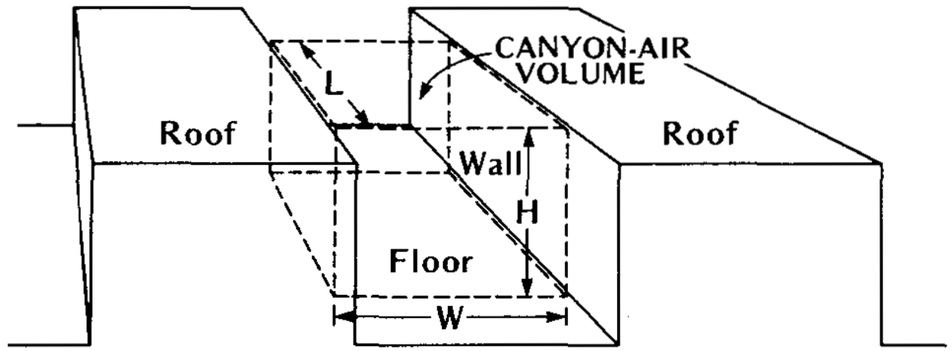
A typical July day in Budapest

Array of cubes



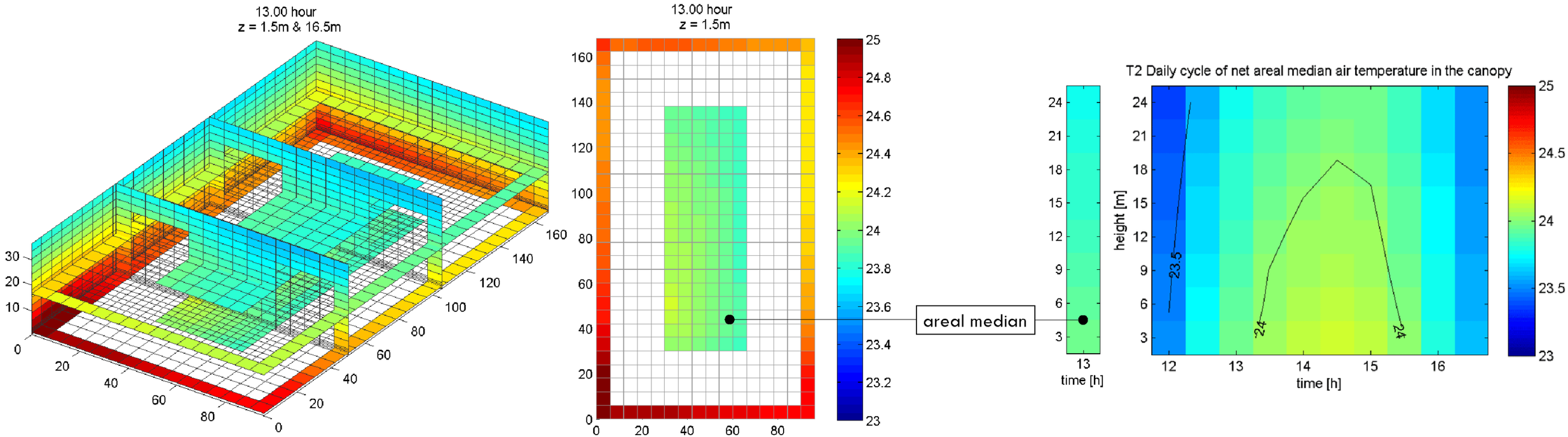
Nunez, M. & Oke, T. R. (1977). The energy balance of an urban canyon. *Journal of Applied Meteorology*, 16(1), p12.

Urban canyon



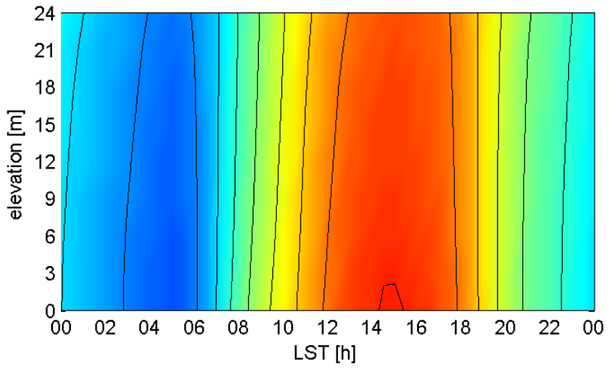
Mills, G. (1997). An urban canopy-layer climate model. *Theoretical and Applied Climatology*, 57(3), p.230.

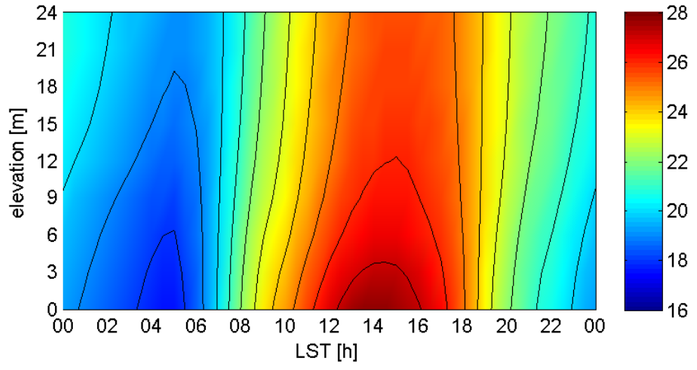
The areal median approach

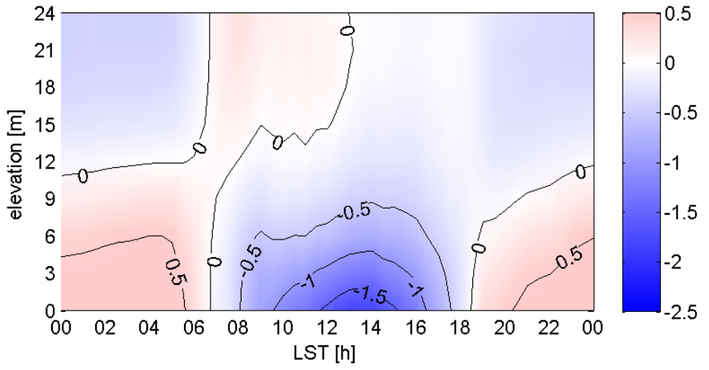


Gál, C. V. (2014). The influence of built form and vegetation on the canopy layer microclimate within urban blocks. *Acta Climatologica et Chorologica*, 47/48, p.43-52.

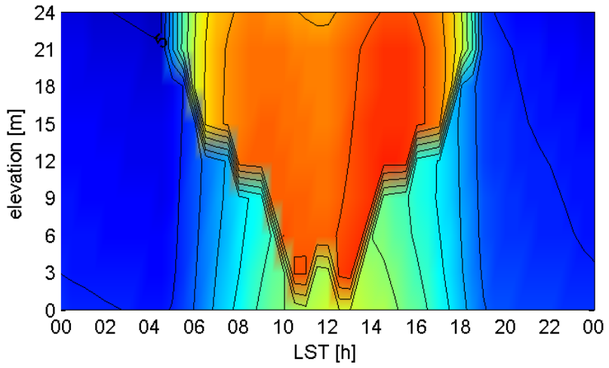
T1 **T0** **Δ = T1-T0**

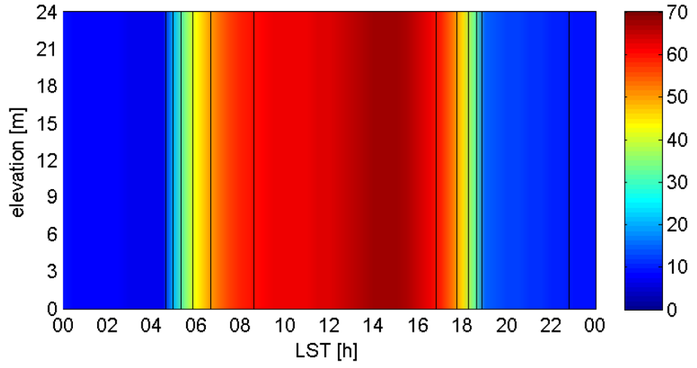


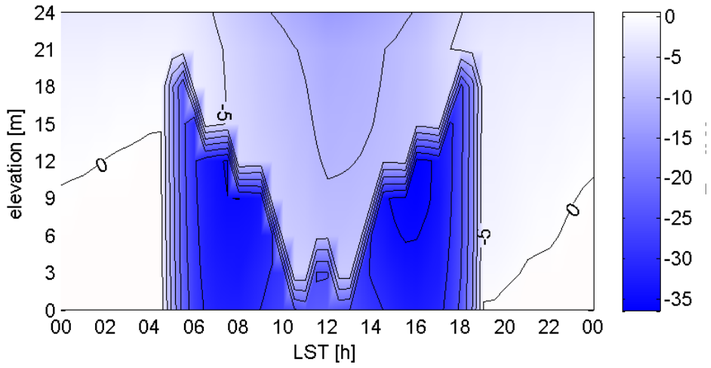




potential temperature



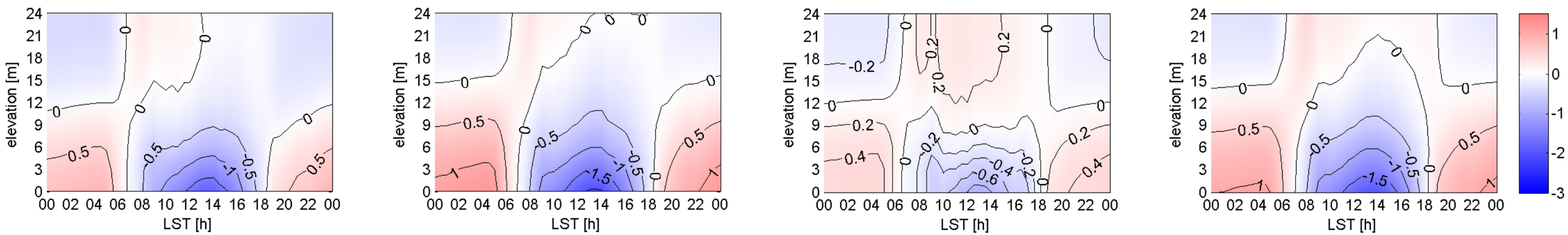




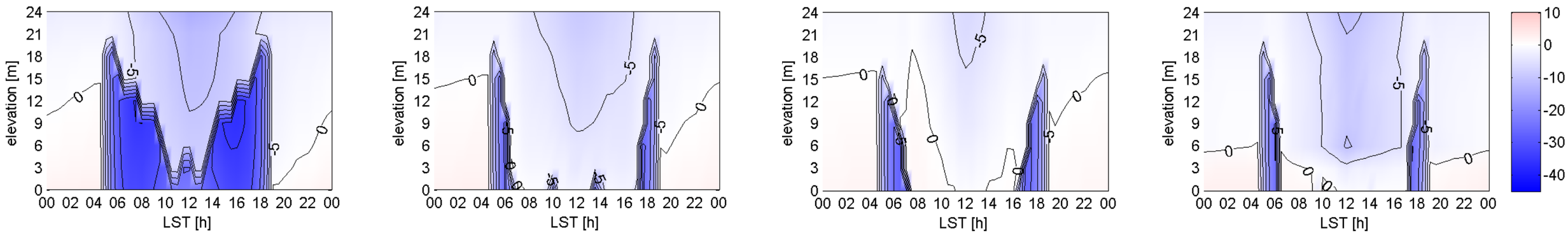
mean radiant temperature

The influence of built form

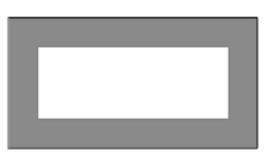
potential temperature relative to baseline (T0)



mean radiant temperature relative to baseline (T0)

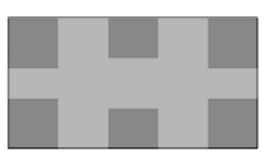


T1



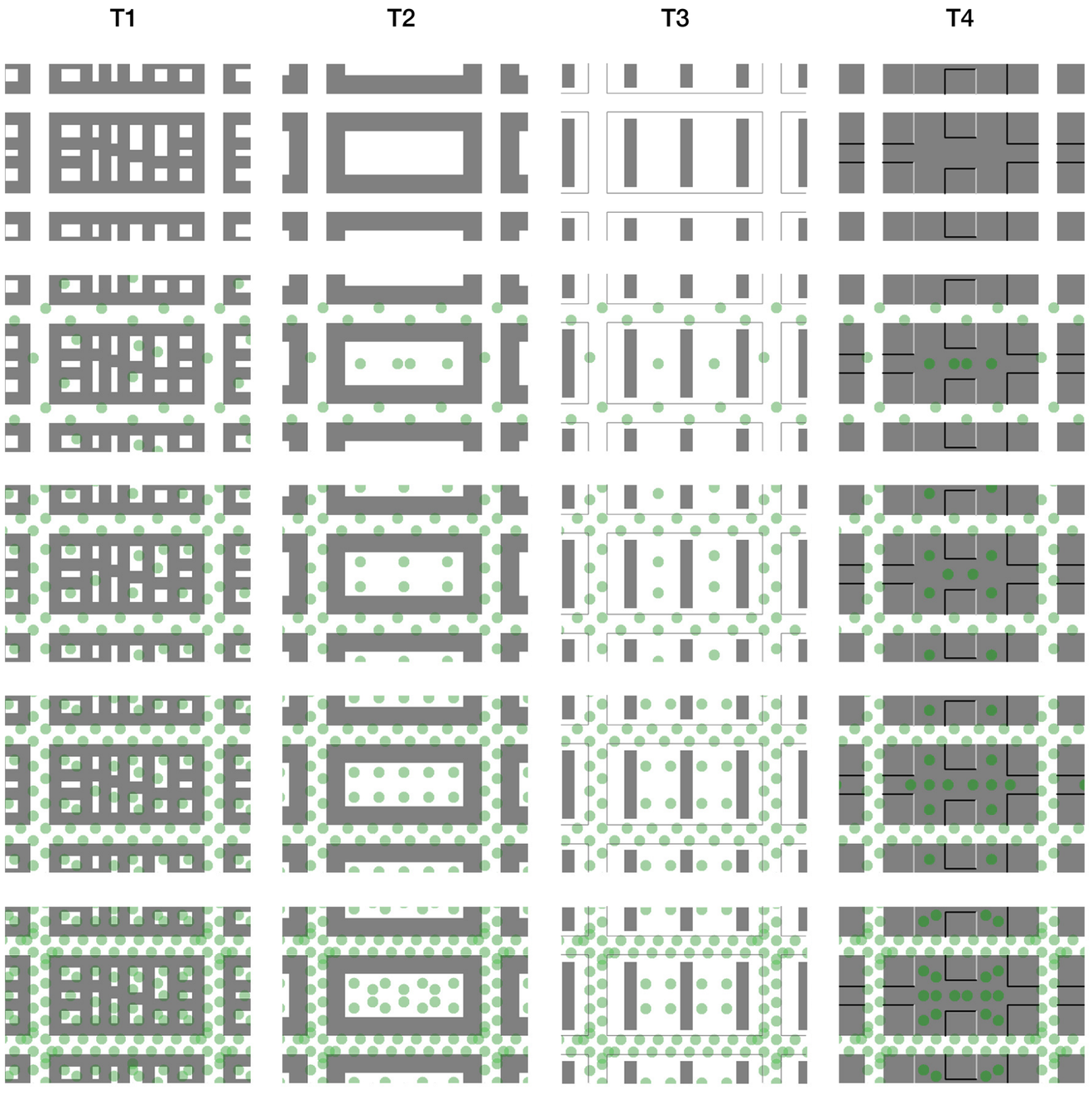
T2

T3



T4

Shade trees
The effect of canopy cover ratio



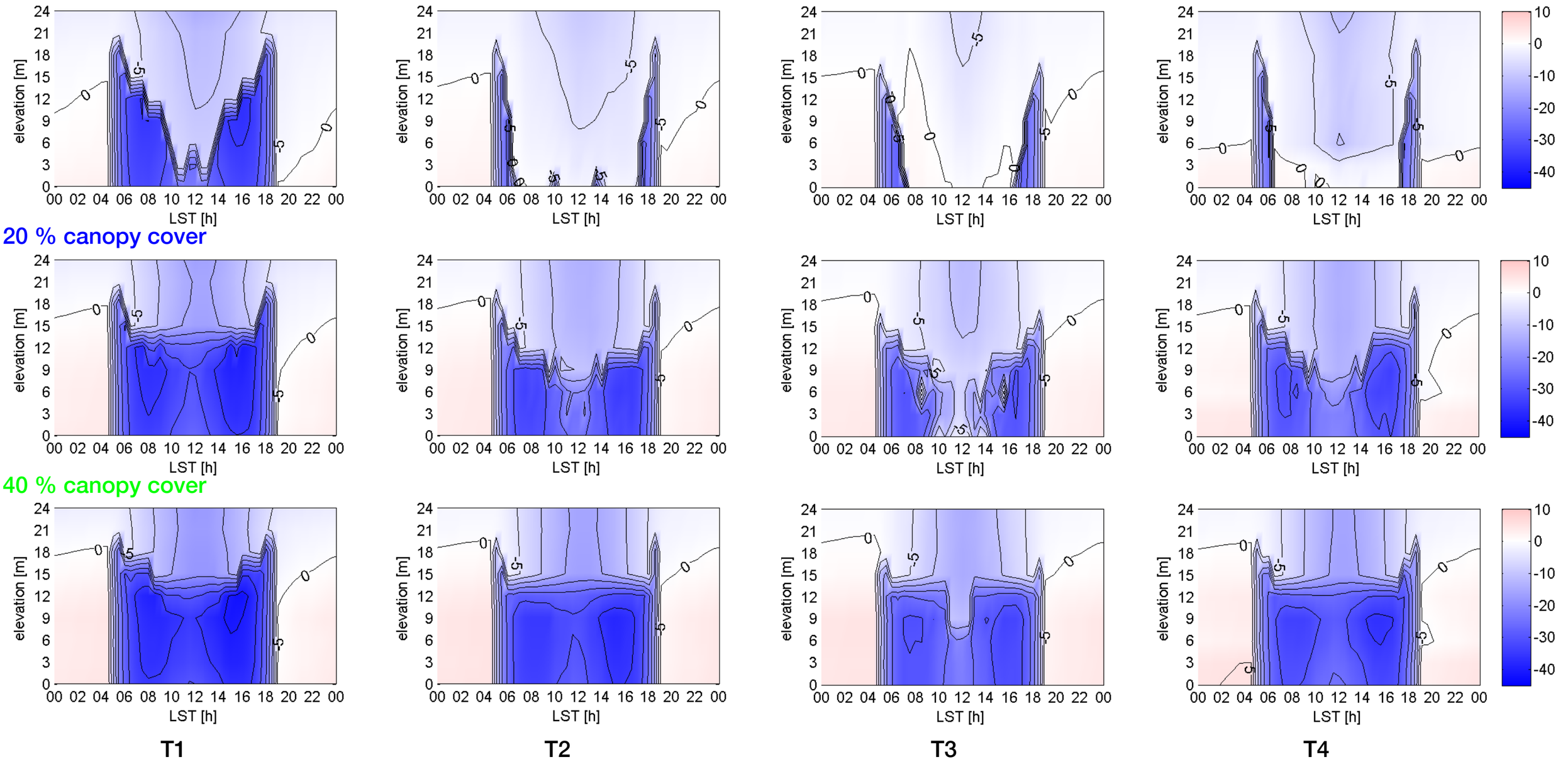
18 m tall London plane trees

mean radiant temperature relative to baseline (T0)

form

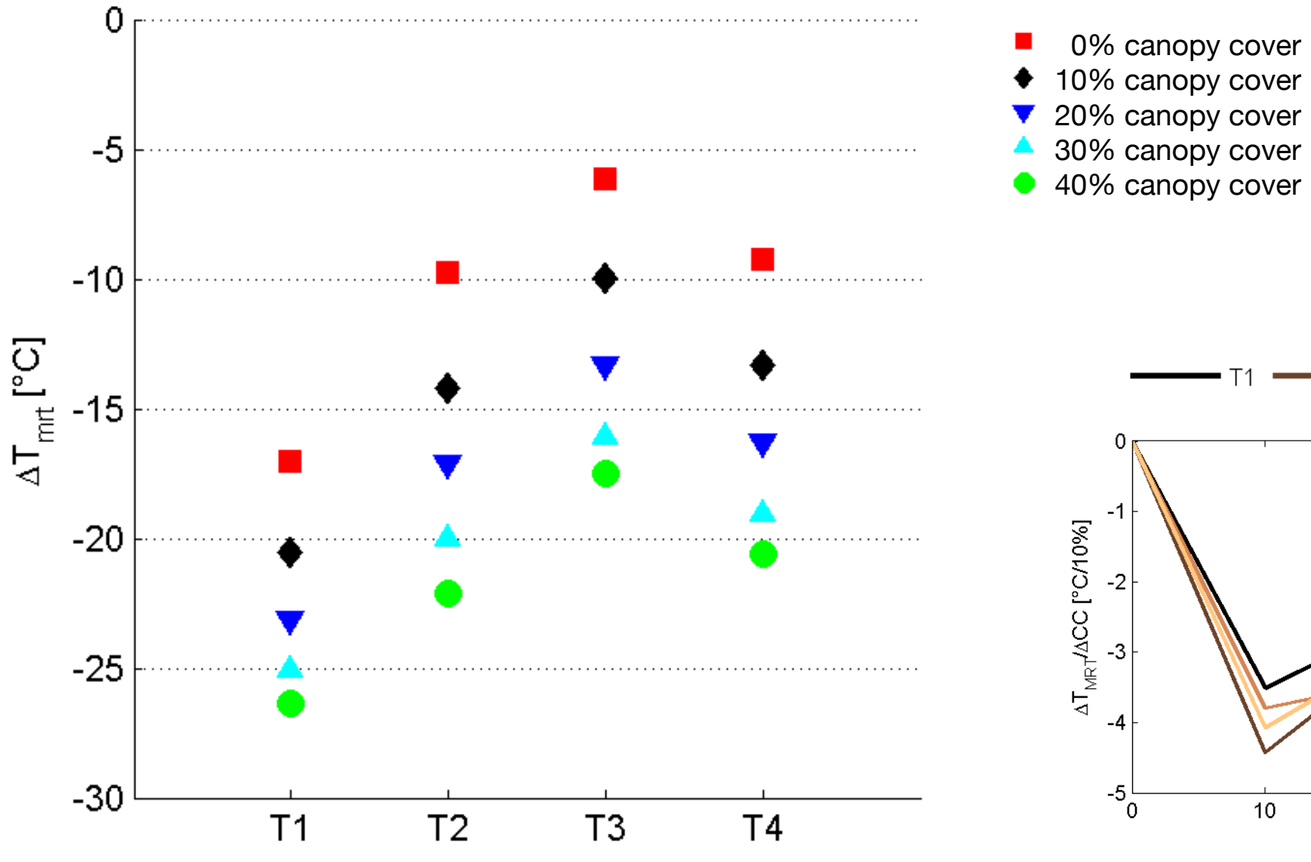
20 % canopy cover

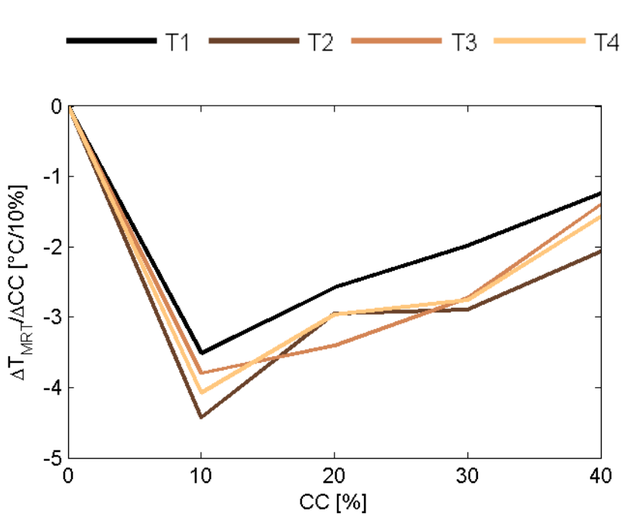
40 % canopy cover



T1 T2 T3 T4

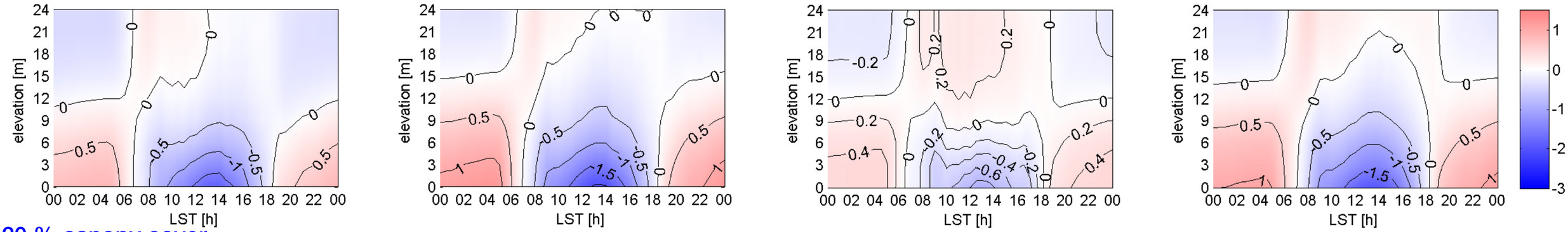
mean radiant temperature relative to baseline (T0)



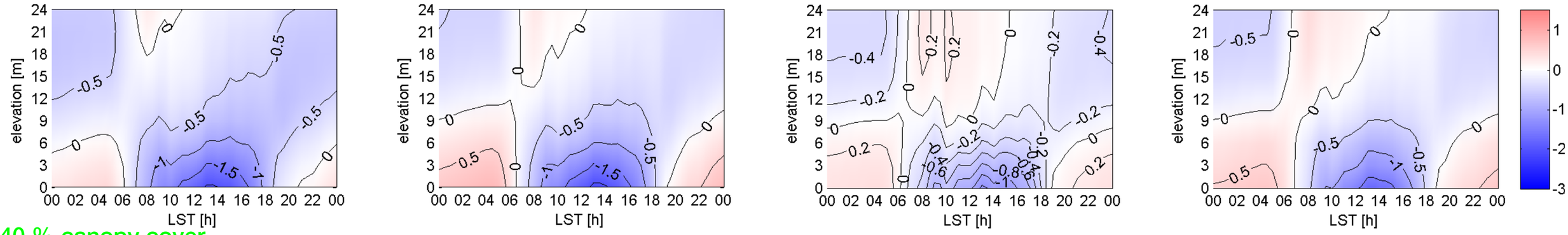


potential temperature relative to baseline (T0)

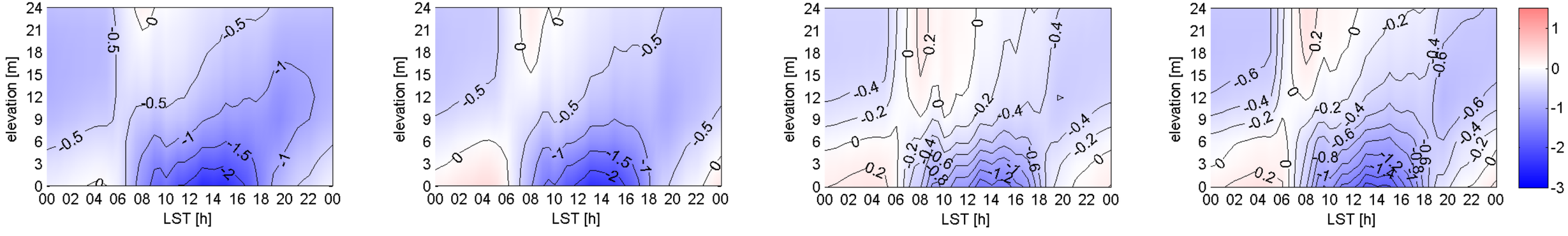
form



20 % canopy cover

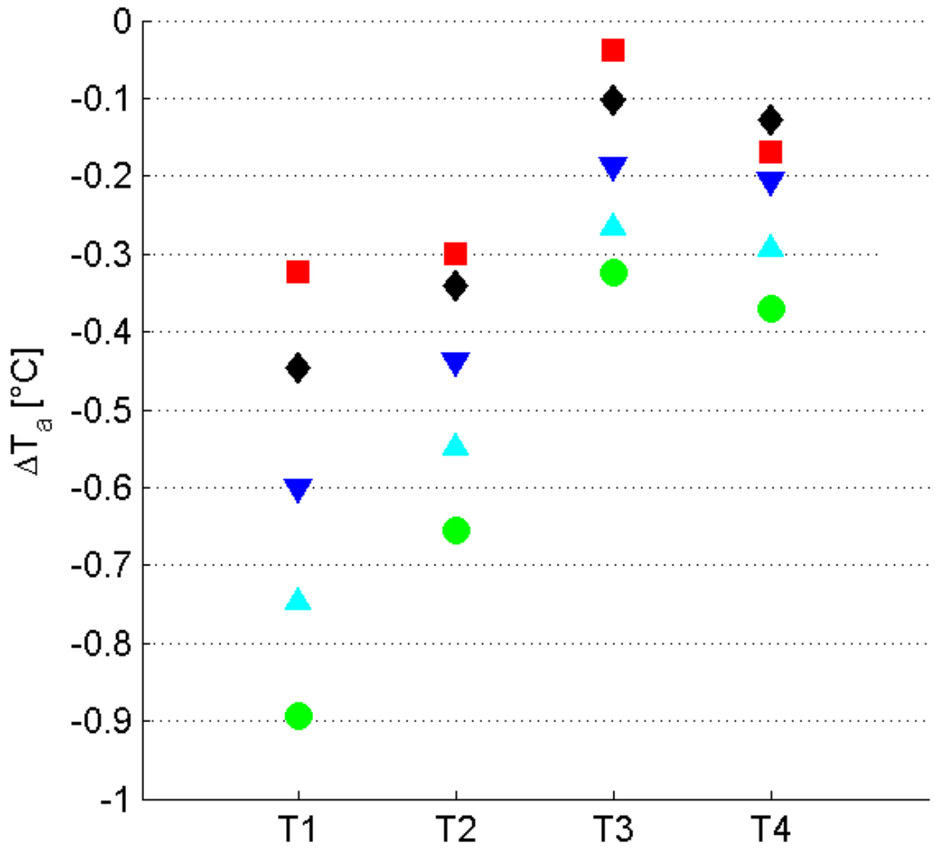


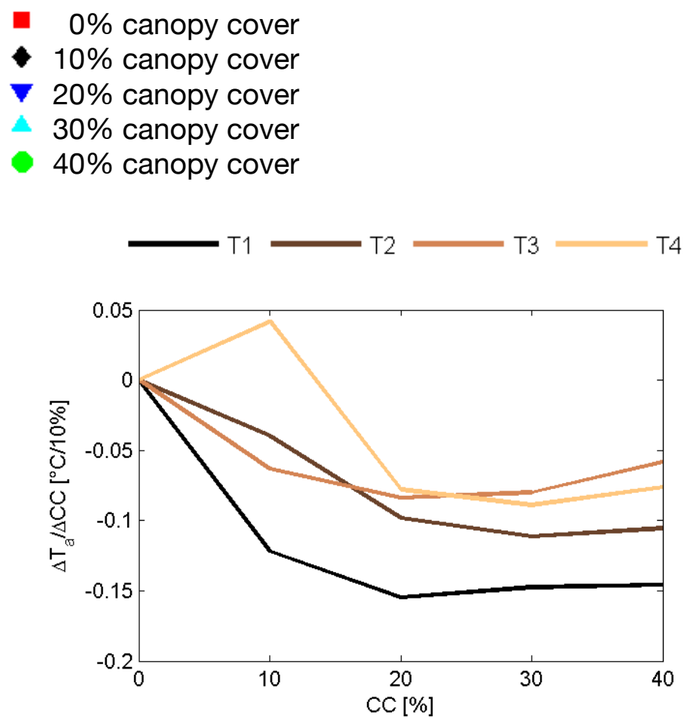
40 % canopy cover



T1 T2 T3 T4

potential temperature relative to baseline (T0)





Shade trees
The role of tree distribution

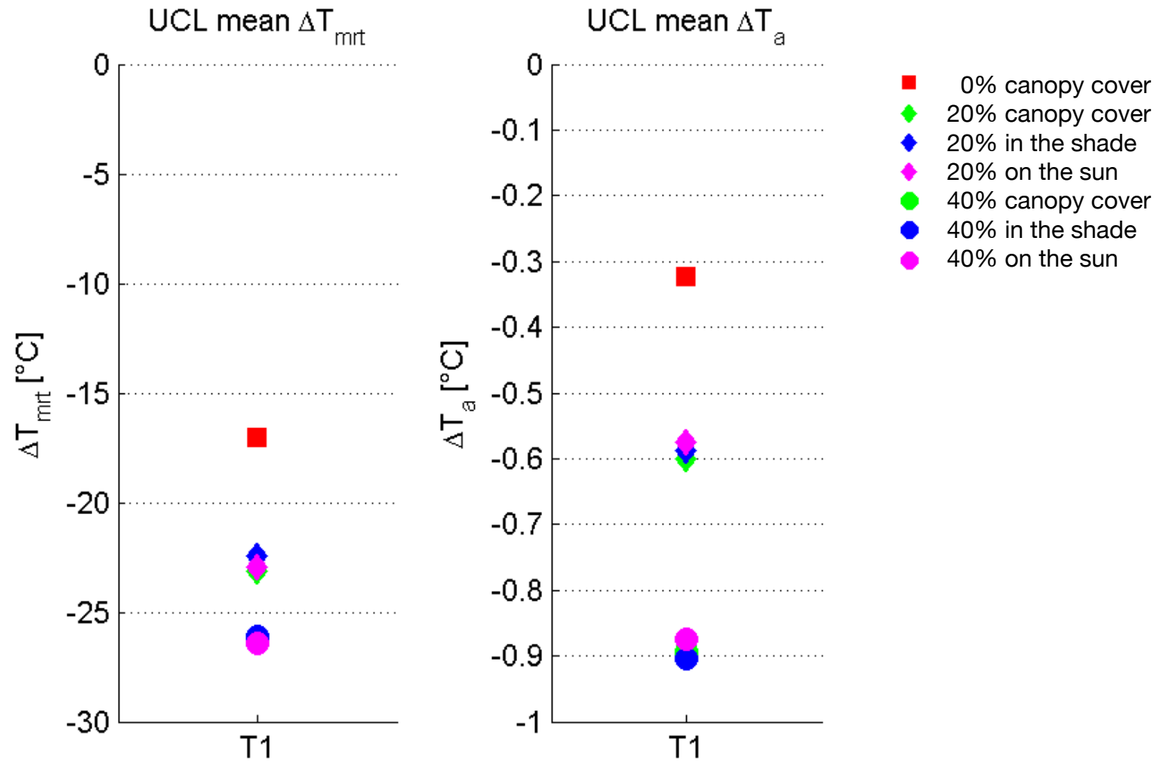
canopy cover

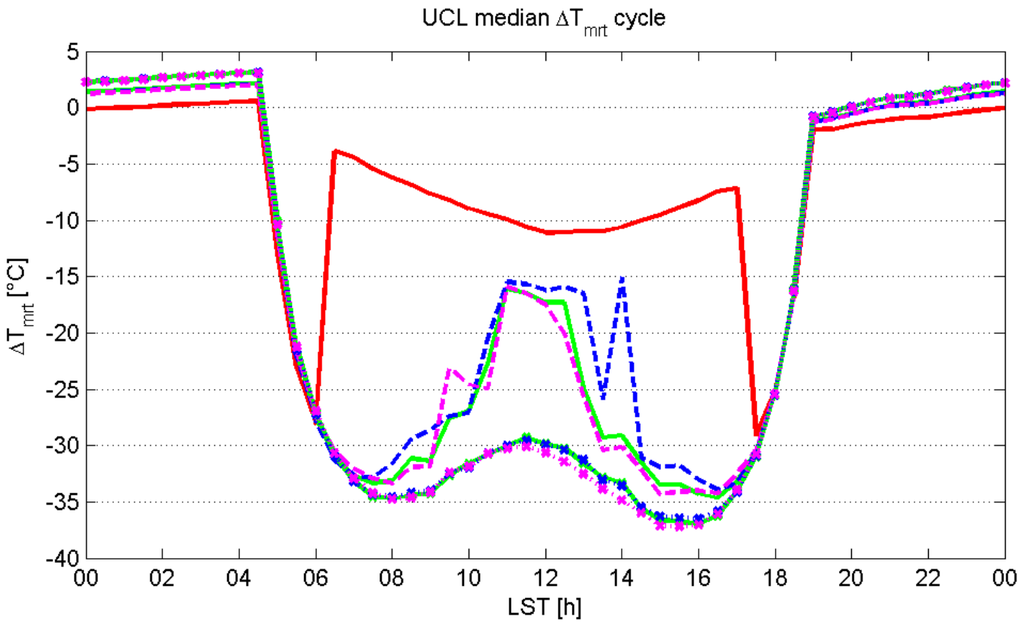
standard shade sun

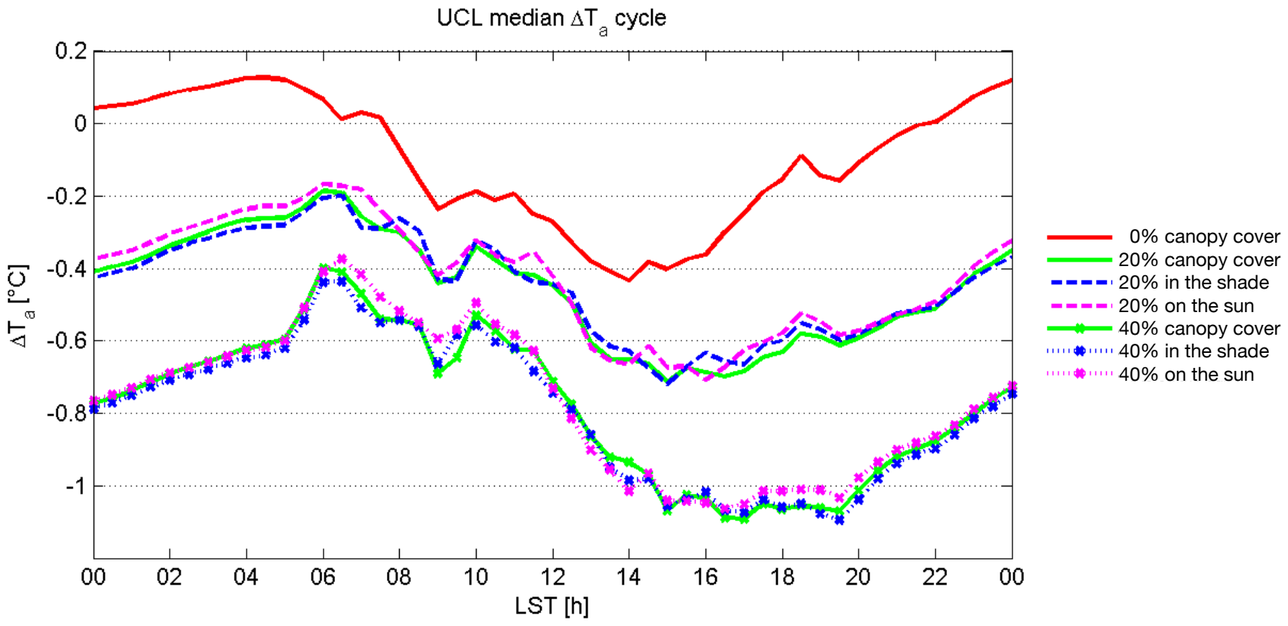
0%

20%

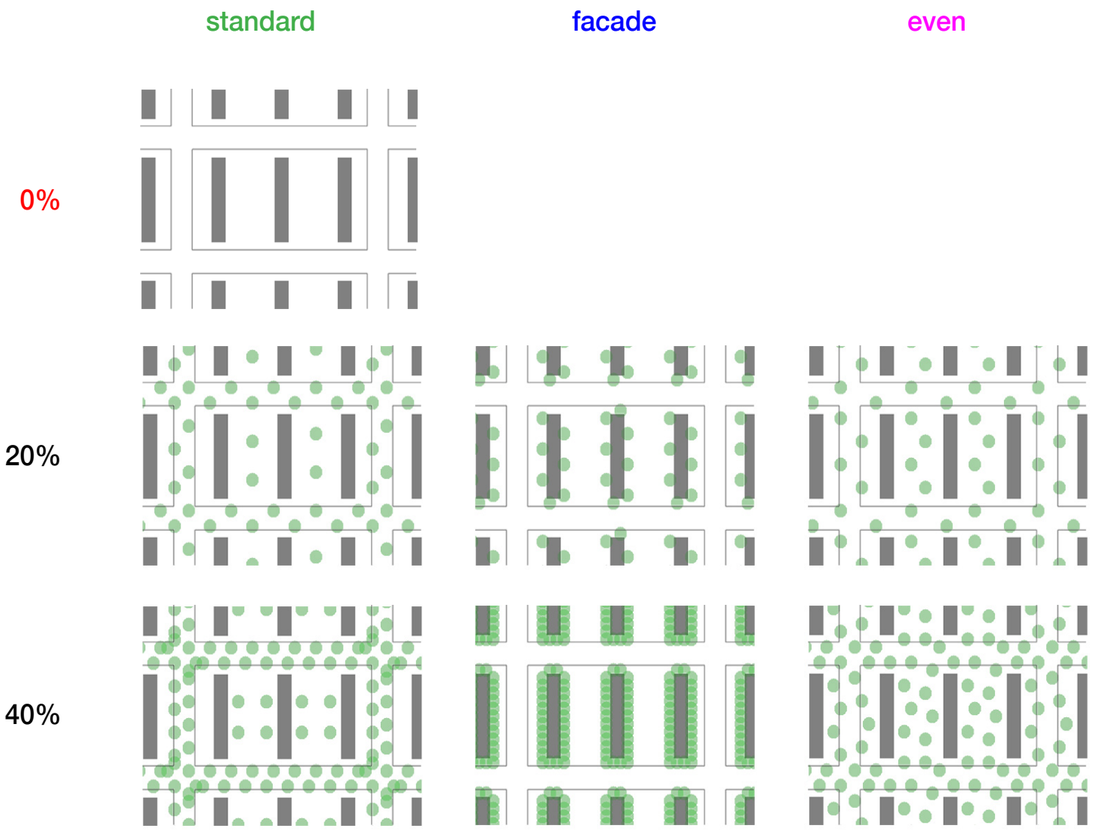
40%

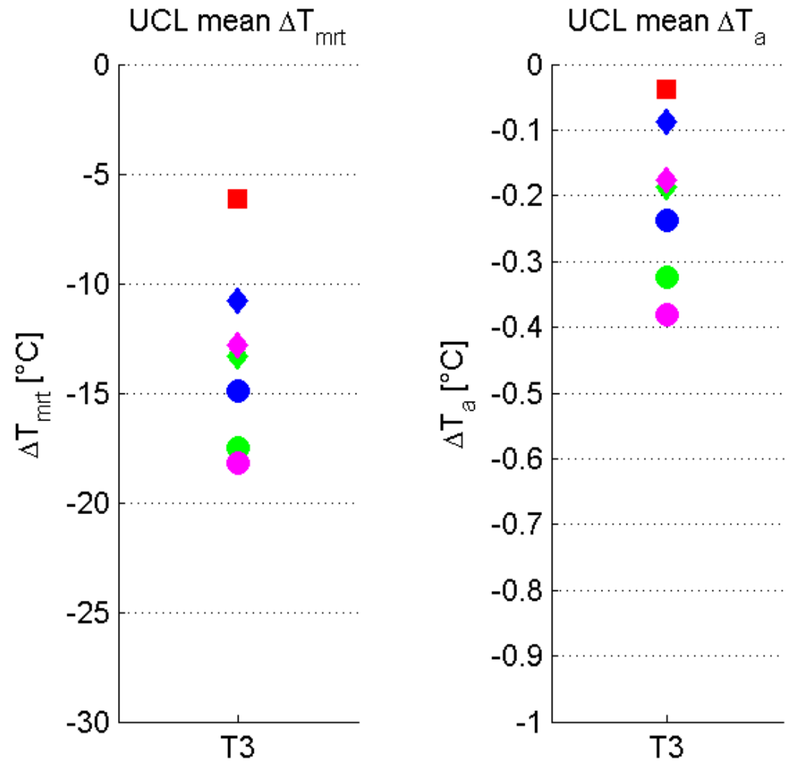


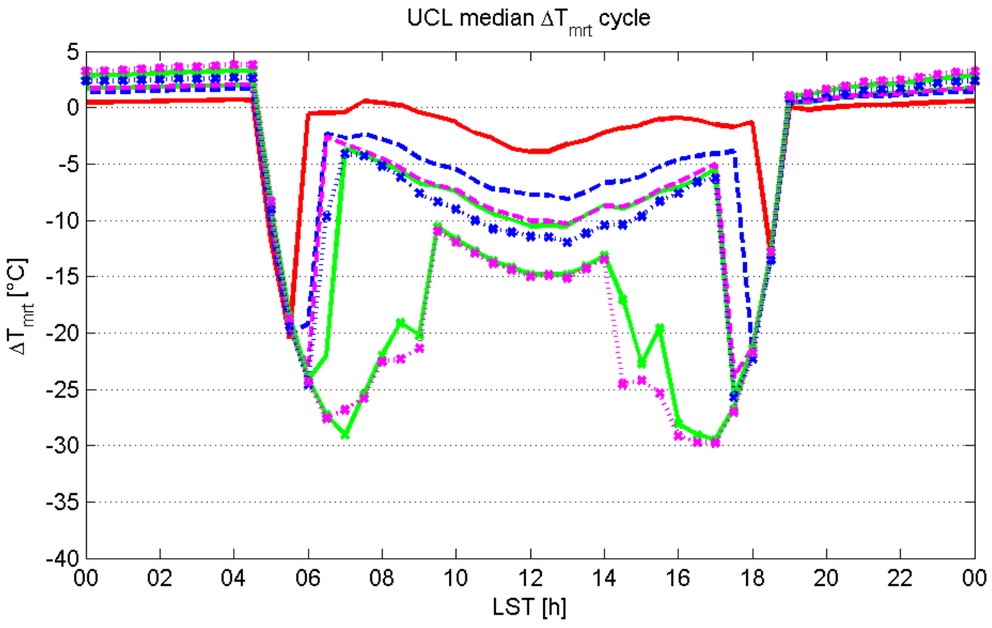

UCL median ΔT_mrt cycle
ΔT_mrt [°C]
5
0
-5
-10
-15
-20
-25
-30
-35
-40
00 02 04 06 08 10 12 14 16 18 20 22 00
LST [h]

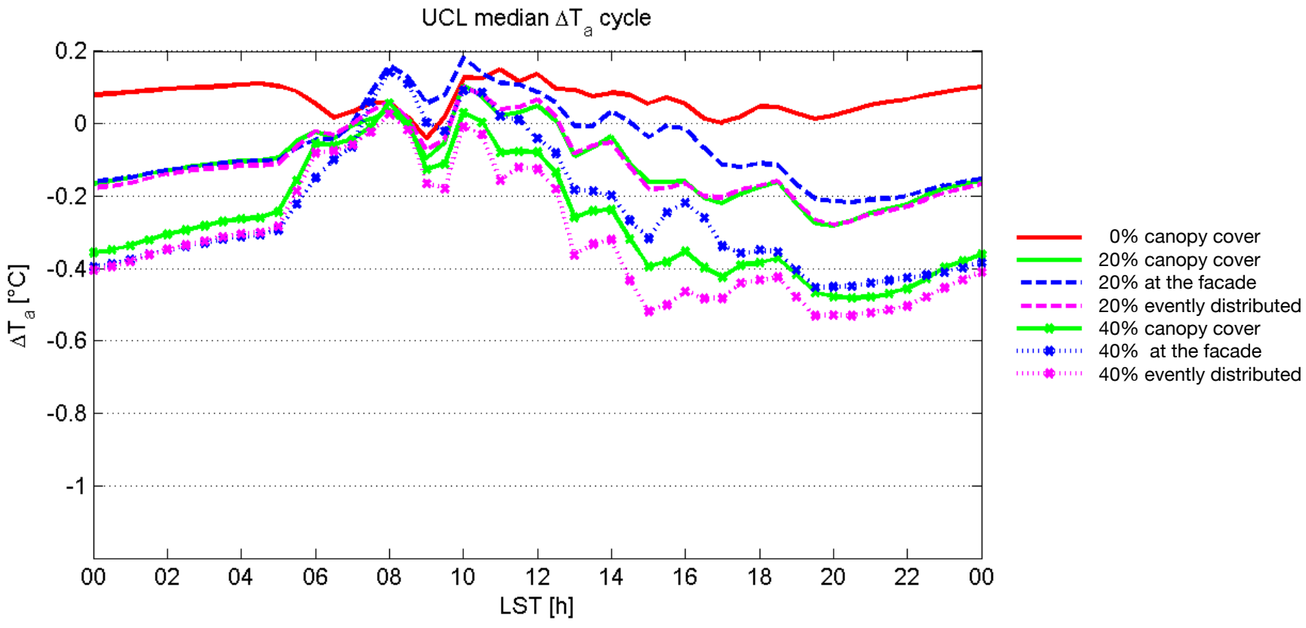

UCL median ΔT_a cycle
ΔT_a [°C]
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
00 02 04 06 08 10 12 14 16 18 20 22 00
LST [h]
0% canopy cover
20% canopy cover
20% in the shade
20% on the sun
40% canopy cover
40% in the shade
40% on the sun

canopy cover






UCL median ΔT_mrt cycle
ΔT_mrt [°C]
5
0
-5
-10
-15
-20
-25
-30
-35
-40
00 02 04 06 08 10 12 14 16 18 20 22 00
LST [h]


UCL median ΔT_a cycle
ΔT_a [°C]
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
00 02 04 06 08 10 12 14 16 18 20 22 00
LST [h]
0% canopy cover
20% canopy cover
20% at the facade
20% evently distributed
40% canopy cover
40% at the facade
40% evently distributed

- Increasing the tree canopy cover decreases air temperatures in the UCL and prolongs the cooling effect of trees (both in space and time)

- The effectiveness of shade trees as daytime heat mitigation measures is strongly influenced by the shape of the built environment

- Spatial enclosures, such as courtyards, intensify the cooling effect of trees

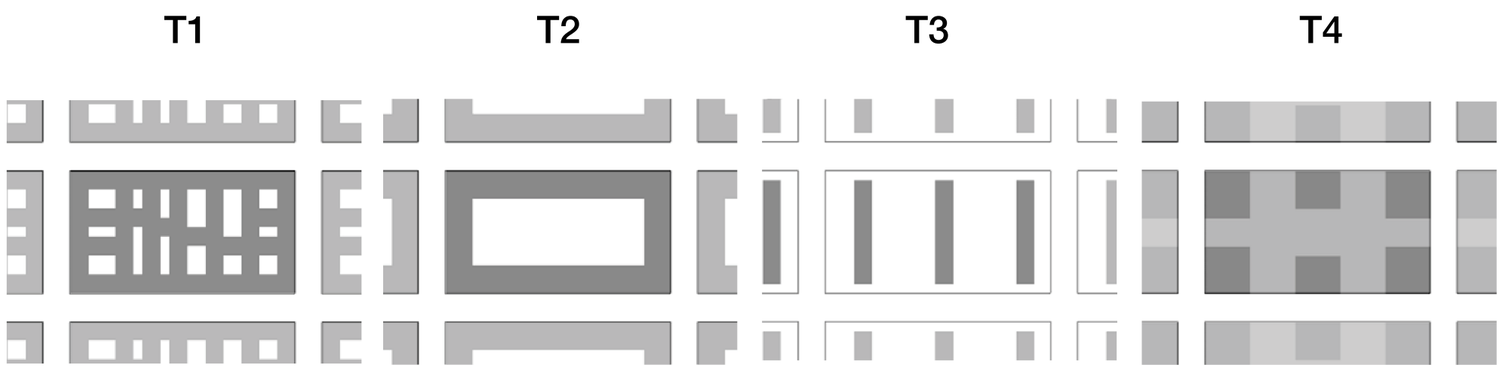
- Trees are most effective in reducing mean radiant temperatures in urban canopies were shading is sparse (i.e. where large open spaces are present)

- The influence of tree layouts on UCL air and radiant temperatures is greatest in open configurations with low building surface fraction

The combined influence of shade trees and high albedo surfaces

The scenarios are the combinations of cool roof, cool road and two canopy cover schemes.

The shade tree schemes evaluated the effect of 15% and 30% canopy covers, utilizin 18 m tall shade trees.

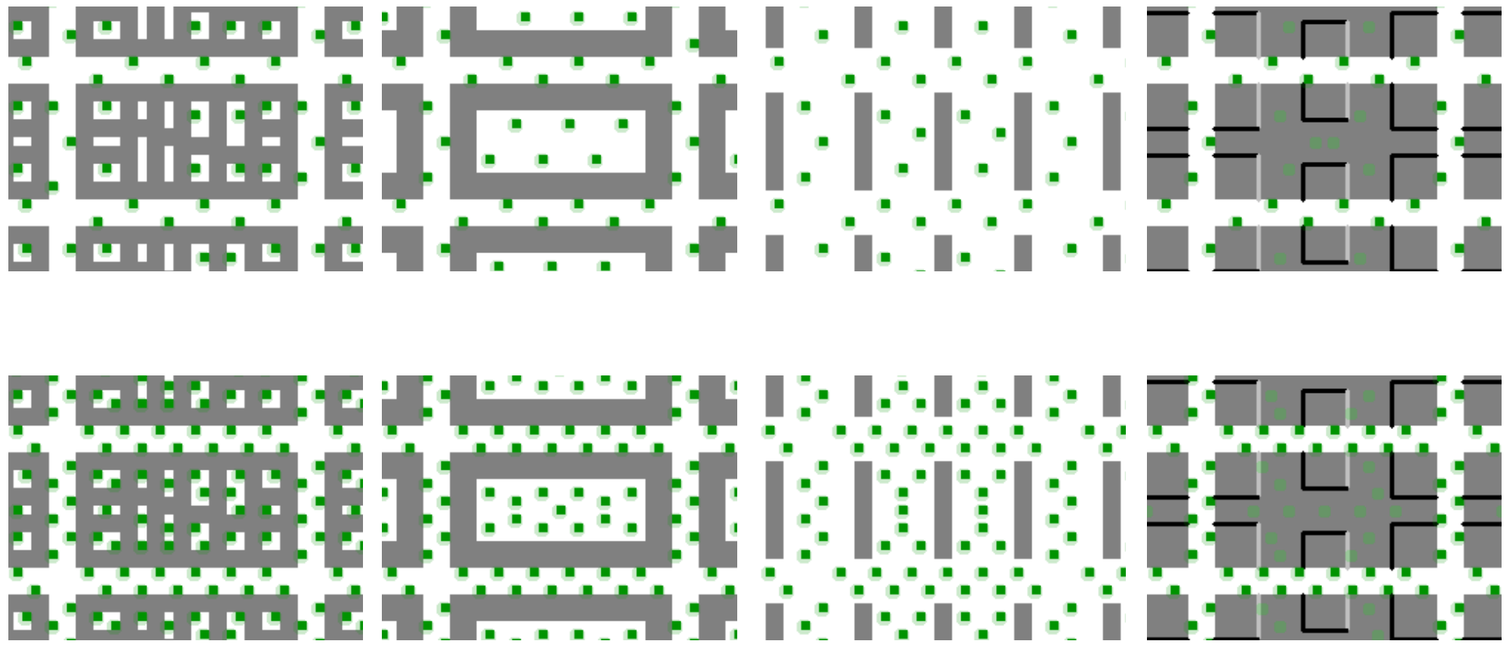


The evaluated scenarios are:

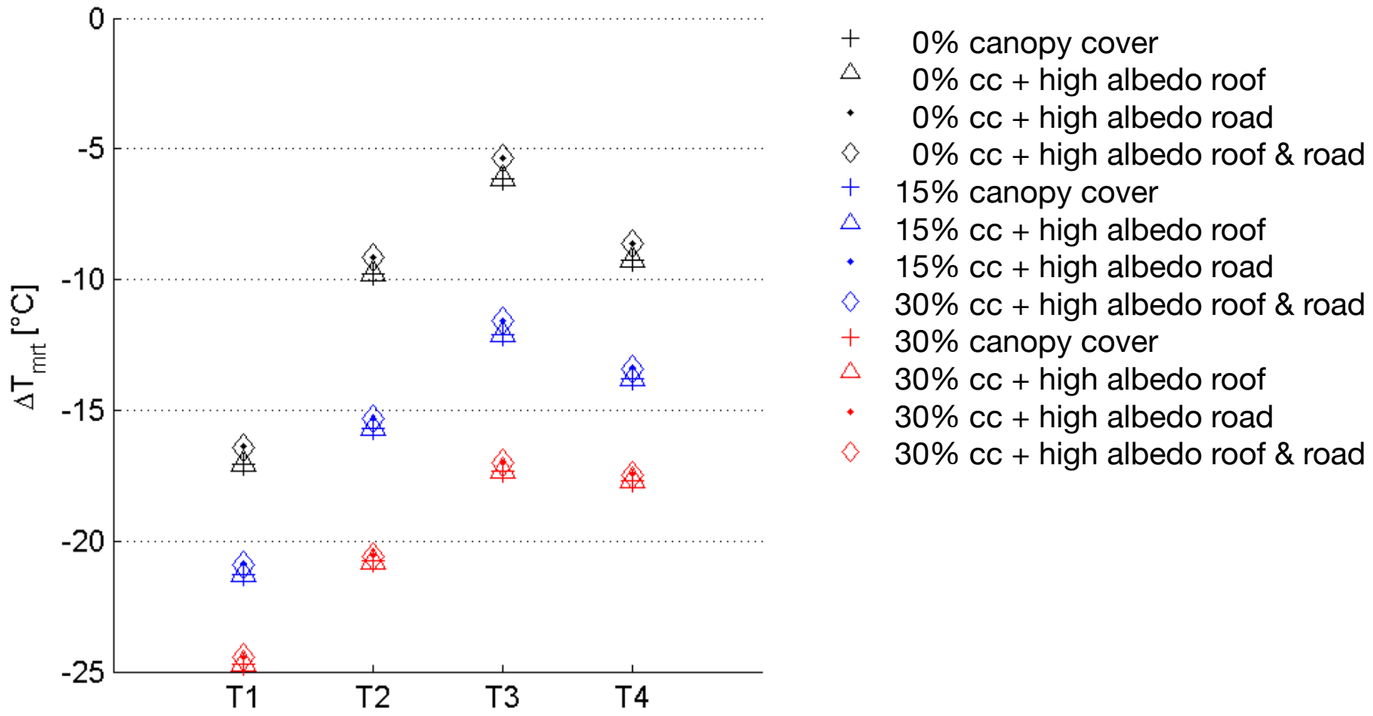
(1) base cases;
(2) high-albedo roofs (0.4 >> 0.65);
(3) high-albedo roads (0.3 >> 0.55);
(4) high-albedo roofs + roads;

(5) 15% canopy cover;
(6) 15% cc & high-albedo roofs;
(7) 15% cc & high- albedo roads;
(8) 15% cc & high-albedo roofs + roads;

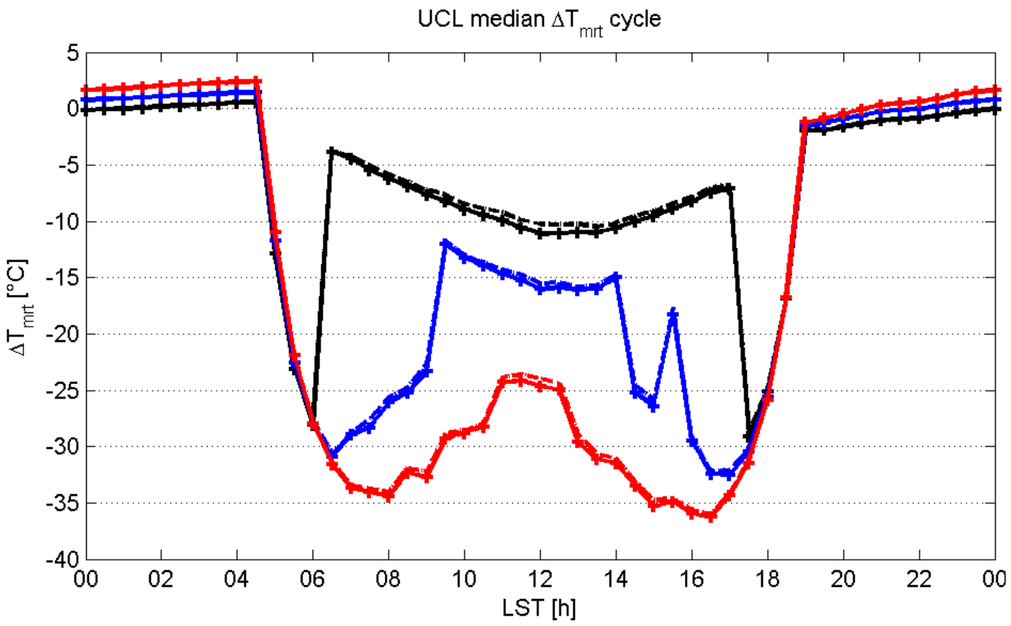
(9) 30% canopy cover;
(10) 30% cc & high-albedo roofs;
(11) 30% cc & high- albedo roads;
(12) 30% cc & high-albedo roofs + roads.

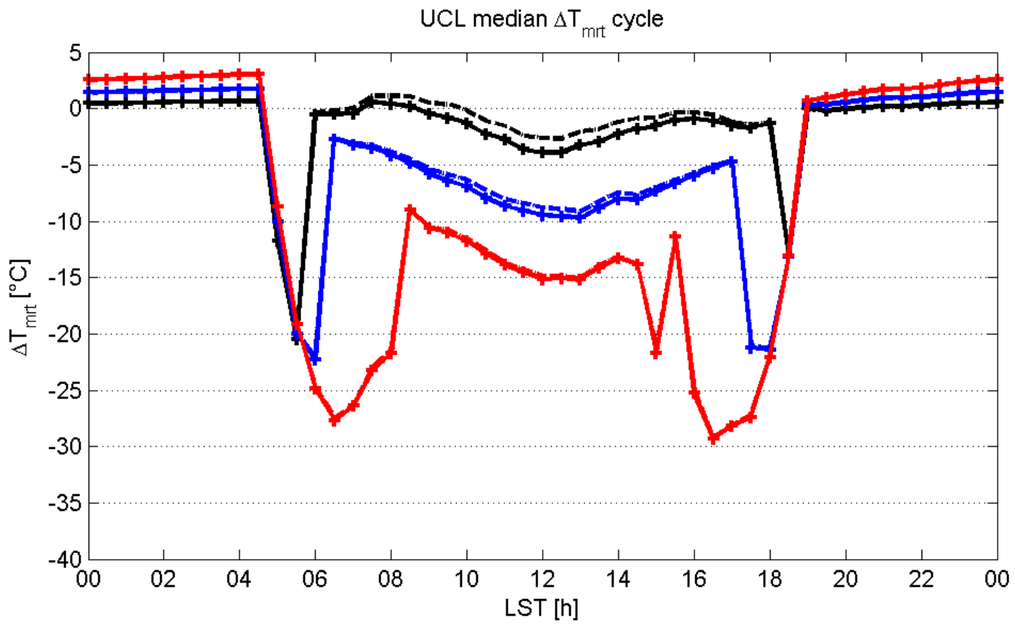


mean radiant temperature relative to baseline (T0)



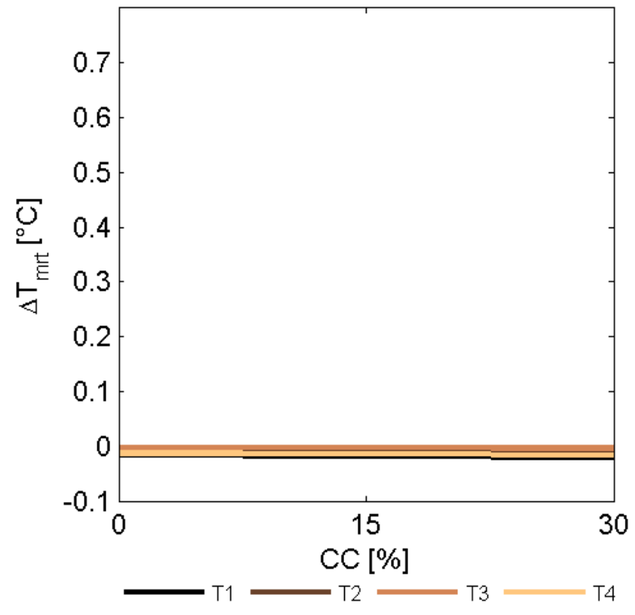
mean radiant temperature relative to baseline (T0)



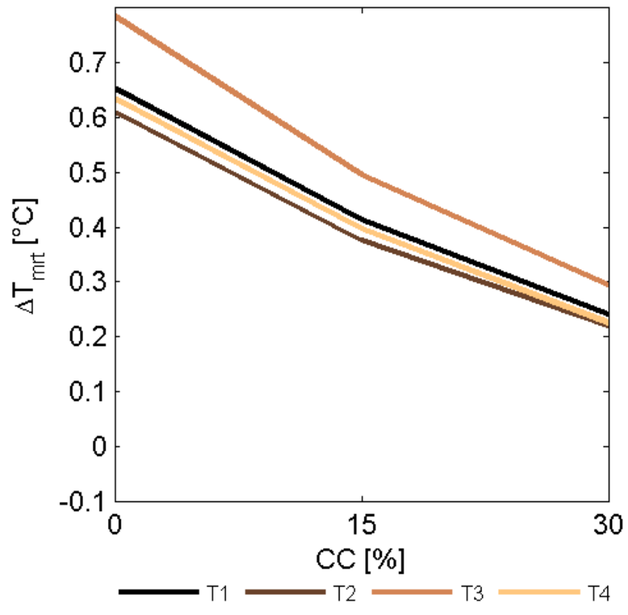


mean radiant temperature change

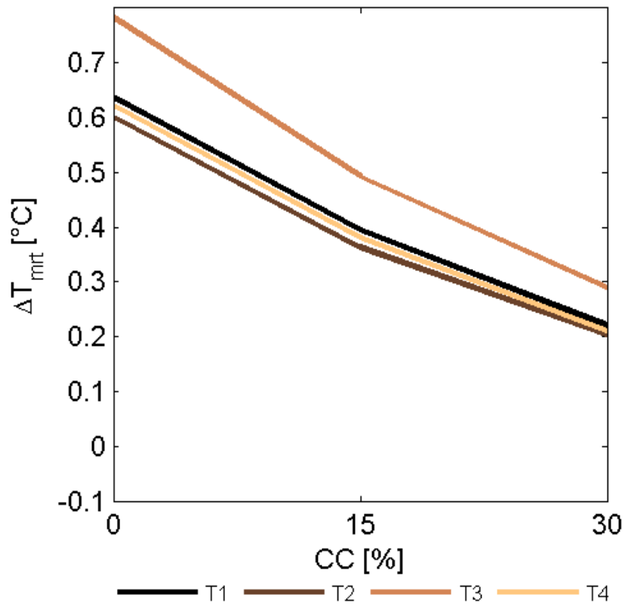
roof



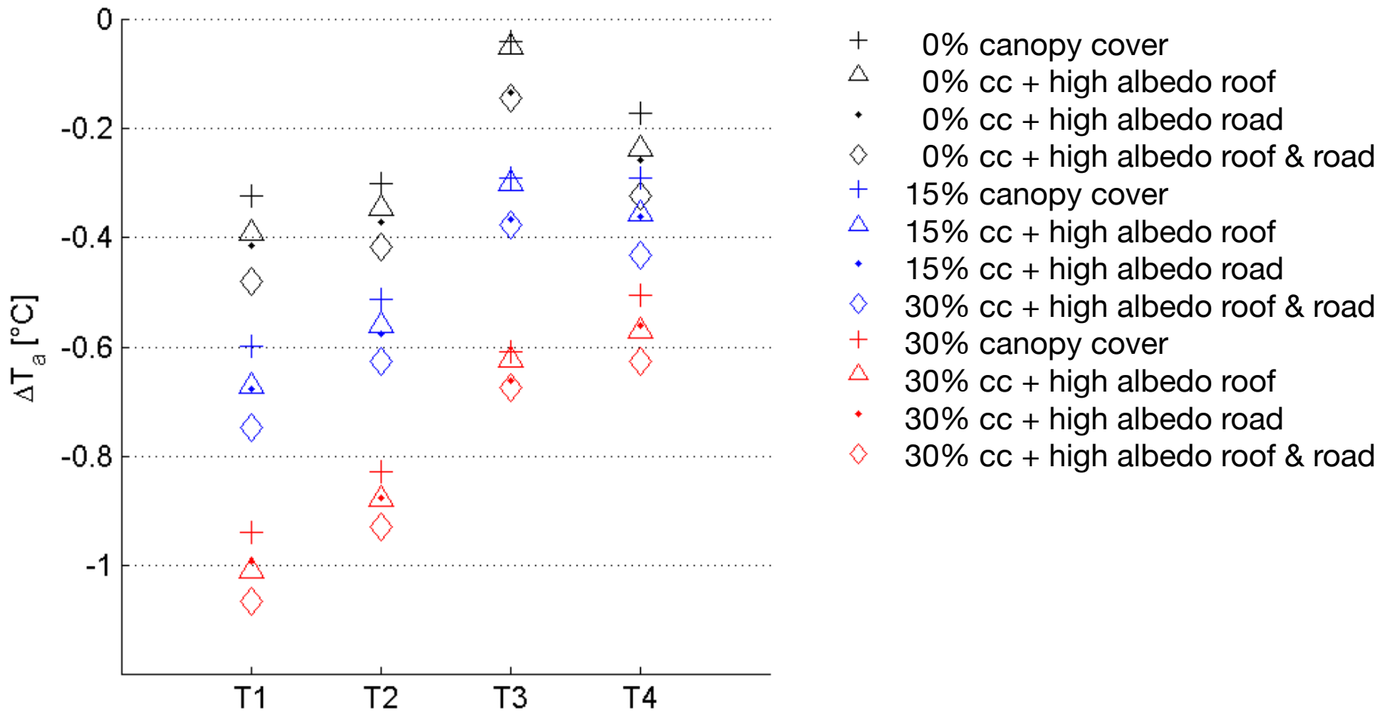
road



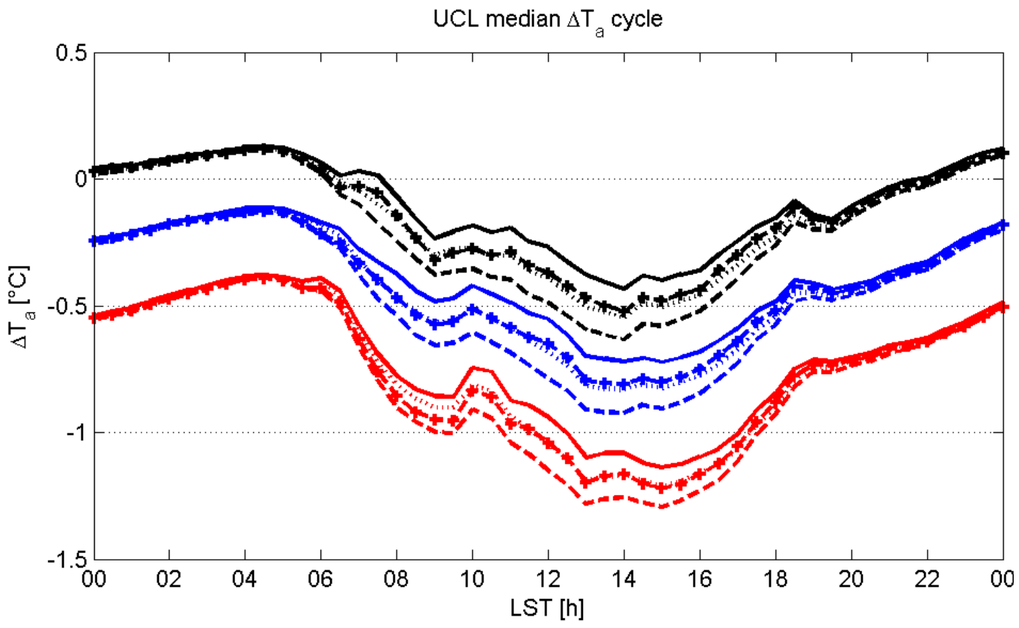
roof & road

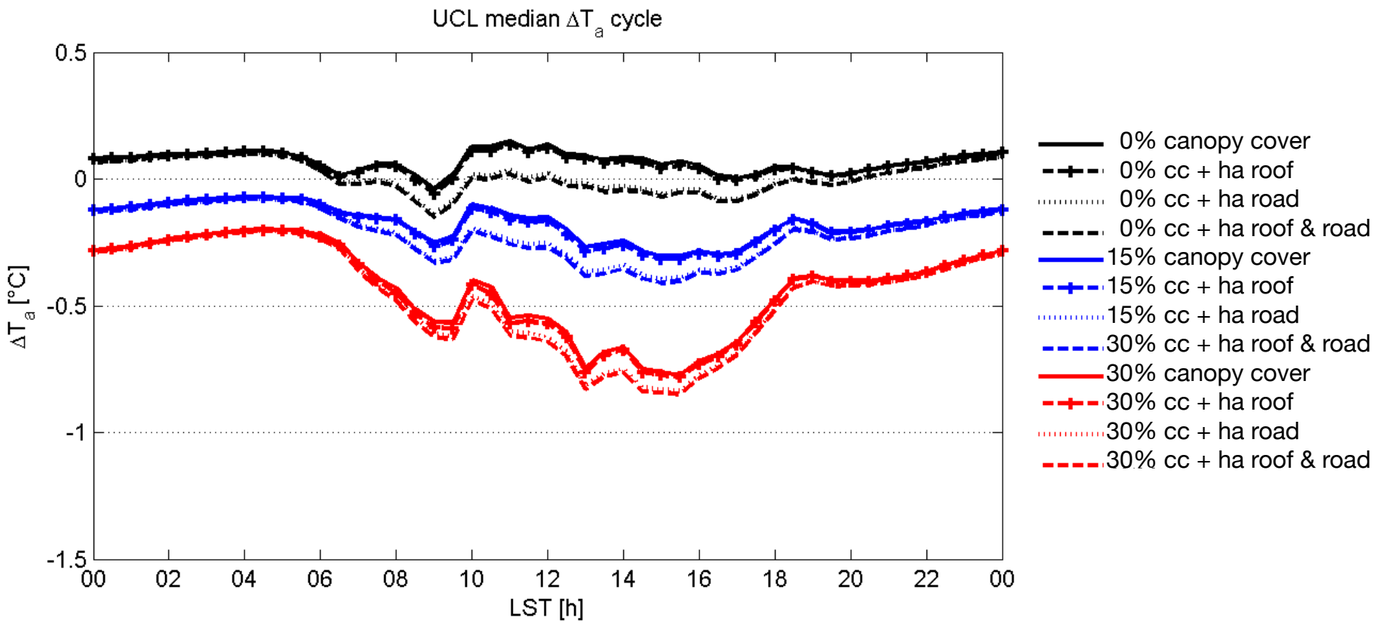


potential temperature relative to baseline (T0)



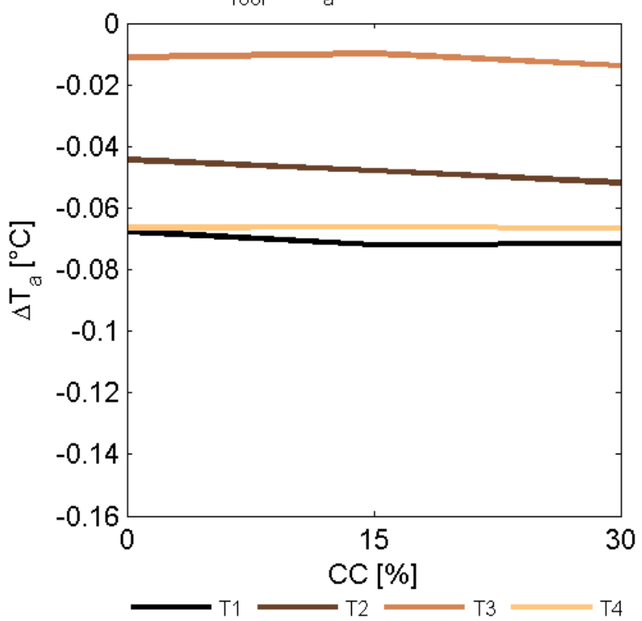
potential temperature relative to baseline (T0)



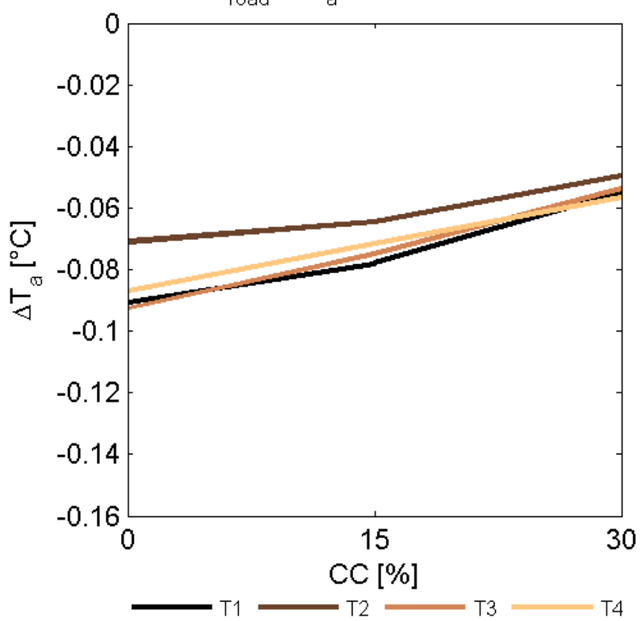


potential temperature change

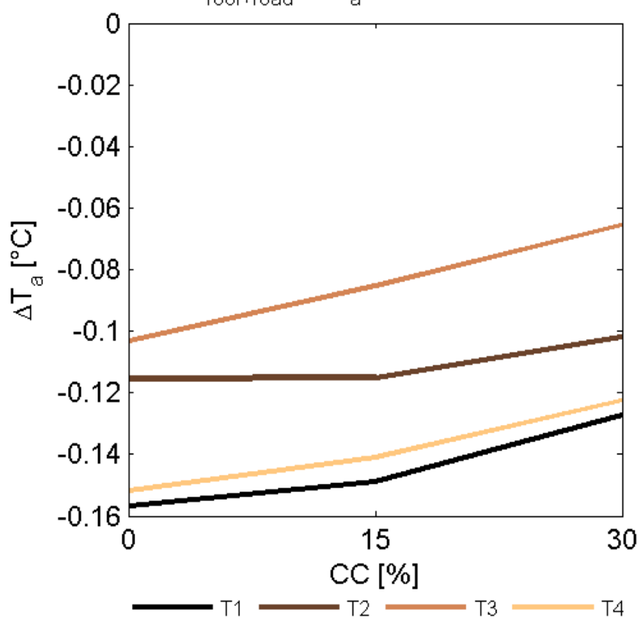
roof



road



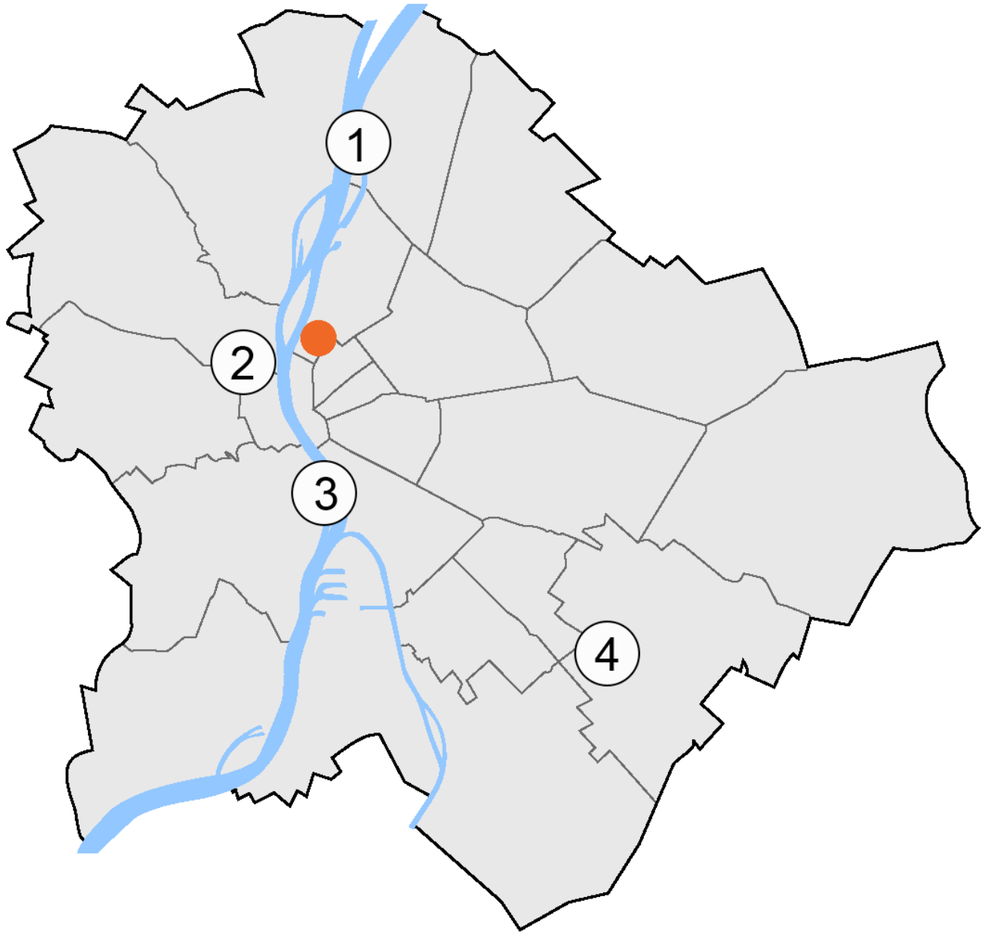
roof & road



- shading—both from buildings and from trees—has a decisive role in governing the climate within the urban canopy layer
- increasing tree canopy cover is the most effective heat mitigation strategy for the evaluated cases
- high-albedo surfaces that aim to reduce near surface temperatures by decreasing surface temperatures have their reduced effectiveness when:
  1. they are shaded, and/or
  2. when their surface ratio is relatively small compared to other surfaces (e.g. roofs in the case of T3).
- when applied jointly, certain heat mitigation strategies can diminish each other's mitigation potential, hence the effect of various approaches are not necessarily cumulative

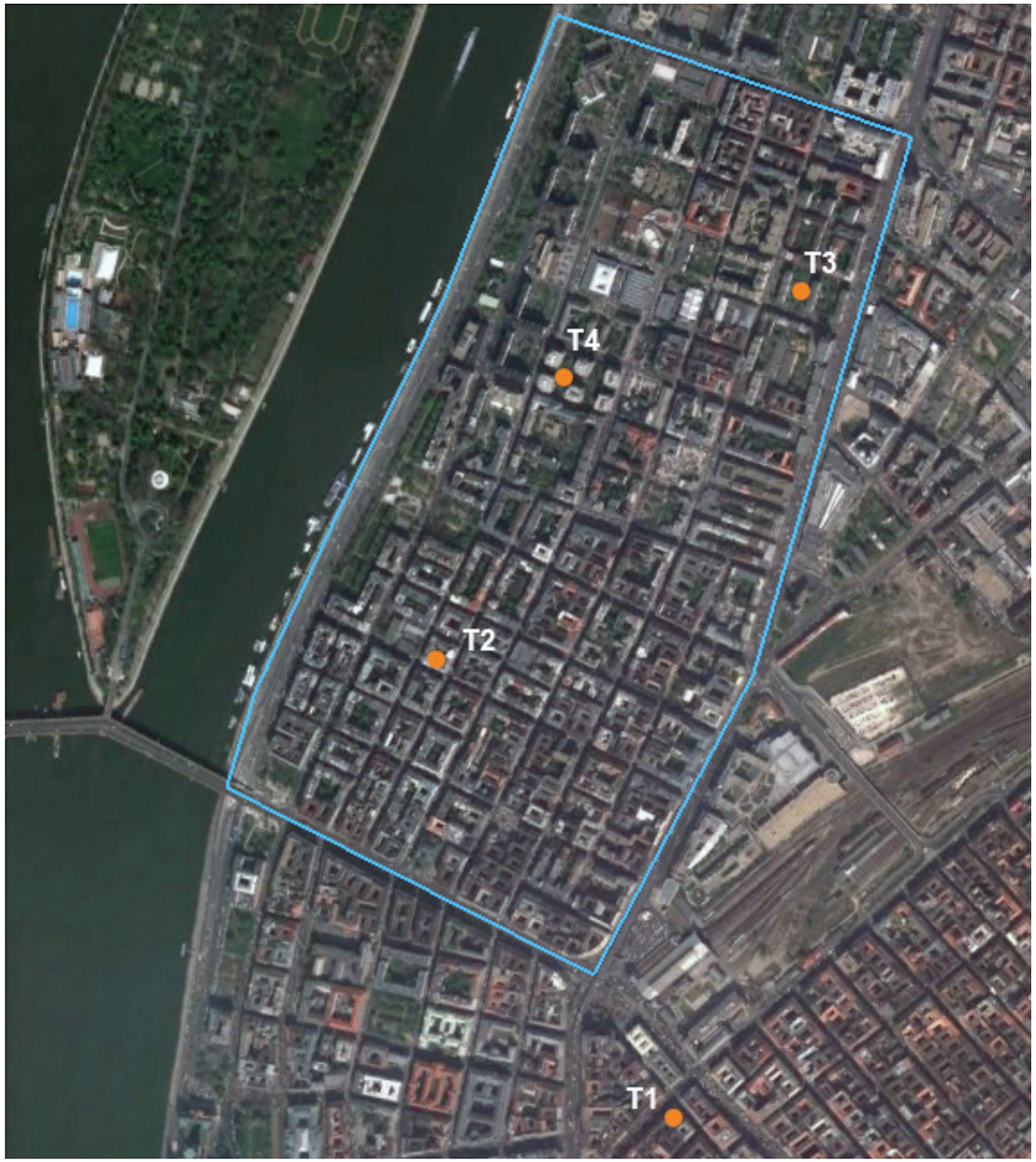
Field experiment

Weather stations of the Hungarian Meteo Service

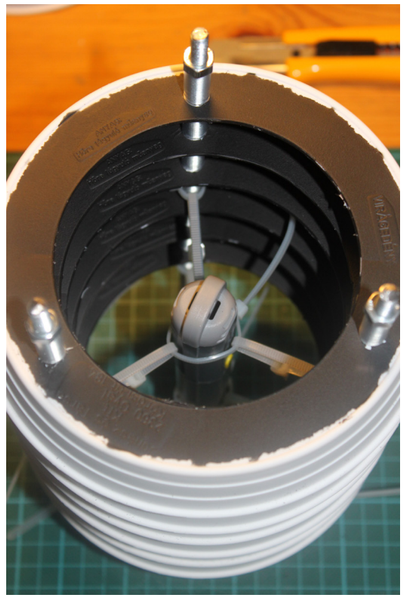


Weather stations maintained by the Hungarian Meteorological Services in Budapest: (1) Újpest, (2) Kitaibel Pál Street, (3) Lágymányos and (4) Pestszentlőrinc.

Measurement sites within Újlipótváros

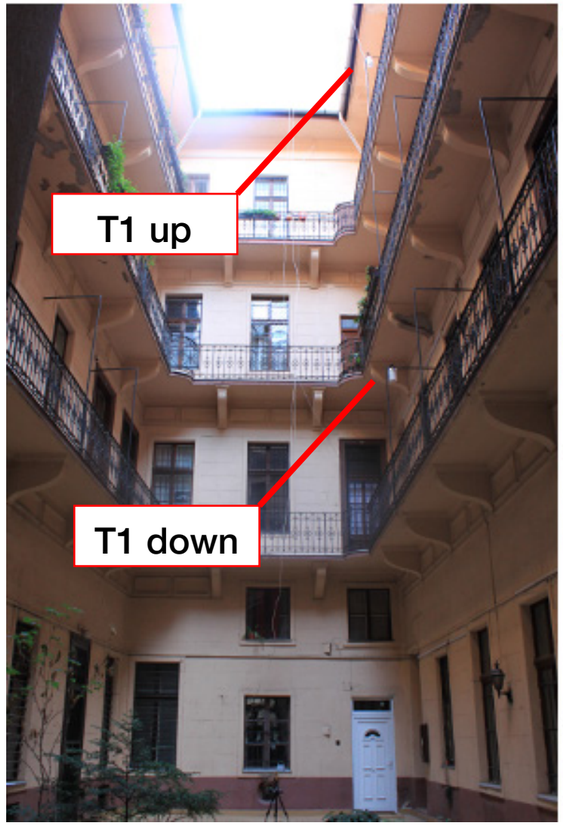


Instrumentation

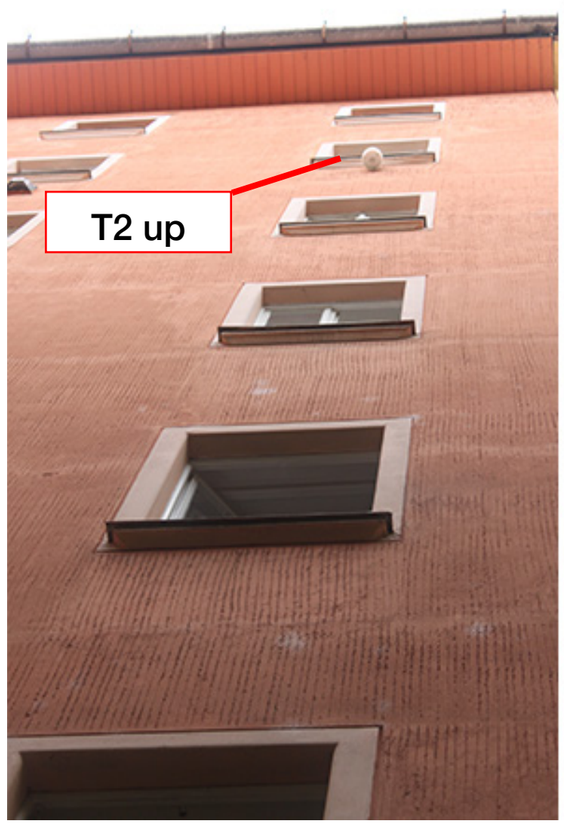


Measurement type / Parameter	Instrument	Frequency	Accuracy
Continuous			
Air temperature	GT HT10 Logger	5 min/rec	0.4 C
Rel. humidity	GT HT10 Logger	5 min/rec	±3%
Instantaneous			
Air temperature	KESTREL 4500	1 min/rec	0.5 C
Rel. humidity	KESTREL 4500	1 min/rec	3%
Wind speed	KESTREL 4500	1 min/rec	> of 3% of reading, least significant digit or 0.1 m/sec


100 m
Image © 2013 DigitalGlobe


T1 up
T1 down


T1 down

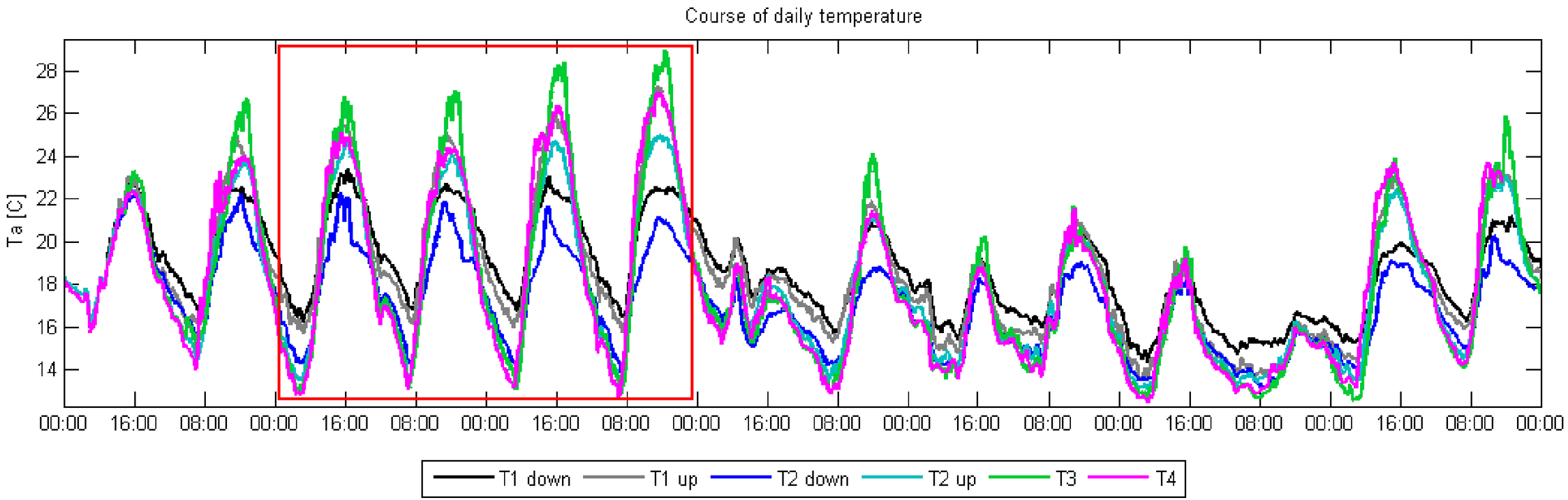

T2 up


T2 down


T3

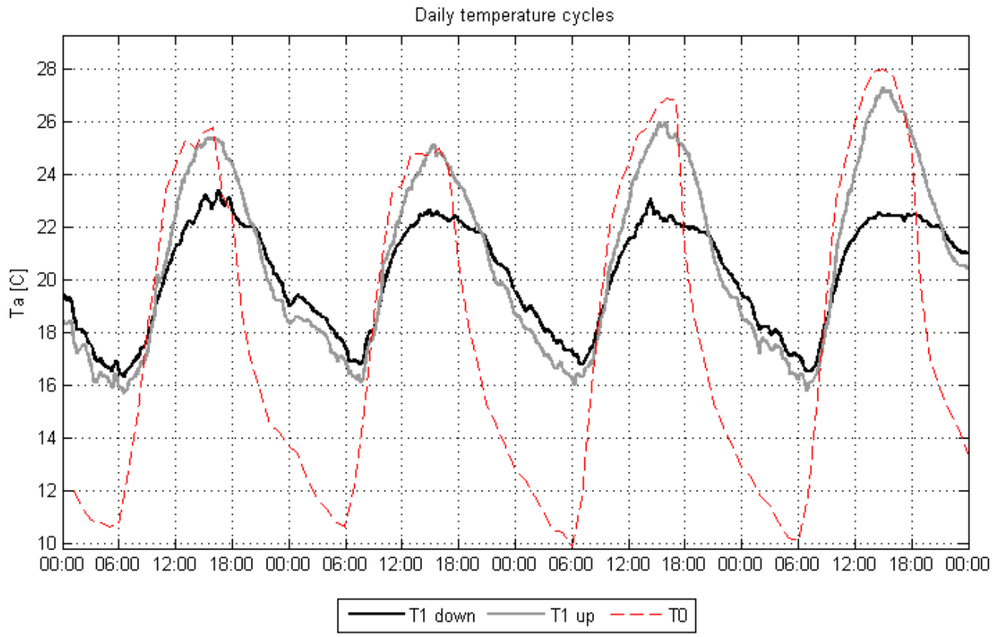

T3

The aggregate temperature data from the six loggers between the 3rd and the 16th of September 2013

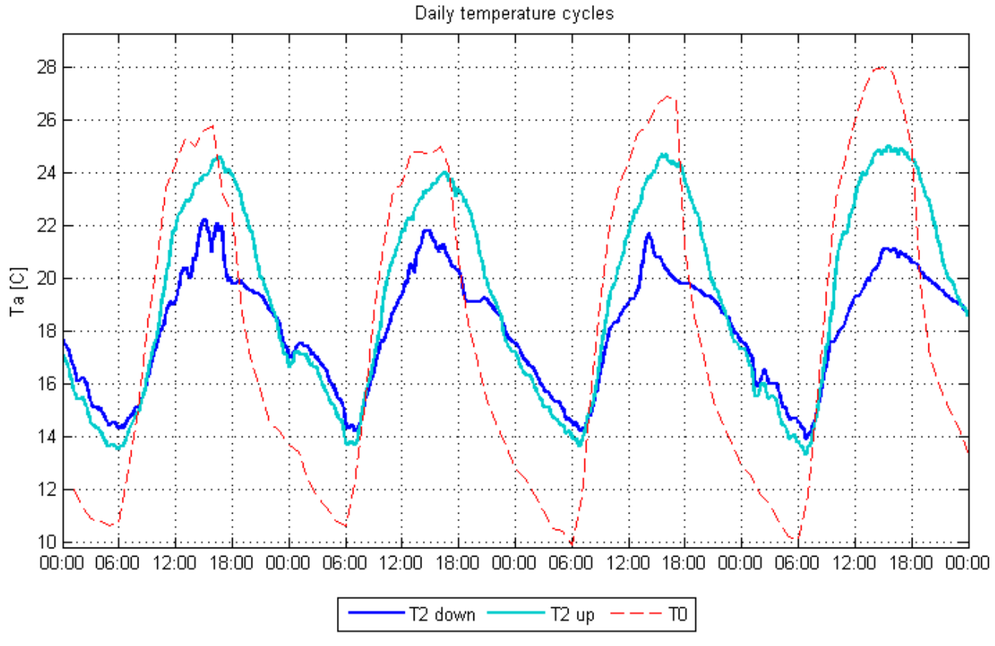


The period from the 5th to the 9th of September with clear anticyclonic conditions was selected for analysis.

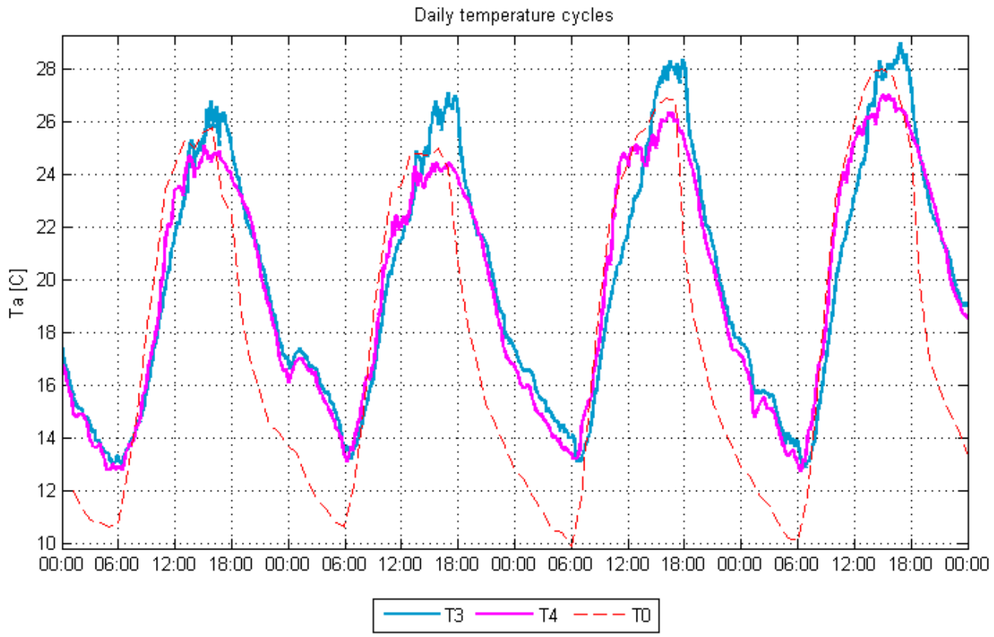
T1



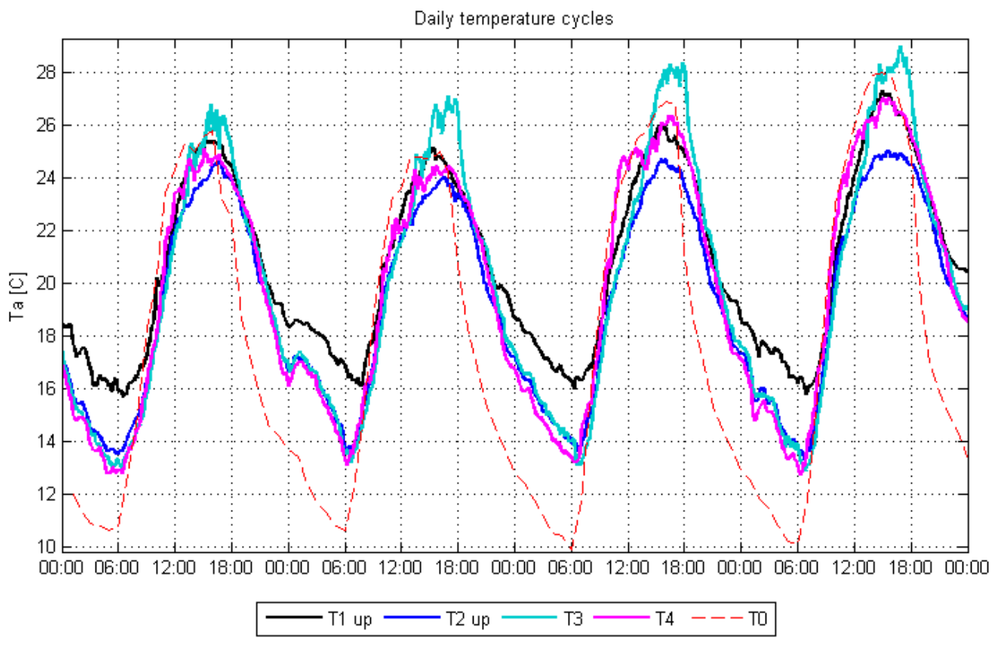
T2

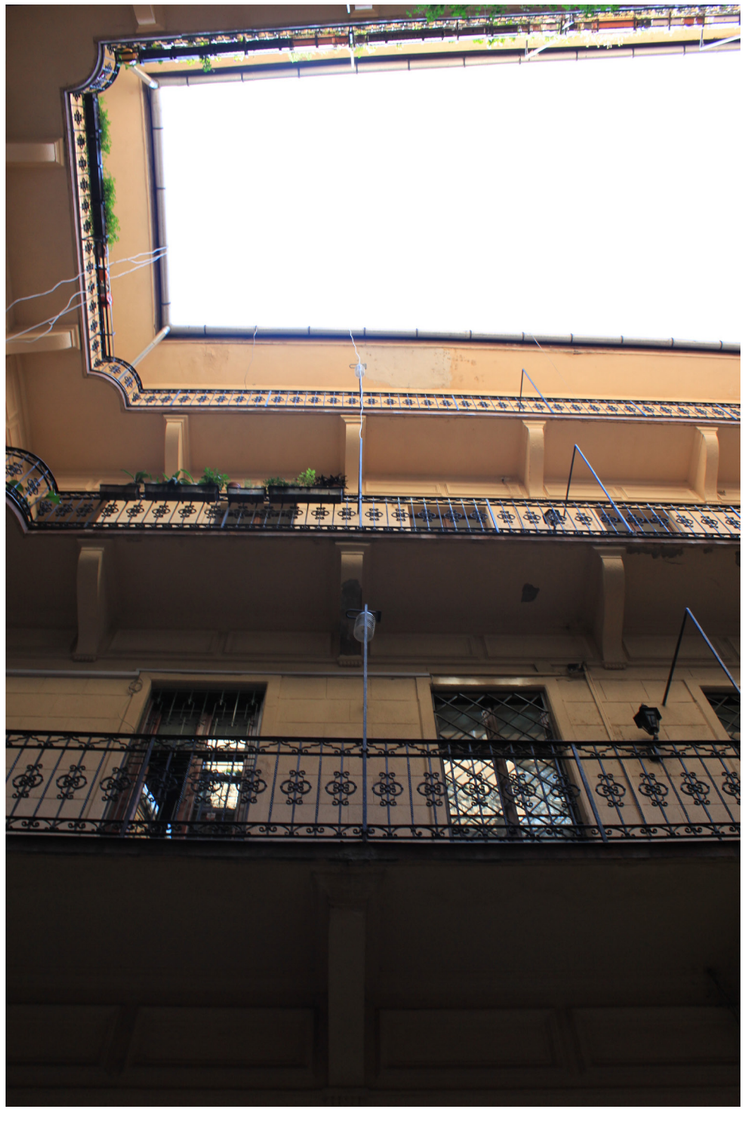


T3 & T4



T1-4 up





- in the courtyard conficurations (T1, T2) inversion developed during the daytime
- as a result, T1 and T2 remained coolest during the day (the cool islad reached reached 6-7 ºC on the hottest day)
- nighttime heat island was greates in the non-vegetated T1 configuration (up to 6 ºC)
- conditions in the open configurations (T3, T4) followed most closely the background climate, as measured at the Upest station
- afternoon anomalies observed in the case of T3 are the results of solar irradiation (lack of aspiration, influence of radiated surfaces)
- sensors located close to the canopy top registered similar conditions, diffrences observed were as follows
  1. afternoon peaks at T3 due to sensor location
  2. 1-3 ºC lower daytime peaks in the vegetated courtyard (T2)
  3. 1-3 ºC higher nighttime lows in the case of the non-vegetated courtyard configuration (T1)

Given limitation of the numerical simulation progtam

- further studies are needed to understand the microclimate implications of thermal mass in exterior walls,
- detailed radation measurements are needed to access the model's accuracy with regards to radiative environment predictions.

Given the limitations of the measurement campaign

- follow-up study is needed to access the microclimatic behavior of various urban block typologies before, during and after heatwaves.

These studies would shed further light on the thermal behaviour of our buildt environment and hence would aid the future work of architects, urban planners and public health officials in their attempt to adopt effective heat mitigation strategies in the future.

Thank you!

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