The influence of facade properties on the canopy layer microclimate within city blocks

Csilla V Gal
cgal@iit.edu

The application of high albedo surfaces and highly reflective (‘cool’) materials is often advocated as a means to mitigate urban heat island. Beyond their initially proposed utilization on flat roofs and open roads, reflective coatings are increasingly recommended for walls as well.

The goal of this study is to investigates the role of facade surface properties on the canopy layer microclimate in a dense urban context.

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

1) What is the role of the facade albedo in affecting the UCL microclimate?

2) What it the role of the facade thermal conductivity (U-value)?

3) How does the combination of these two parameters influence the climate conditions within the canopy layer?

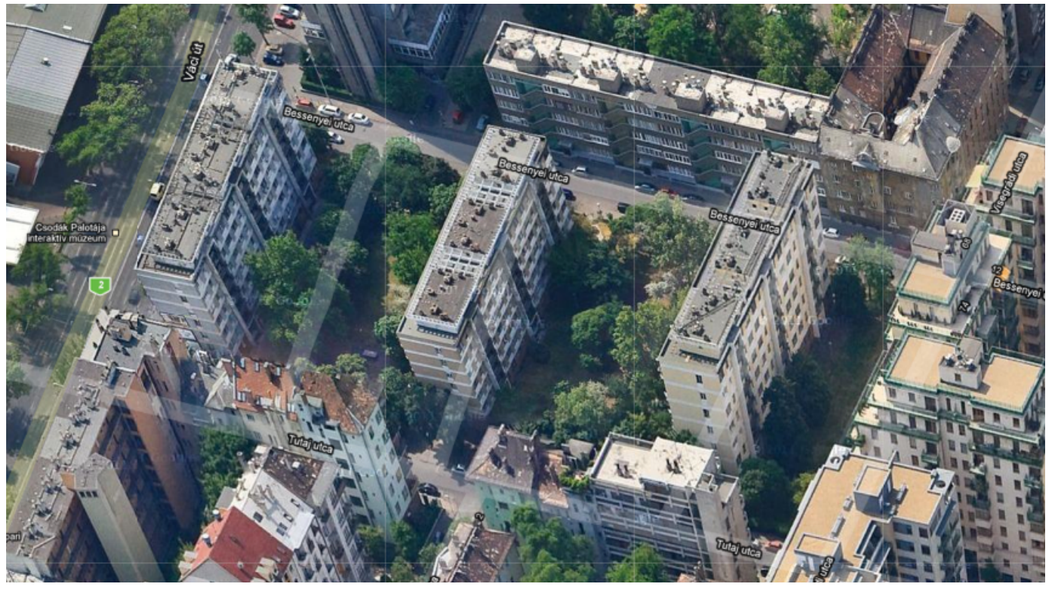
4) What is the impact of the fenestration ratio?

5) How does the effects of these parameters play out in different dense urban configurations?

T1

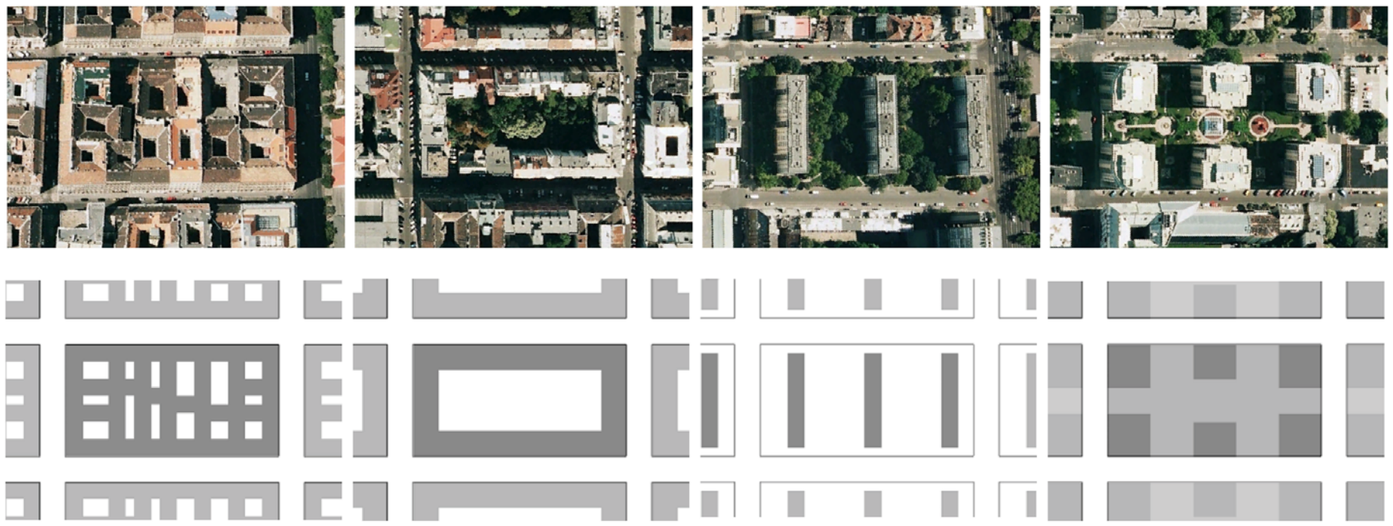
T2

T3


Vác út
Bessenyei utca
Bessenyei utca
Bessenyei utca
Vörösmarty utca
Bessenyei
Turlaj utca
Turlaj utca

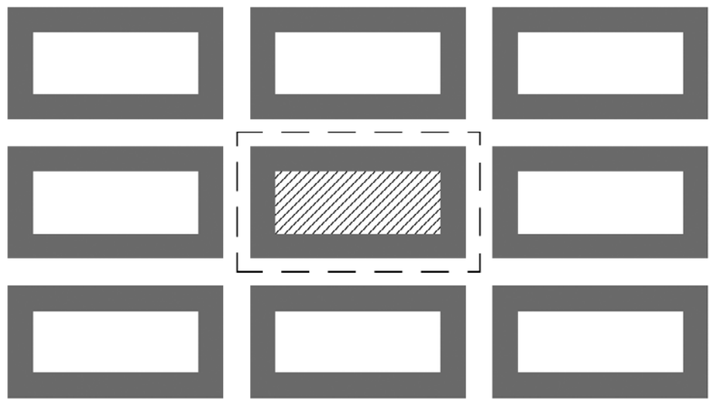
T4

T1 T2 T3 T4



Scenarios		U [W/m²K]	a [ ]	w [%]
_	(initial)	1.10	0.40	
U	(U-value only)	0.30	0.40	
a	(albedo only)	1.10	0.80	
Ua	(U & a values)	0.30	0.80	
w	(mod U, a values)	0.80	0.55	35

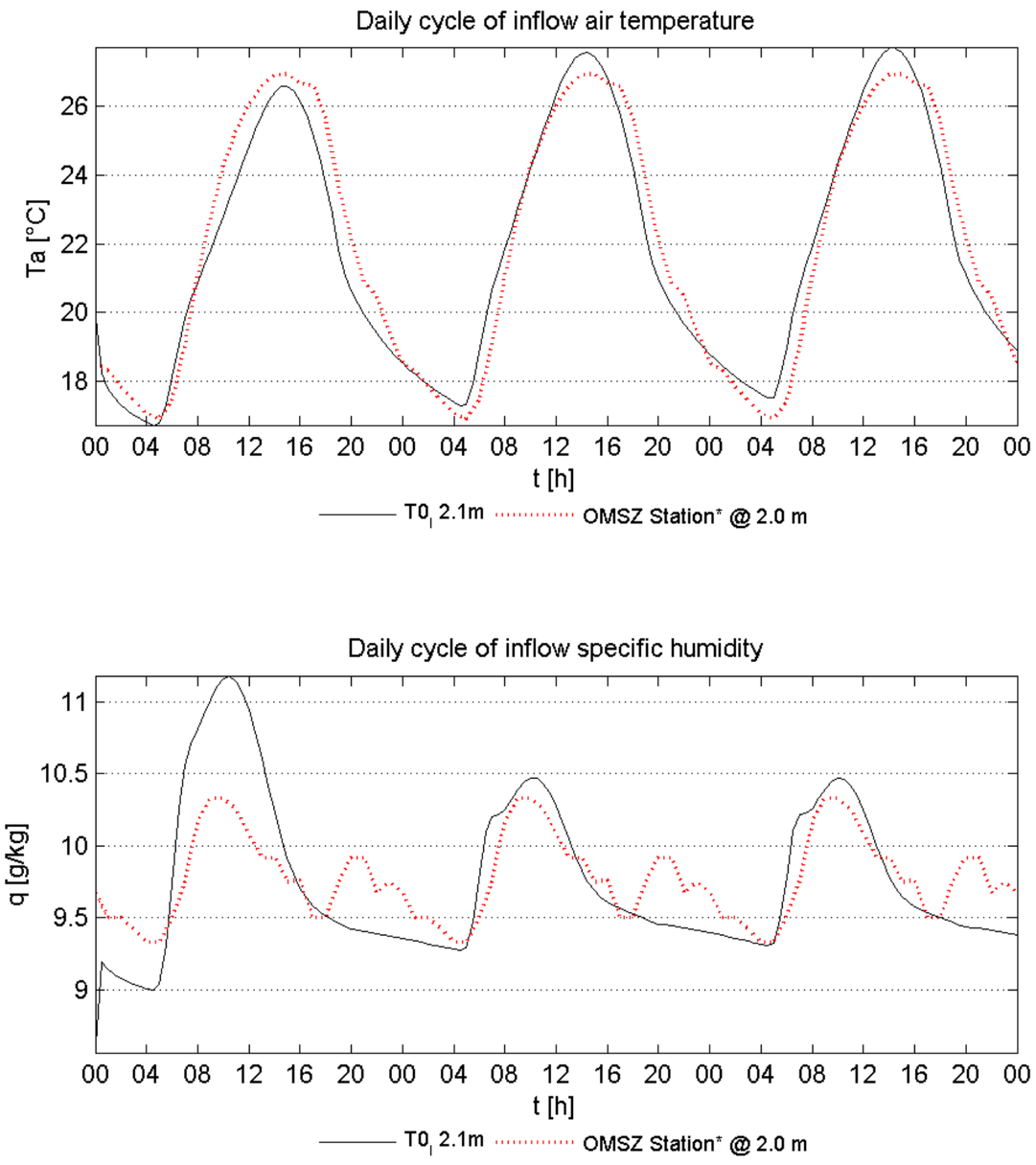
Note: Roof properties were kept constant thorough the scenarios at U = 1.10 W/m²K and a = 0.4



The study utilized ENVI-met (Version 3.1 beta V) for microclimate simulation (Bruse, 2010) and MATLAB (Version 7.12) for the analysis and visualization of the results.

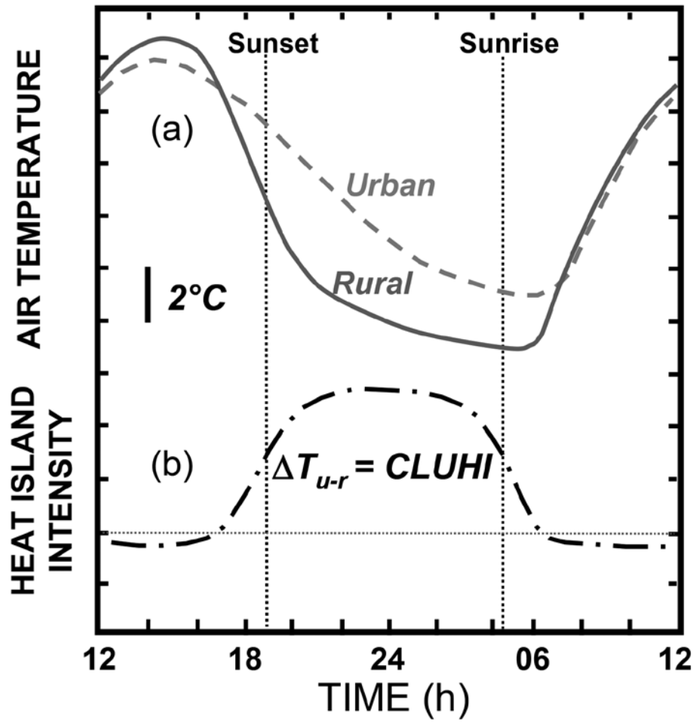
Bruse, M. (2010). ENVI-met (Version 3.1 BETA V) [Computer software]. Retrieved from http://www.envi-met.com/
MATLAB (Version 7.12) [Computer software]. (2011). Natick, MA: MathWorks.

The baseline case (T0):

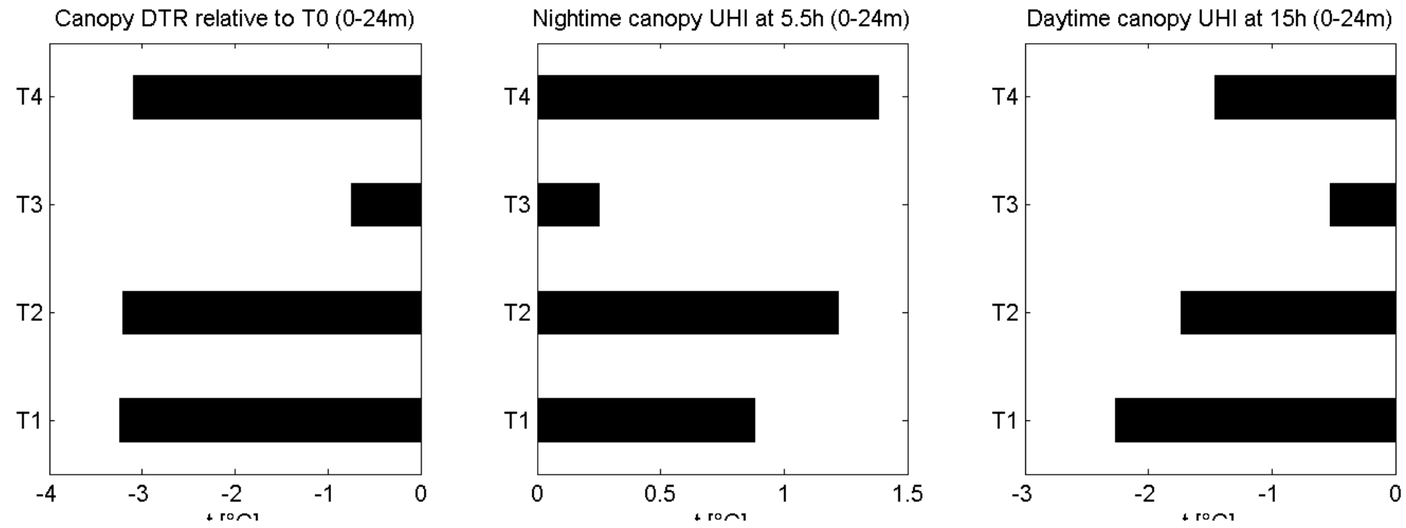



```
% ---- Basic Configuration File for ENVI-met  Version 3.1-V ------
% ---- MAIN-DATA Block ---------------------------------------
Name for Simulation (Text):                    =T0
Input file Model Area                          =[ENVIinbox]\T0_63a.i
Filebase name for Output (Text):               =T0
Output Directory:                              =[mCLIMATE]\T0
Start Simulation at Day (DD.MM.YYYY):          =07.07.2005
Start Simulation at Time (HH:MM:SS):           =00:00:00
Total Simulation Time in Hours:                =48.00
Save Model State each ? min                    =30
Wind Speed in 10 m ab. Ground [m/s]            =2.8
Wind Direction (0:N..90:E..180:S..270:W..)     =315
Roughness Length z0 at Reference Point         =0.1
Initial Temperature Atmosphere [K]             =293.0
Specific Humidity in 2500 m [g Water/kg air] =8.7
Relative Humidity in 2m [%]                    =60
Database Plants                                =Plants.dat
[SOILDATA] ____________________________________Settings for Soil
Initial Temperature Upper Layer (0-20 cm)    [K]=293.0
Initial Temperature Middle Layer (20-50 cm) [K]=293.0
Initial Temperature Deep Layer (below 50 cm)[K]=289.5
Relative Humidity Upper Layer (0-20 cm)         =32
Relative Humidity Middle Layer (20-50 cm)       =52
Relative Humidity Deep Layer (below 50 cm)      =60
[SOLARADJUST] _____________________________________
Factor of shortwave adjustment (0.5 to 1.5) =0.88
```

Urban heat island intensity

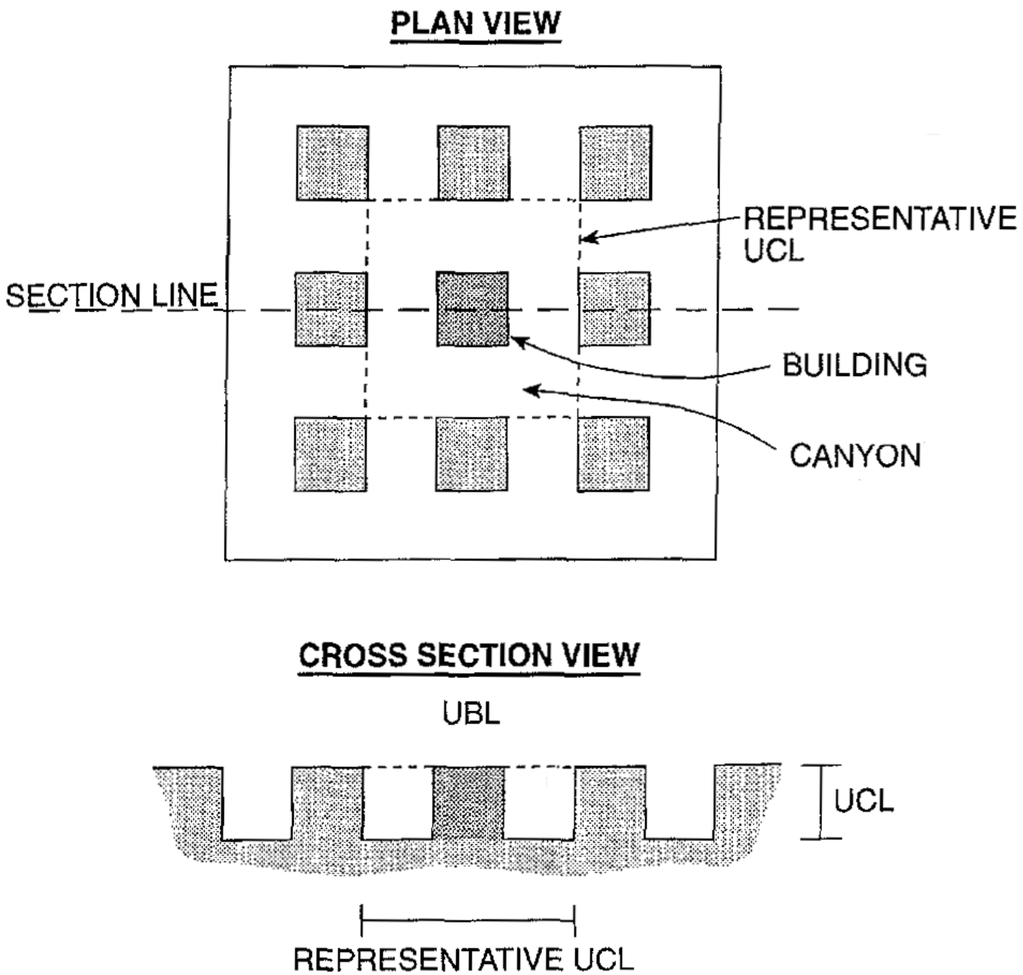


Temperature range, nighttime and daytime heat island



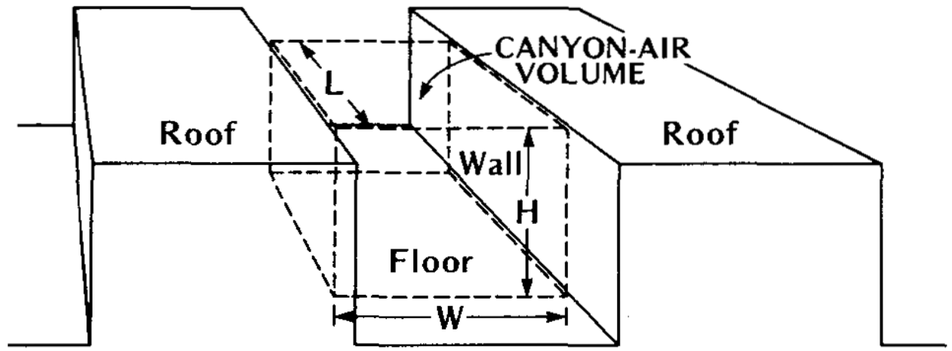
Oke, T. R. (1987). *Boundary layer climates*. Cambridge, Cambridgeshire: Cambridge University Press.

Array of cubes



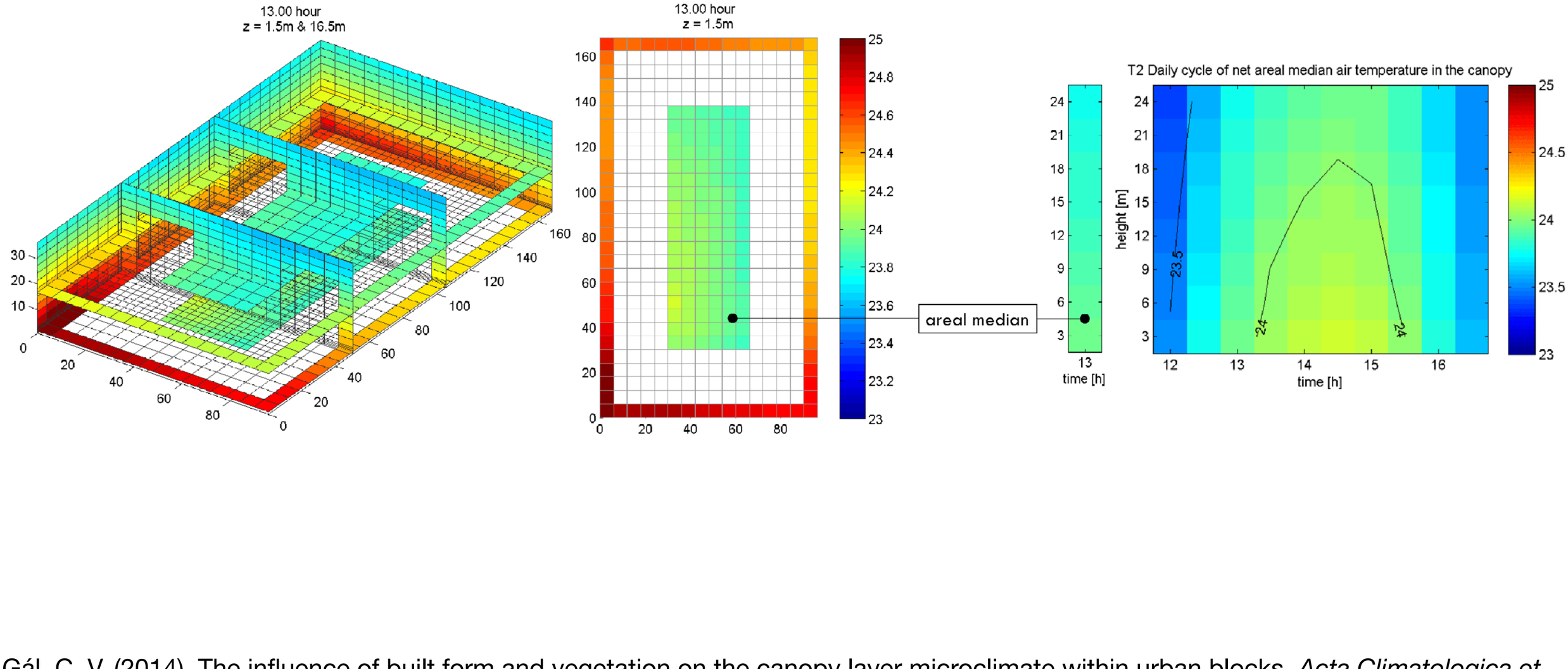
Nunez, M. & Oke, T. R. (1977). The energy balance of an urban canyon. *Journal of Applied Meteorology*, 16(1), p12.

Urban canyon



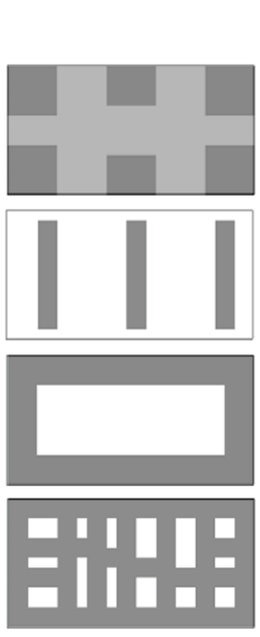
Mills, G. (1997). An urban canopy-layer climate model. *Theoretical and Applied Climatology*, 57(3), p.230.

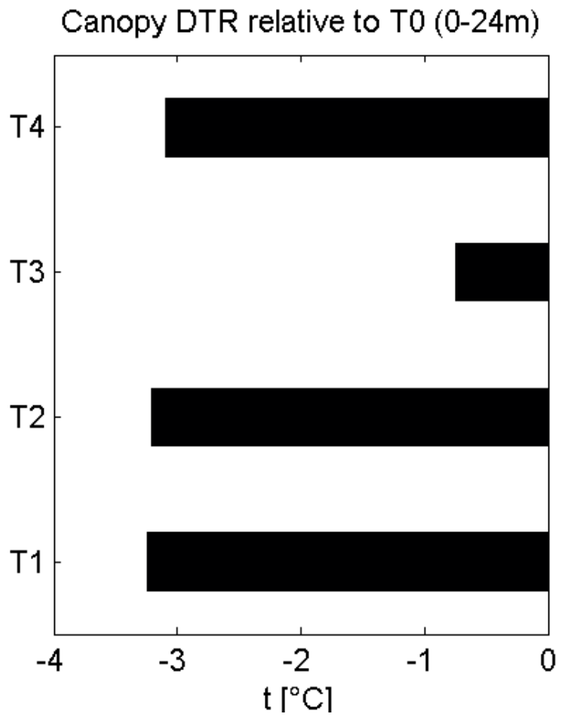
UCL microclimate assessment

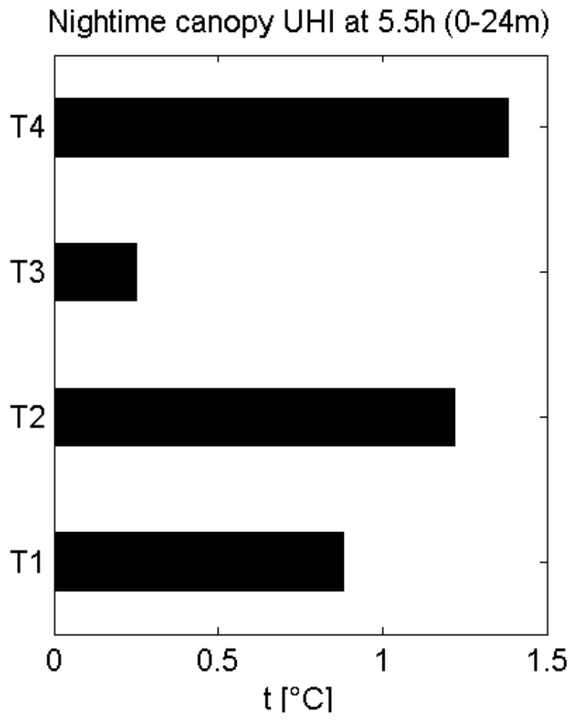


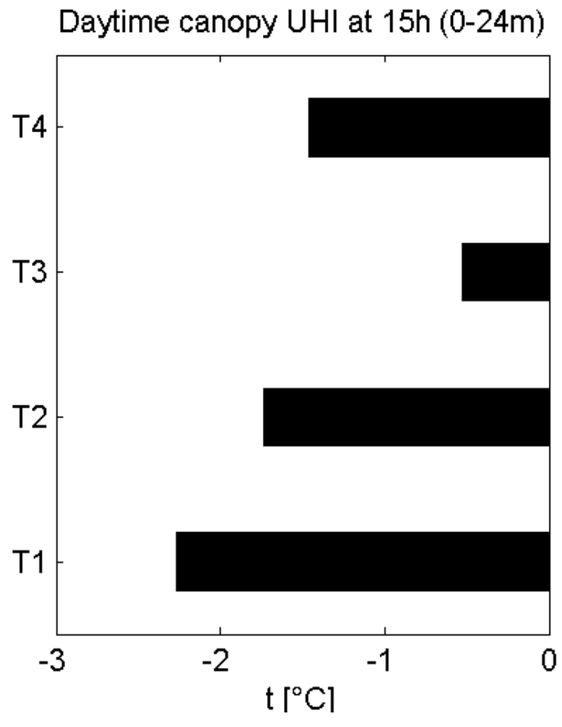
Gál, C. V. (2014). The influence of built form and vegetation on the canopy layer microclimate within urban blocks. *Acta Climatologica et Chorologica*, 47/48, p.43--52.

The initial configurations : the influence of form

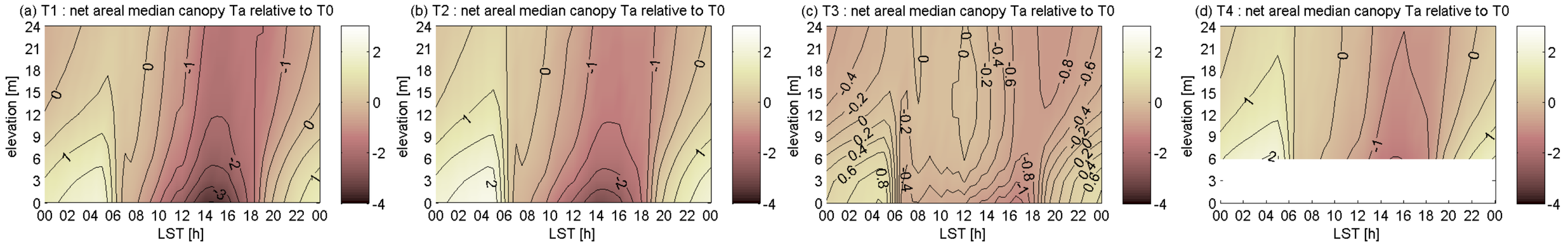




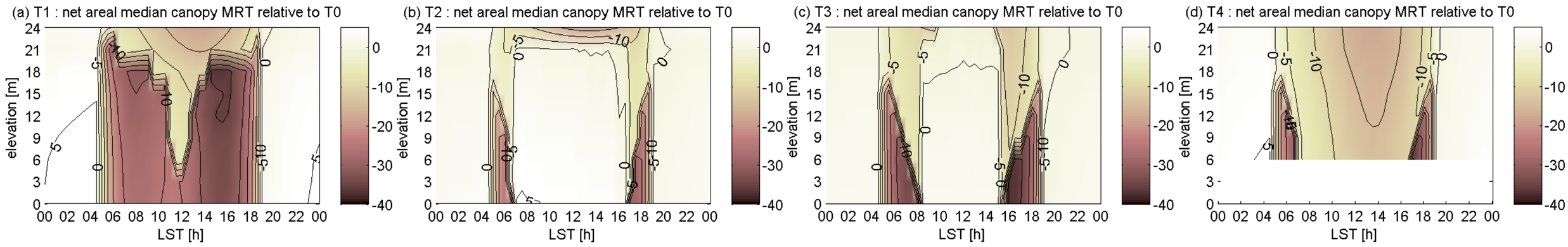




T1 T2 T3 T4

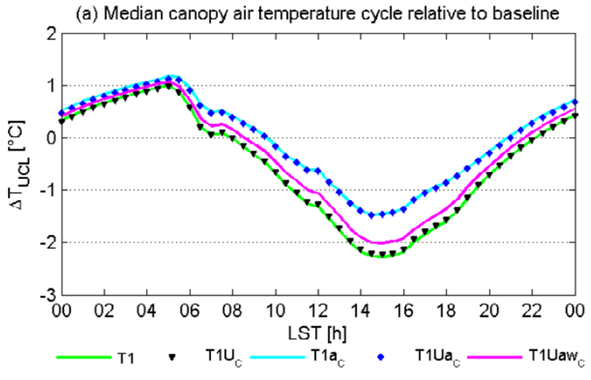


potential temperature relative to baseline (T0)

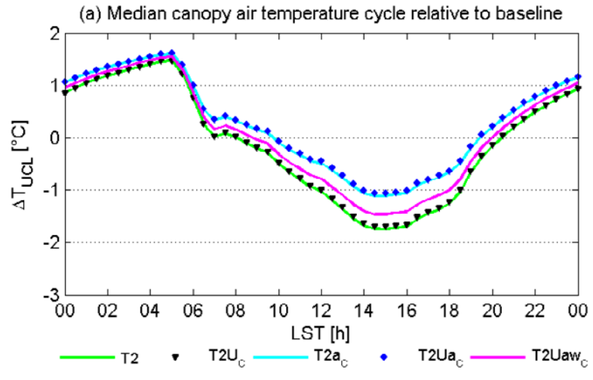


mean radiant temperature relative to baseline (T0)

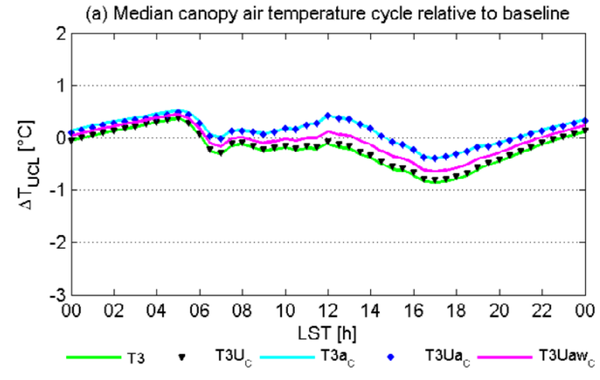
T1



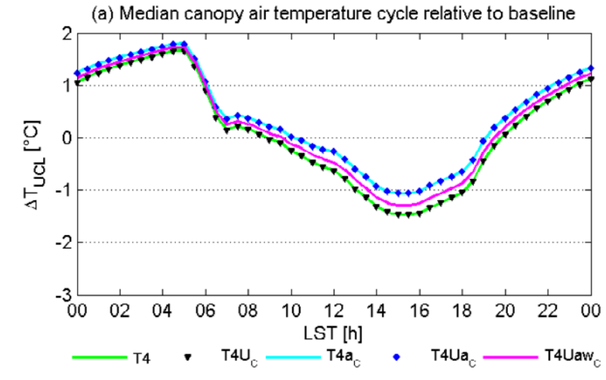
T2



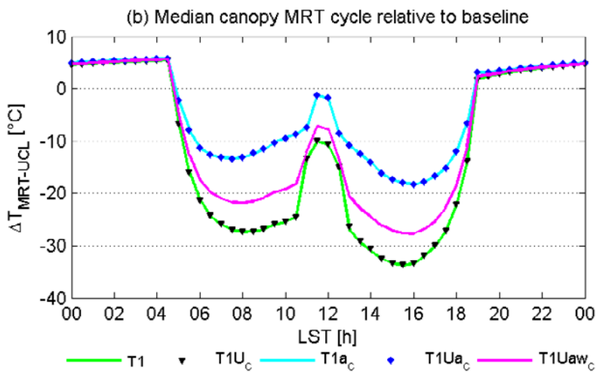
T3

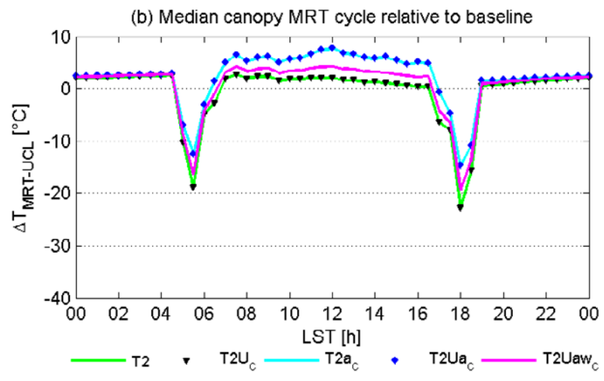


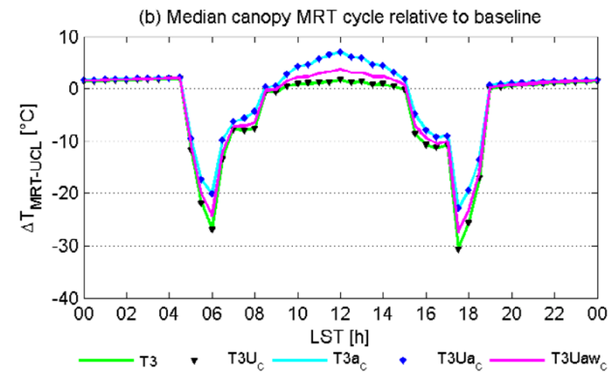
T4

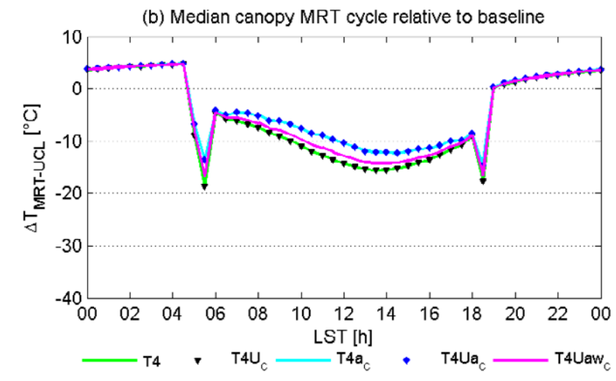


potential temperature relative to baseline (T0)

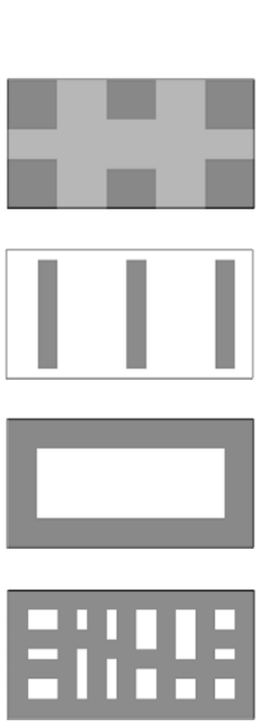


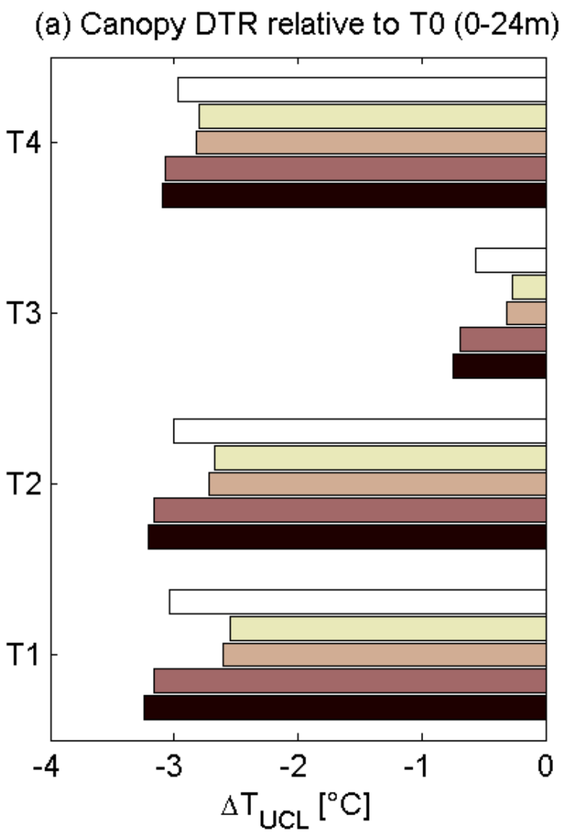


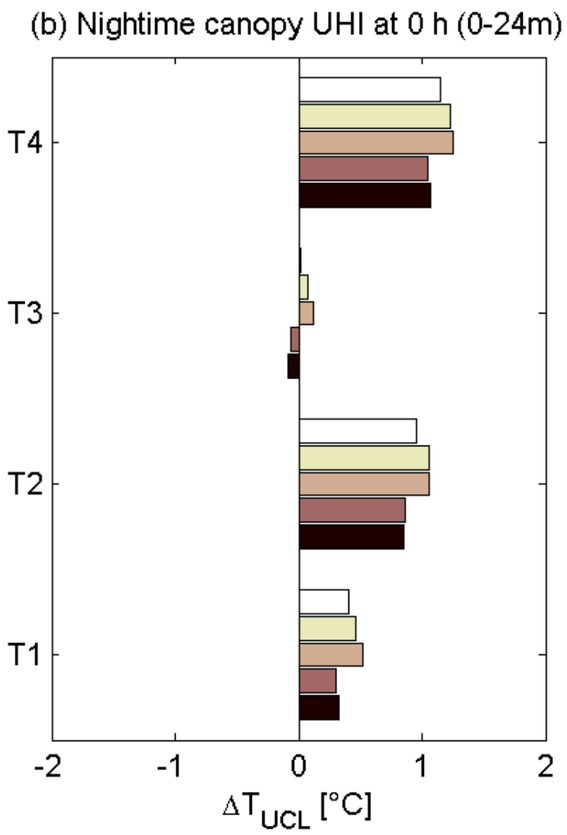


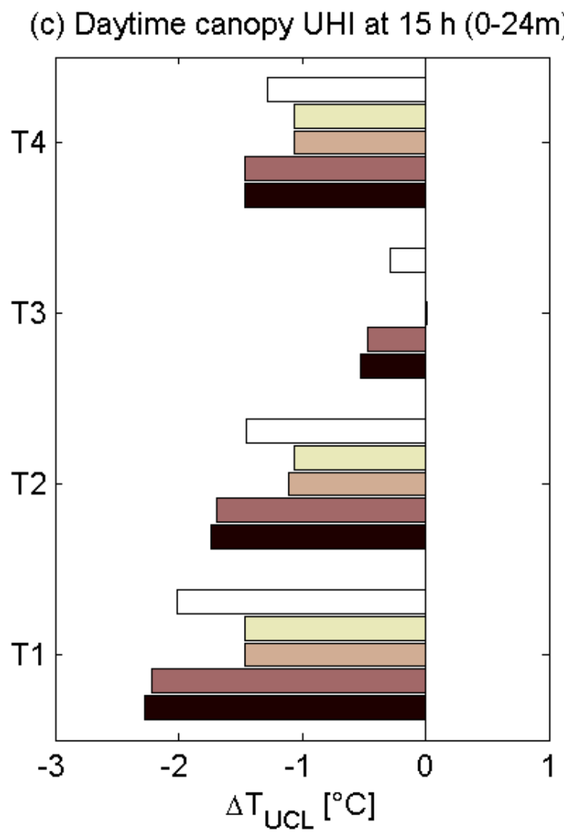


mean radiant temperature relative to baseline (T0)




(a) Canopy DTR relative to T0 (0-24m)
T4
T3
T2
T1
-4
-3
-2
-1
0
ΔT_UCL [°C]


(b) Nightime canopy UHI at 0 h (0-24m)
T4
T3
T2
T1
-2
-1
0
1
2
ΔT_UCL [°C]


(c) Daytime canopy UHI at 15 h (0-24m)
T4
T3
T2
T1
-3
-2
-1
0
1
ΔT_UCL [°C]

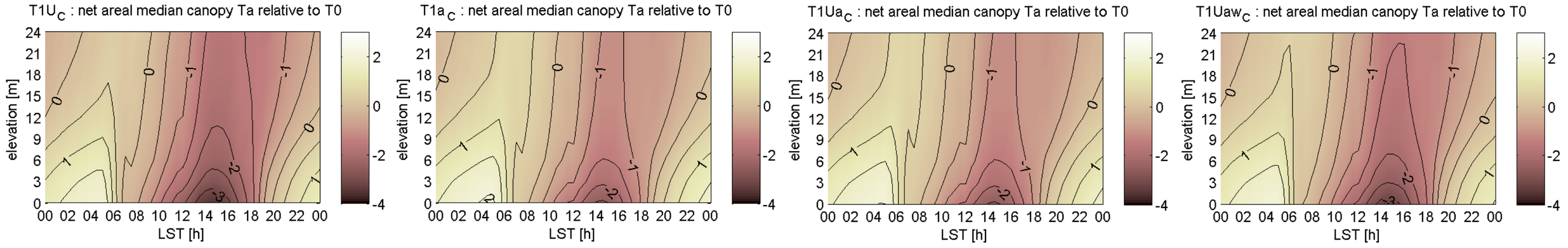

initial
U
a
Ua
w

T1 | U

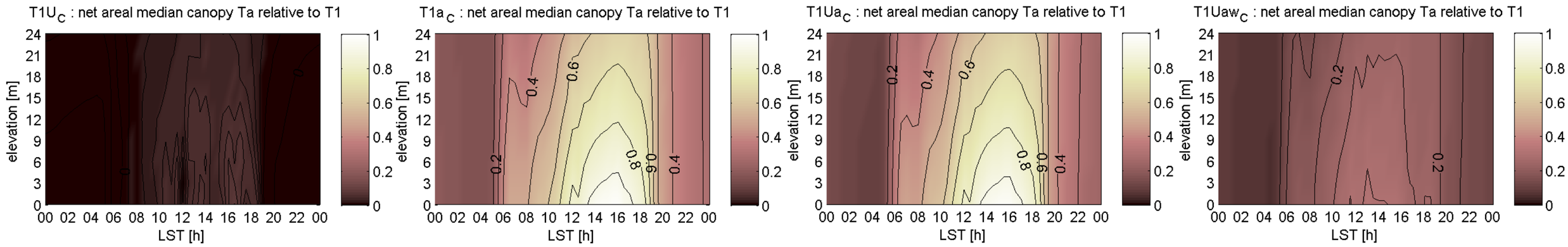
T1 | a

T1 | Ua

T1 | Uaw



potential temperature relative to baseline (T0)



potential temperature relative to the inifital configuraion (T1)

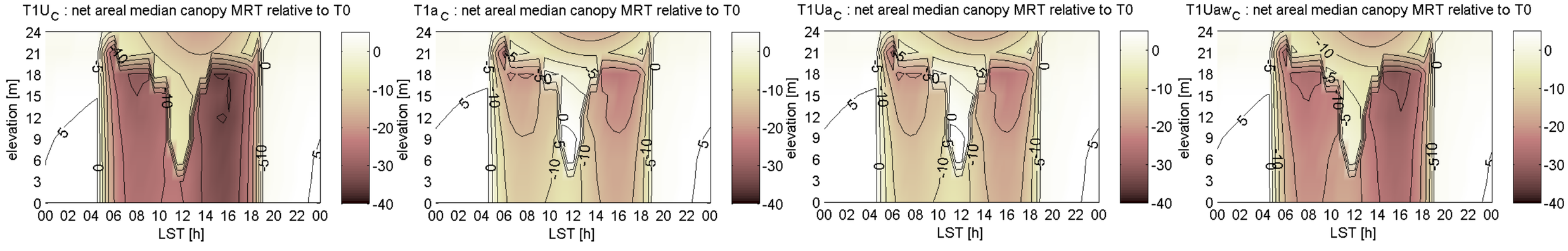
a = 0.4	a = 0.8	a = 0.8	a = 0.55
U = 0.3	U = 1.1	U = 0.3	U = 0.8

T1 | U

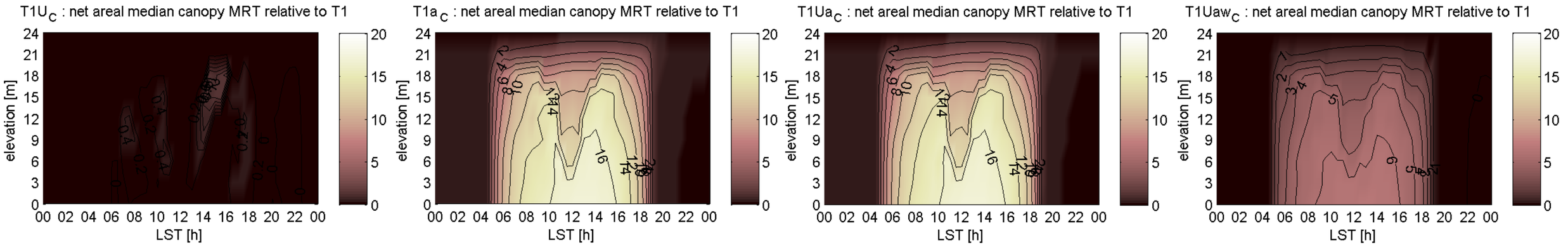
T1 | a

T1 | Ua

T1 | Uaw



mean radiant temperature relative to baseline (T0)



mean radiant temperature relative to the inifital configuraion (T1)

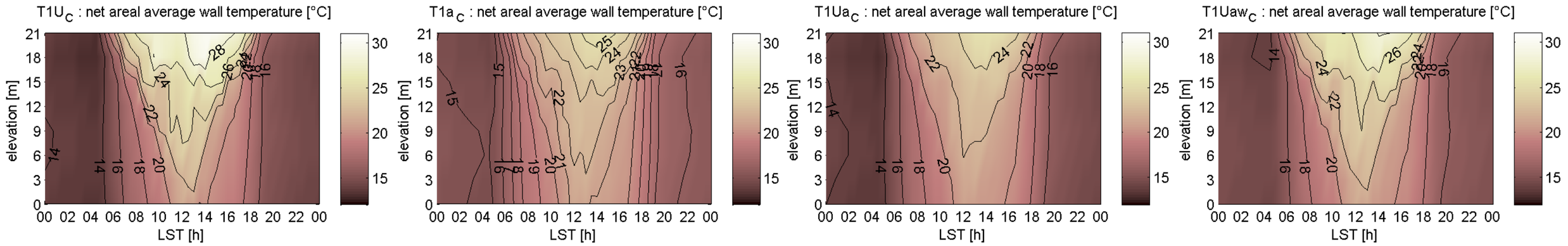
a = 0.4	a = 0.8	a = 0.8	a = 0.55
U = 0.3	U = 1.1	U = 0.3	U = 0.8

T1 | U

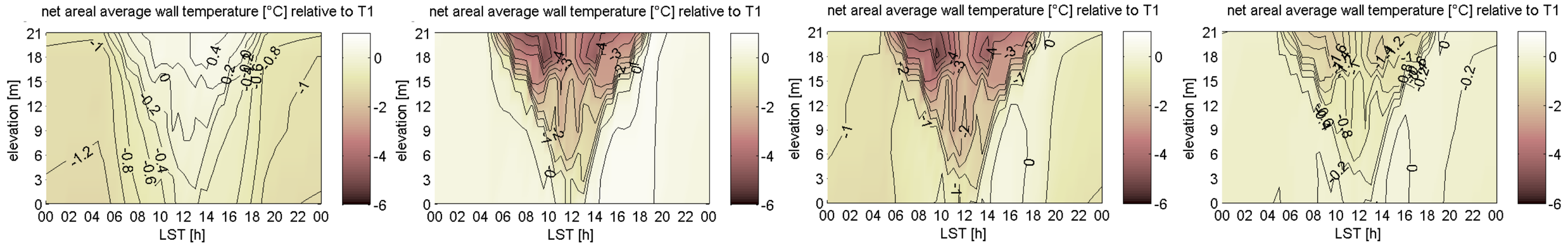
T1 | a

T1 | Ua

T1 | Uaw



average facade temperature



average facade temperature relative to the initial configuration (T1)

a = 0.4	a = 0.8	a = 0.8	a = 0.55
U = 0.3	U = 1.1	U = 0.3	U = 0.8

1) Among the investigated facade parameters albedo drives the canopy layer microclimate.

2) The influence of heat transmission coefficient is found to be marginal.

3) In the combined effect of albedo and U-value, the contribution of the latter is insignificant.

4) The impact of fenestration ratio is primarily exerted though the albedo, indirectly, as increasing fenestration ratio decreases the albedo of walls.

5) Compared to form, facade properties alwasy play a secondary role in influencing the UCL microclimate.

Thank you!

Csilla V Gal
cgal@iit.edu

The work was partially supported by the 2010–2011 James A. Speyer Scholarship.