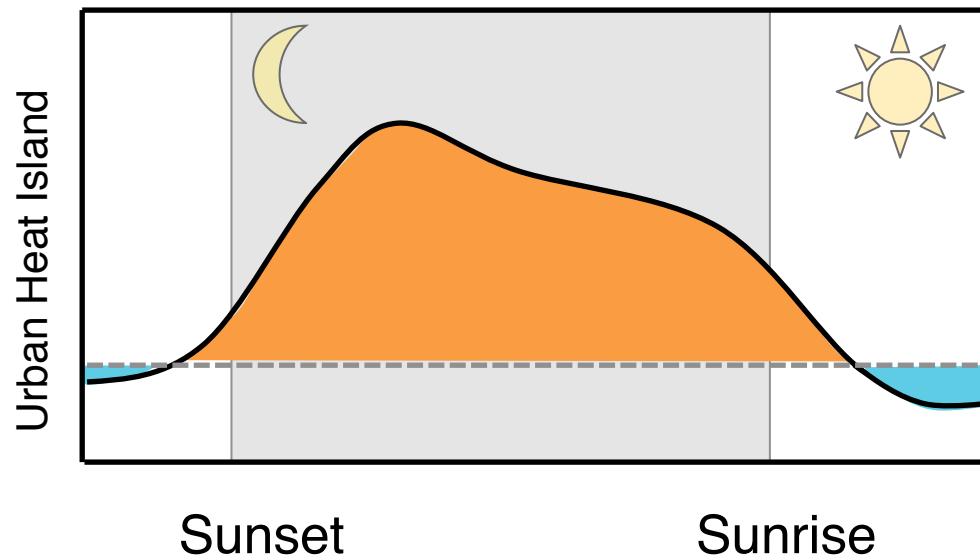


A breath of fresh air in UHI studies

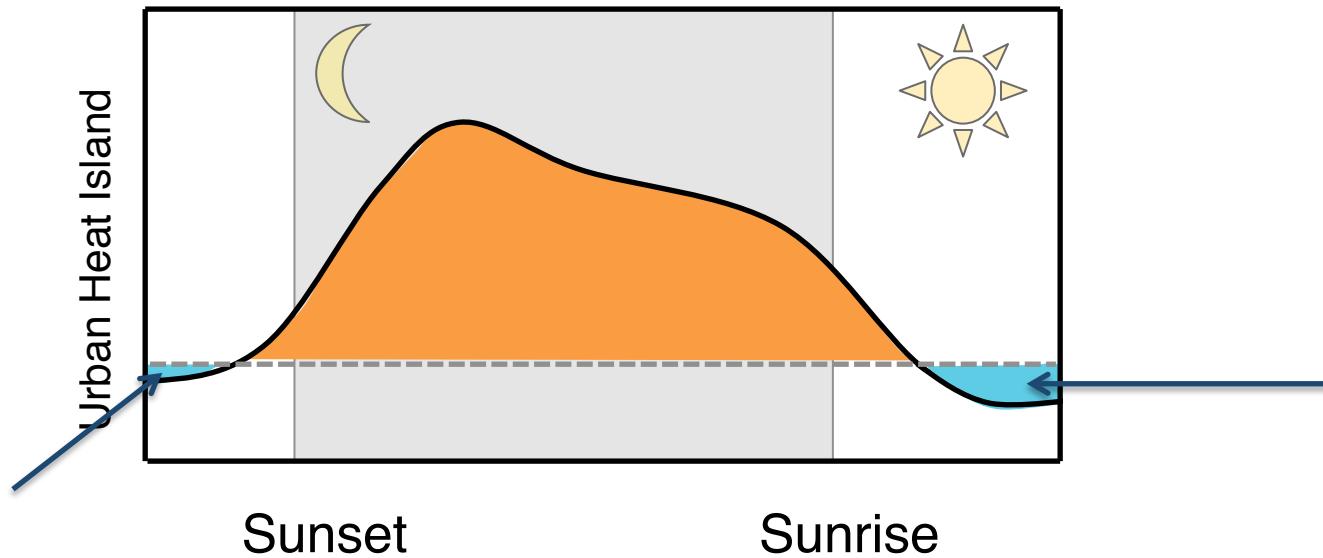
On the formation of the urban cool island



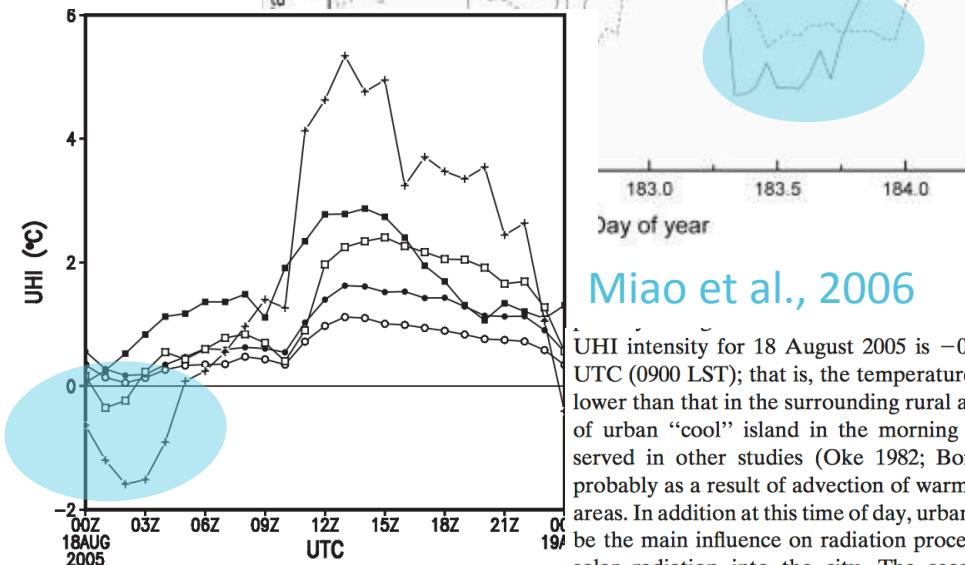
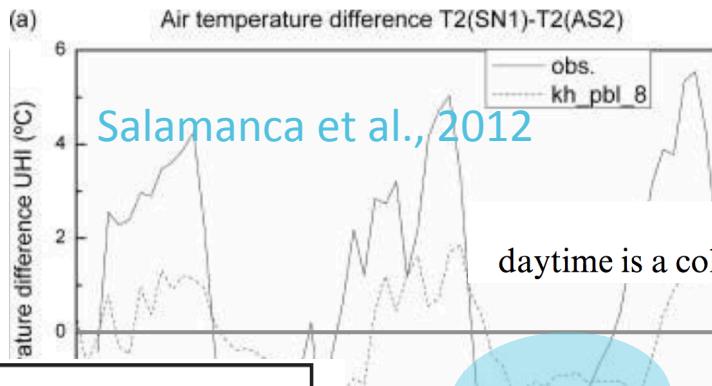
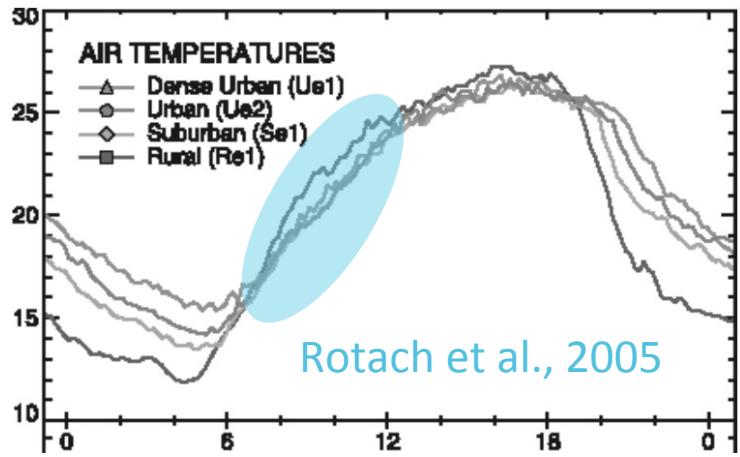
Natalie Theeuwes, Gert-Jan Steeneveld, Reinder Ronda
and Bert Holtslag

A breath of fresh air in UHI studies

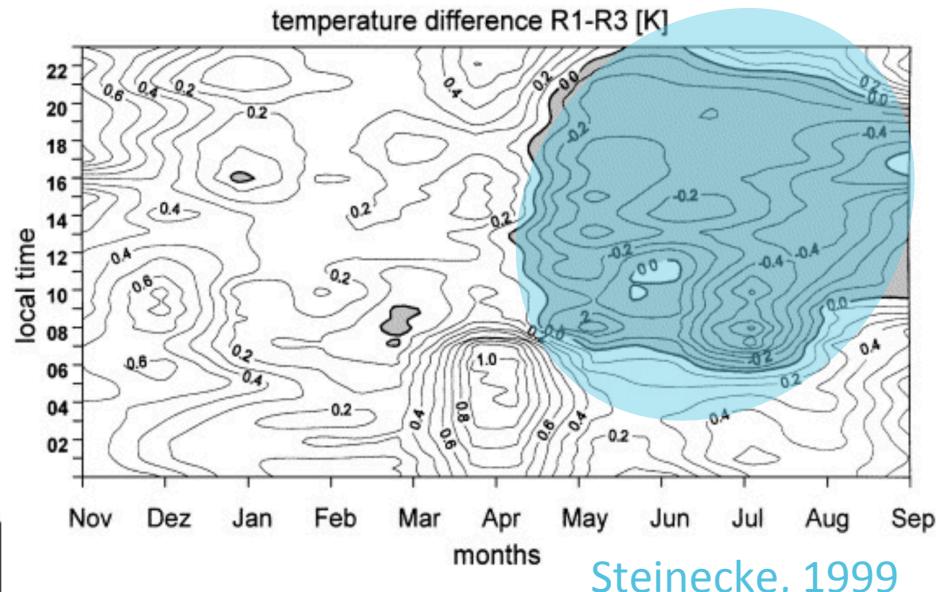
On the formation of the urban cool island



Natalie Theeuwes, Gert-Jan Steeneveld, Reinder Ronda
and Bert Holtslag

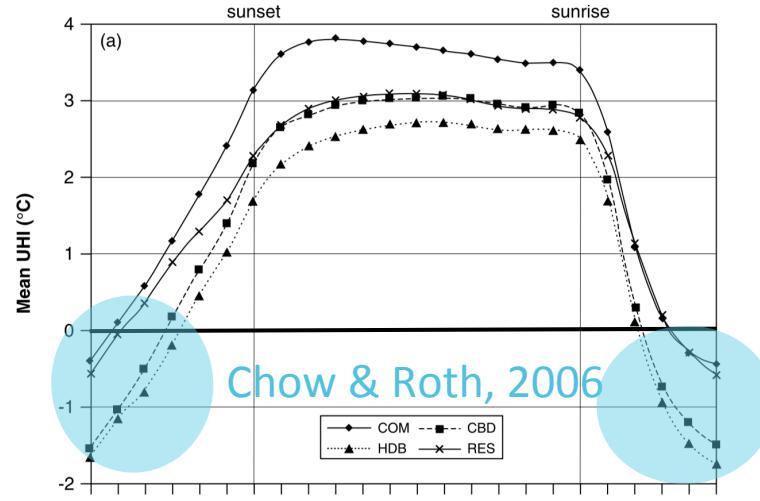


UHI intensity for 18 August 2005 is -0.35°C at 0100 UTC (0900 LST); that is, the temperature in the city is lower than that in the surrounding rural area. This type of urban “cool” island in the morning time was observed in other studies (Oke 1982; Bornstein 1987), probably as a result of advection of warmer air to rural areas. In addition at this time of day, urban aerosols may be the main influence on radiation processes, reducing solar radiation into the city. The second minimum



the urban area in daytime is a cold island because of the attenuation of solar radiation by aerosols.

Sang et al., 2000

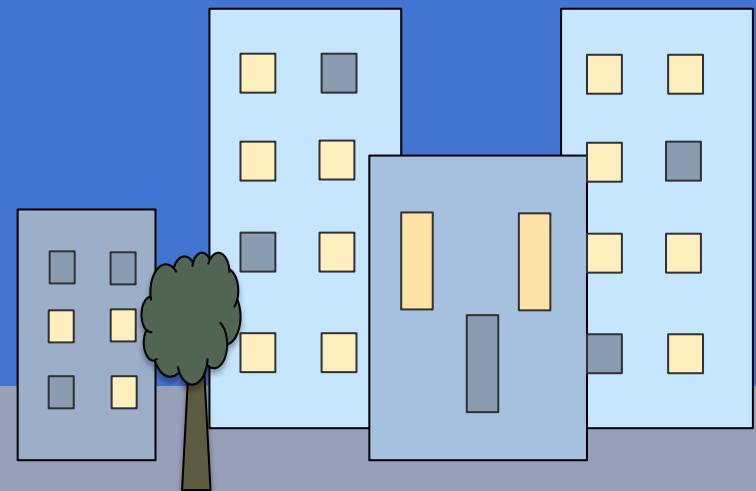
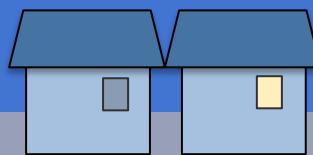


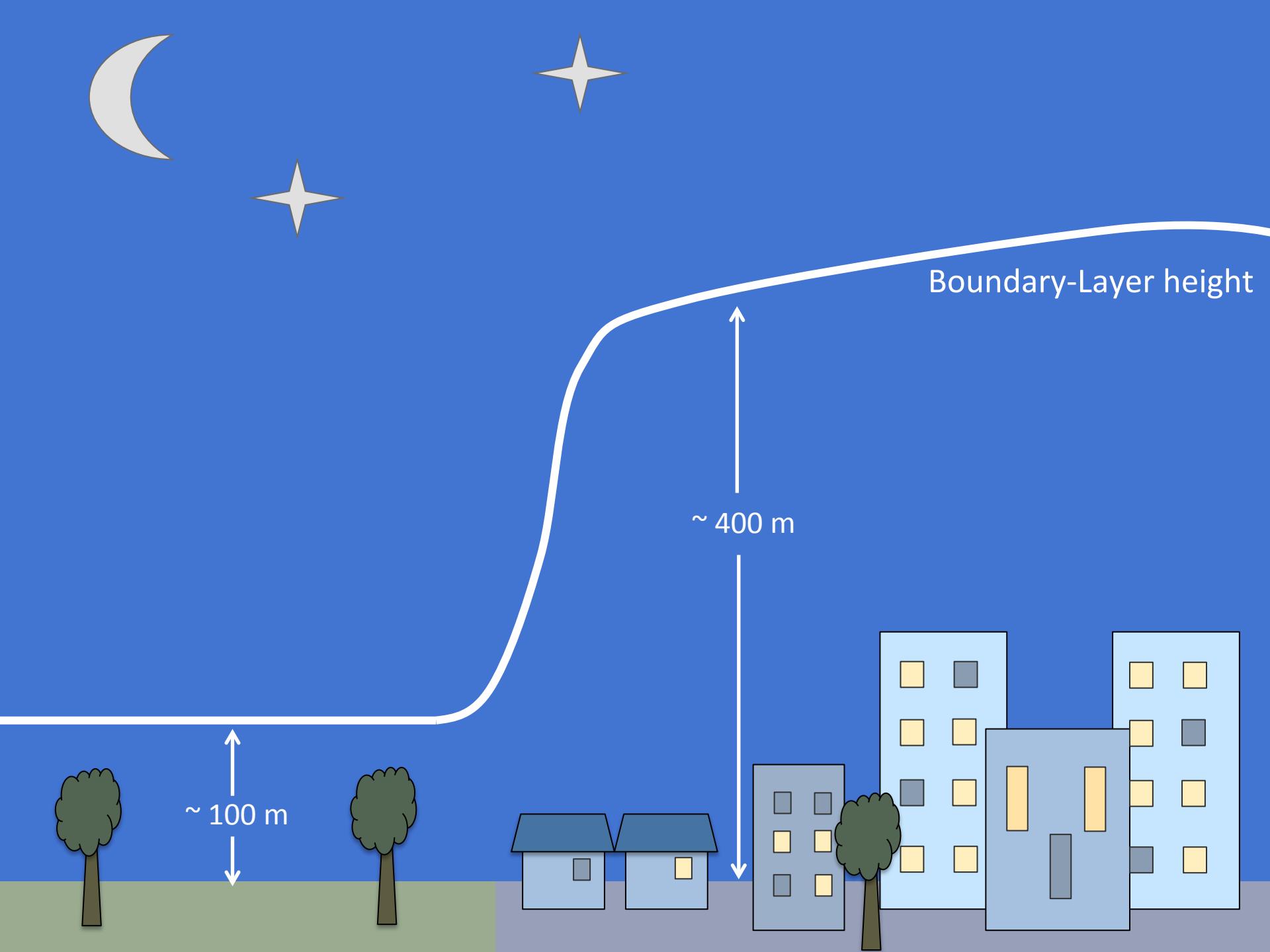
What do we know about the UCI?

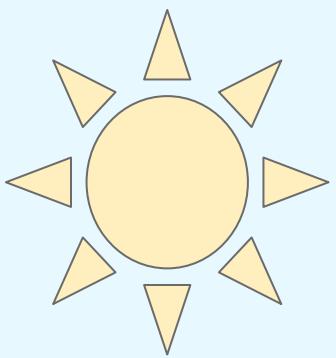
- Mostly found in fair-weather, low wind speed conditions.
- Strongest in the morning, in some cases can last throughout entire day.
- In most cases $UCI < 2^{\circ}\text{C}$.

Our hypothesis:

The UCI is formed through atmospheric boundary-layer dynamics



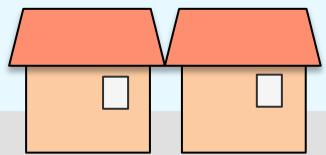


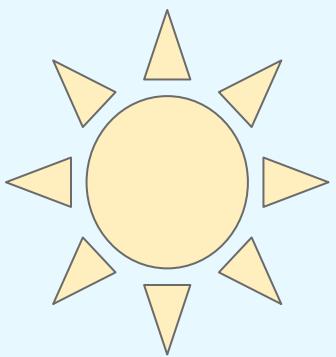


Boundary-Layer height

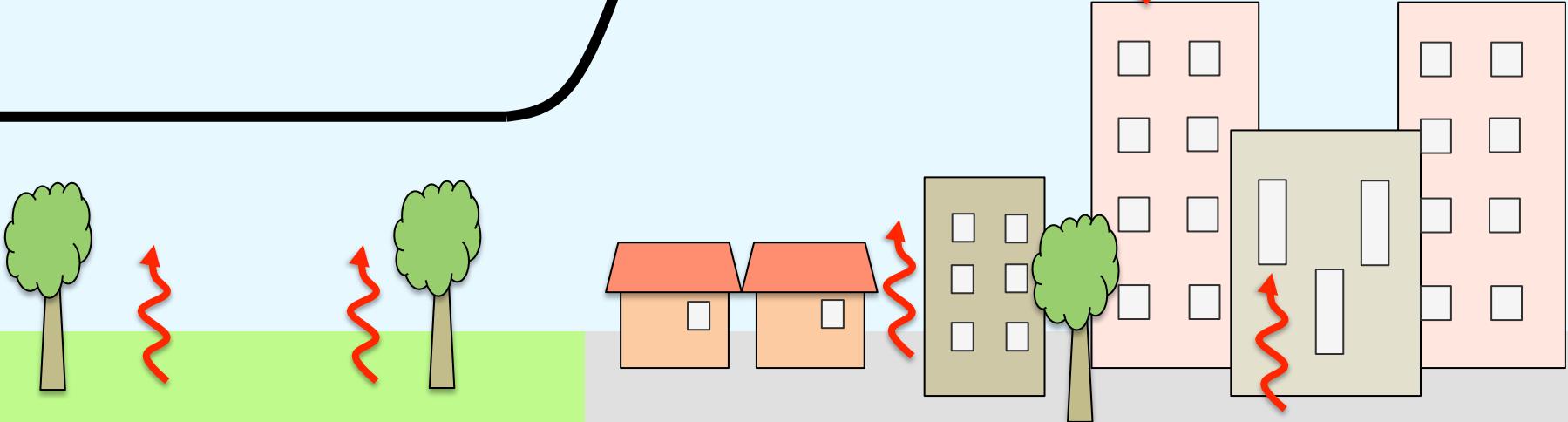
~ 400 m

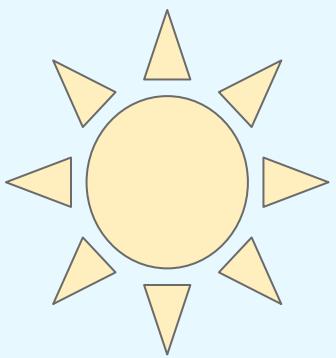
~ 100 m





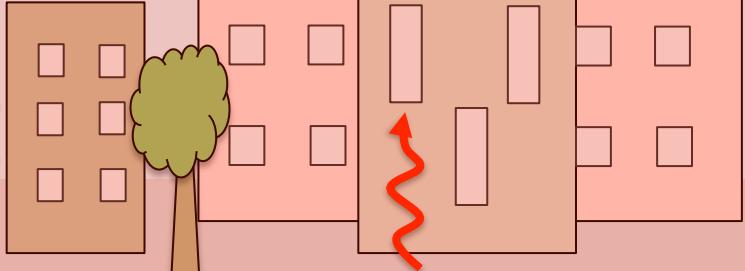
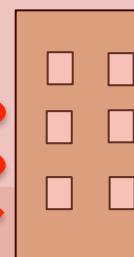
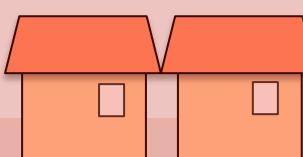
Boundary-Layer height





Boundary-Layer height

Sensible heat flux



How do we test this hypothesis?

We use the following tools:

- Mixed layer equations, forced by land surface model
- Observations from the BUBBLE campaign.

$$\frac{\partial \langle \theta_v \rangle}{\partial t} = \frac{\overline{w' \theta'_v} - b \cdot \overline{w' \theta'_v}}{h}$$

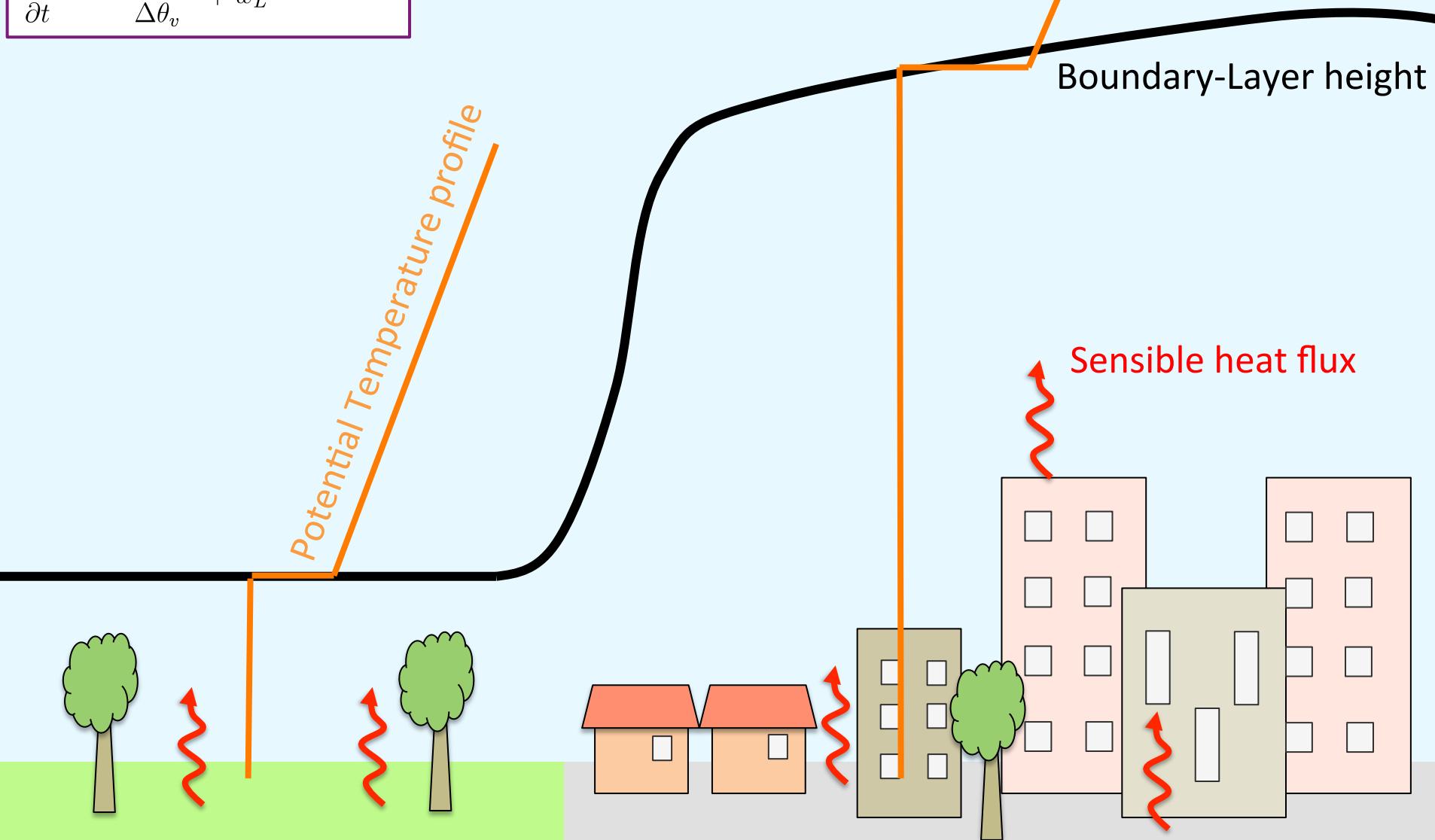
$$\frac{\partial \Delta \theta_v}{\partial t} = -\frac{b \cdot \overline{w' \theta'_v}}{\Delta \theta_v} \gamma_\theta - \frac{\partial \langle \theta_v \rangle}{\partial t}$$

$$\frac{\partial h}{\partial t} = -\frac{b \cdot \overline{w' \theta'_v}}{\Delta \theta_v} + w_L$$

Mixed-Layer equations

Tennekes 1973 (J. Atm. Sc.)

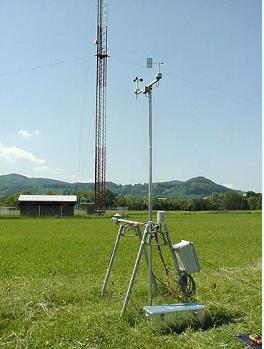
Coupled to land surface model



BUBBLE observations

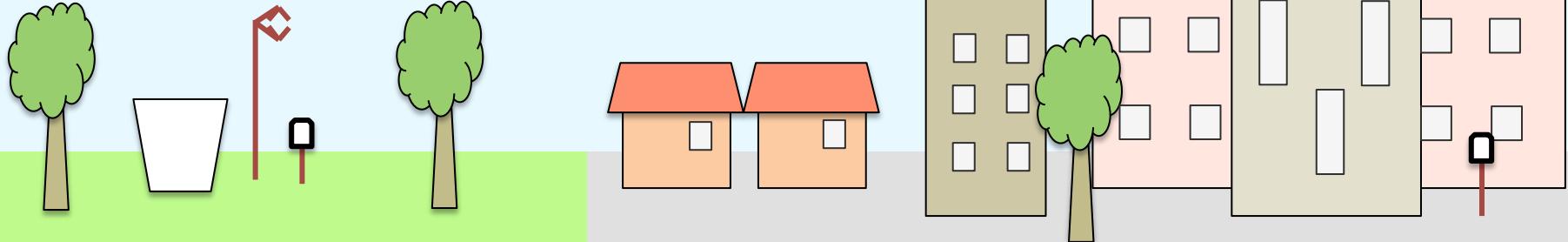
Rotach et al., 2005 (Th. Appl. Clim.)

Case based on 26 June 2002

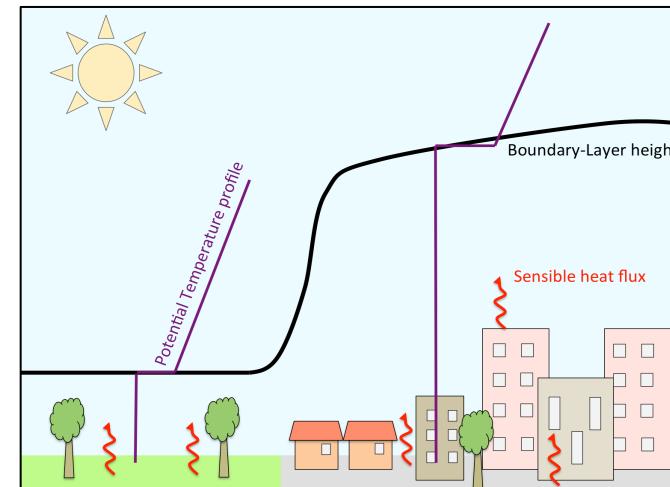
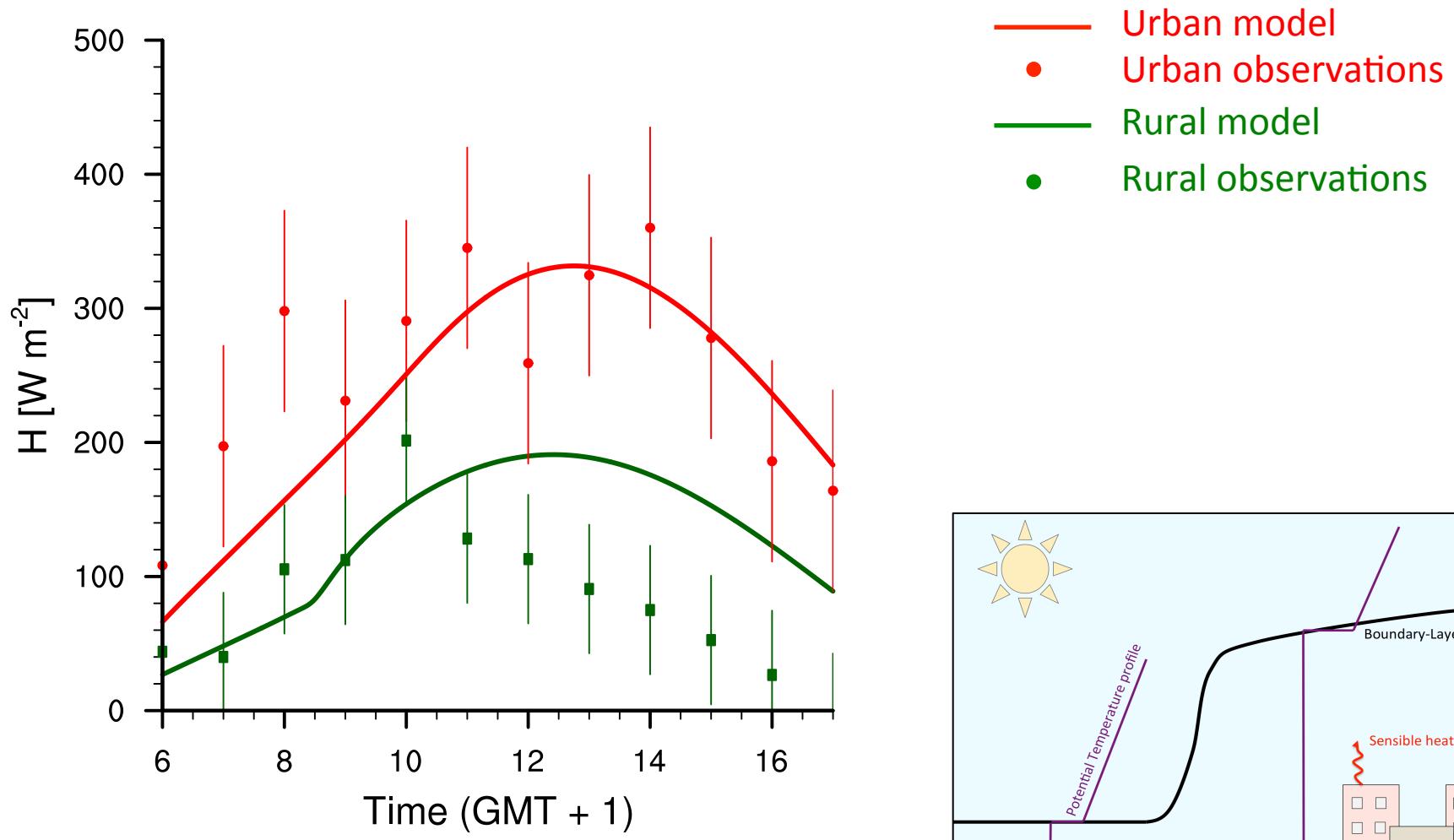


Rural:
Grenzach

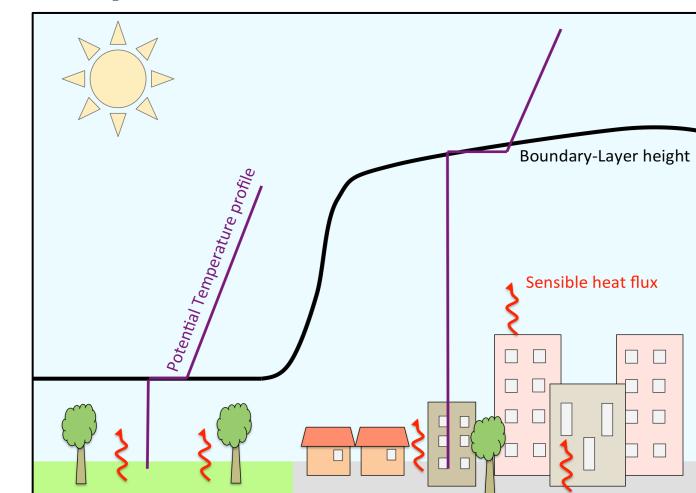
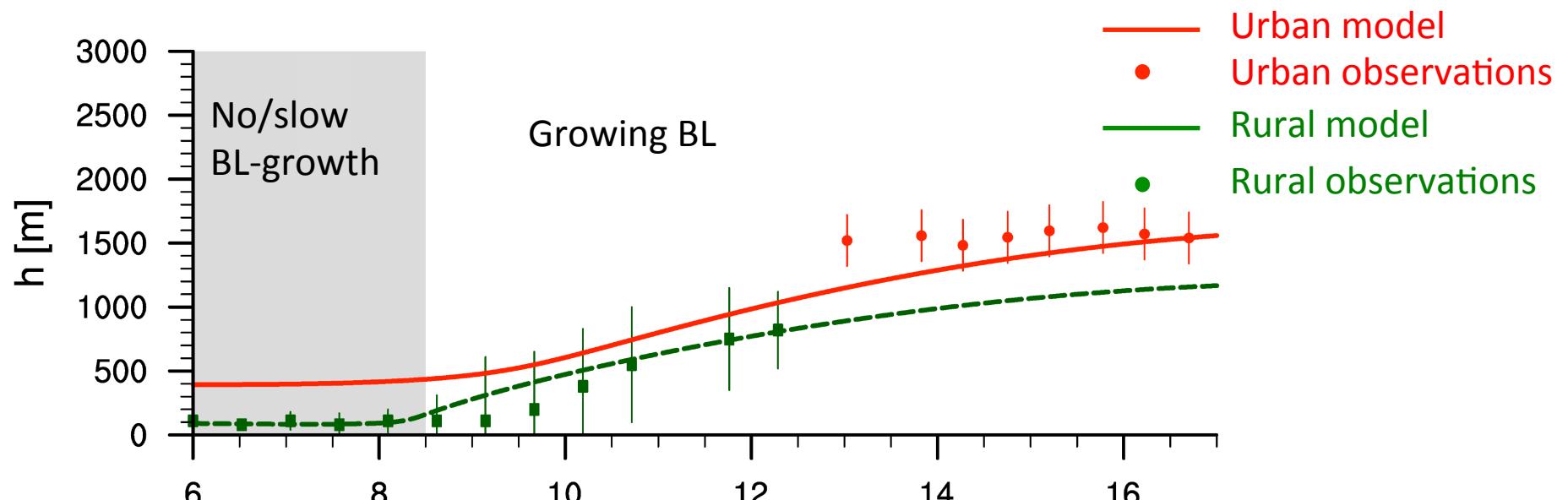
Urban:
Basel - Spalenring



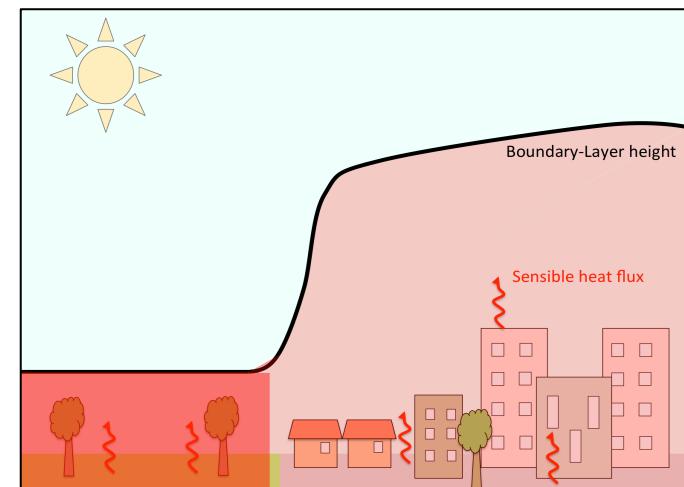
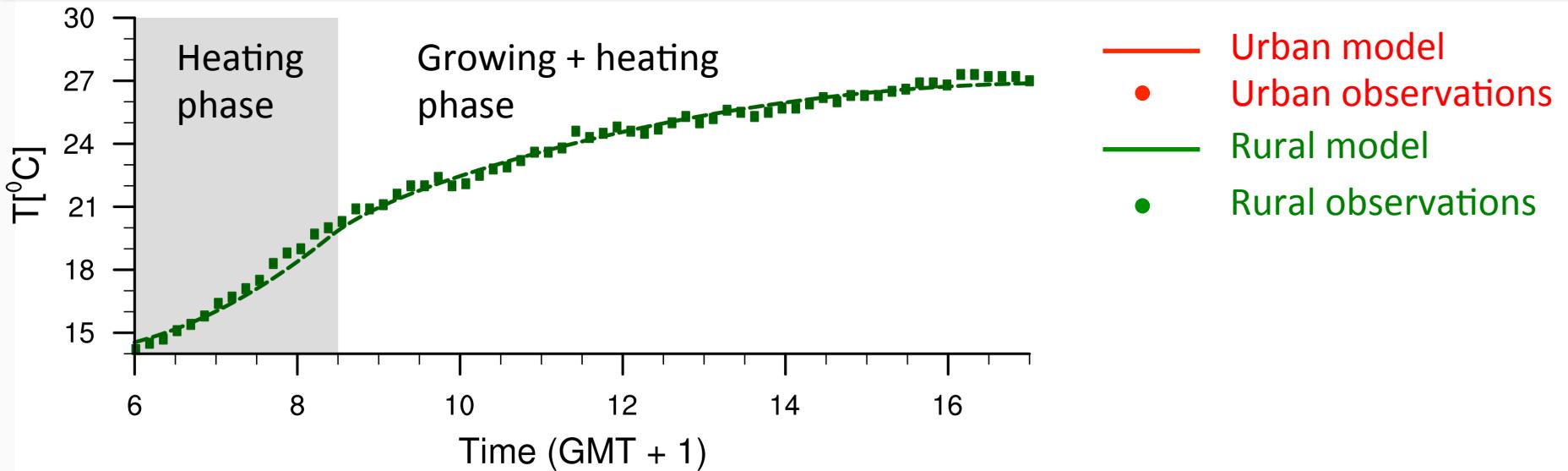
Results: sensible heat flux



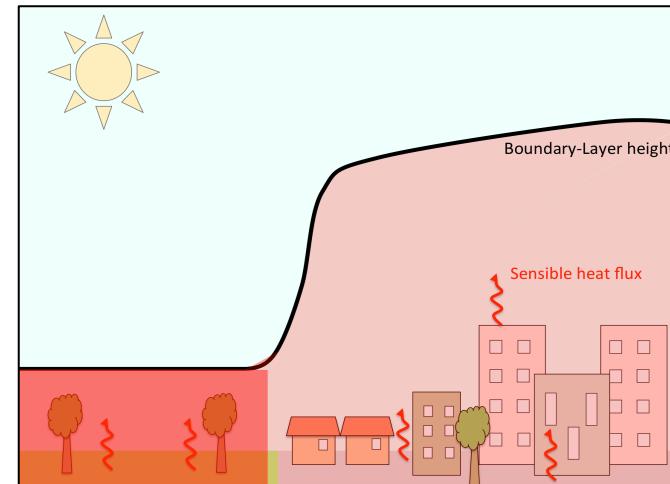
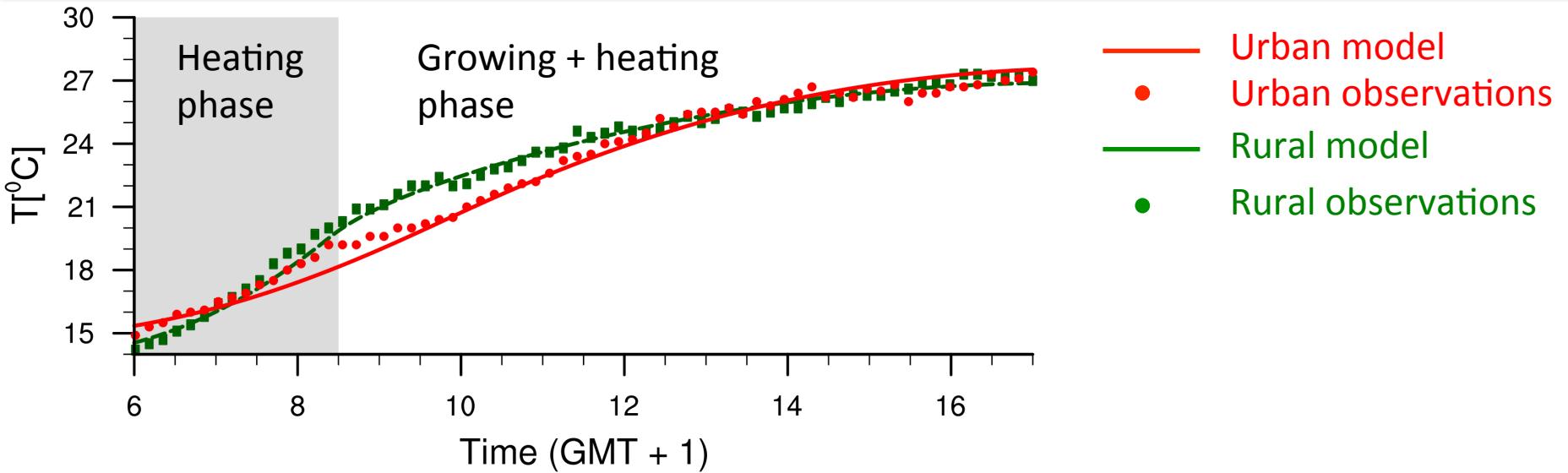
Results: boundary-layer growth



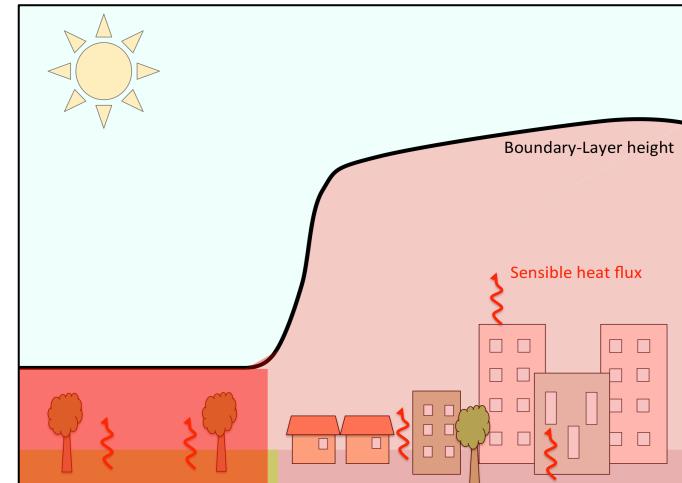
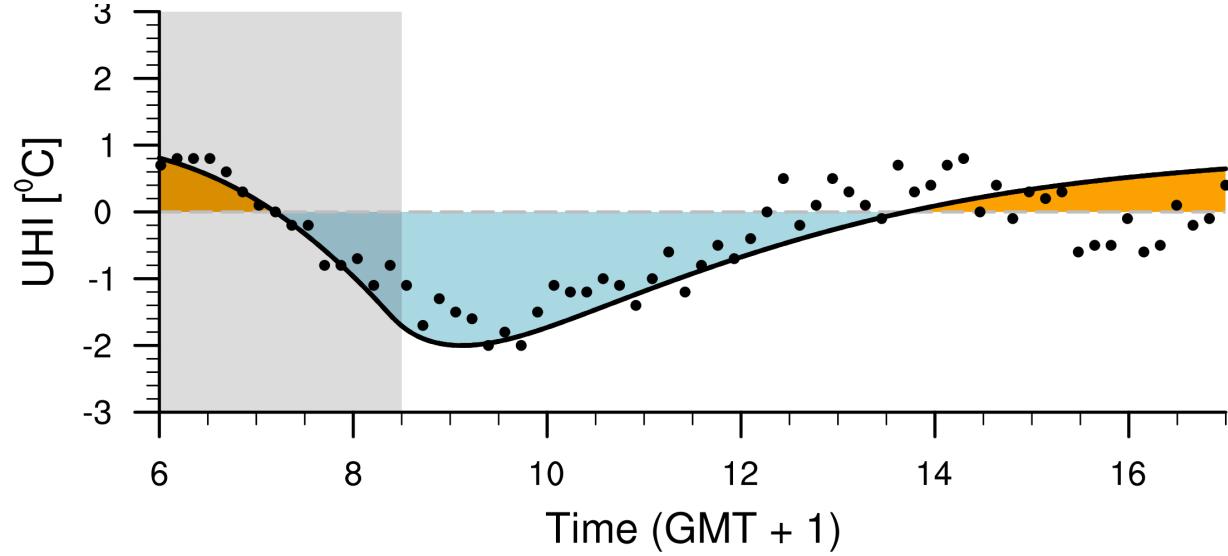
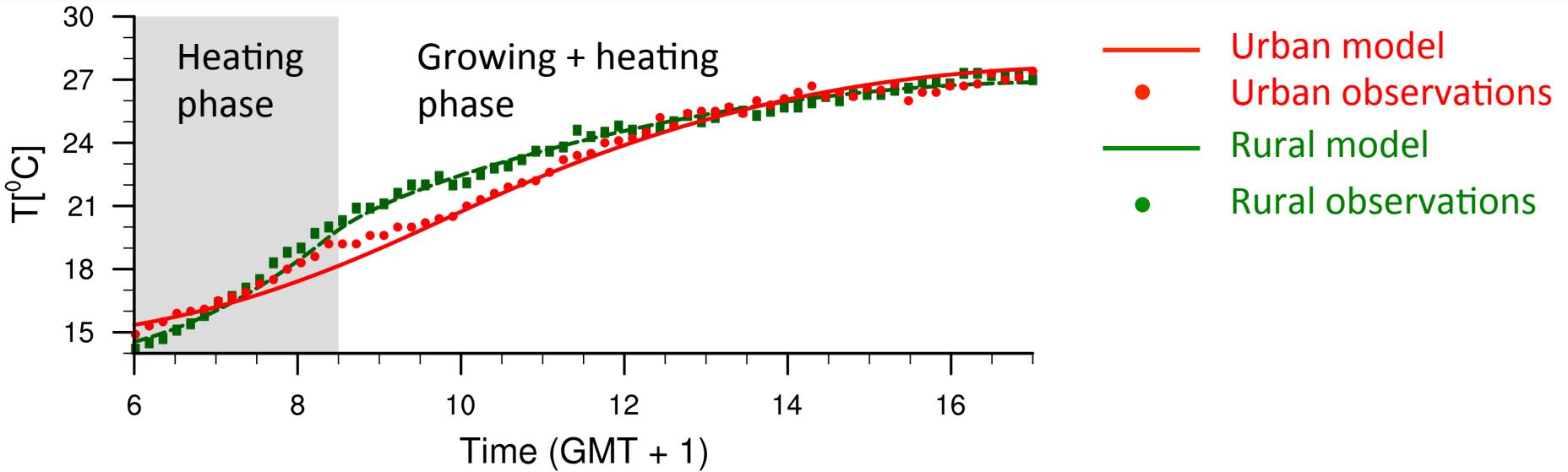
Results: temperature evolution



Results: temperature evolution



Results: temperature evolution



Sensitivity analysis

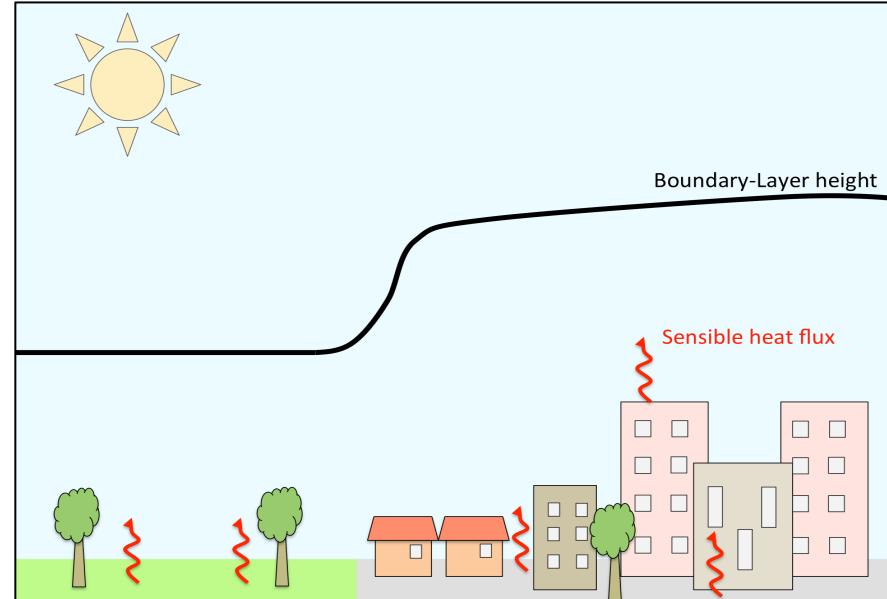
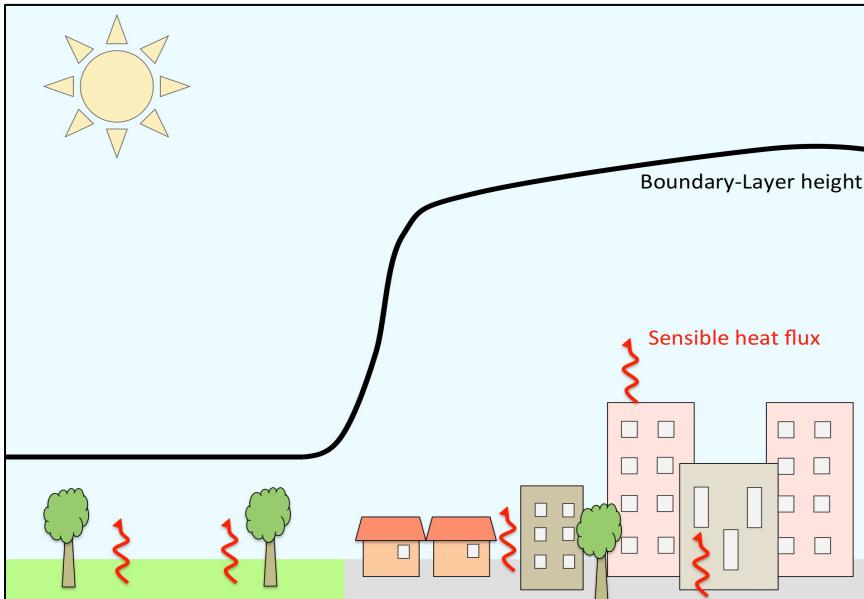
The urban cool island can be explained using different early-morning boundary-layer heights.

What is the UCI sensitivity to initial boundary-layer heights?

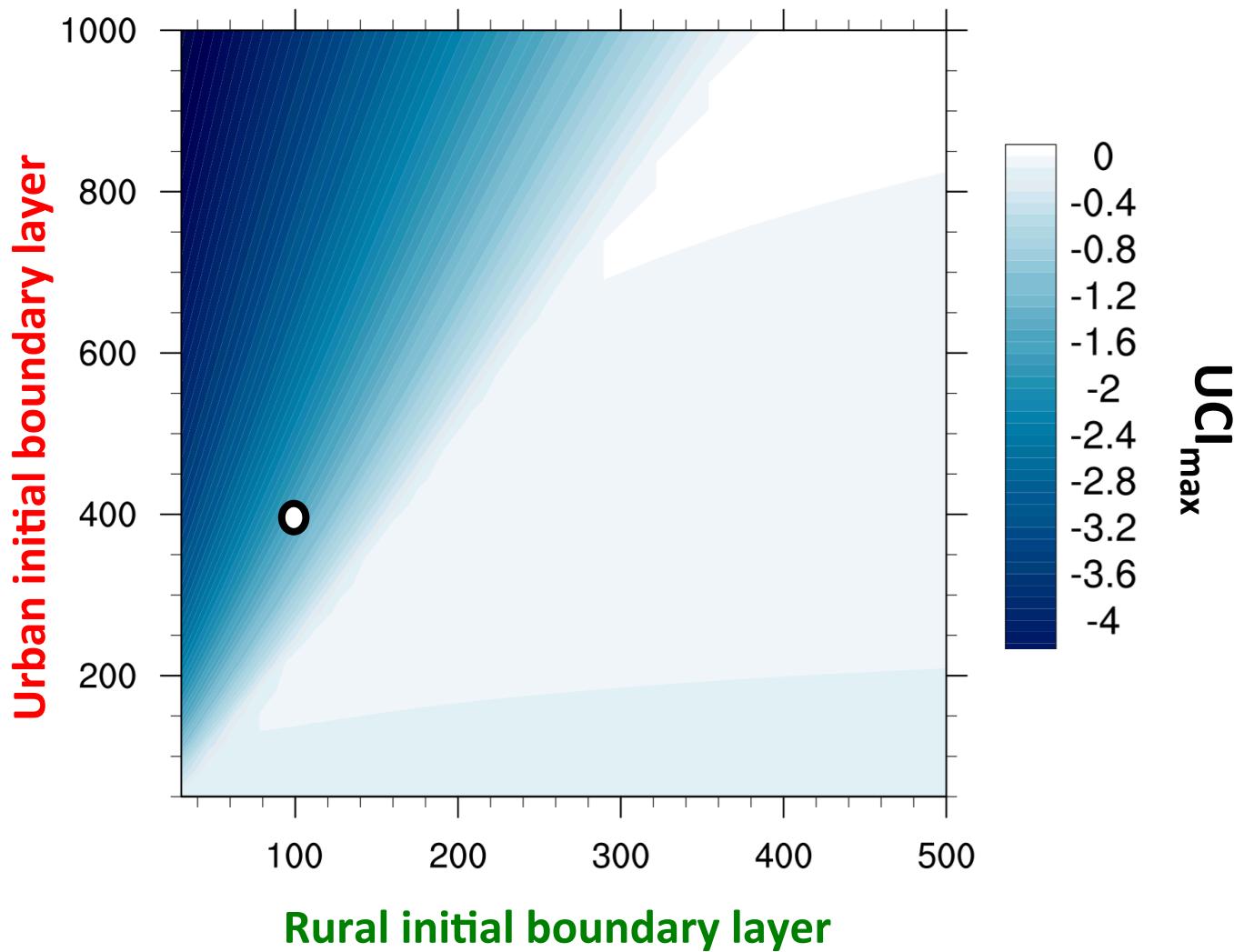
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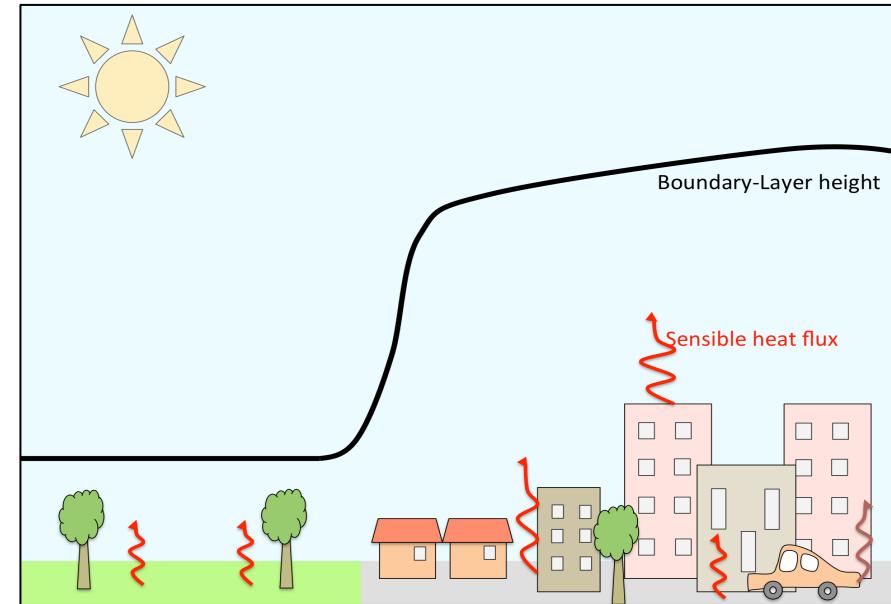
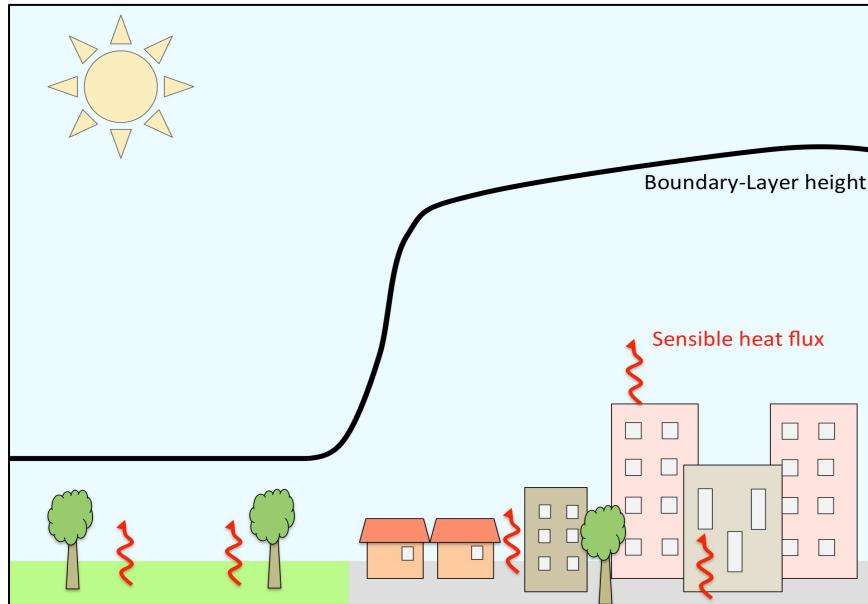
UCI and boundary layer heights



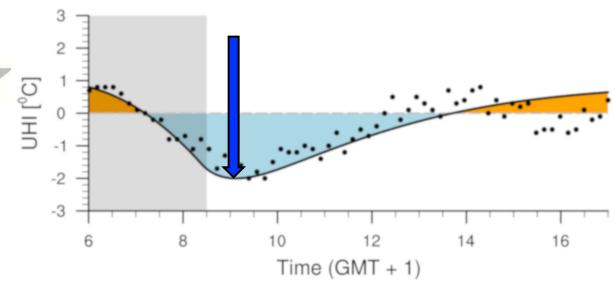
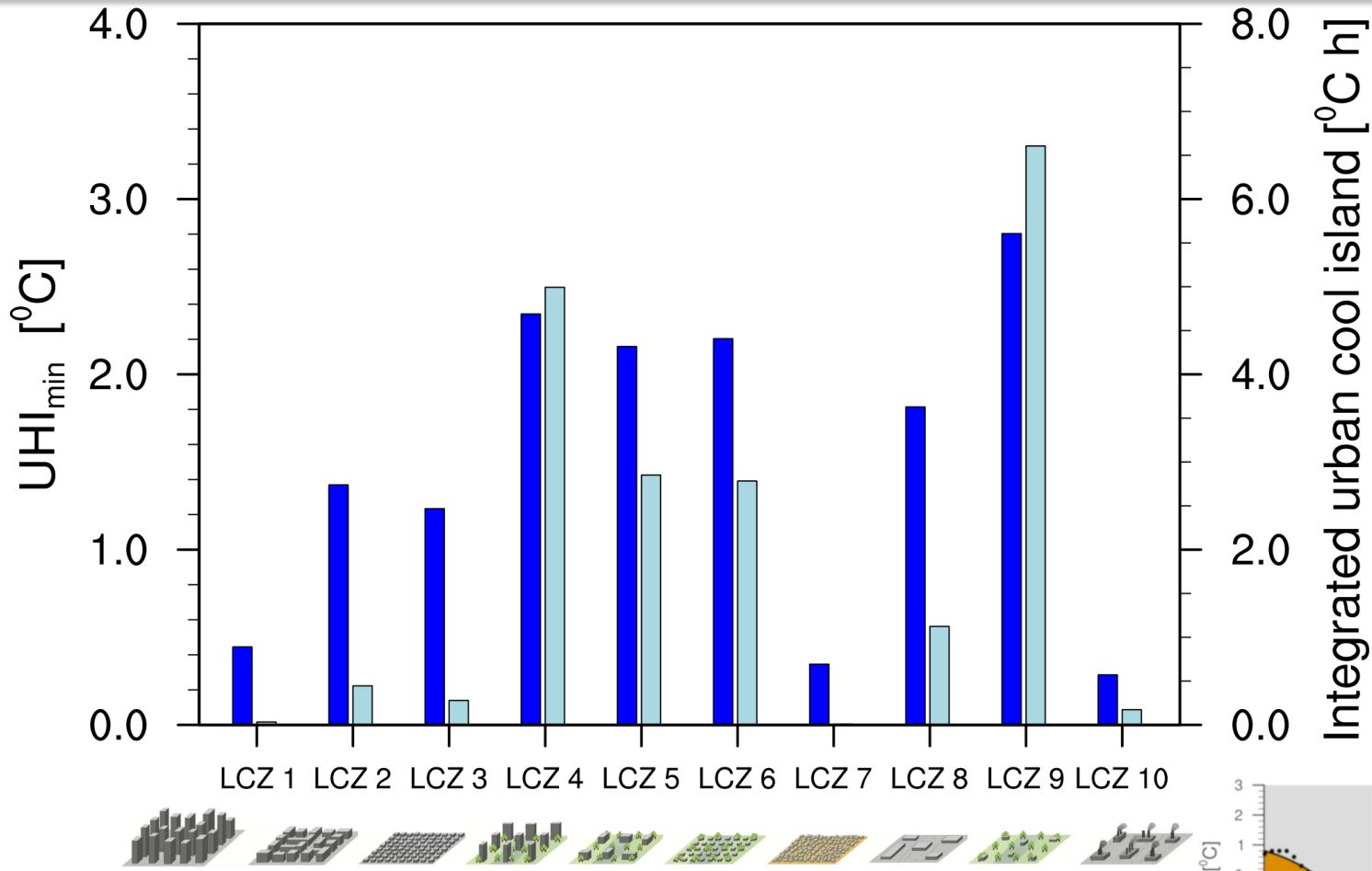
Sensitivity analysis

The urban cool island can be explained using different early-morning boundary-layer heights.

What is the UCI sensitivity to urban surface parameters?



UCI and local climate zones

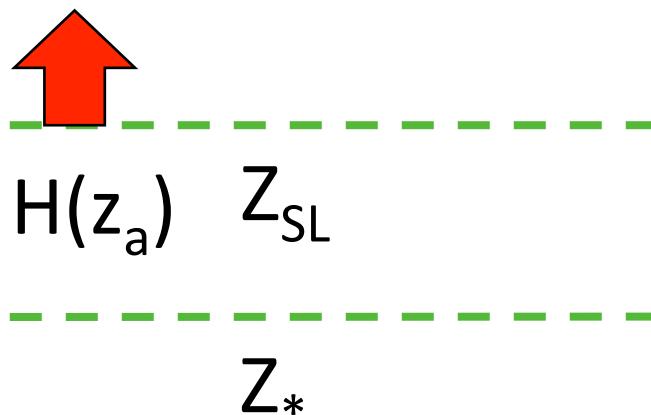


Conclusions

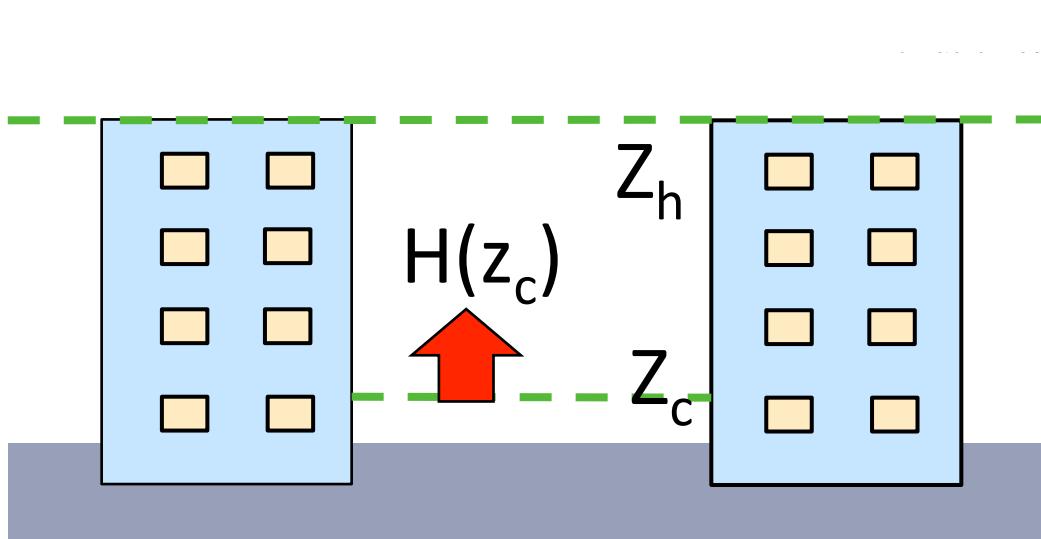
The urban cool island can be explained using different early-morning boundary-layer heights.

- LCZ with anthropogenic heat compensates UCI
- LCZ with vegetation enhances UCI

Back-up slides



$$\theta(z) = <\theta> + \frac{H(z) \cdot r_{ah}}{\rho C_p}$$



Christen, 2005:

$$H(z) = H(z^*) e^{-k}$$

$$k = \frac{c_h(z_e - z)}{z_e}$$

