

The urban wind island from a three-dimensional perspective

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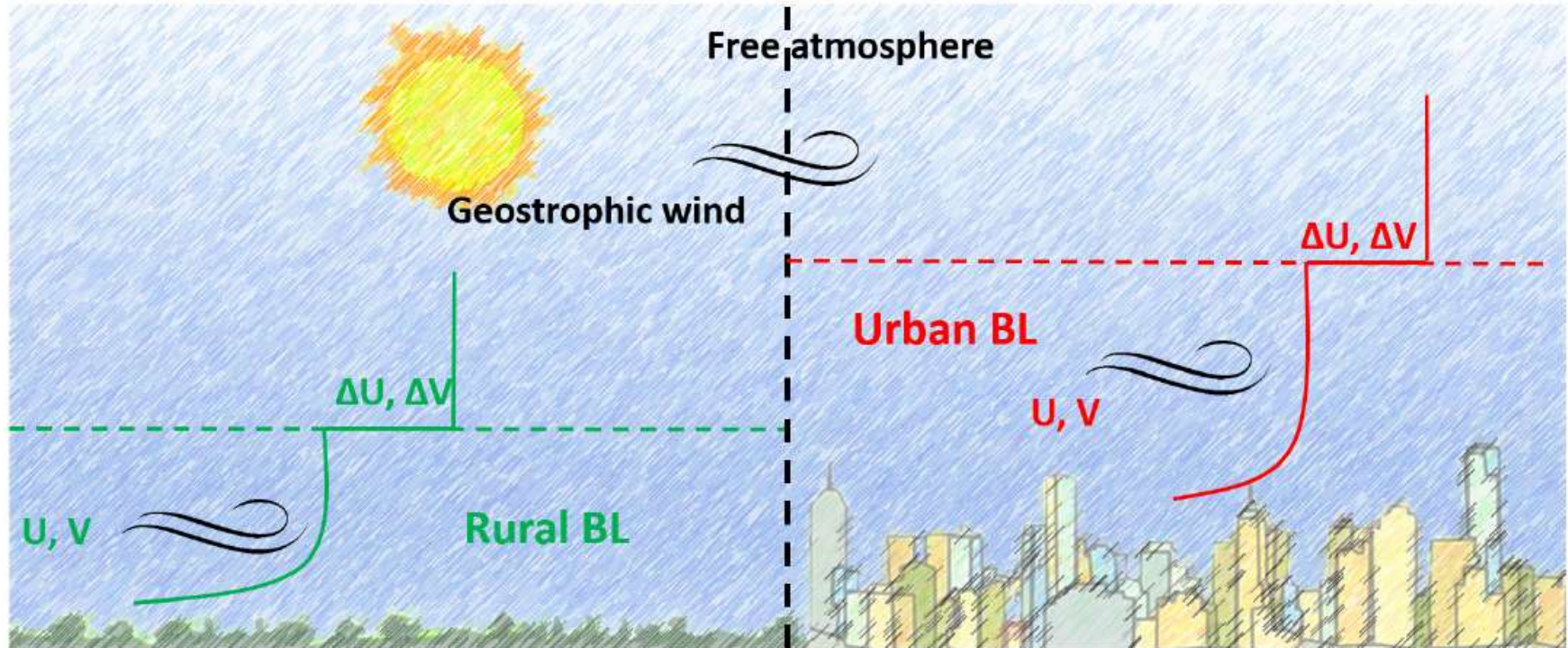
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Context and Aim

- In general wind speeds are reduced in urban areas which hampers a good air quality and human thermal comfort
- In an earlier study we introduced the urban wind island effect: under certain conditions of the boundary layer, the bulk urban wind speed exceeds the rural wind speed
- That study used a simple bulk model for the convective boundary layer. Here we investigate whether the urban wind island effect also occurs in 3D WRF over Amsterdam

Conceptual picture

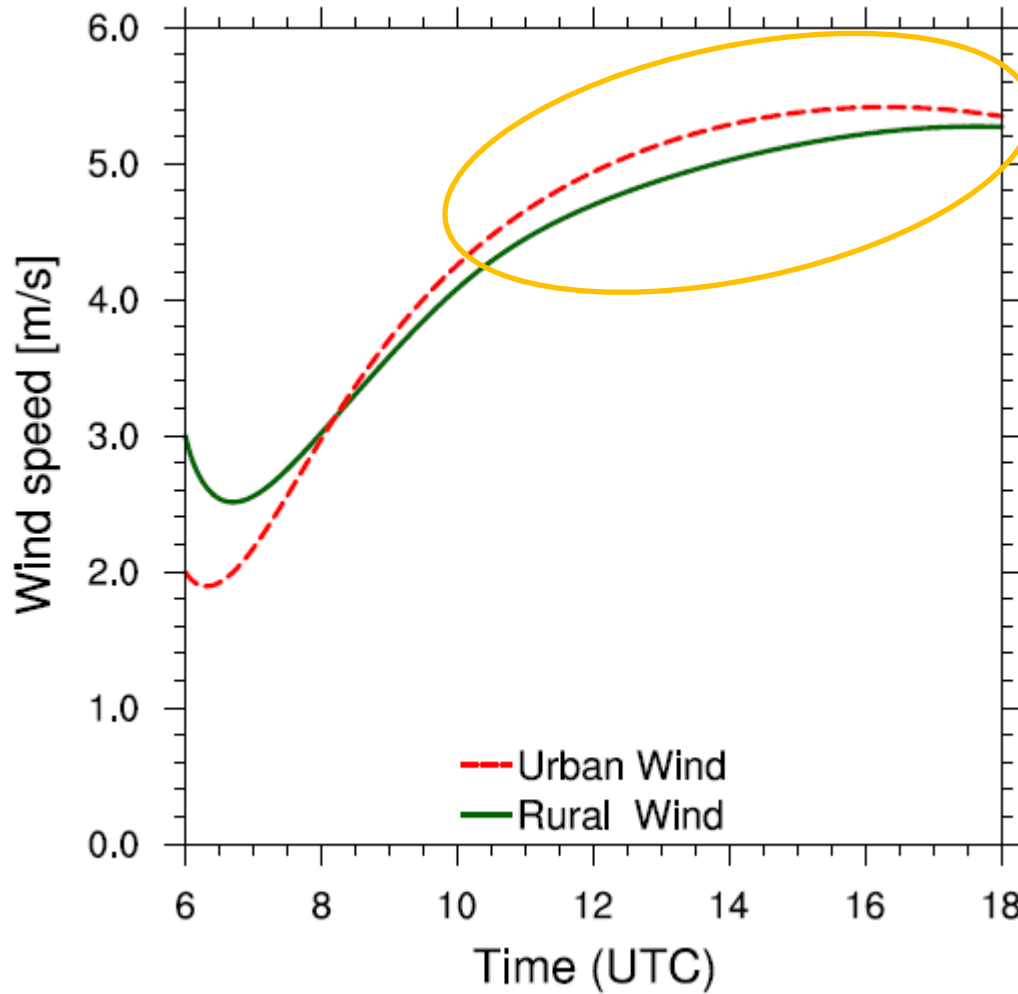


Use bulk model equations for separate urban and rural column

$$\frac{dU}{dt} = f(V - V_{geo}) + \frac{1}{h}(\overline{u'w'_s} - \overline{u'w'_h})$$

$$\frac{dV}{dt} = -f(U - U_{geo}) + \frac{1}{h}(\overline{v'w'_s} - \overline{v'w'_h})$$

Time evolution in bulk model

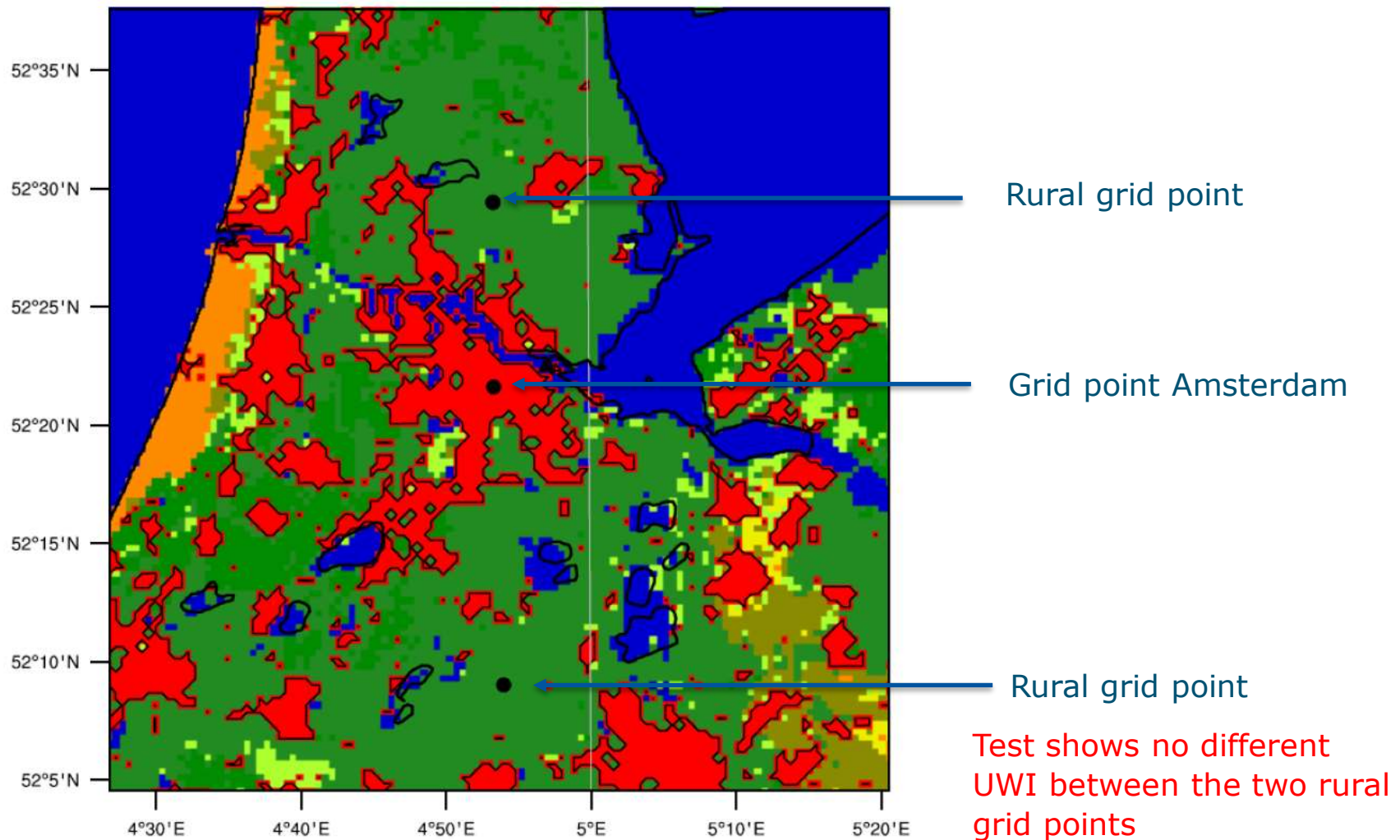


Urban wind island (UWI)

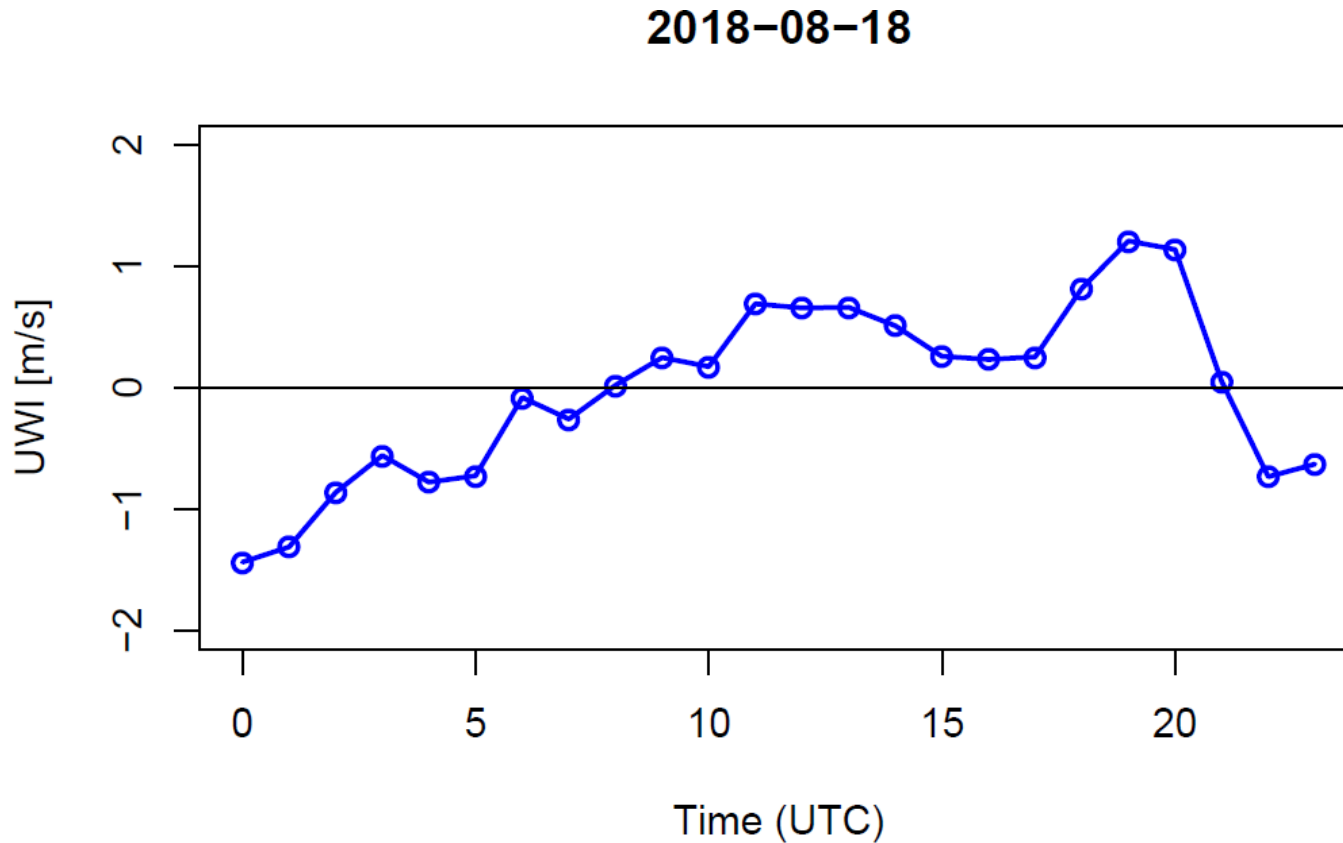
Ideal model,
Ideal conditions,

But what happens
in a more realistic
3D world?

Two summers of WRF at 500 m around Amsterdam (Rainy days excluded).



Urban wind island in sunny and clear sky



Urban wind island also present in 3D WRF



Hourly urban wind island stats

Results: wide tails show rather high UWI values

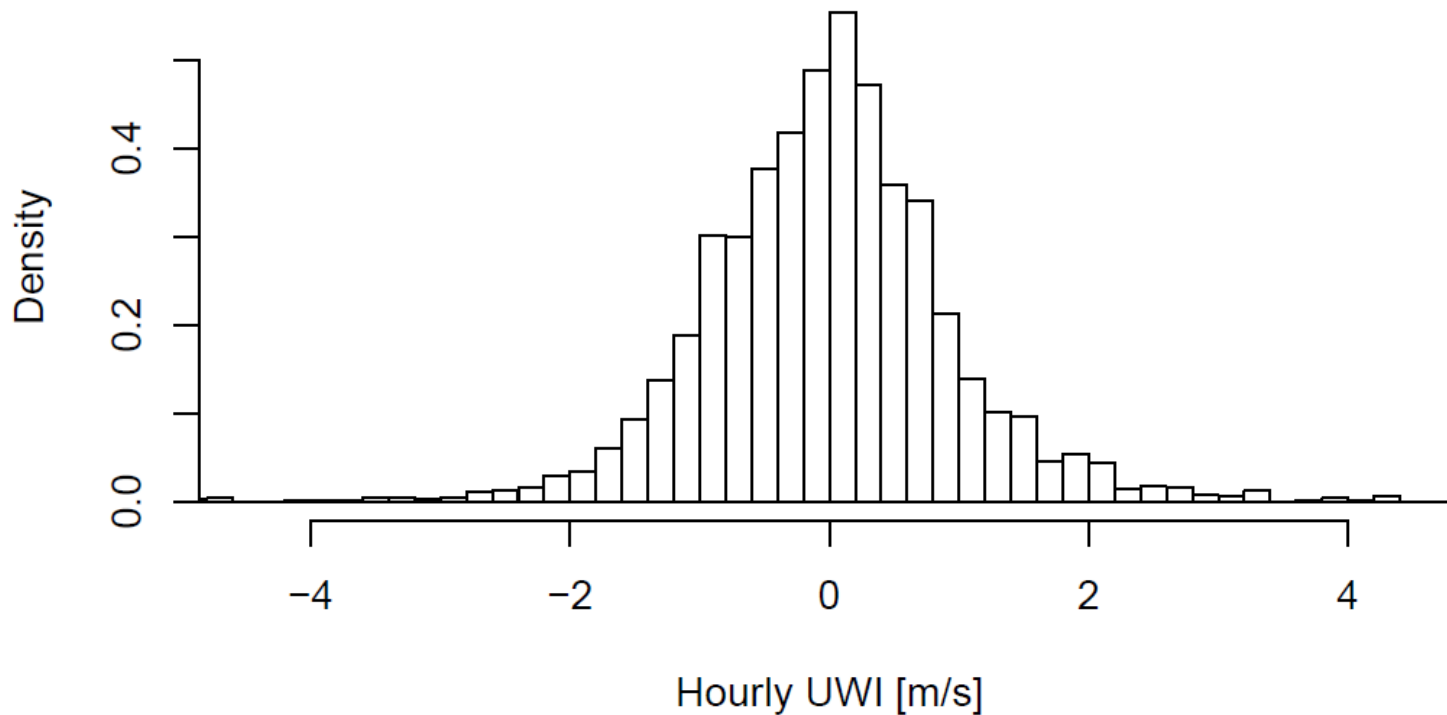
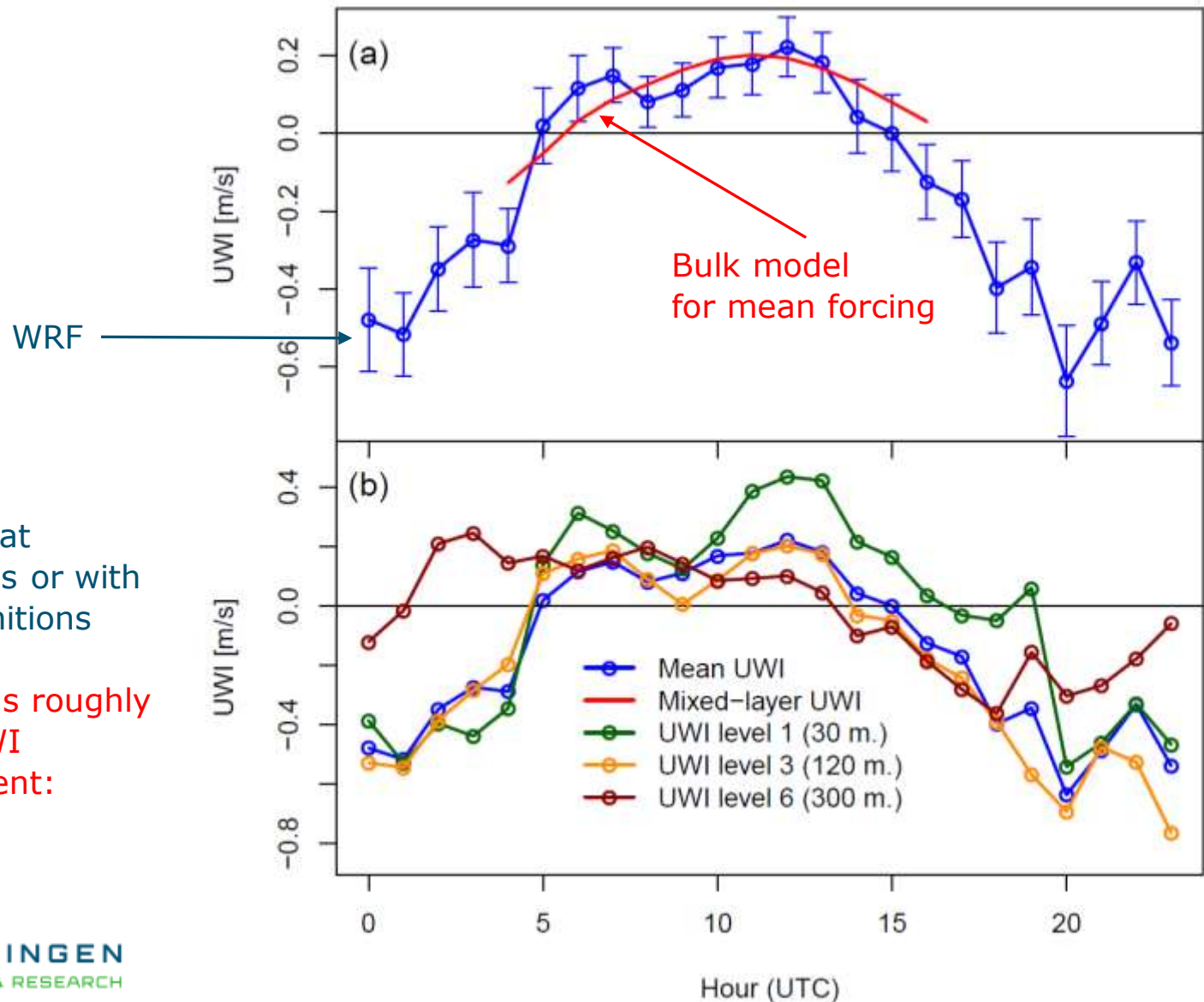


Figure 6.3.1: Histogram of the modelled hourly UWI over Amsterdam over 2017 and 2018. Each bin is 0.2 m/s, totalling 4135 hours.

Climatology of UWI diurnal cycle

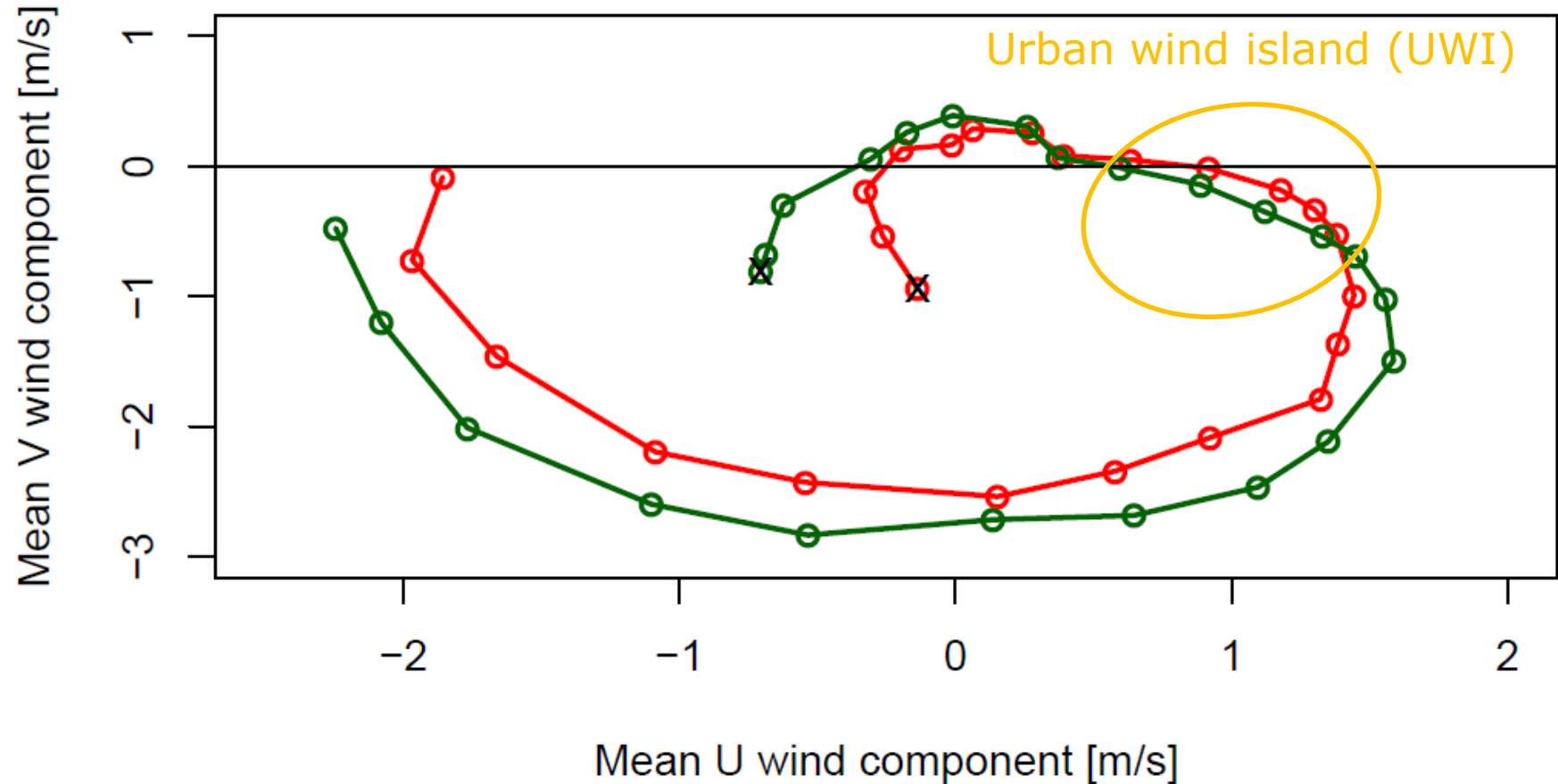
Diurnal cycle



Diurnal cycle at different levels or with different definitions

Signal remains roughly the same, UWI remains present: robots result

Mean hodograph of UWI from WRF



UWI diurnal cycle for days with high UWI in evening

Two characteristic moments for UWI maximum

1. Around 10 UTC (as in Droste 2018)
2. After sunset: later decoupling of turbulence in urban boundary layer than rural boundary layer.

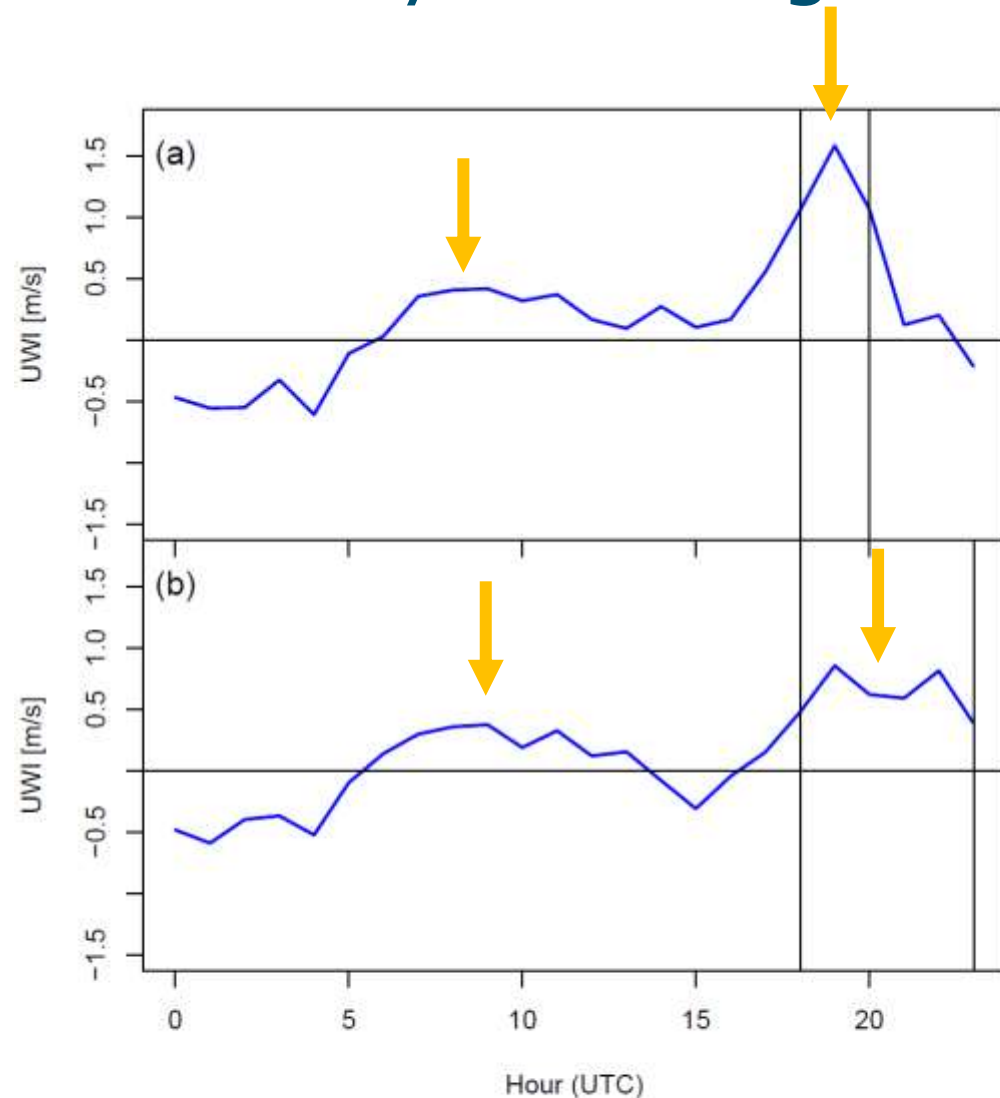


Figure 6.3.5: Hourly UWI for days that have the maximum daily UWI occur between 18:00 UTC and 20:00 UTC (a) or 18:00 UTC and 23:00 UTC (b). Vertical black lines denote the timeframe where the maximum daily UWI occurs, which coincides roughly with the evening transition of the PBL.

Similar mechanism as in Droste 2018?

Large UWI occurs for urban PBL > rural PBL in early morning

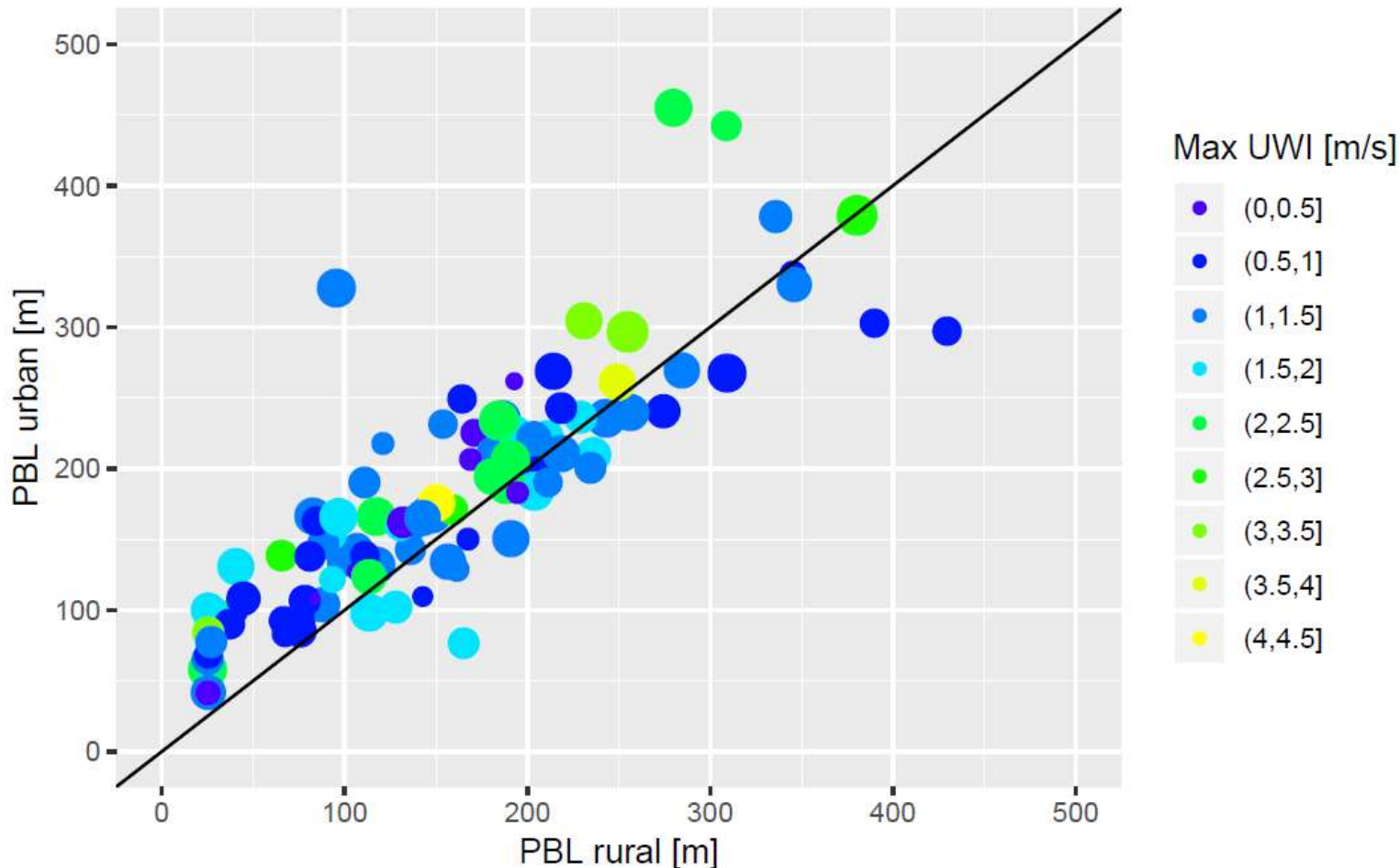


Figure 6.3.6: Modelled boundary-layer depth (rural and urban on x and y axis, respectively) at 4:00 UTC (6:00 LT) related to the modelled maximum daily UWI (colours). The size of the points is an indication of the duration of a positive UWI episode of that day: consecutive positive UWI values.

Conclusions

- The urban wind island effect is an episode in the diurnal cycle when the boundary-layer mean urban wind speed exceeds the rural wind speed.
- High resolution WRF simulations over Amsterdam for two summers reveal the urban wind island also exists in a 3D model context.