Applications of urban observations

Illustrations through the Amsterdam Atmospheric Monitoring Supersite

Gert-Jan Steeneveld, with contributions from Bert Heusinkveld, Oscar Hartogensis, Sytse Koopmans, Aristofanis Tsiringakis, Reinder Ronda, Sophie van der Horst, Luuk Bersee, Lucas Hulsman, Clara Keuken, Fidessa Zantinge ...

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AMS Amsterdam Institute for Advanced Metropolitan Solutions

FAIRNESS

netherlands eScience center

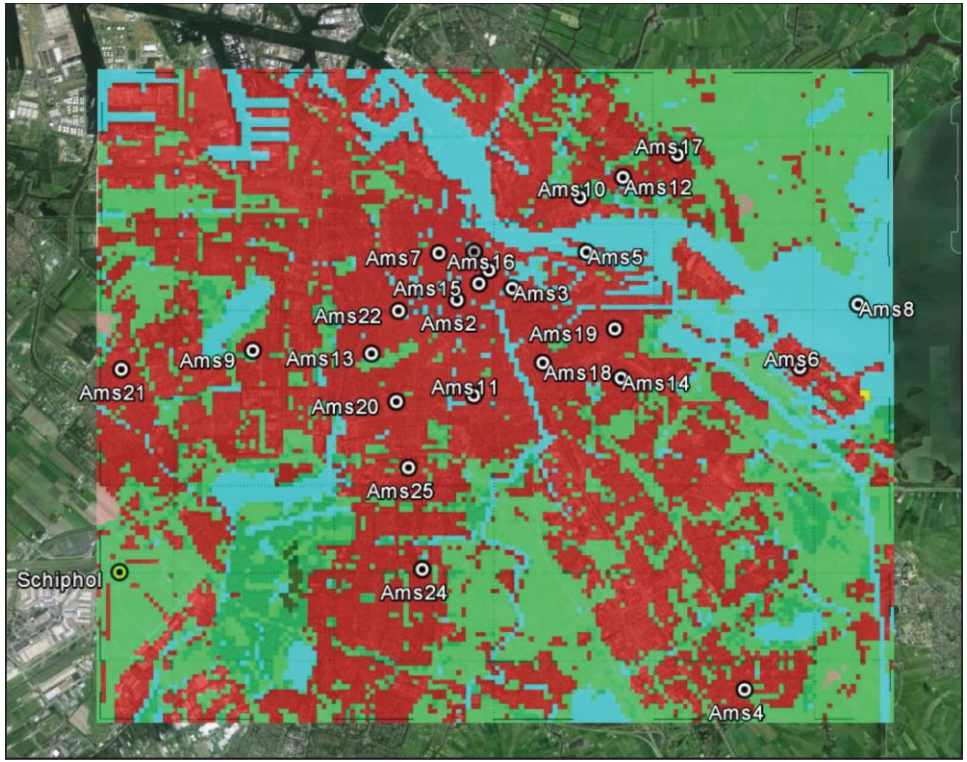
Ruisdael observatory

Gemeente Amsterdam

Content

1. About the network + extreme weather
2. Winter hardiness maps
3. HR Weather forecasting and data assimilation
4. Estimating fluxes from network data

1. Amsterdam Atmospheric Monitoring Supersite



24 stations measuring:
Temperature,
Spec Humidity
Wind speed and variability

Extended by (summer 2017):
Flux measurements of heat, water vapour, methane and CO2

Scintillometer (H, LE)
Radiation balance

Since 3 weeks: precipitation and black globe temp

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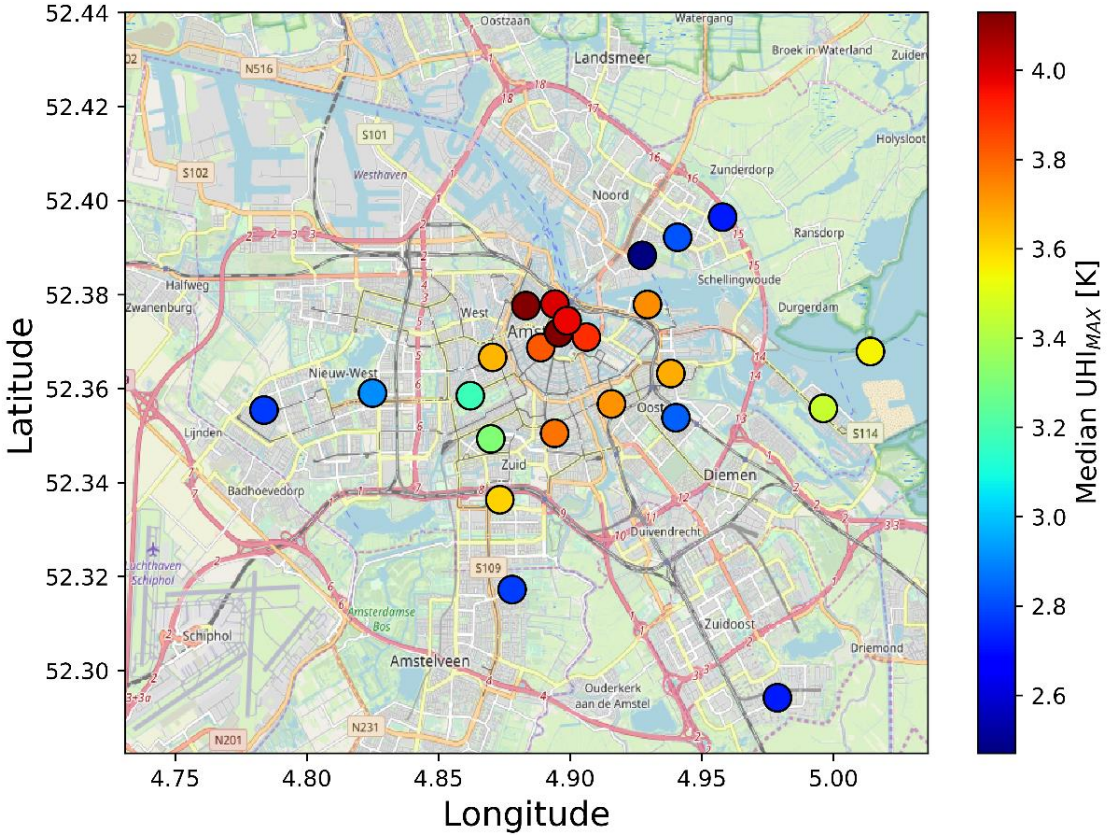
Ronda, R.J., G.J. Steeneveld, B.G. Heusinkveld, J.J. Attema, and A.A.M Holtslag, 2017: Urban fine-scale forecasting reveals weather conditions with unprecedented detail, Bulletin of the American Meteorological Soc., **98**, 2675–2688.

The urban heat island in summer



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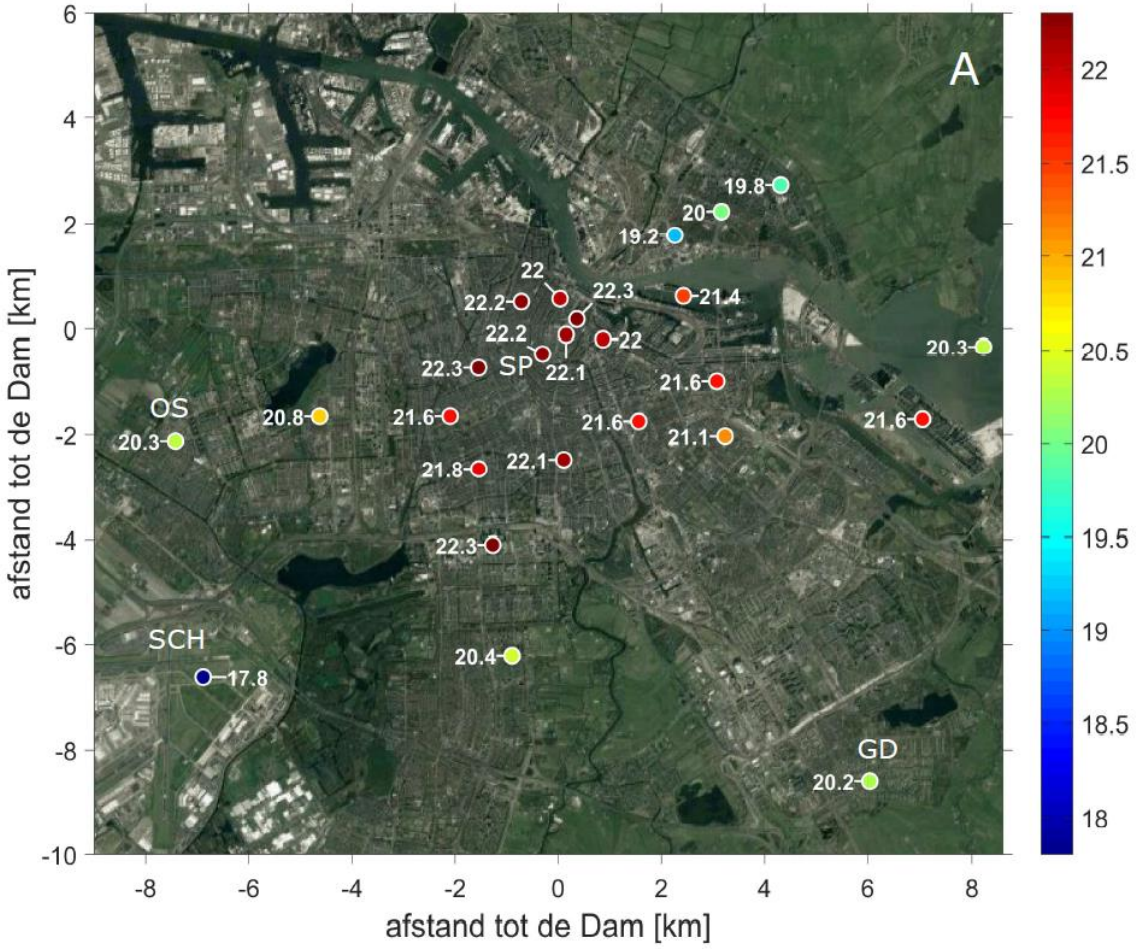
Heat wave 23-25 July 2019

Minimum temperatures 25 Jul 2019



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Heat wave 23-25 July 2019

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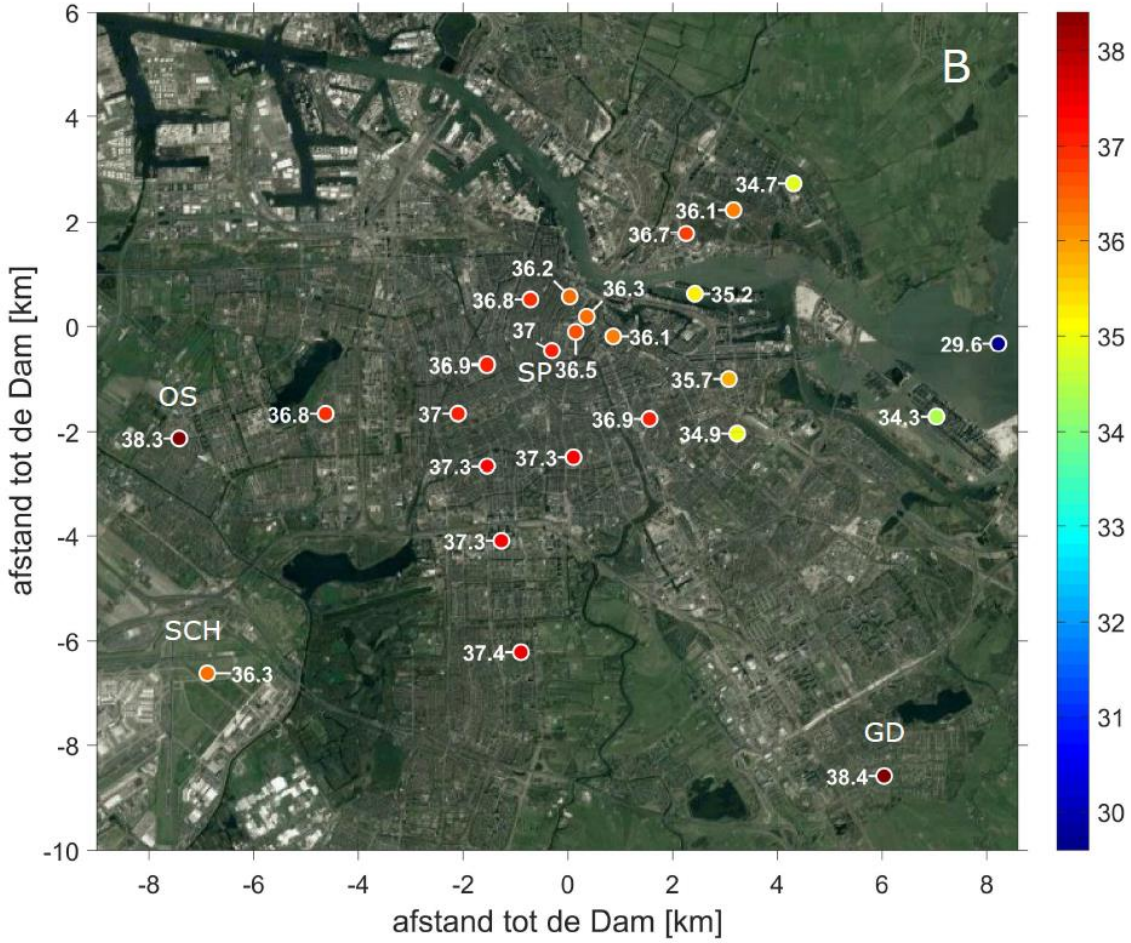

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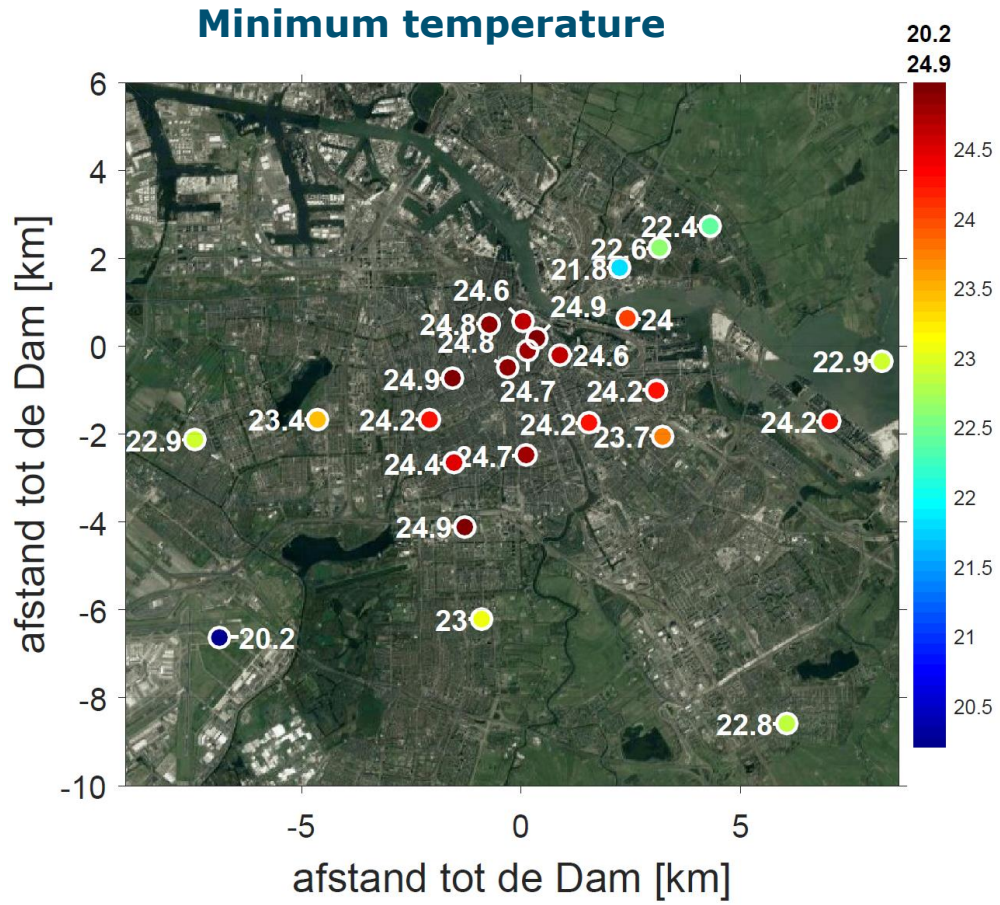
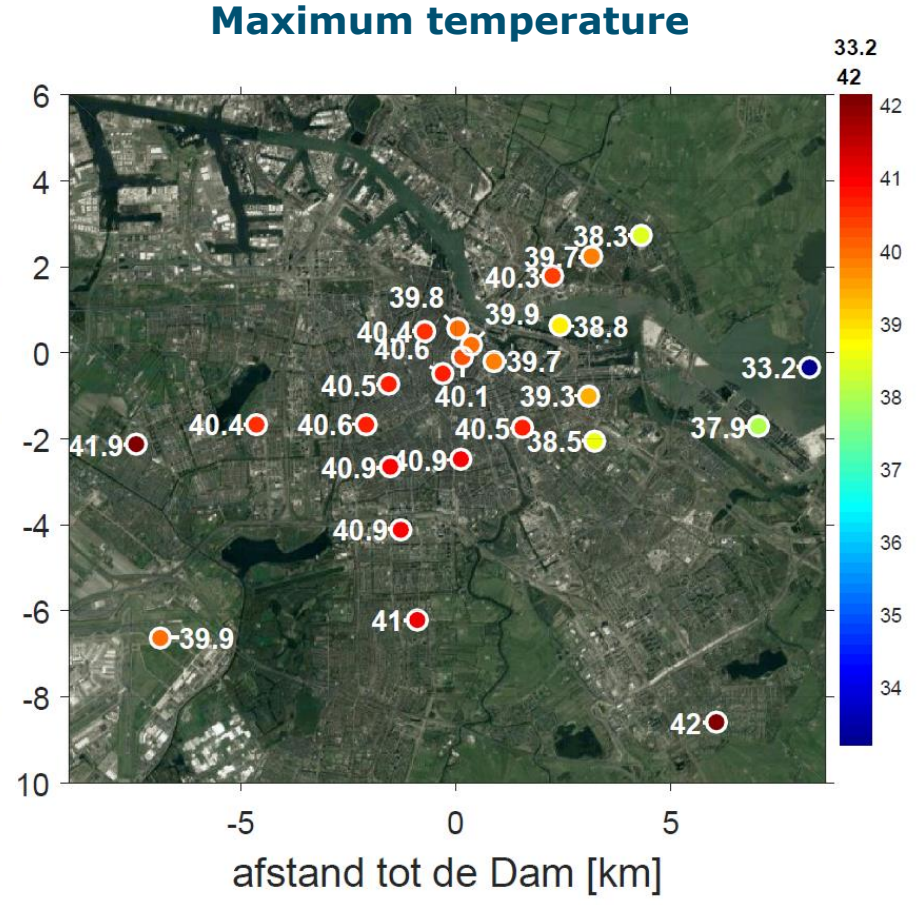
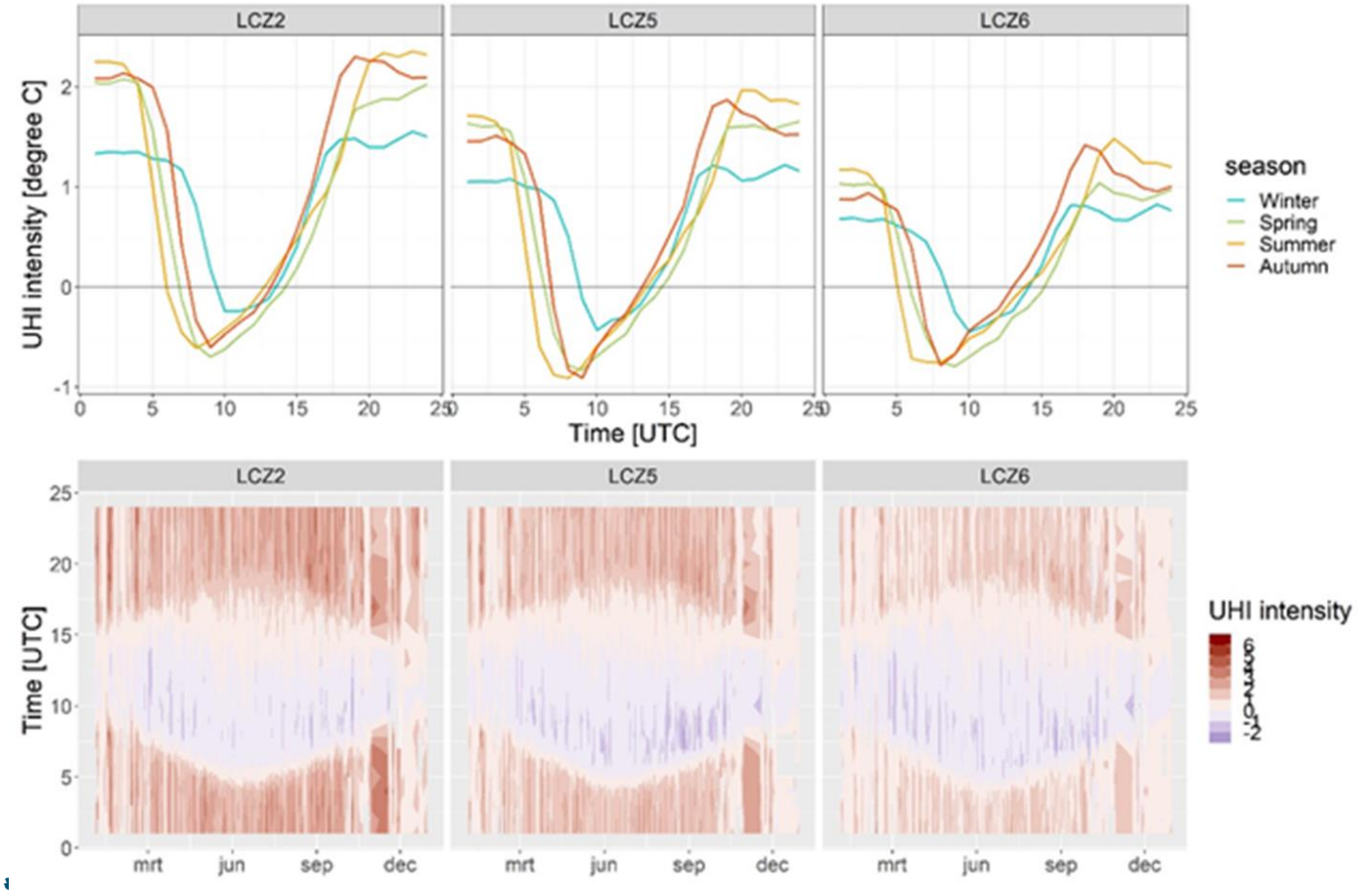
How does the same heatwave feel in 2050 in future climate (KNMI WH-scenario)?



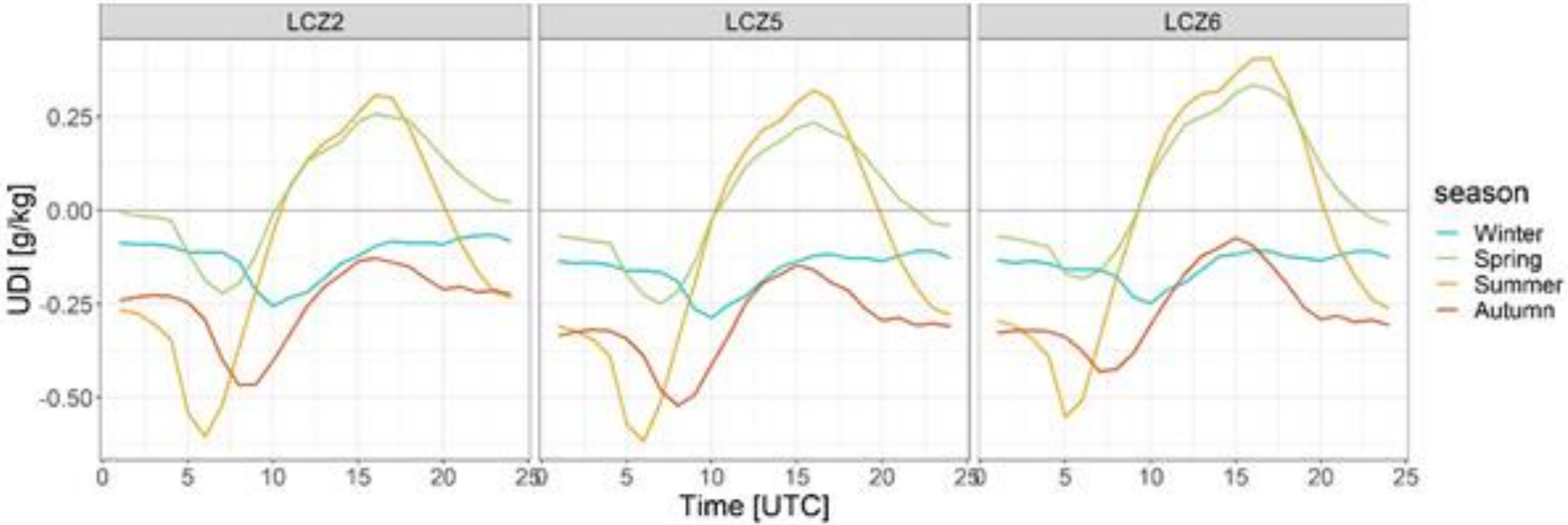


Typical UHI behaviour



Keuken, 2022

Typical Urban Dry Island behaviour. Still a mistery... (UDI=q_{city}-q_{rural})



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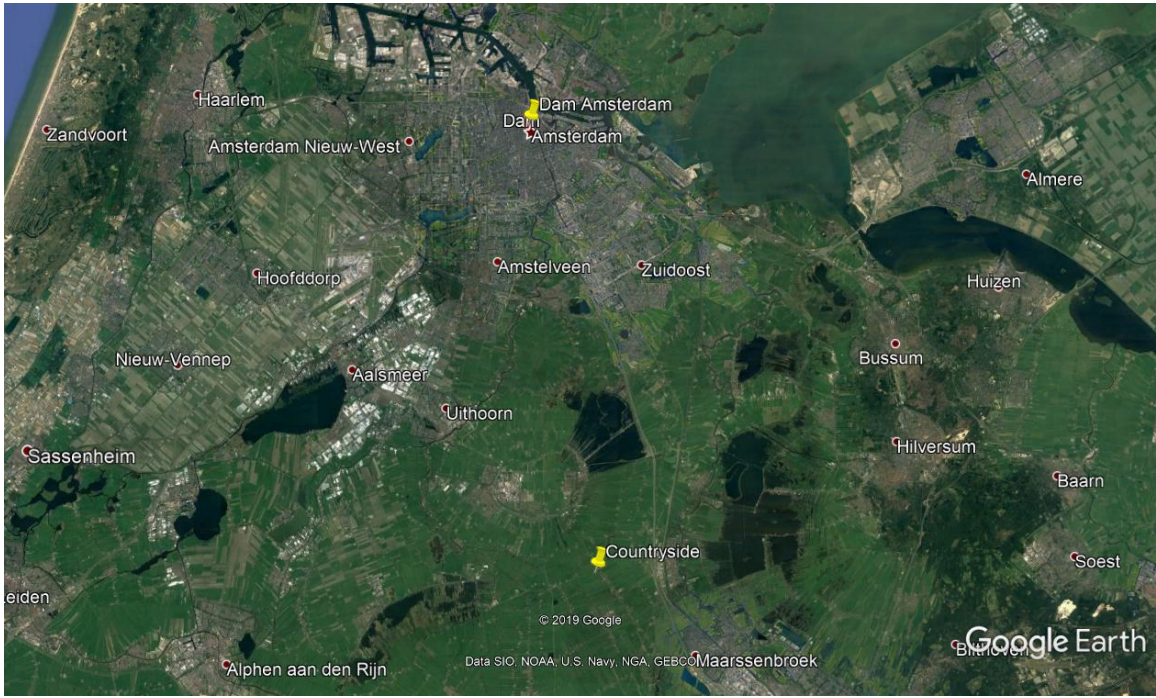
Keuken, 2022

Intensive field campaign: Balloons, network, sodar 23-25 July 2019

Balloon launches every 2 h 23&24 Jul



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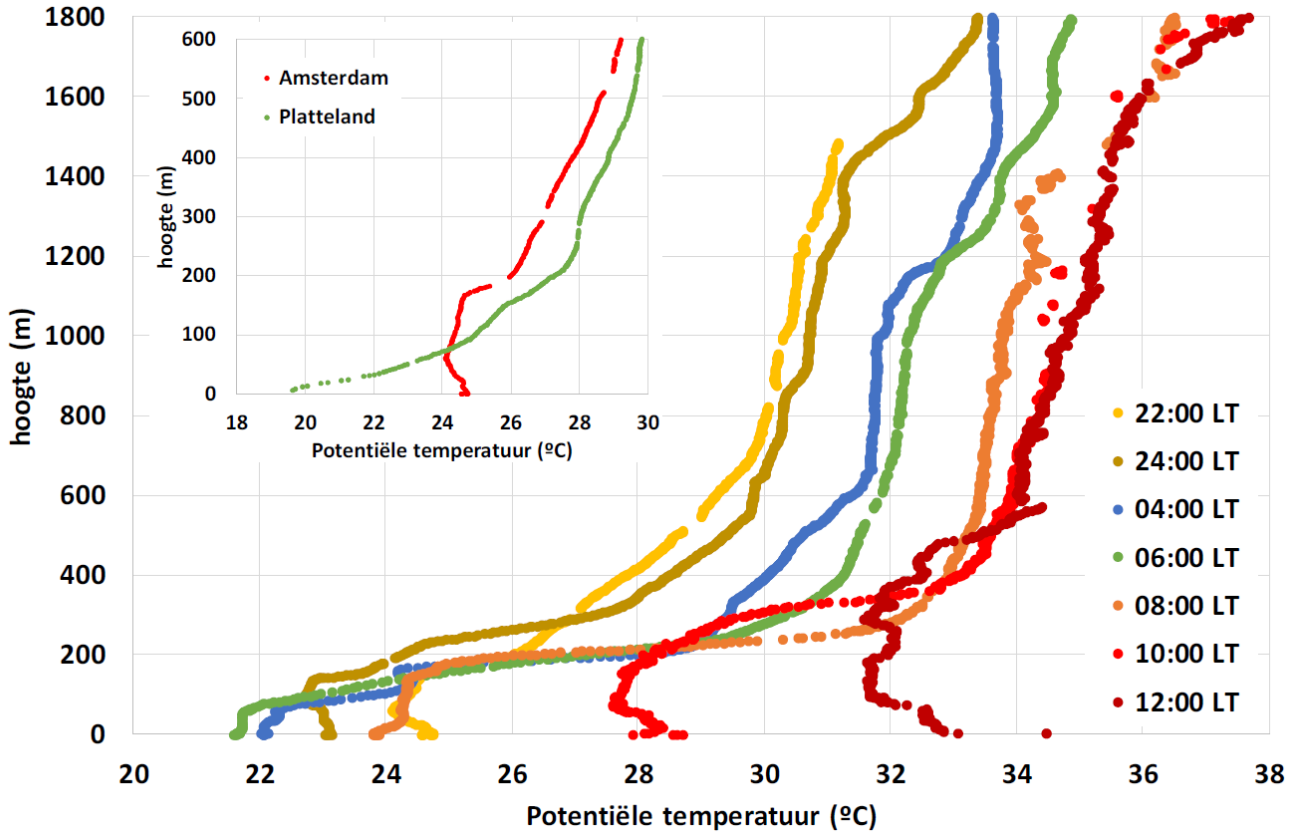
Intensive field campaign: Balloons, network, sodar 23-25 July 2019



Balloon launches
23&24 Jul 2019

Steeneveld et al., 2019

2. Winter hardiness zones

Motivation: ecosystem services by urban trees (shade & evapotranspiration)

Which tree species to select in a changing climate?

Winterhardiness is a criterion (latest frost so far did not change)

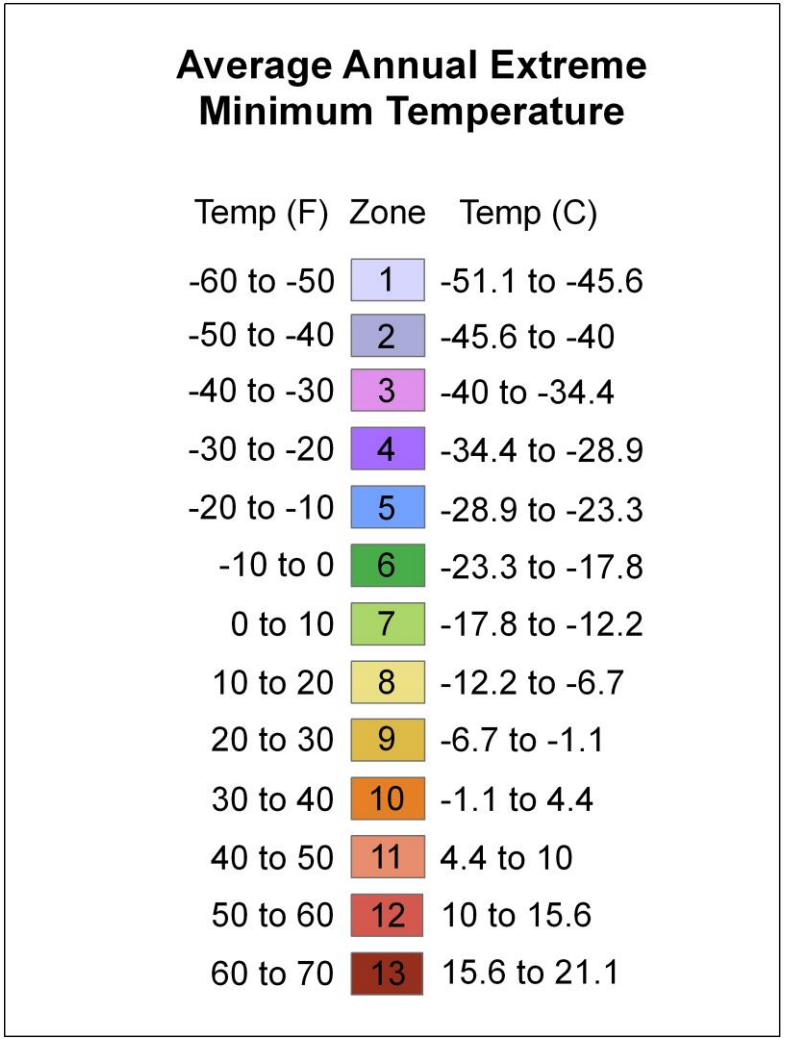
Most recent winterhardiness maps from 1951-1980 (and handdrawn)
How to include cities?

Winter hardiness zones

How defined: 30-mean of ***yearly*** minimum temperature (USDA)

Only on rural AWS data

Input: ECA-D dataset



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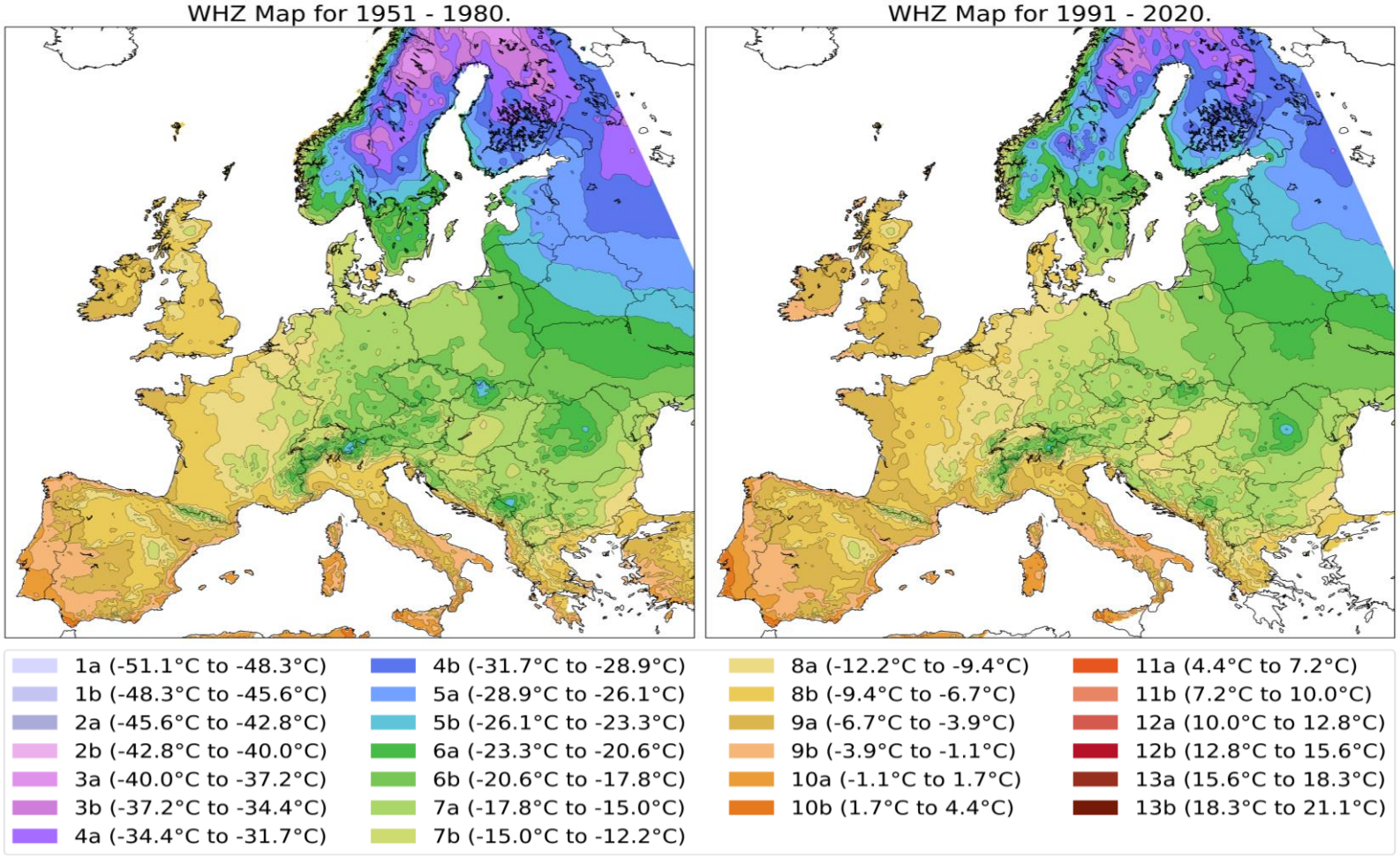
Winter hardiness zones



Hulsman et al., in prep

Winter hardiness zones: transpose rural to urban minimum temp.

Derive projection for yearly mininmum temperature from a rural site to the city with the help of urban networks in *Amsterdam, Rotterdam, Novi Sad, Helsinki, Ghent, and Berlin*

$$TN_{URB} = a + SVF * b + PSF * c + QQ * d + TN_{bg} * e + DTR * f + TN_{bg,pd} * g + DTR_{pd} * h$$

From prev day

SVF: Sky view factor
Q: Daily mean global radiation
DTR: Diurnal temperature range
PSF: Pervious surface fraction
TN_{bg} : Daily minimum rural temperature

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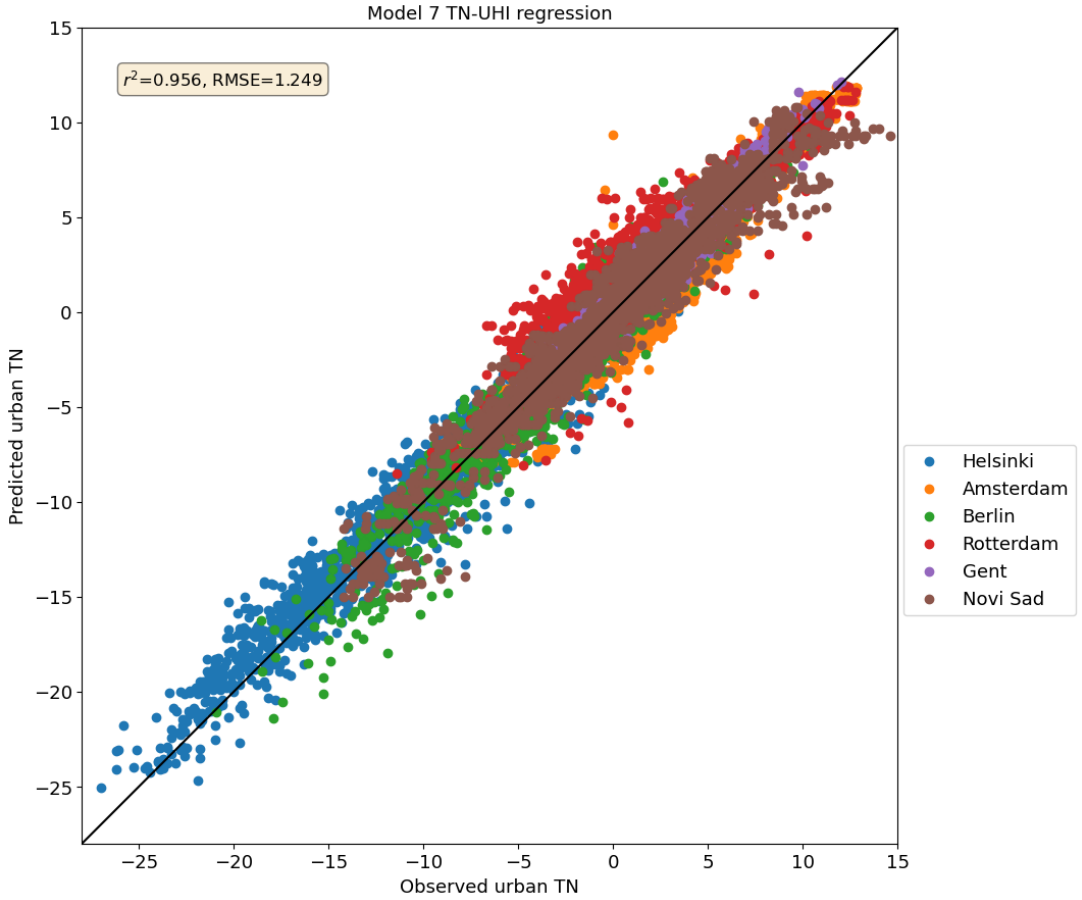
Winter hardiness zones



Hulsman et al., in prep)

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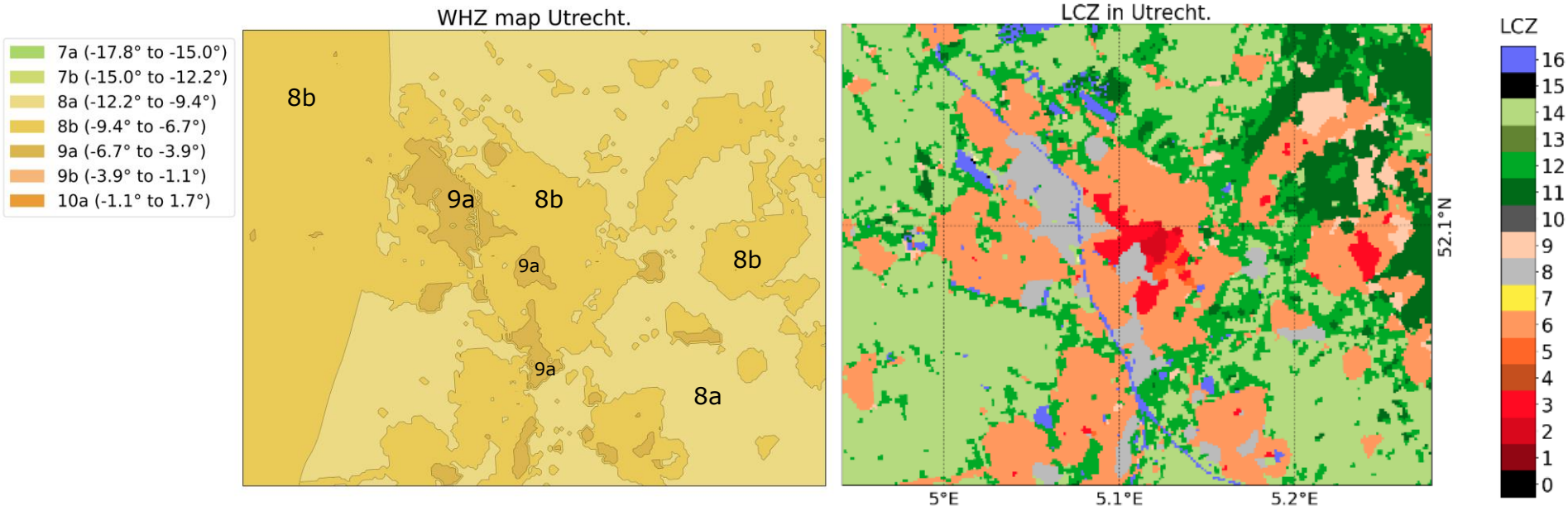
Winter hardiness in cities?



Cities are 1-2 hardiness zones "higher" than the countryside.

Implications for tree species selection: less frost sensitive species allowed

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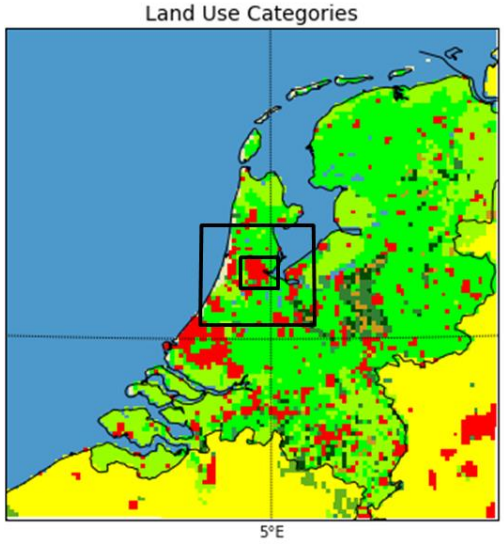
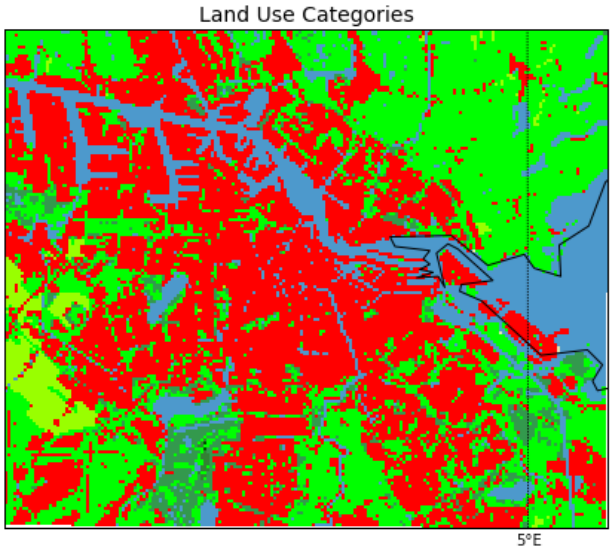
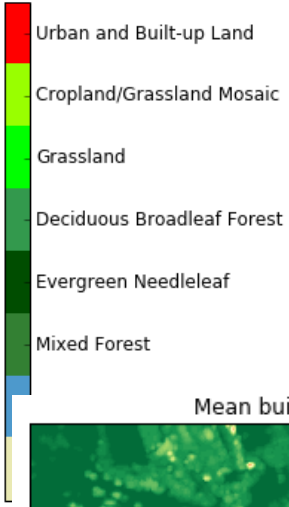
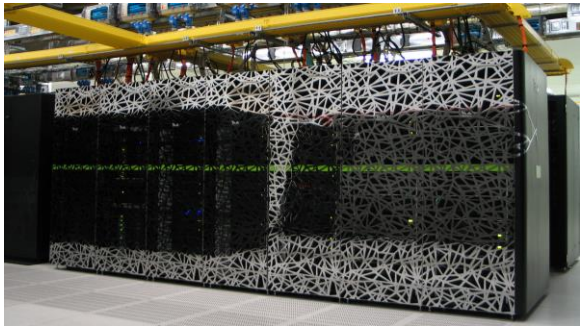
Hulsman et al., in prep

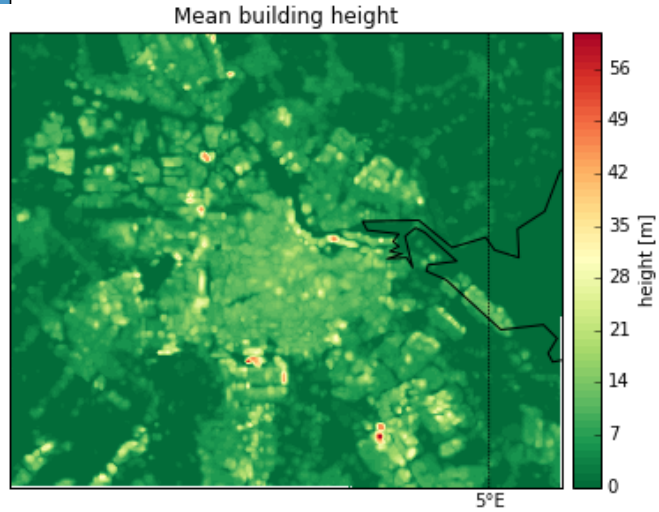
Numerical Weather forecasting models for the urban environment











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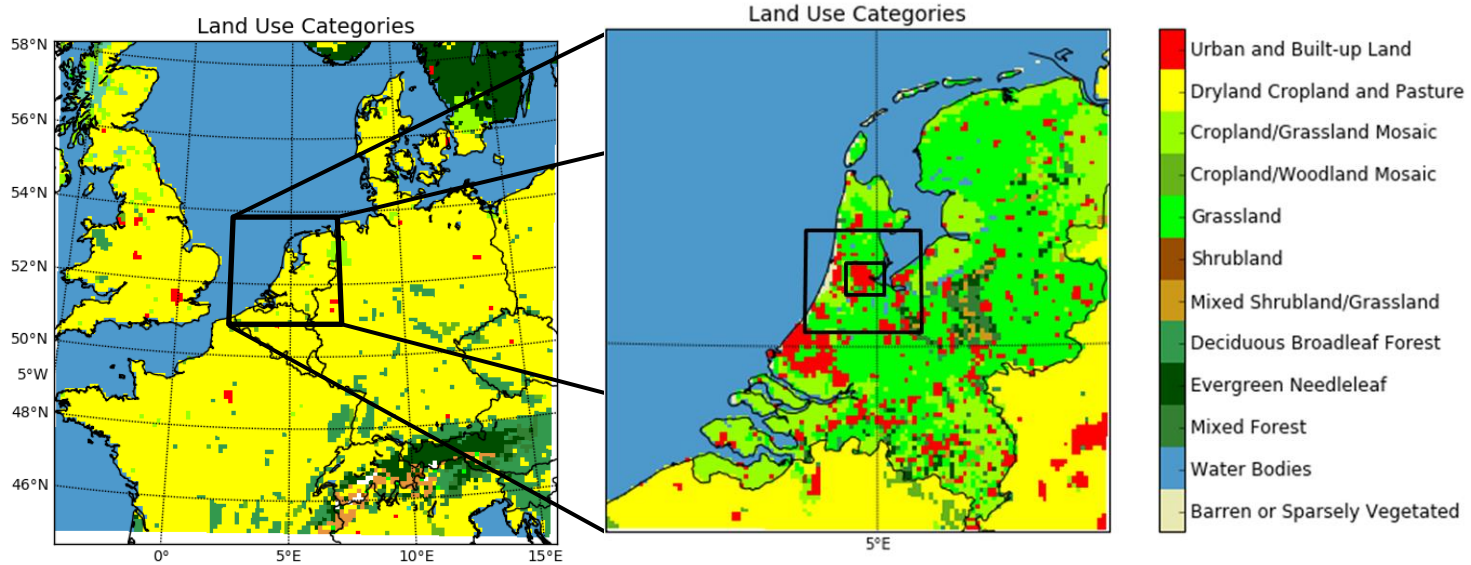
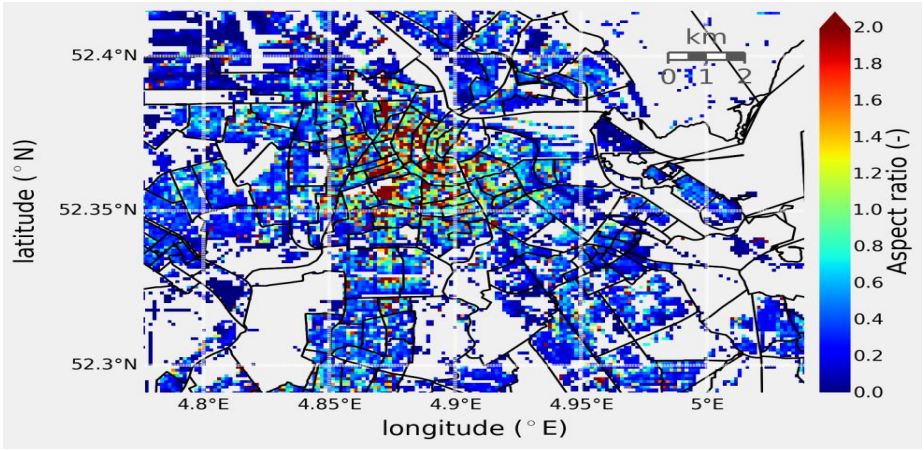
Domains WRF model

- 4 Domains with 12500:2500:500:100 m resolutions
- Use ECMWF boundaries every 6 hours, 0.5⁰ x 0.5⁰

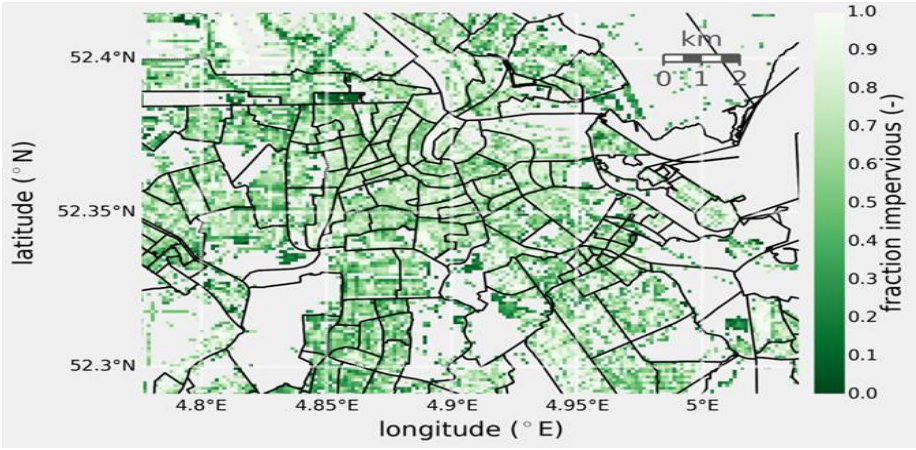


Urban morphology

Aspect ratio (H/W)



Impervious fraction



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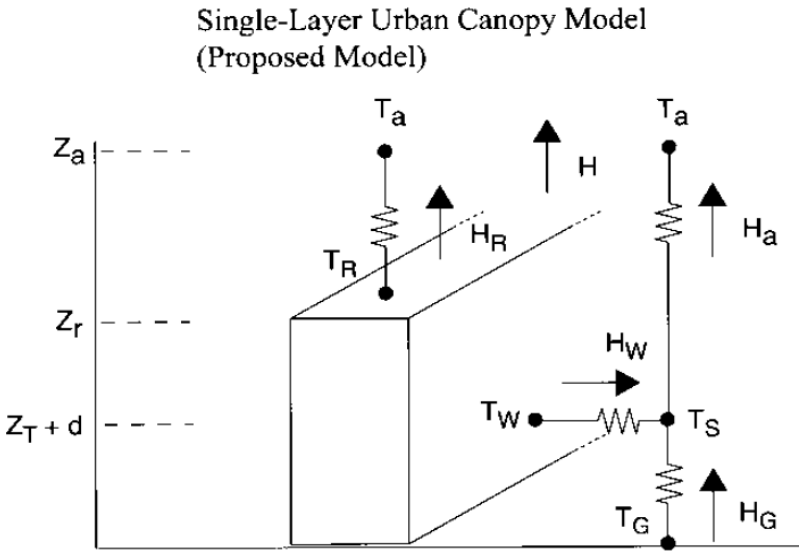
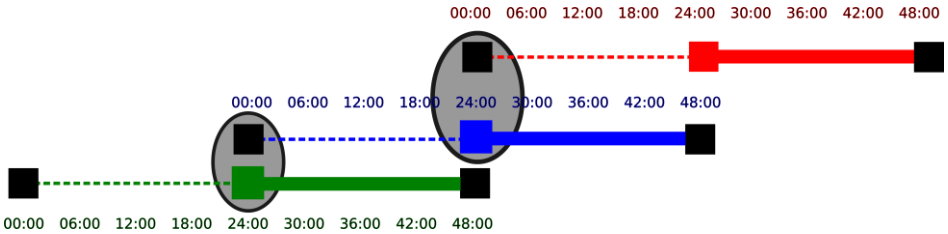
How does WRF know the city?





Kusaka, 2001

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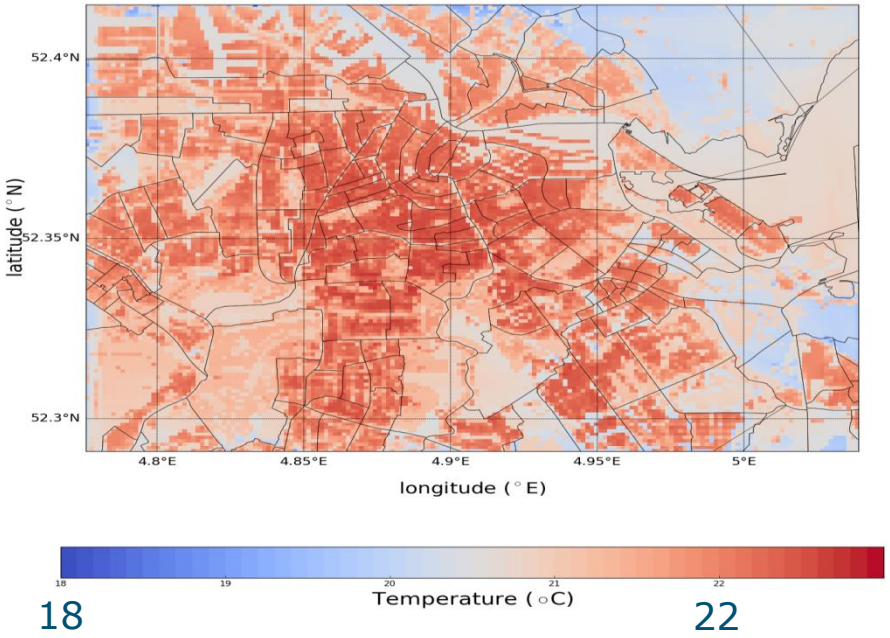
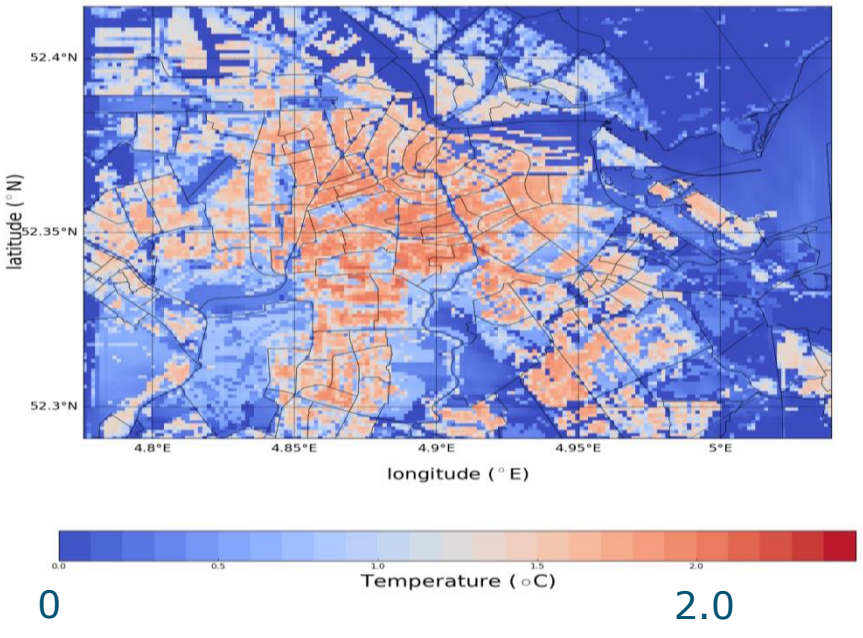
Evening temperature and UHI for JJA 2015 averaged

Temperature



18 22

UHI



0 2.0

Weather Research and Forecasting model at 100 m resolution for a complete summer

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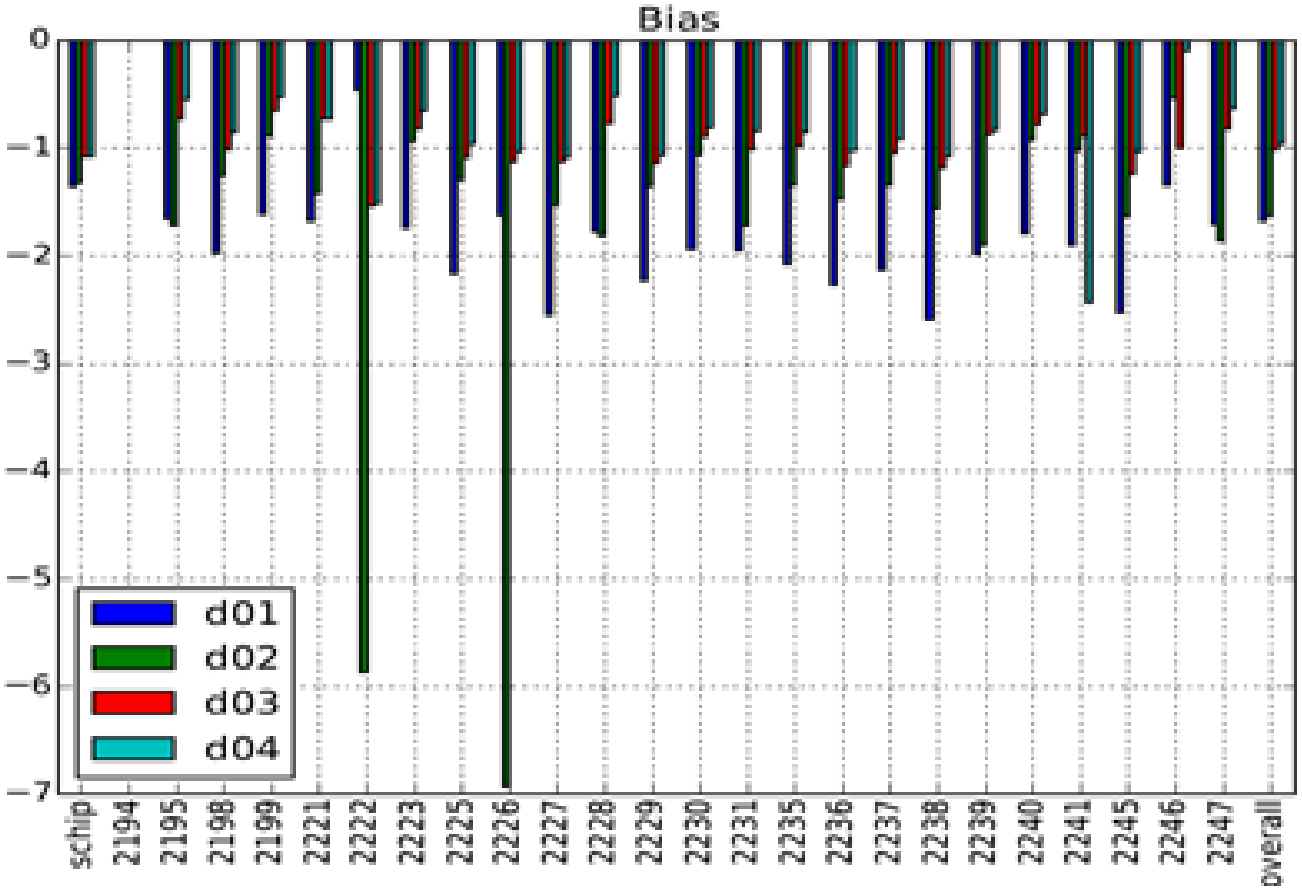
Ronda et al 2017

Does it help?


Bias
0
−1
−2
−3
−4
−5
−6
−7
d01
d02
d03
d04
schip
2194
2195
2198
2199
2221
2222
2223
2225
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2228
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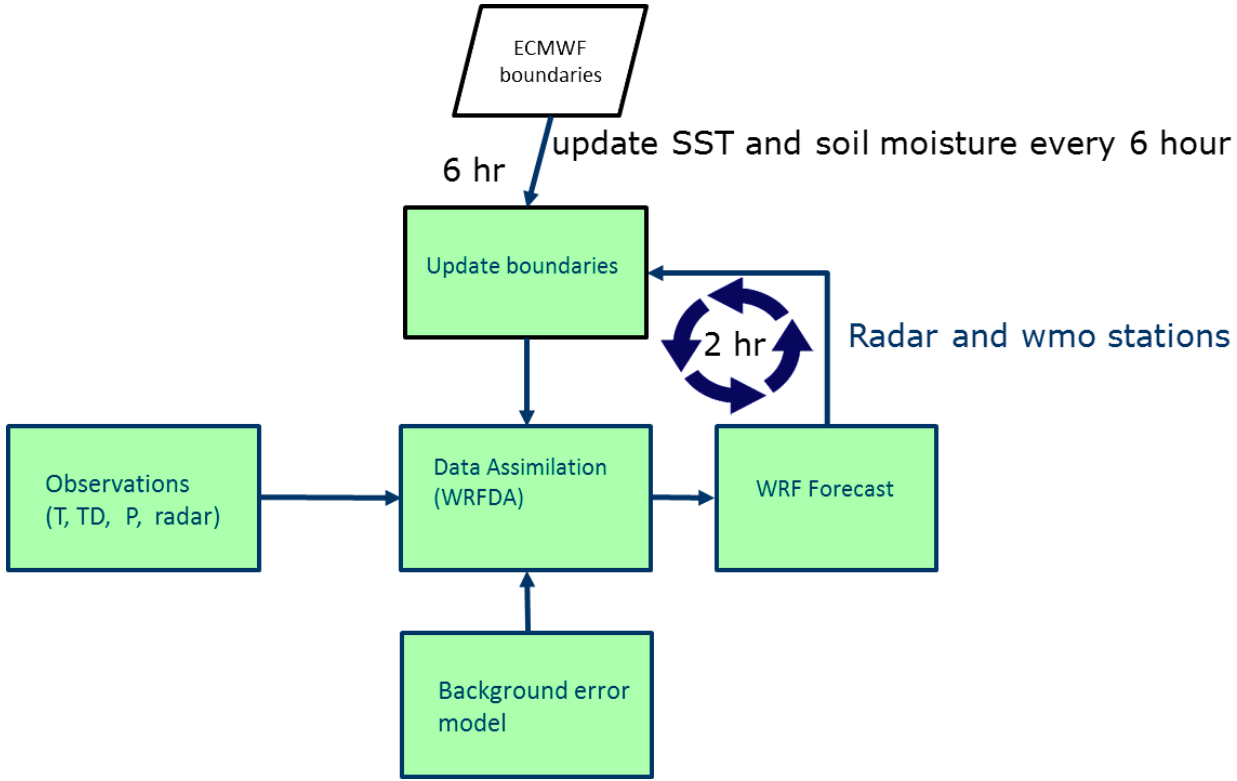
2230
2231
2235
2236
2237
2238
2239
2240
2241
2245
2246
2247
overall

3. ERA-urban: 15 y re-analysis product for Adam at 167 m

- Test model set-up with data-assimilation for Amsterdam
- 2 hourly 3D VAR with WMO data + urban observations assimilated in urban scheme.
- Assimilate:
  - WMO surface weather data
  - KNMI radars
  - Personal weather stations in city

ERA-urban: 15 y re-analysis product for Adam at 167 m



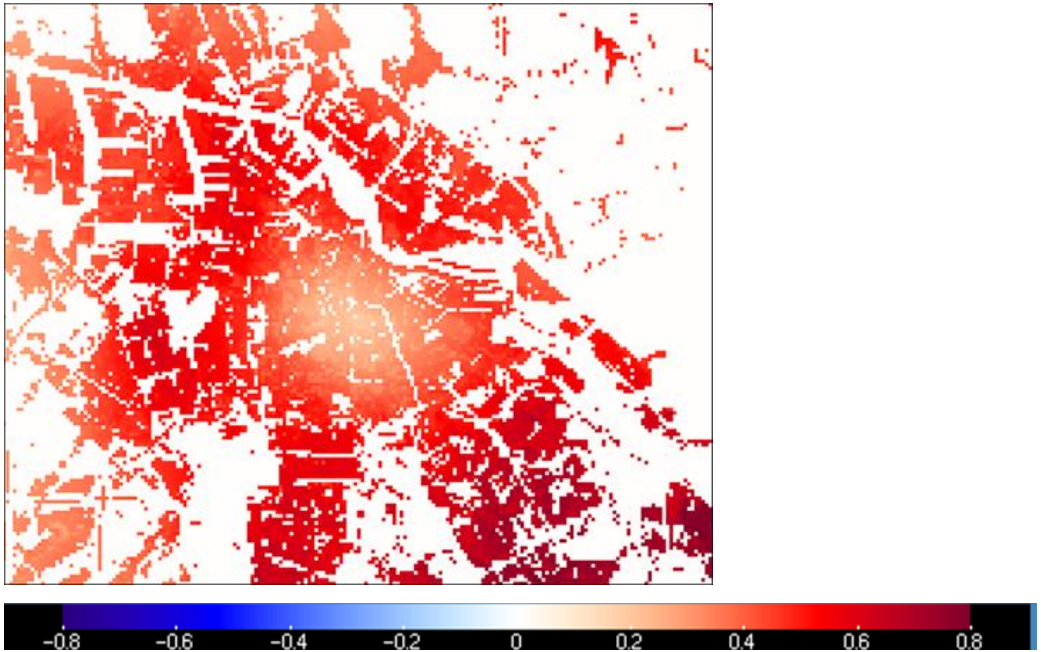
Data assimilation in urban canopy model

- Urban temperatures are nudged by applying correction on urban fabric (walls and roads). Urban fabric has storage to preserve the effect of nudging between 2 cycles.

- $$Correction\ of\ T2m = \alpha * L\downarrow + \beta * U + \gamma$$

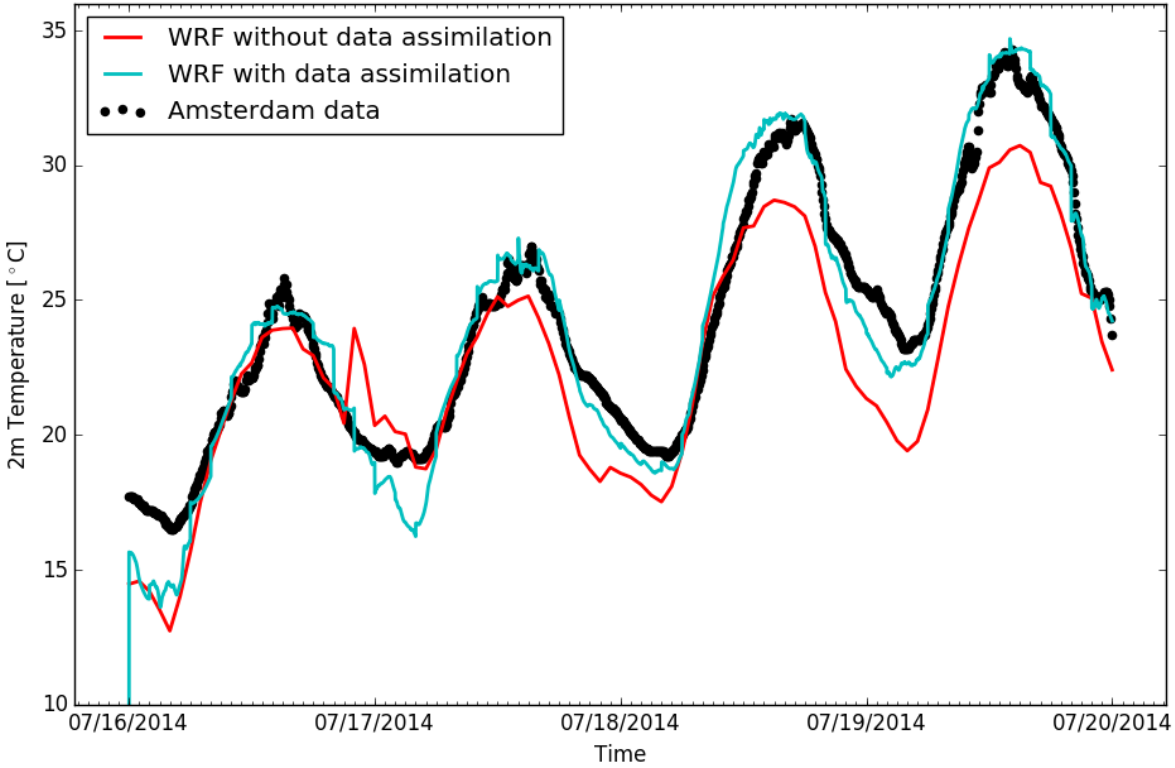
  $L\downarrow =$ *downward longwave radiation* (Wm^{-2})

  $U =$ *wind speed* (ms^{-1})



Example of outer wall temperature correction in the evening. (^{o}C)

ERA-urban: first test on cases



Koopmans et al, 2023

Example hot summer week

ERA-urban: first test on cases

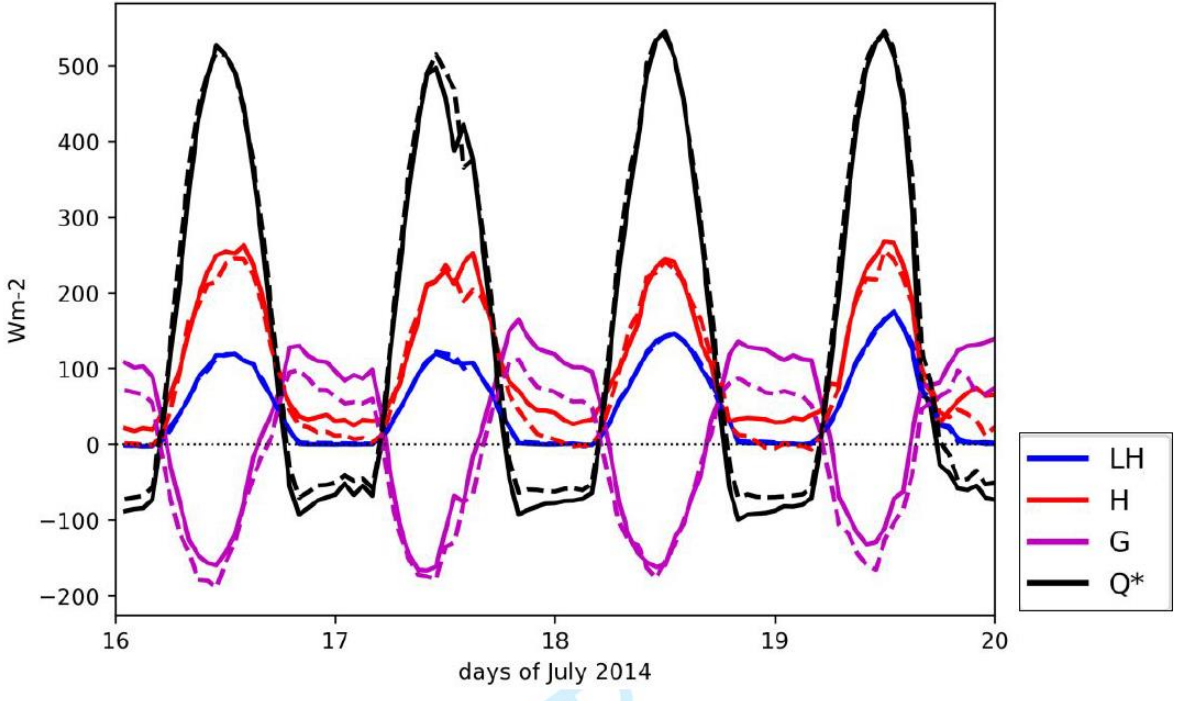
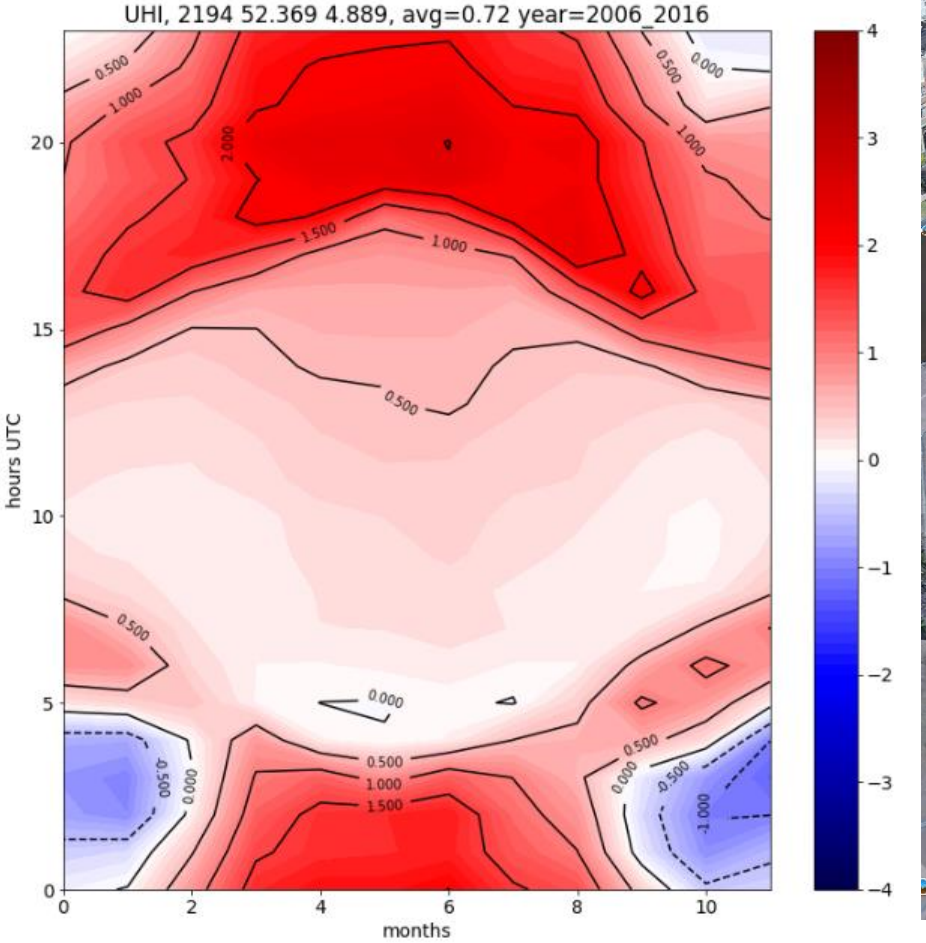


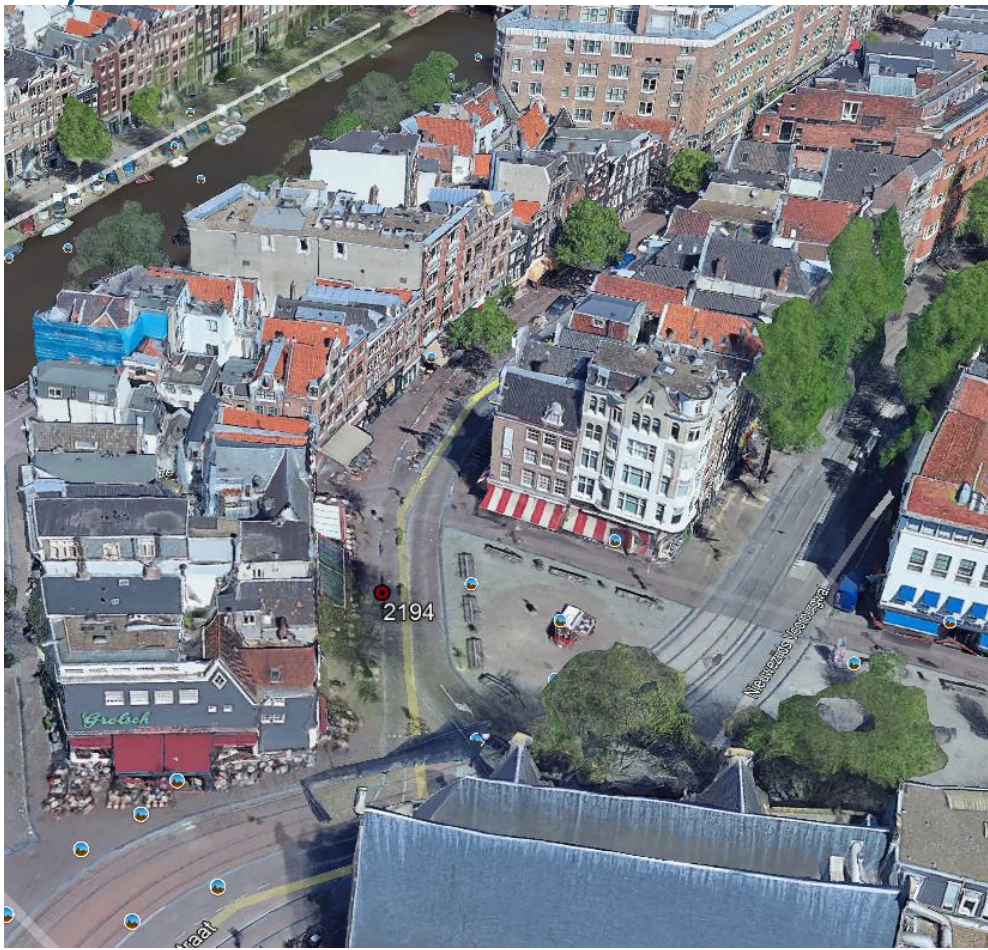
Figure 10: Modelled energy balance for URBAN-DA (full line) and RADAR-DA (dashed line) for the average of the AAMS urban stations locations, for the 4-day warm period (corresponding Figure 6). *H* denotes sensible heat flux, *LH* denotes latent heat flux, *G* denotes storage heat flux, and *Q** denotes the net radiation.

Koopmans et al, 2023

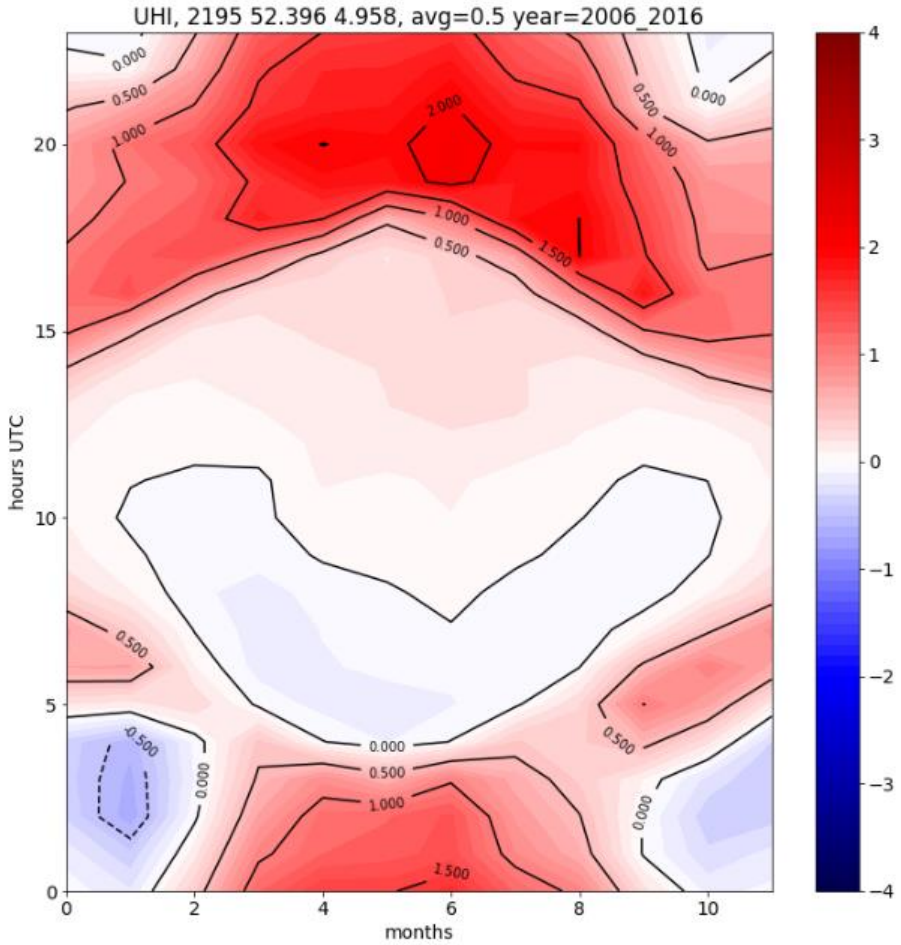
Isopleths: Middle rise (center east)

URB_FRAC = 0.84

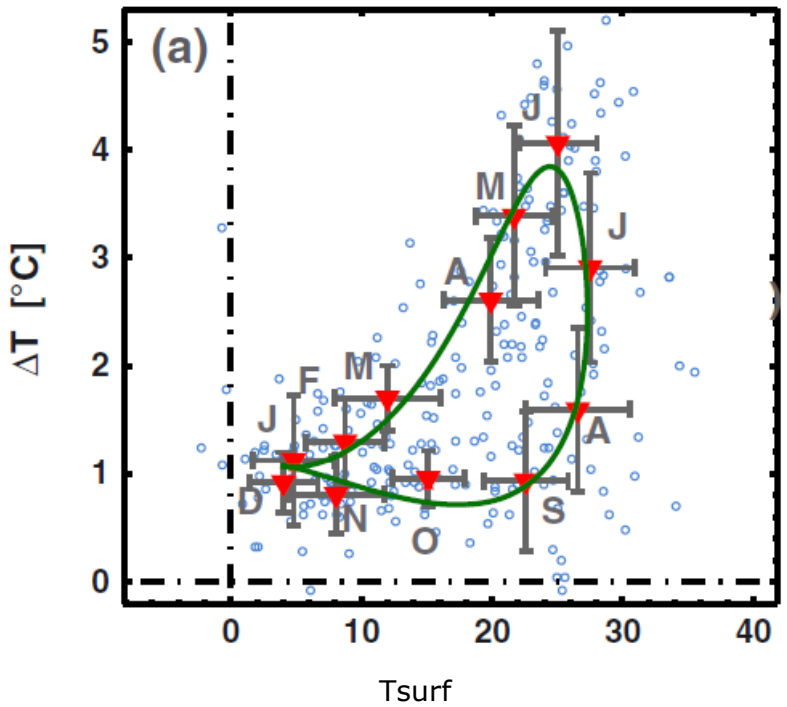




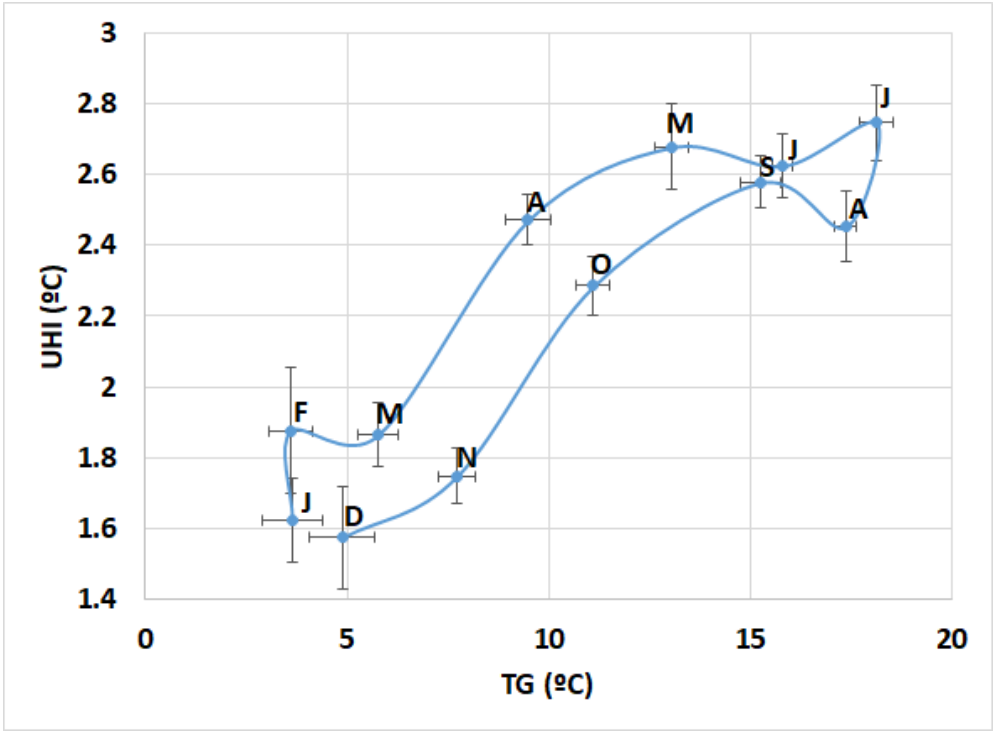
Isopleths: Low rise (A’dam NE)



Urban heat hysteresis



Obs Paris (Zhou et al, 2013)



ERA-urban results

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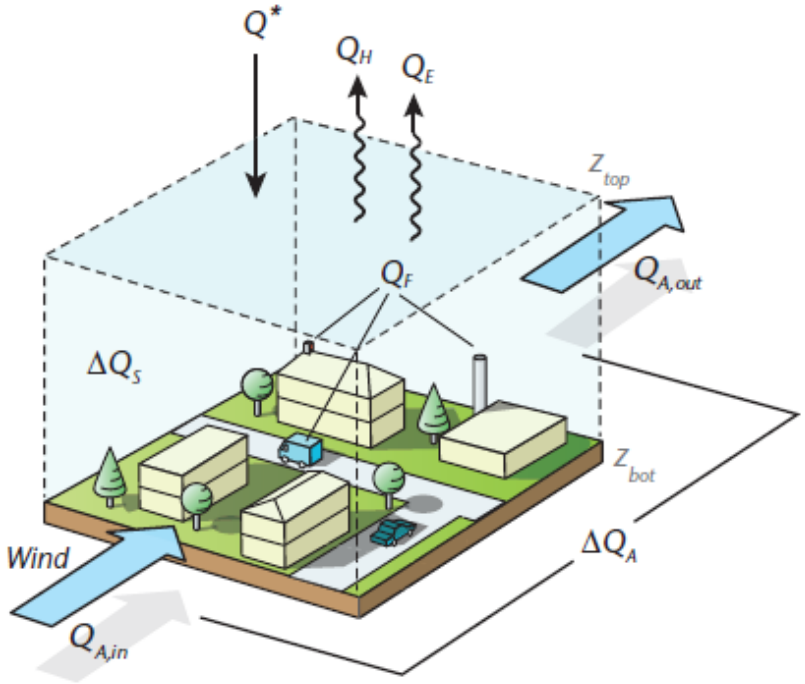
4. Estimating turbulent fluxes from urban networks



$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

Fluxes towers are expensive, cost maintenance, difficult to find suitable locations (>2-5 * building height).

Can we estimate fluxes from *urban* networks?

Works from 1980s successfully estimated fluxes from routine *rural* weather stations.

Extend to urban!

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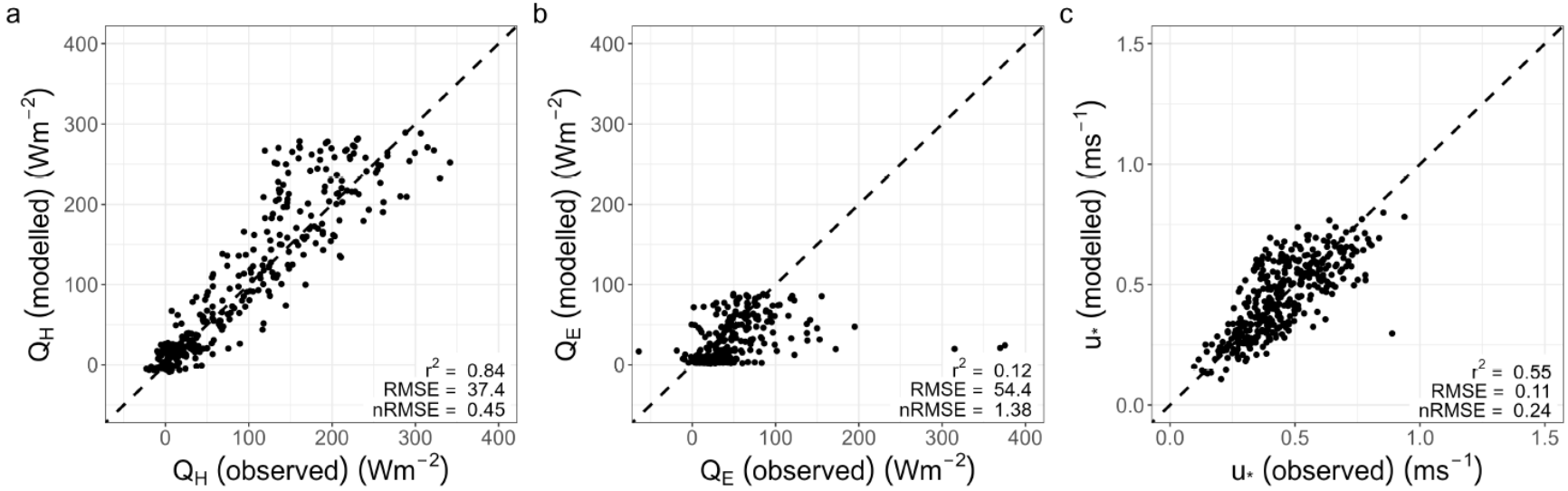
Estimating turbulent fluxes from urban networks



Wijnholds, 2023

THANK YOU

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