The relative impact of climate change and urban land-use change on the heat stress in Belgium

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KU Leuven - BELGIUM

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Modelling atmospheric composition and climate for the Belgian territory

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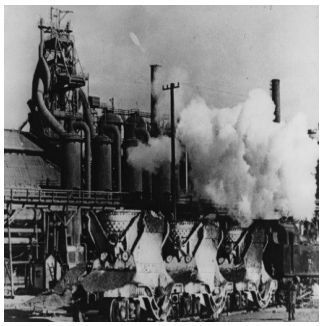
VLAAMSE MILIEUMAATSCHAPPIJ

CLM Community

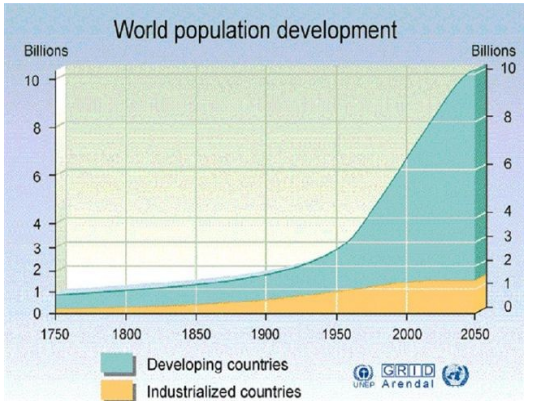
Changes in global society

- Technological and scientific advancements
- Industrialisation, trading, and business



-> growth in assets, services and population

1800 -> 2014: 1 -> 7 Billion



Climate change

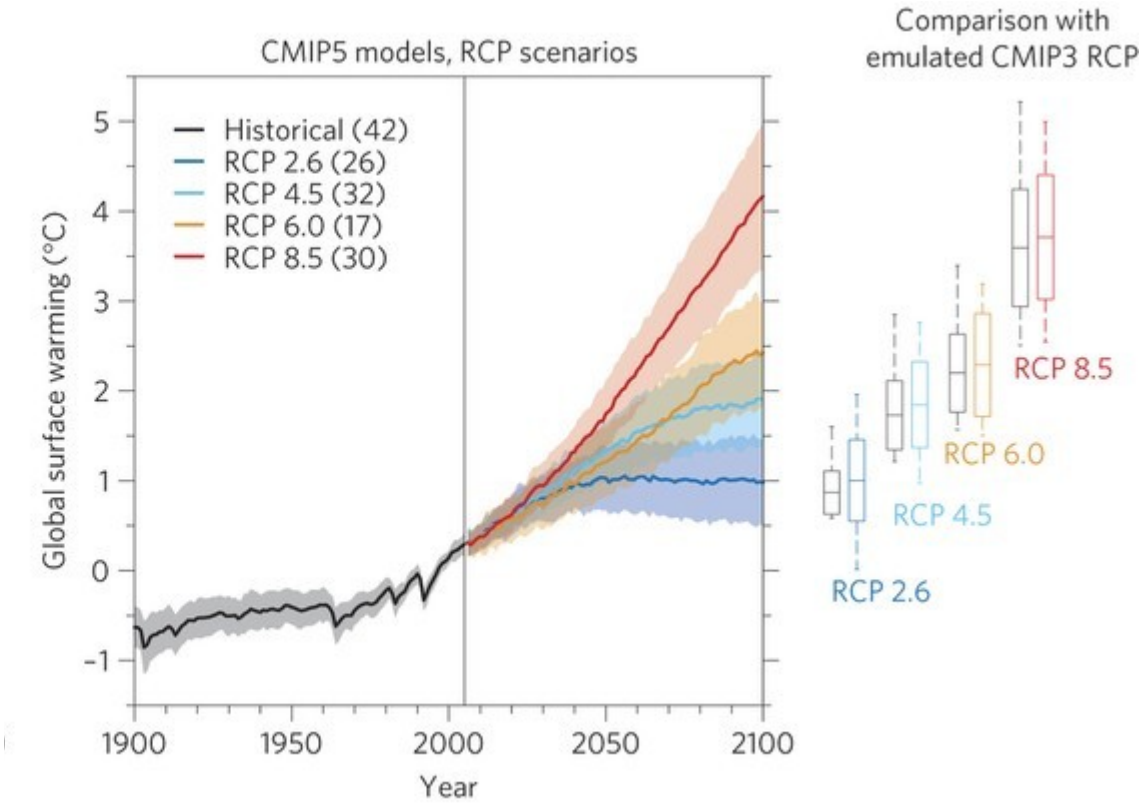
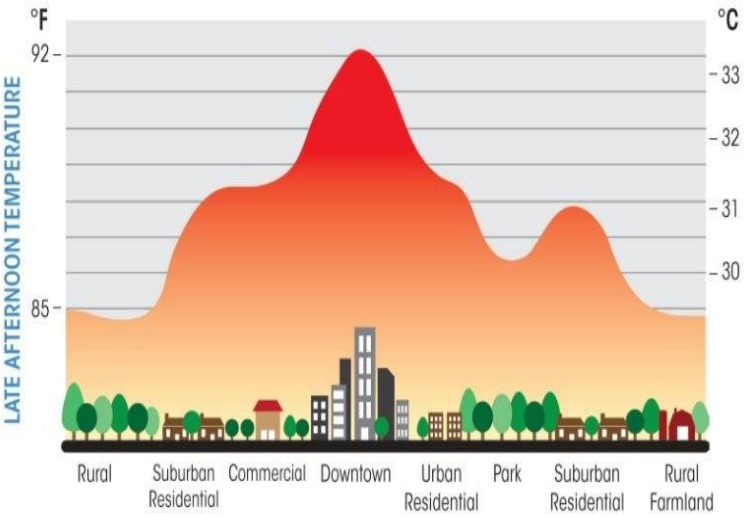


Figure from *Knutti and Sedláček (2012).*

Urban expansion



Objectives

- To reconstruct the present-day heat stress for an extended period and for an extended area (Belgium) based on high-resolution urban climate modelling
- To quantify the impact of climate change and urban land-use change on the heat stress in Belgium

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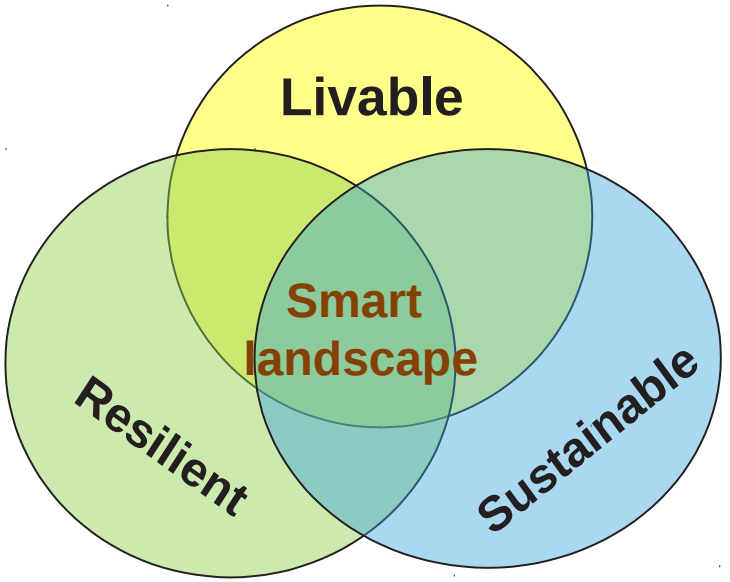


Heat stress index

- Definition by the Federal Agency Public Health of Belgium:
  - Heat wave day (h_i): this is 1 for the days for which the 3-day averaged minimum screen-level temperature exceeds 18.2 °C and averaged maximum exceeds 29.6°C. Otherwise it is 0.
  - Heat-wave Degree Days (*HWDD*): sum over h_i multiplied with the degrees of positive thresshold exceedances at each day:

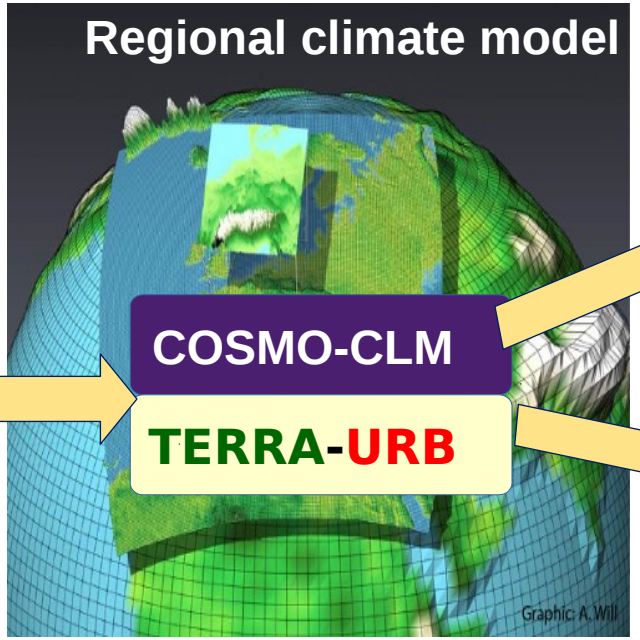
$$HWDD = \sum_i \left[\left(T_{\min,i} - 18.2\ °C \right)^+ + \left(T_{\max,i} - 29.6\ °C \right)^+ \right] h_i \ ,$$

Scenario's

Land-use change

Climate change

Adaptation
– vegetation
– water management
– energy use
– building characteristics



Urban risk assessment

City-level impact and extremes:
– temperature
– precipitation

Local impact models:
– Heat stress
– Air quality modelling (ozone peaks)
– River and sewage models (floods)

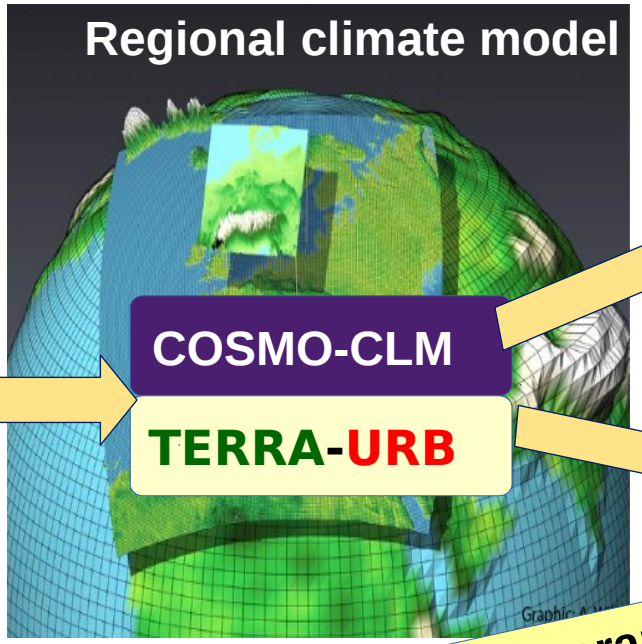
Scenario's

Land-use change

Climate change

Adaptation
– vegetation
– water management
– energy use
– building characteristics

Regional climate model



COSMO-CLM

TERRA-URB

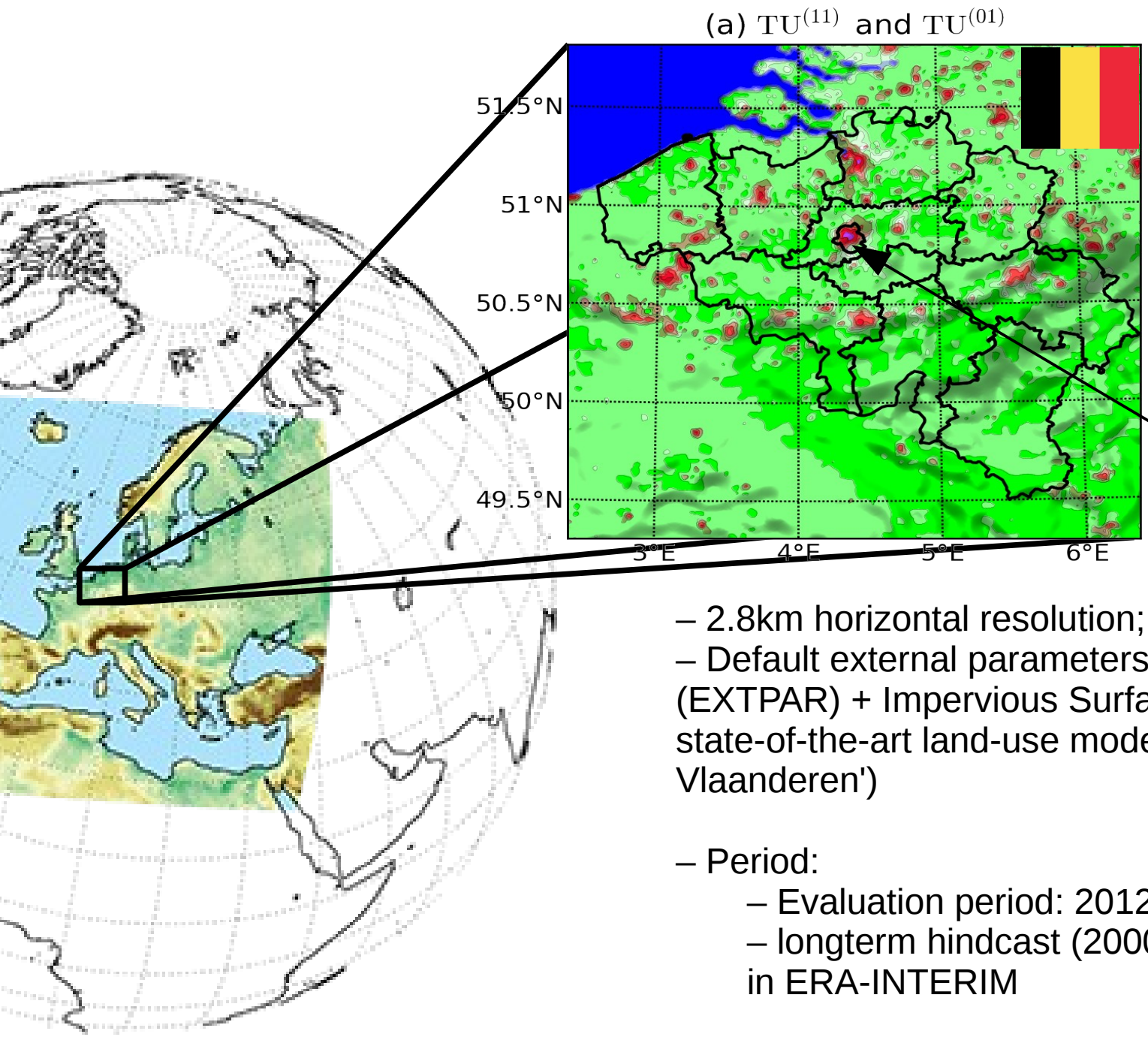
Urban risk assessment

City-level impact and extremes:
– temperature
– precipitation

Local impact models:
– Heat s
lling (ozone peaks)
e models (floods)

See Poster 25: NOMTM - Urban canopy parameterizations on Thursday, 23/Jul/2015: 3:00pm - 4:00pm

COSMO-CLM + TERRA-URB model setup for Belgium



– 2.8km horizontal resolution; 40 vertical layers
– Default external parameters in COSMO-CLM (EXTPAR) + Impervious Surface Area extracted from a state-of-the-art land-use model ('Ruimtemodel Vlaanderen')

– Period:
  – Evaluation period: 2012 (nested in ECMWF)
  – longterm hindcast (2000 – 2010); cascade-nested in ERA-INTERIM

Evaluation daily minimum air temperatures Antwerp

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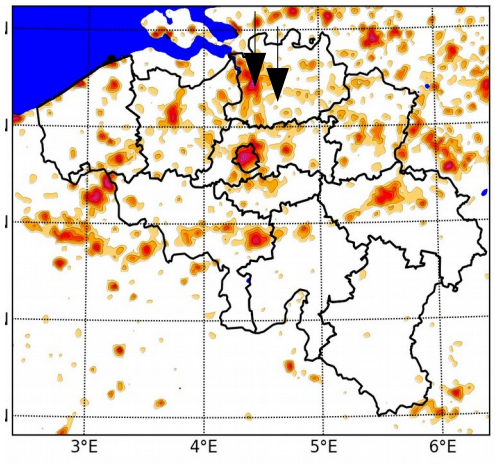

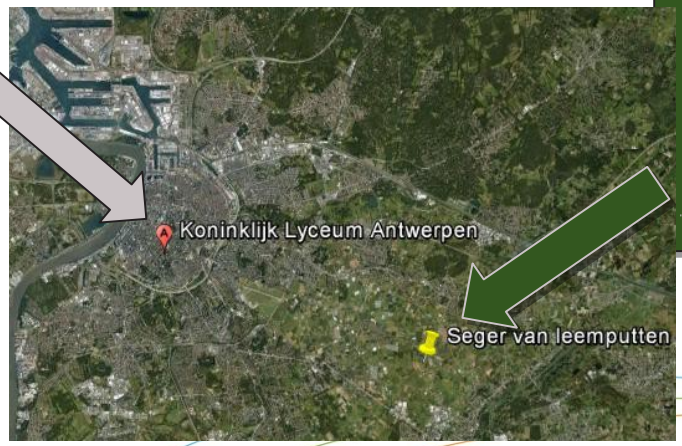

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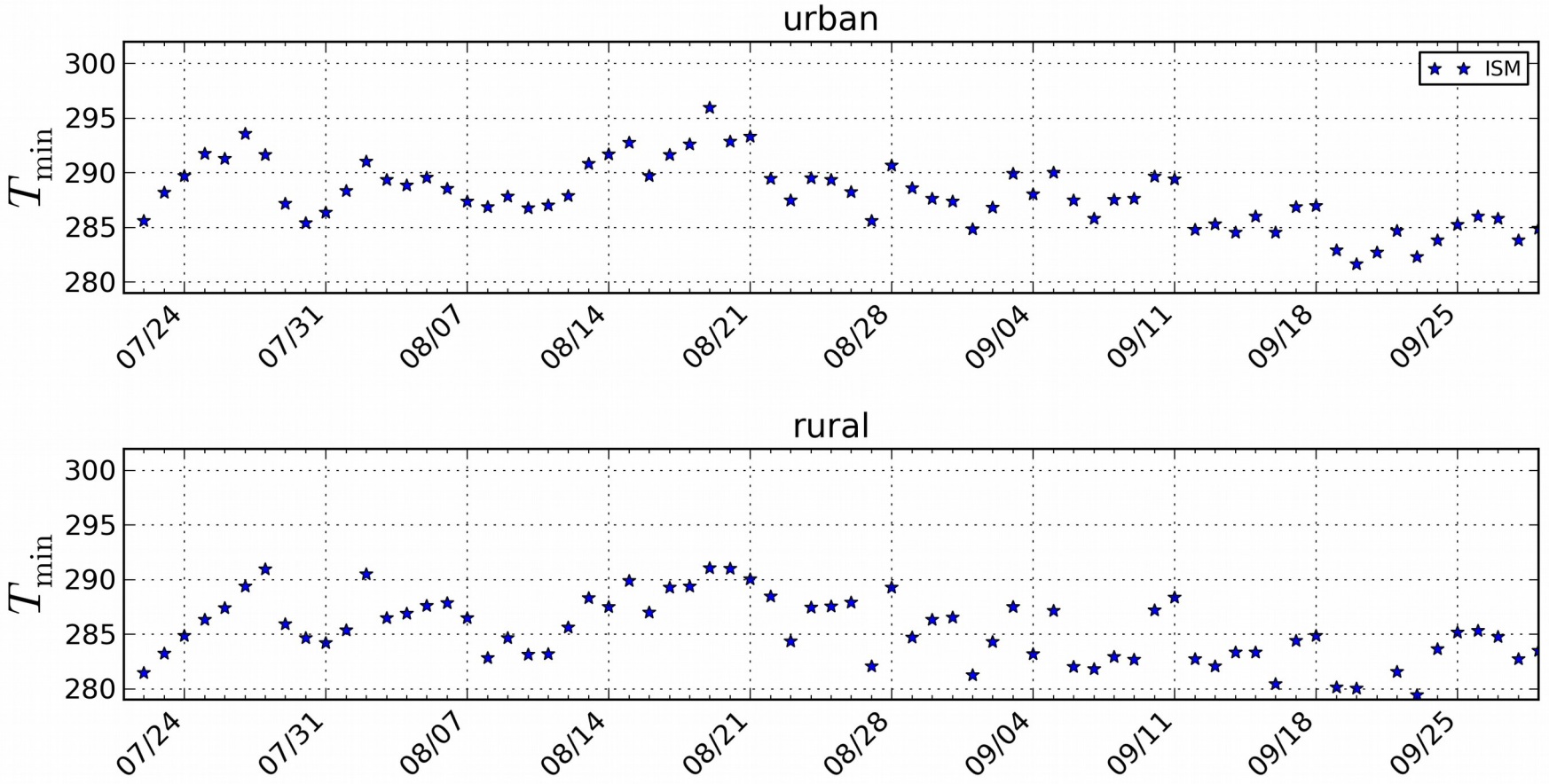

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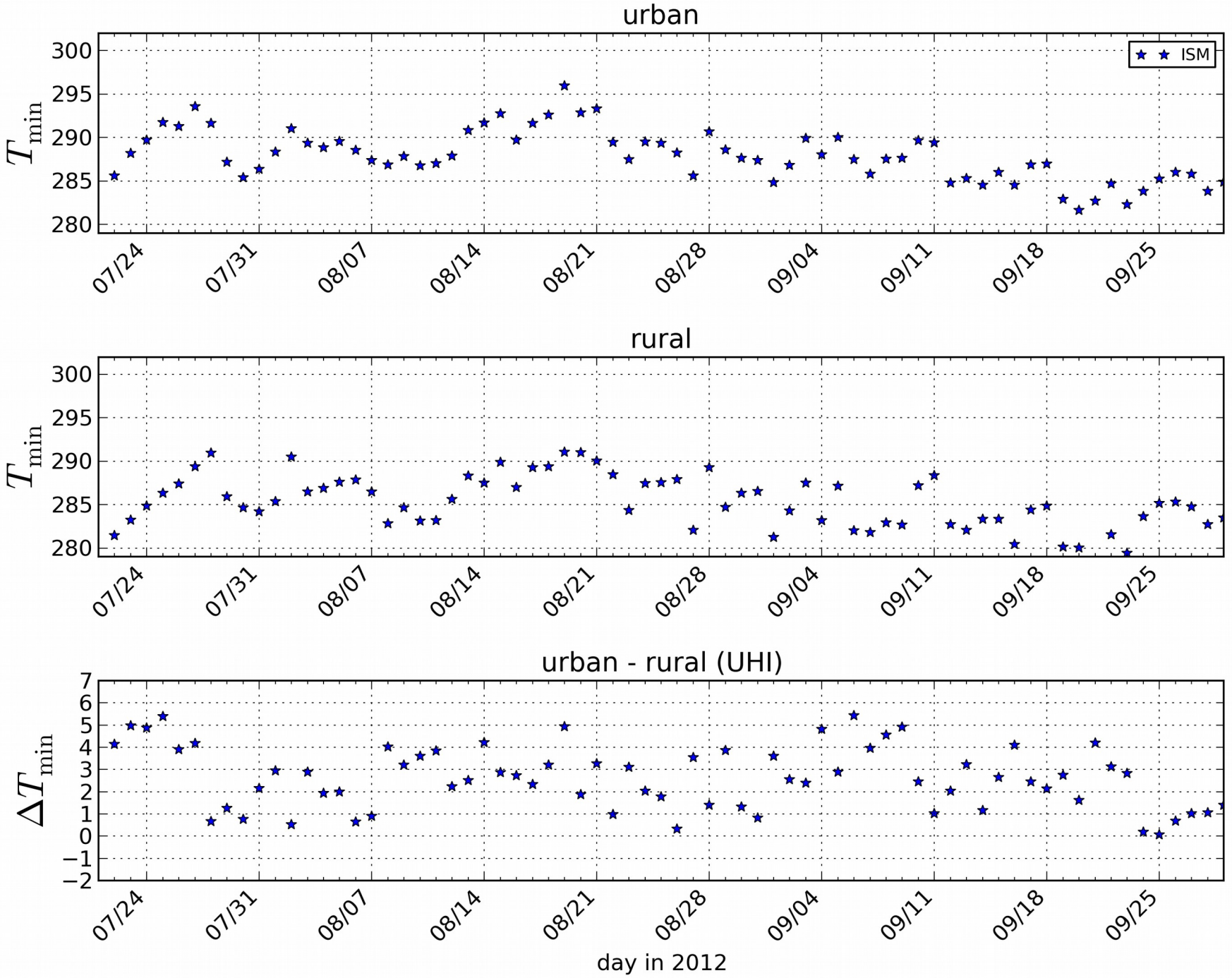

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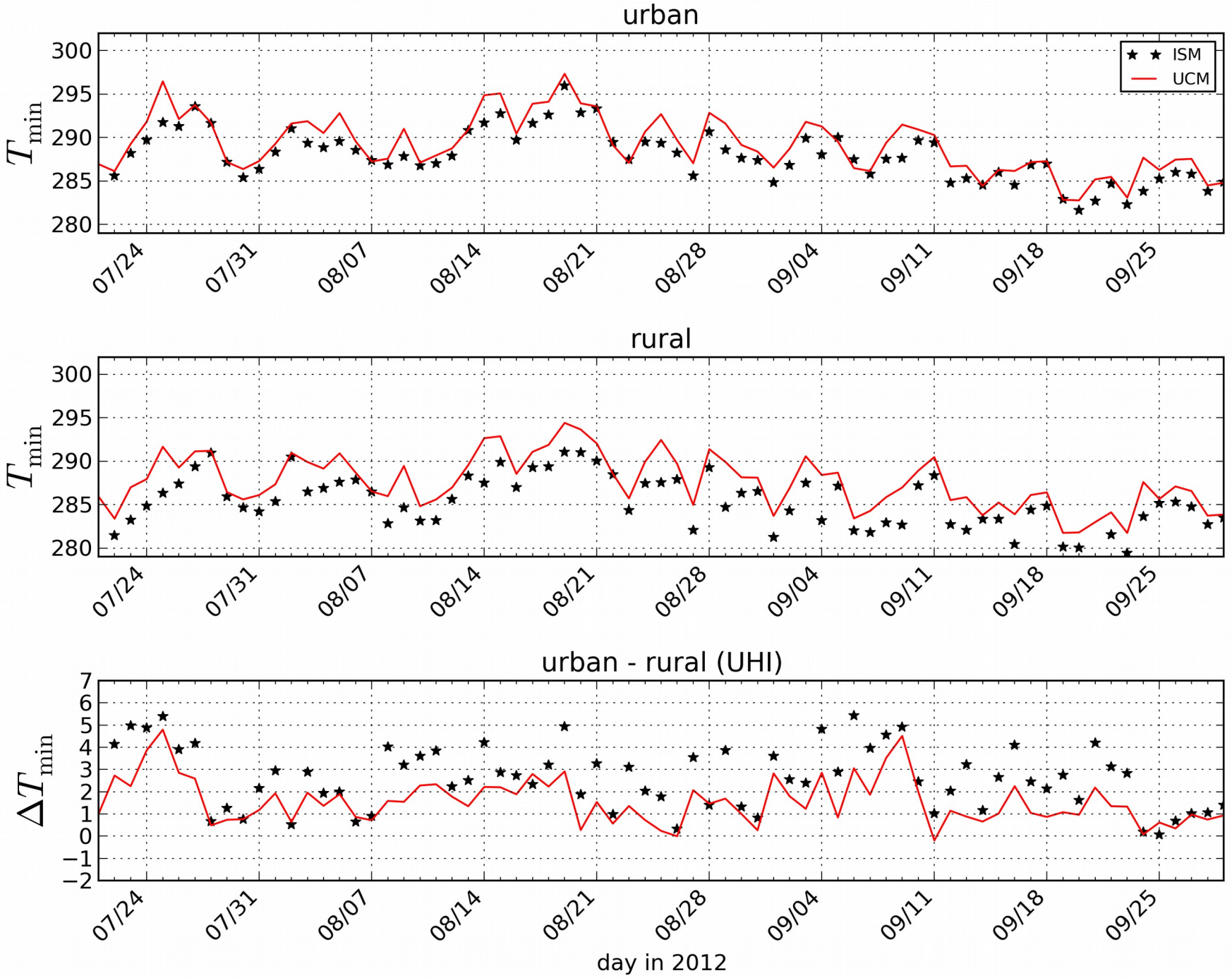

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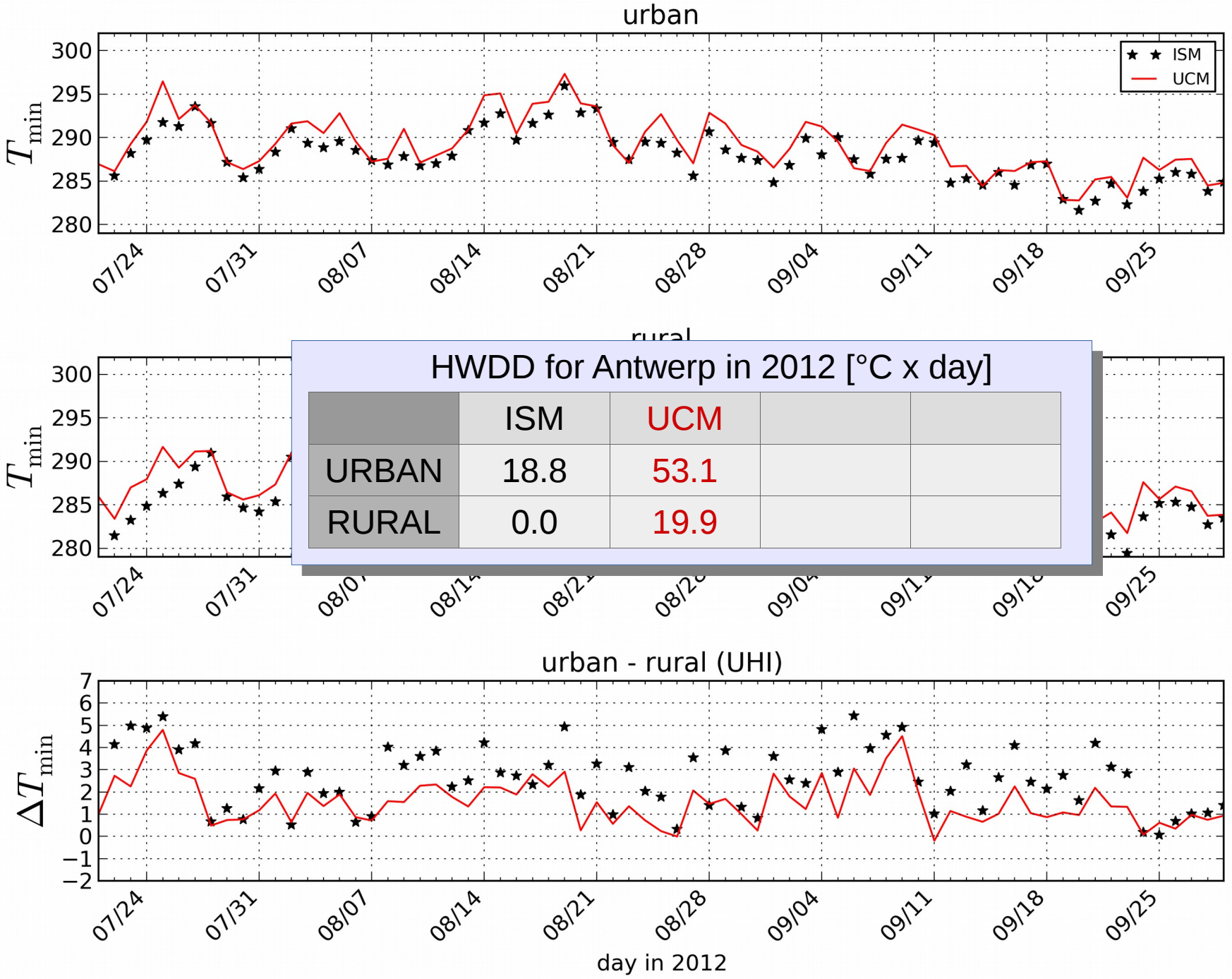

HWDD for Antwerp in 2012 [°C x day]

	ISM	UCM		
URBAN	18.8	53.1		
RURAL	0.0	19.9		

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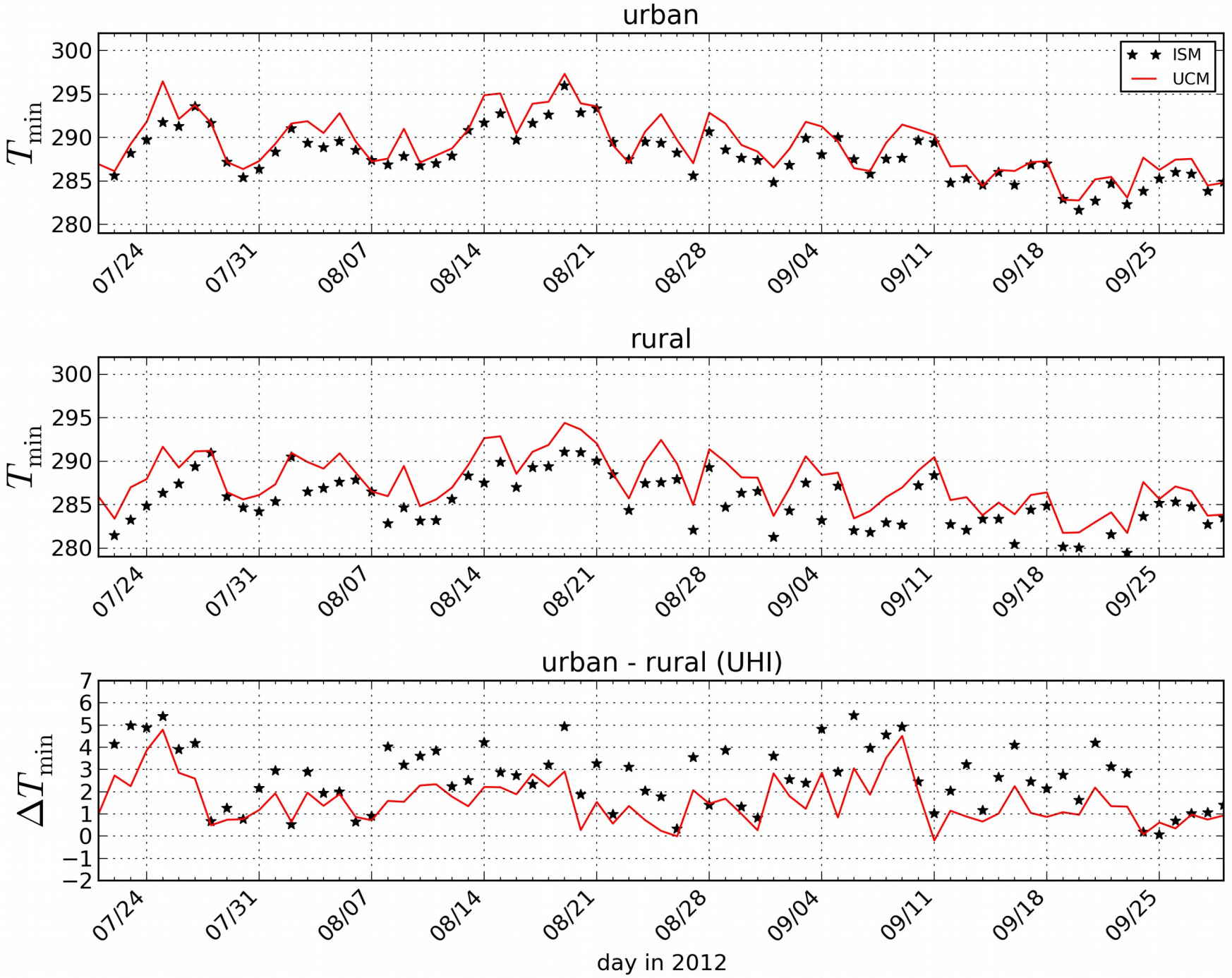

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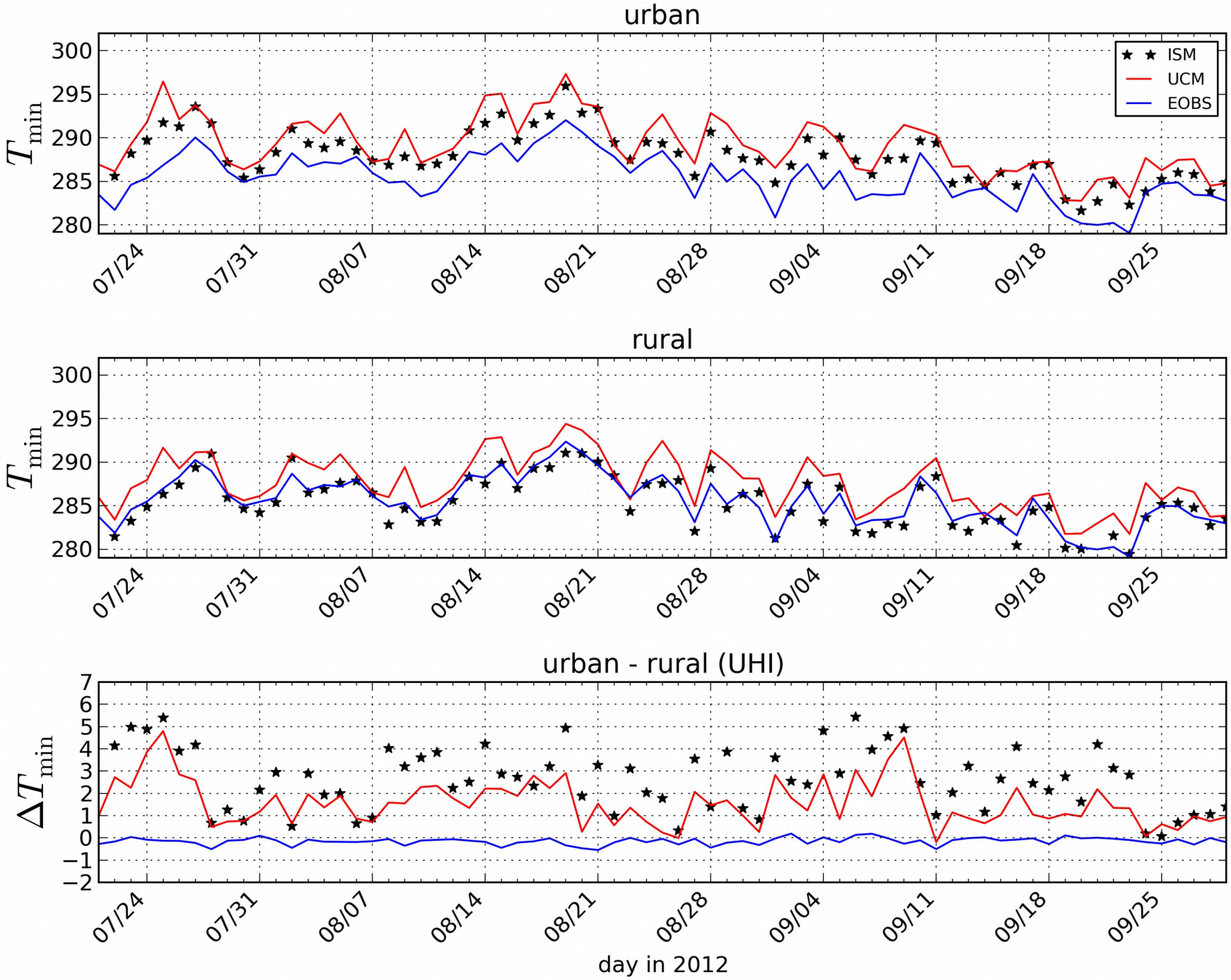

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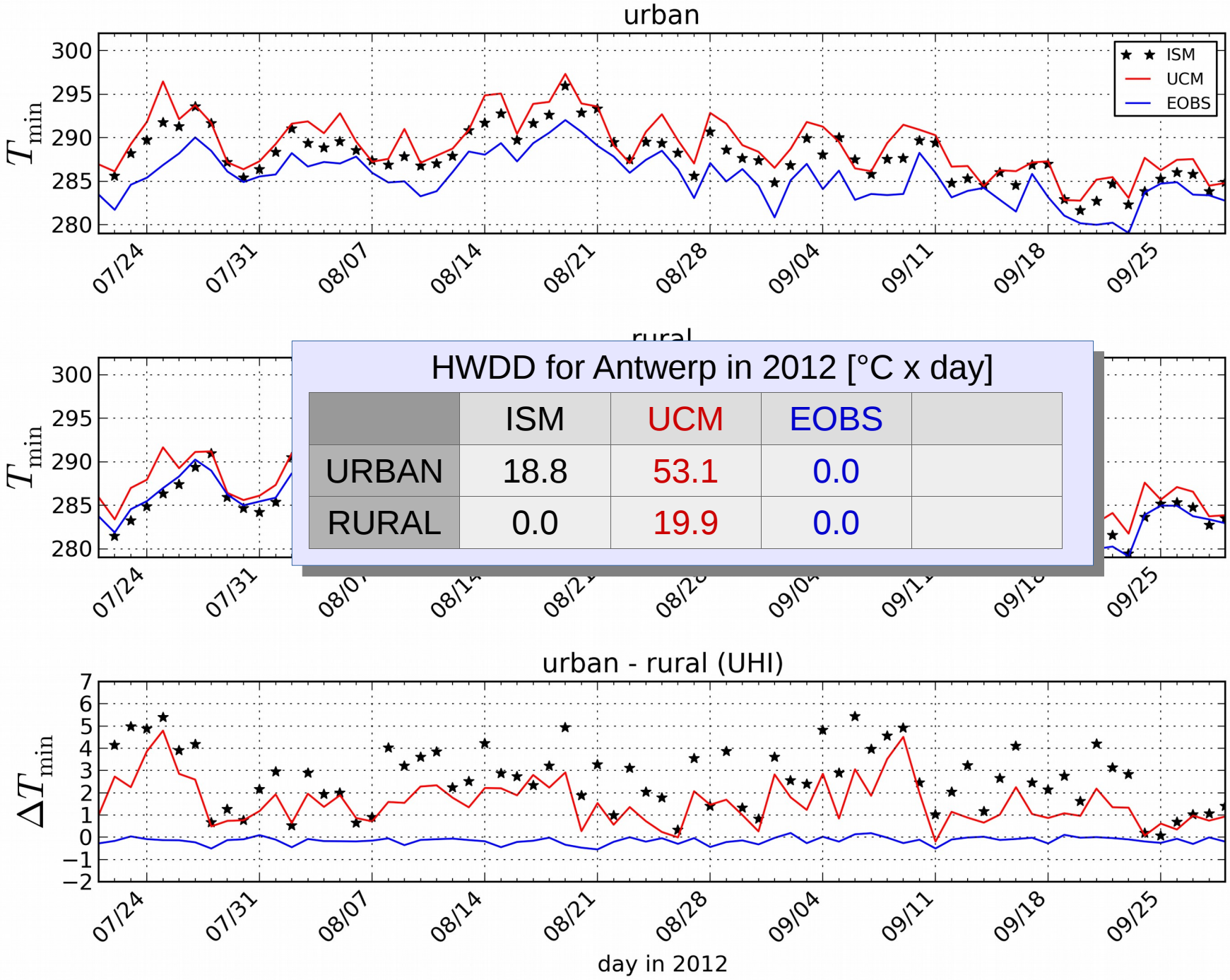

HWDD for Antwerp in 2012 [°C x day]

	ISM	UCM	EOBS	
URBAN	18.8	53.1	0.0	
RURAL	0.0	19.9	0.0	

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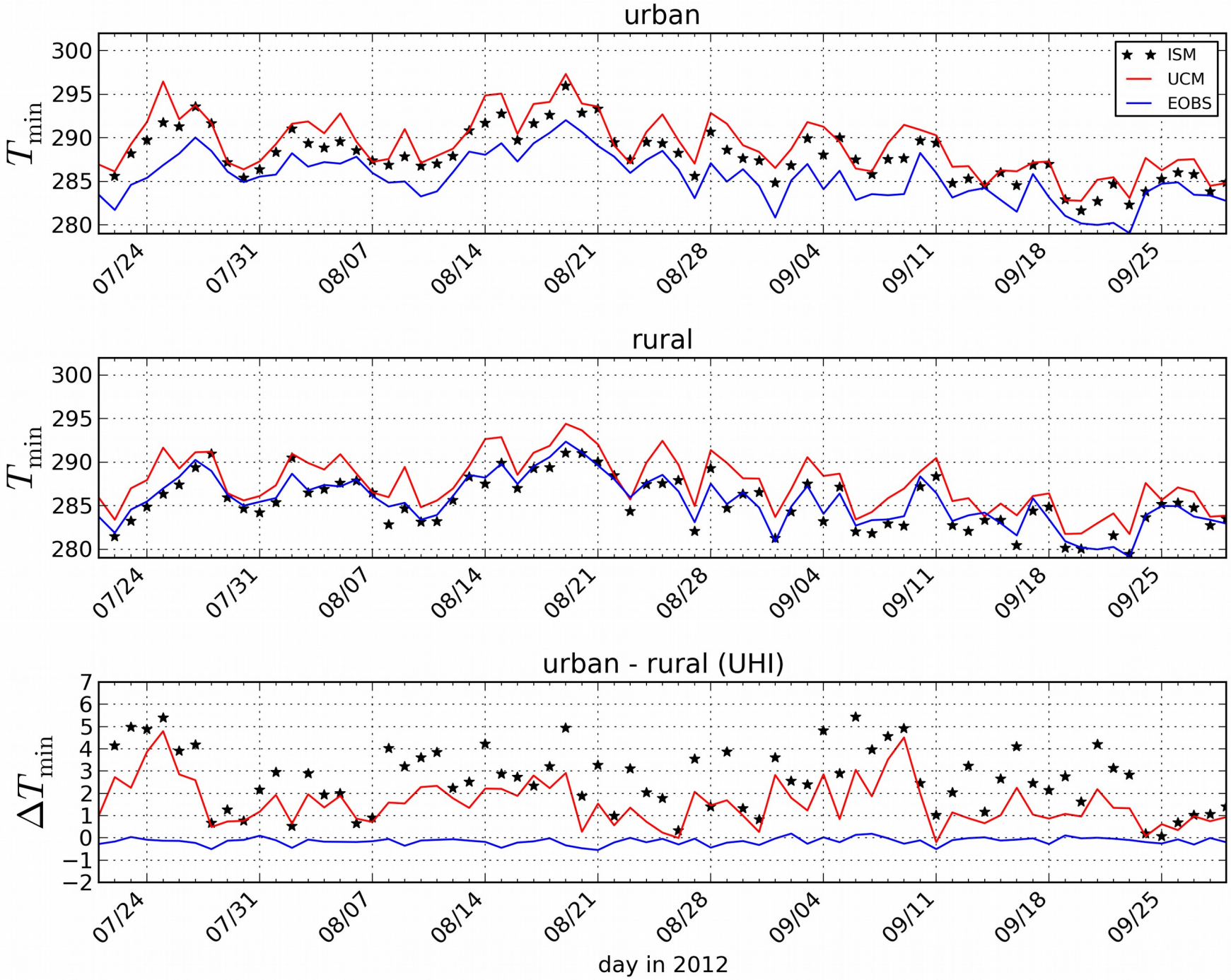

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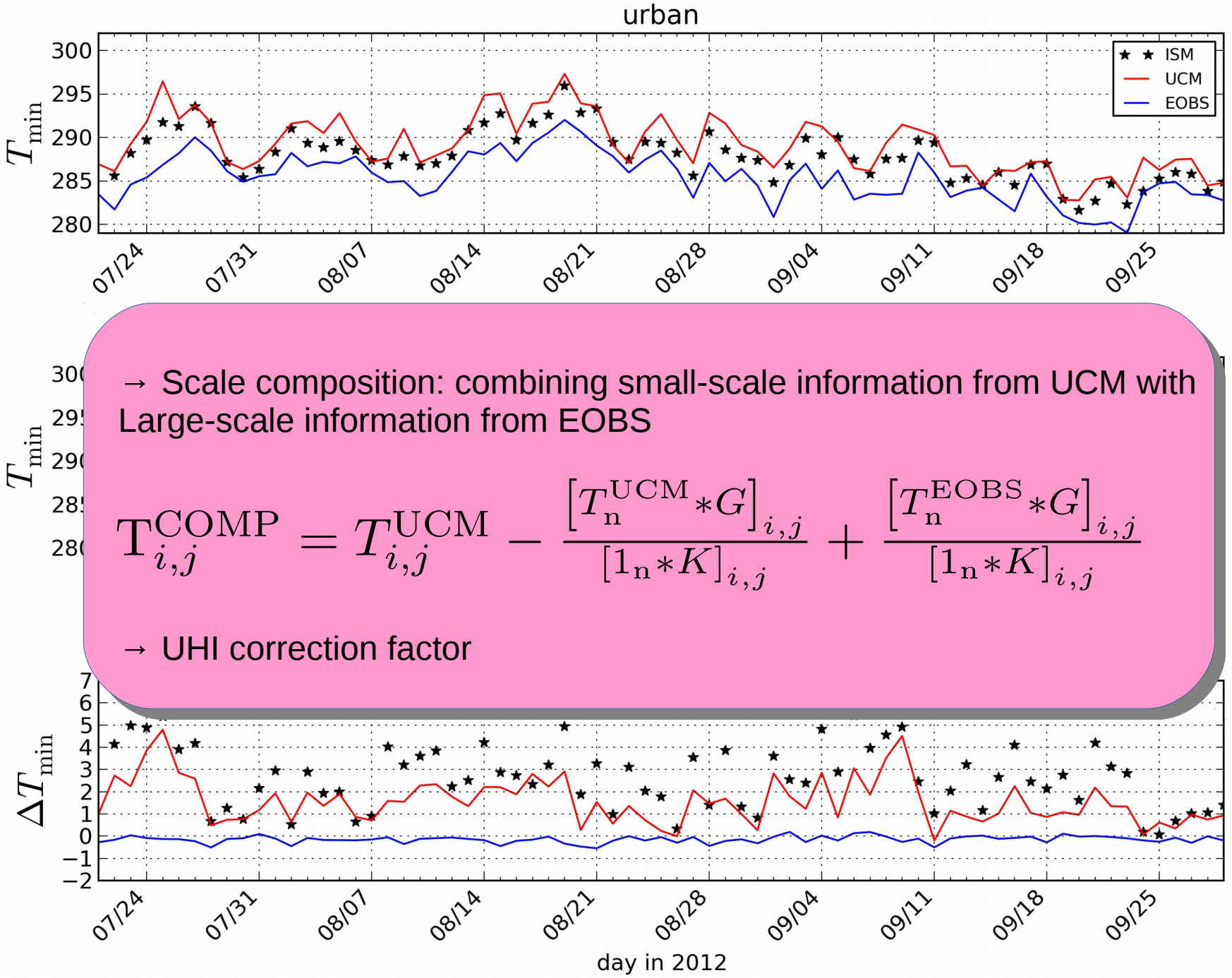
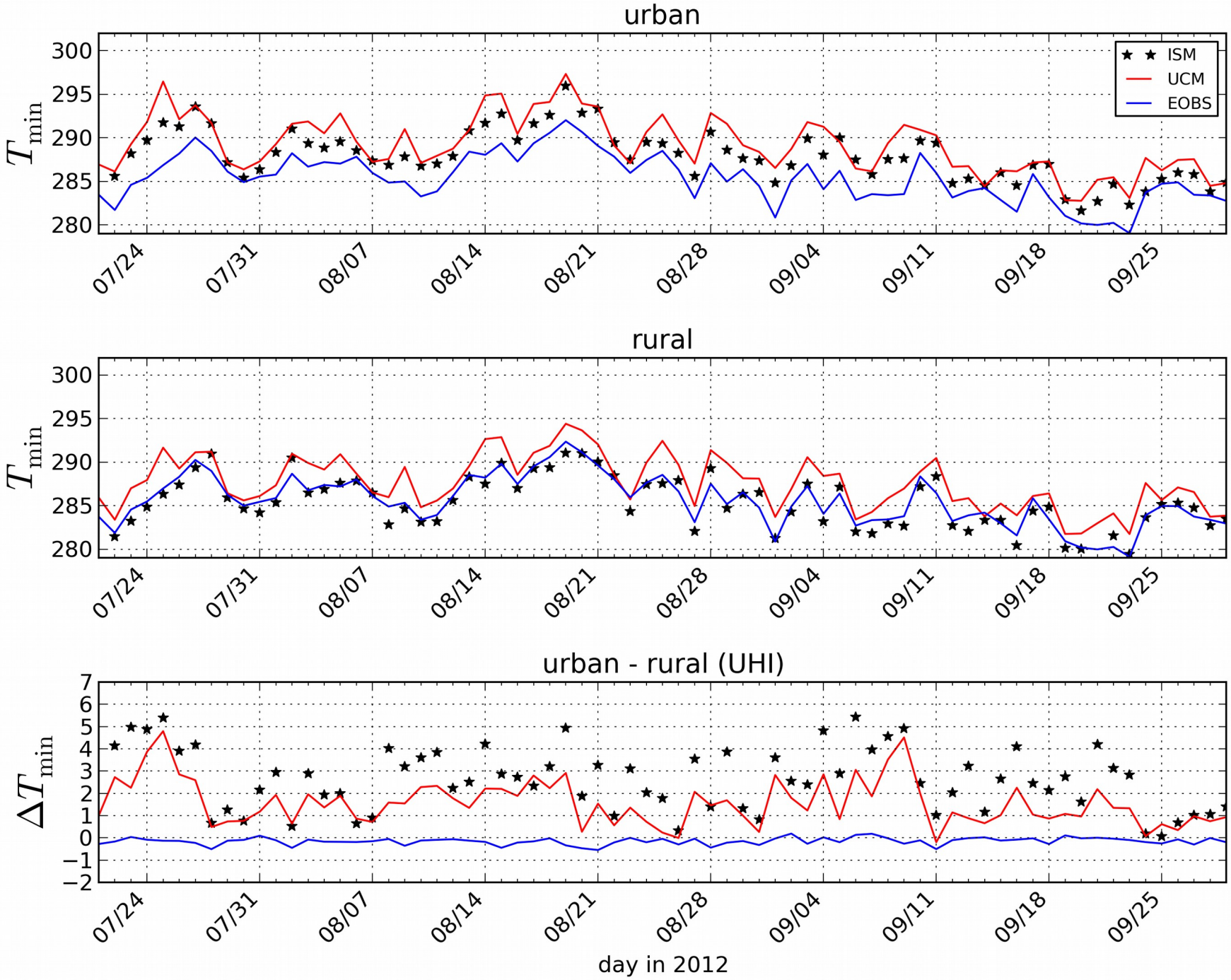


→ Scale composition: combining small-scale information from UCM with Large-scale information from EOBS

$$\mathrm{T}_{i,j}^{\mathrm{COMP}} = T_{i,j}^{\mathrm{UCM}} - \frac{\left[T_{\mathrm{n}}^{\mathrm{UCM}} * G\right]_{i,j}}{\left[1_{\mathrm{n}} * K\right]_{i,j}} + \frac{\left[T_{\mathrm{n}}^{\mathrm{EOBS}} * G\right]_{i,j}}{\left[1_{\mathrm{n}} * K\right]_{i,j}}$$

→ UHI correction factor

Evaluation daily minimum air temperatures Antwerp



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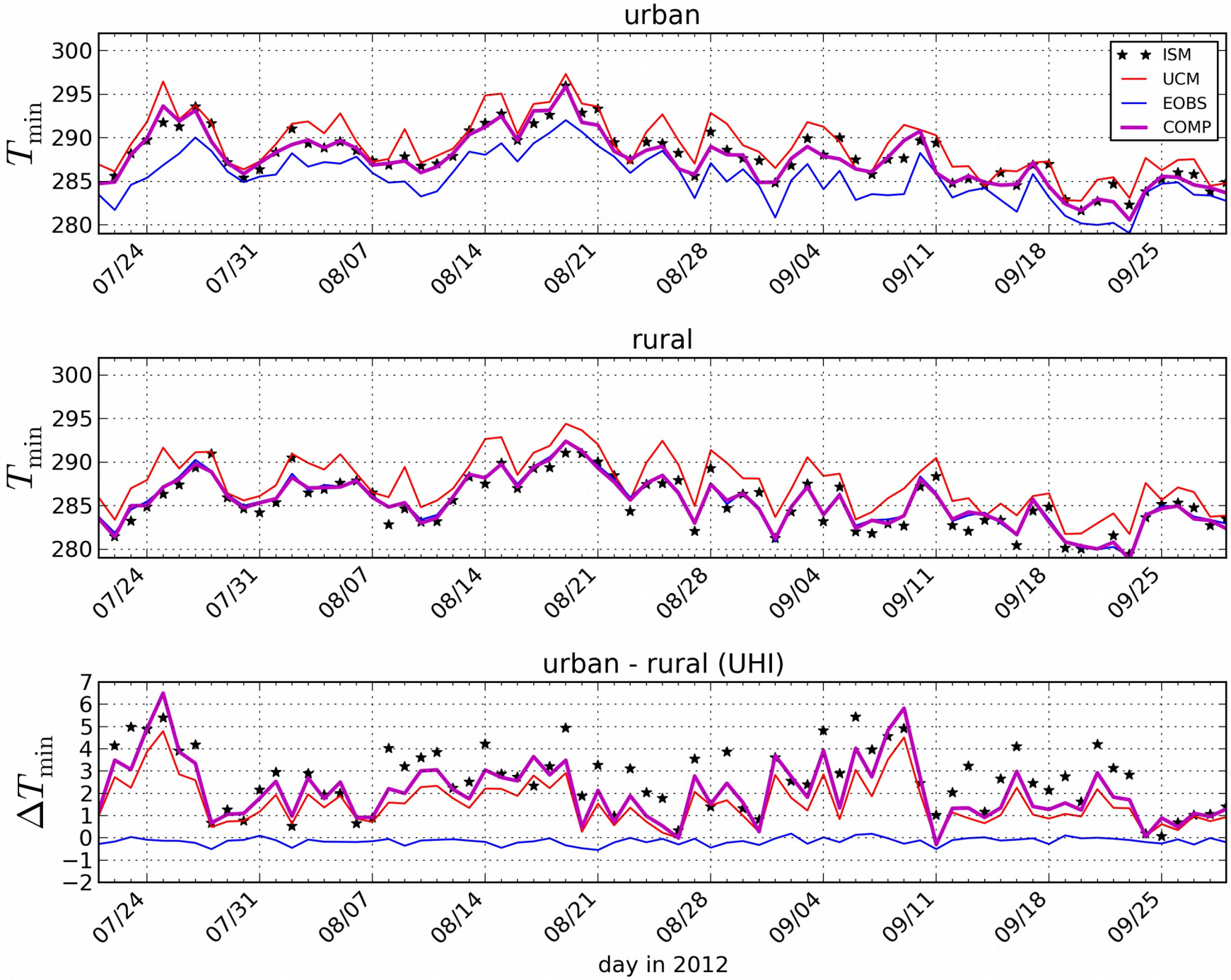

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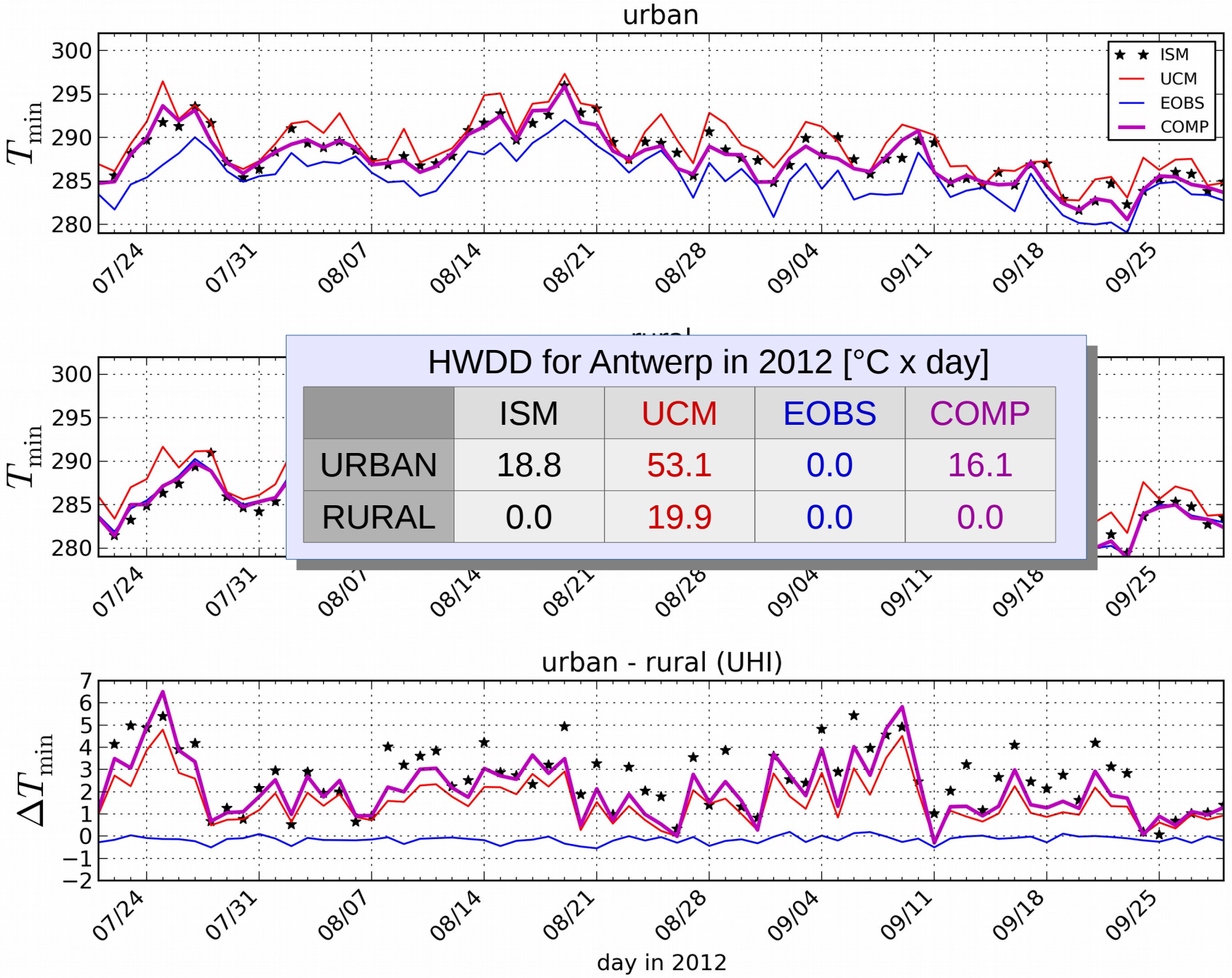
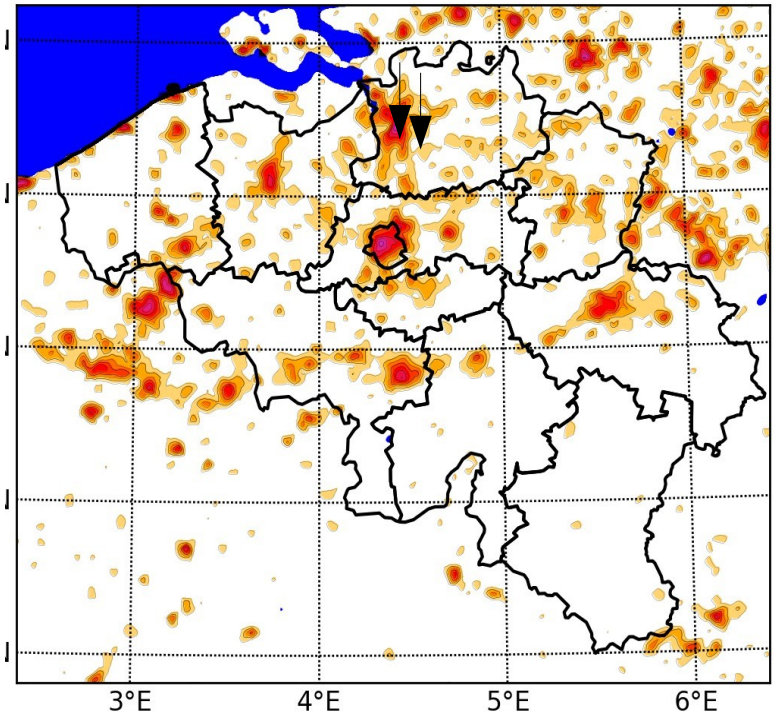


HWDD for Antwerp in 2012 [°C x day]

	ISM	UCM	EOBS	COMP
URBAN	18.8	53.1	0.0	16.1
RURAL	0.0	19.9	0.0	0.0

Reconstruction heat-stress index for 2000-2010

COSMO-CLM + TERRA-URB (composite) cascade-nested in ERA-INTERIM



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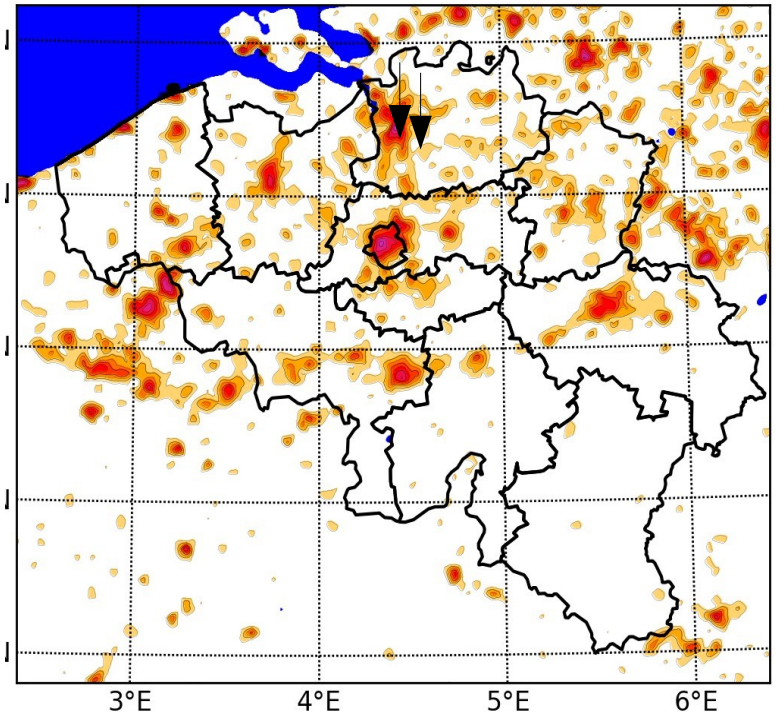

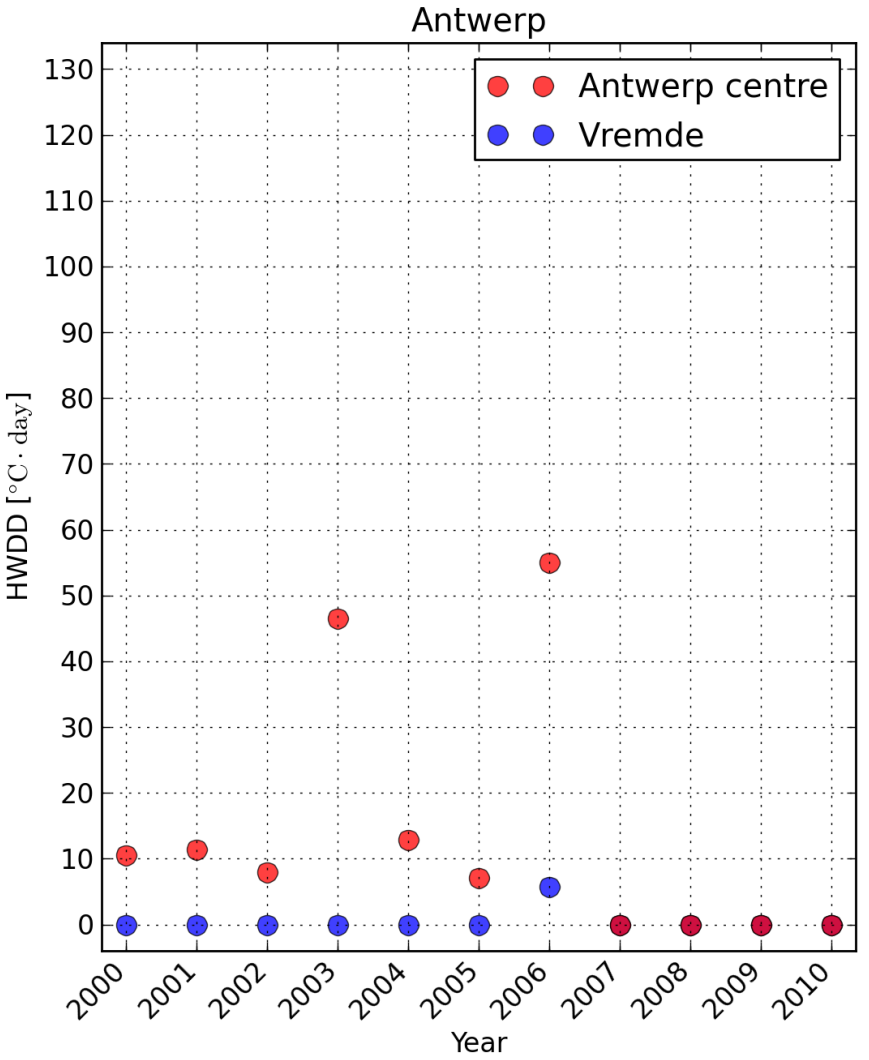

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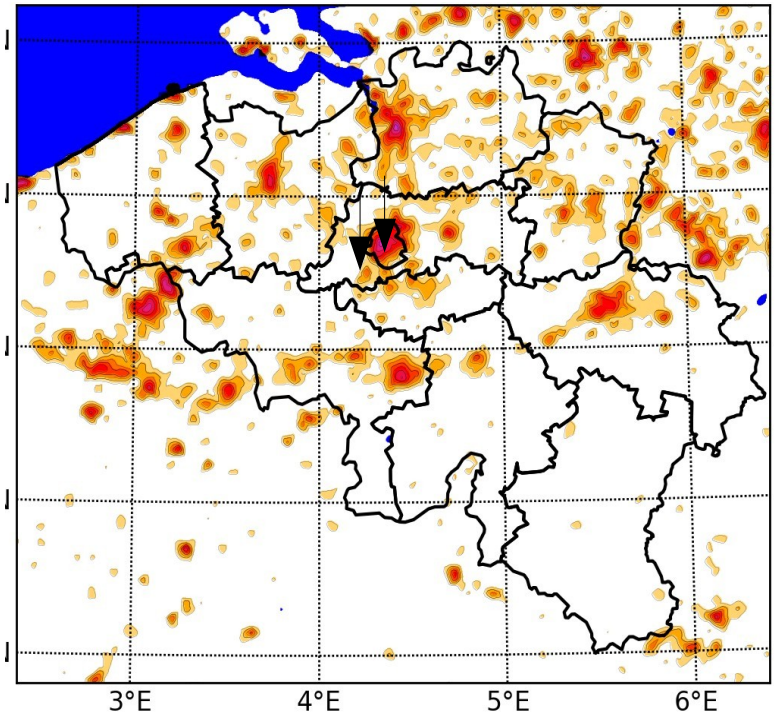

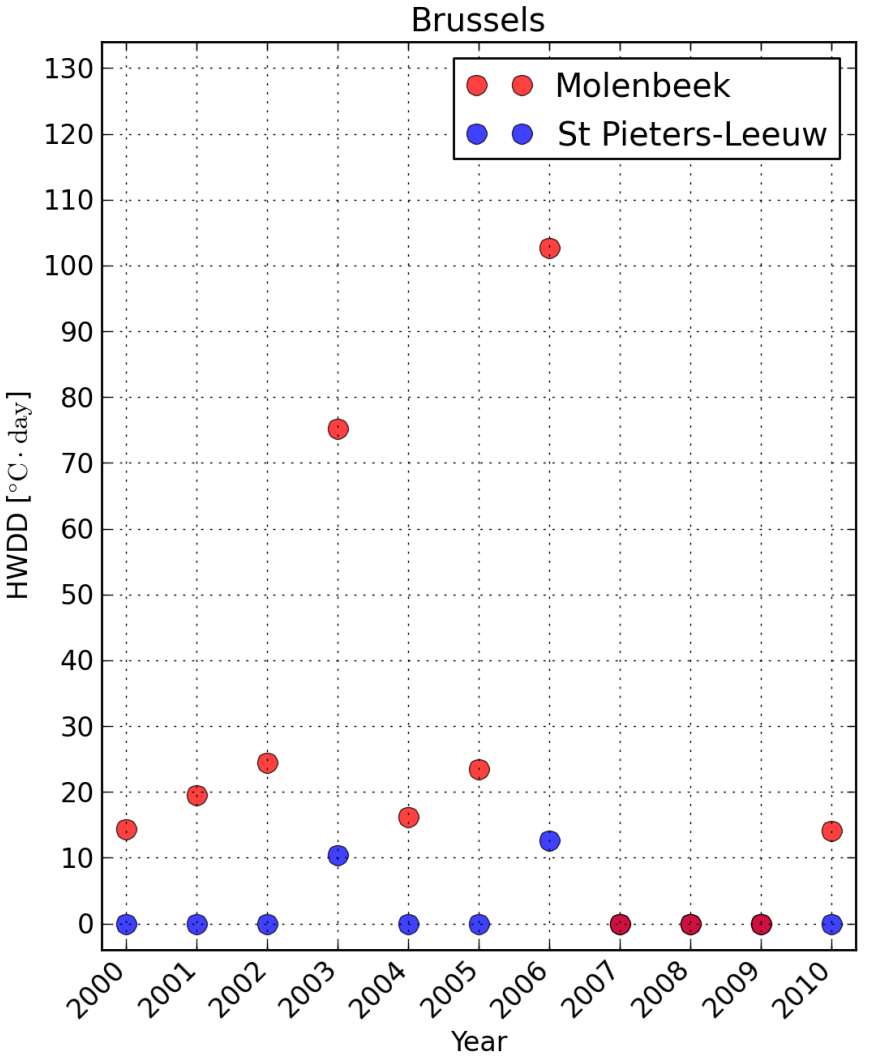

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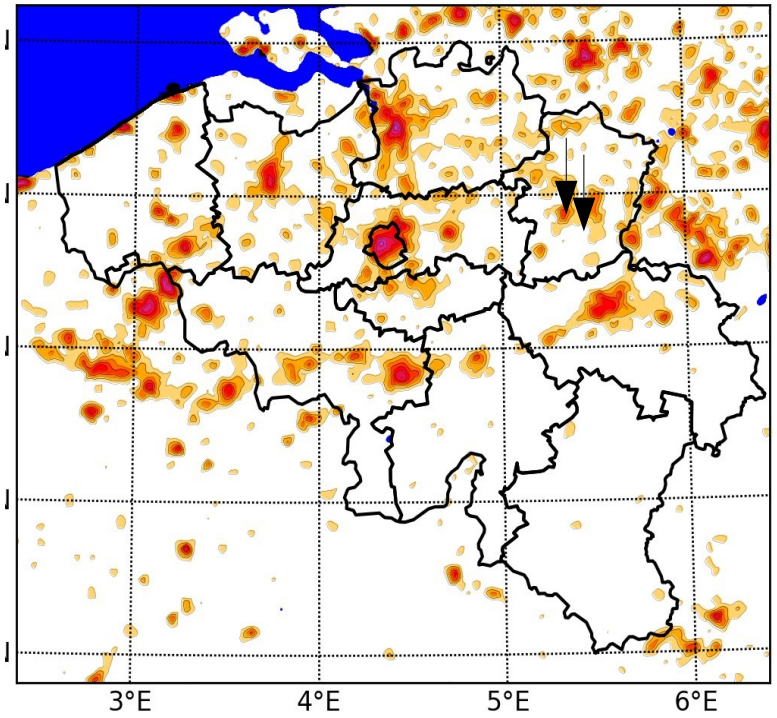

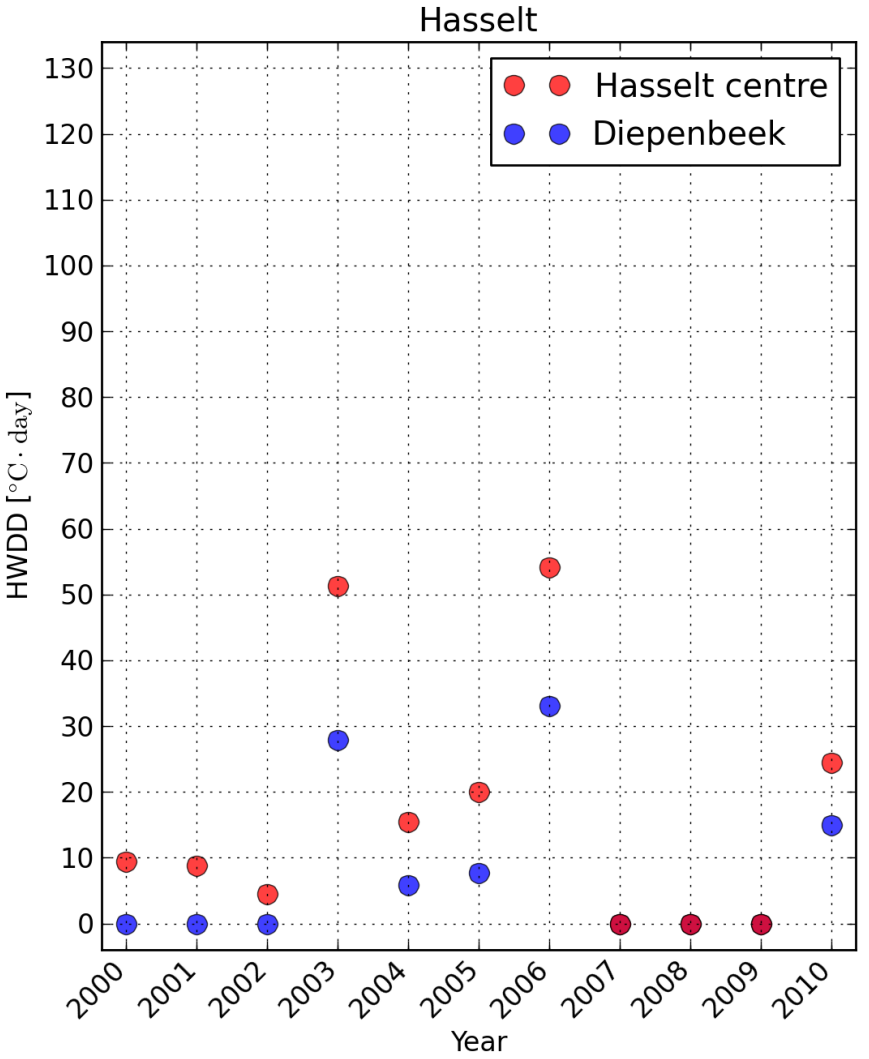

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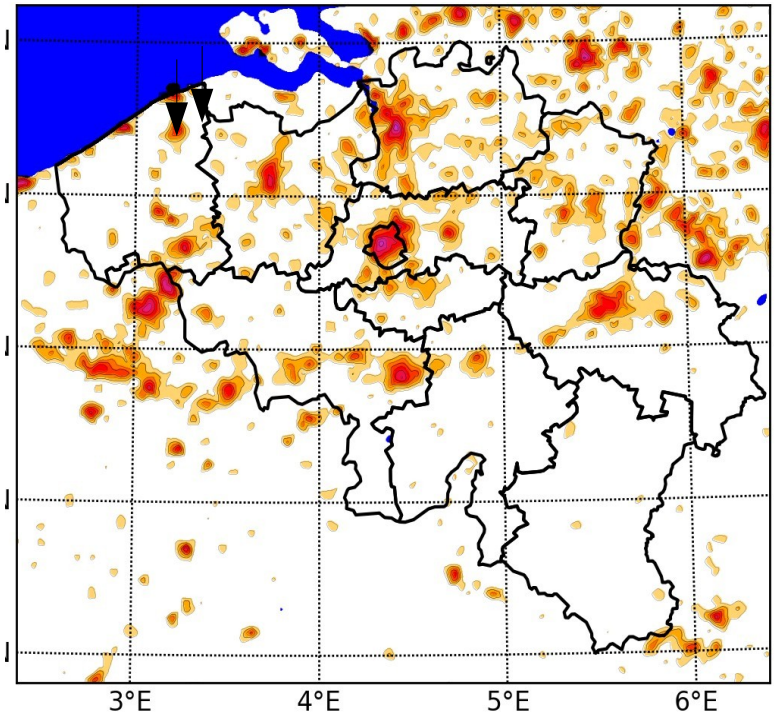

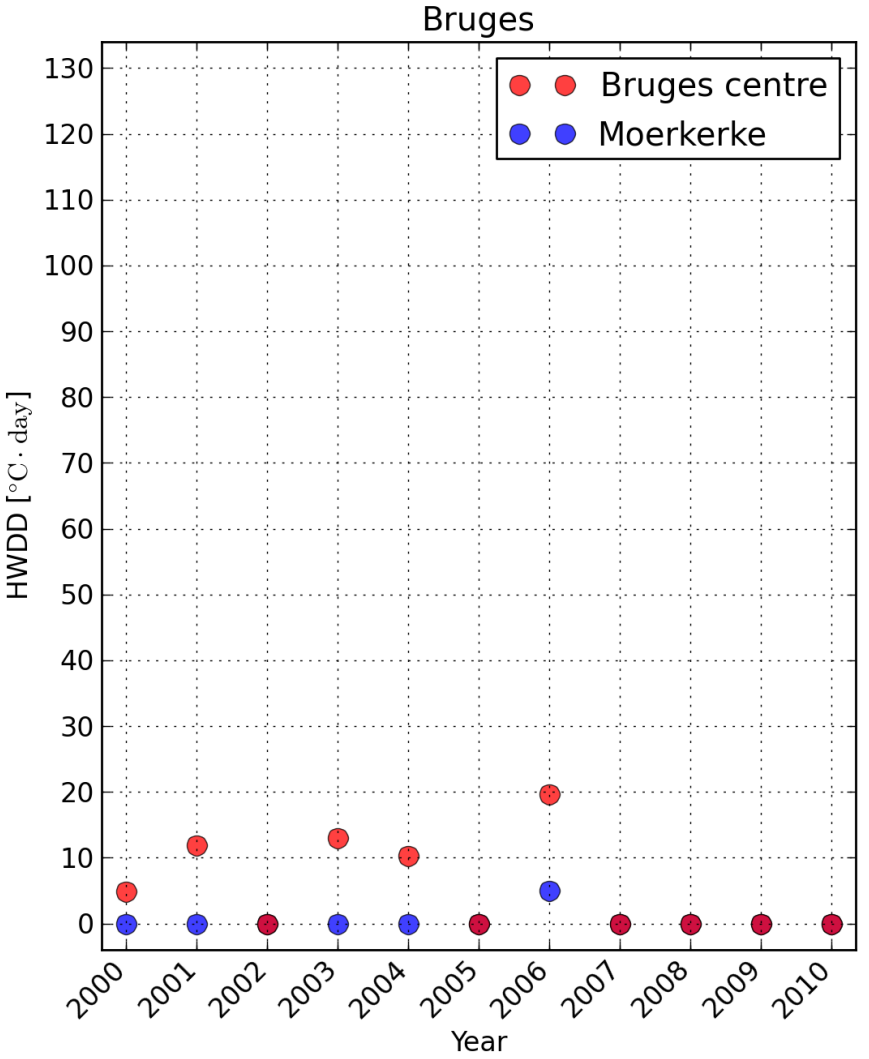

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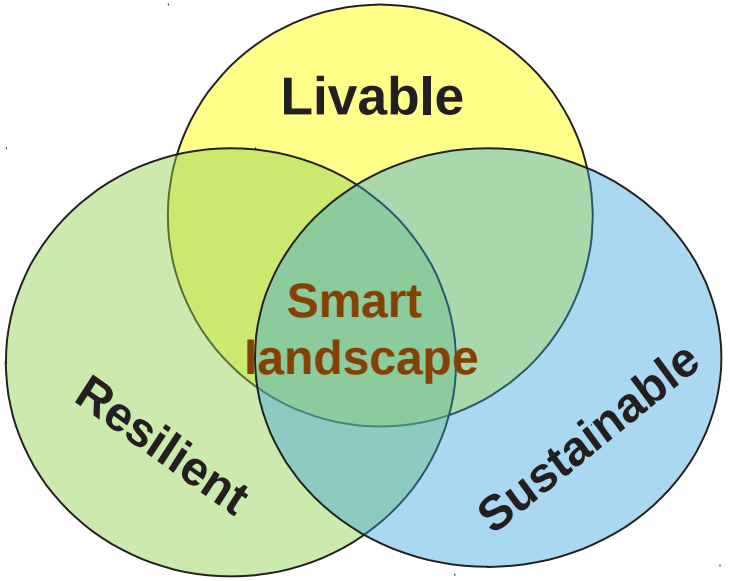

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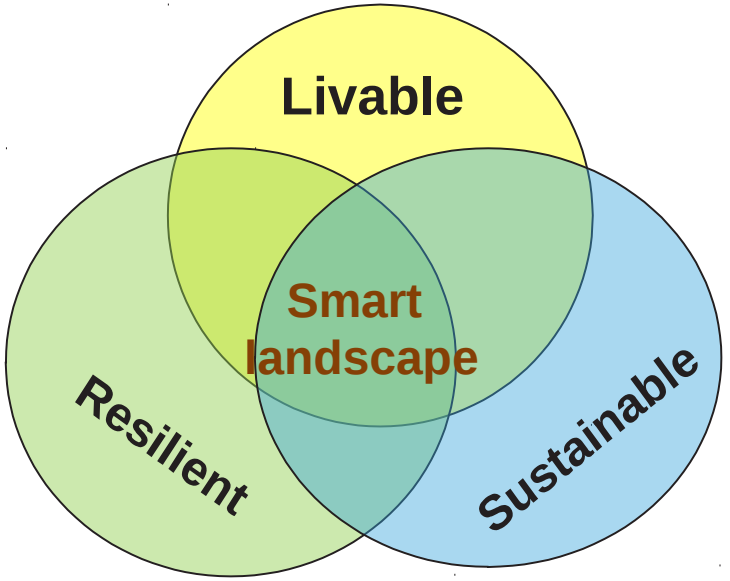
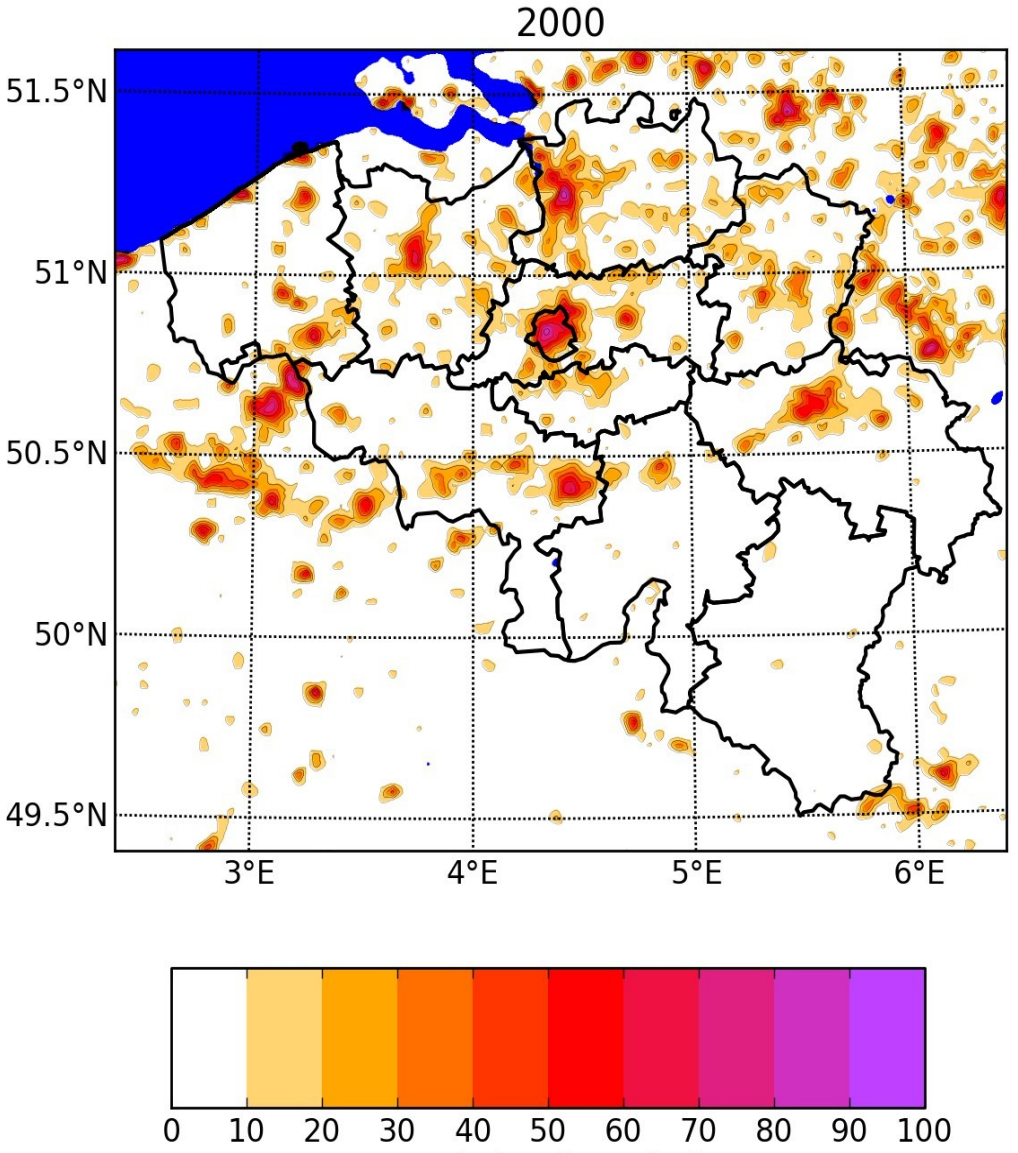


Urban expansion



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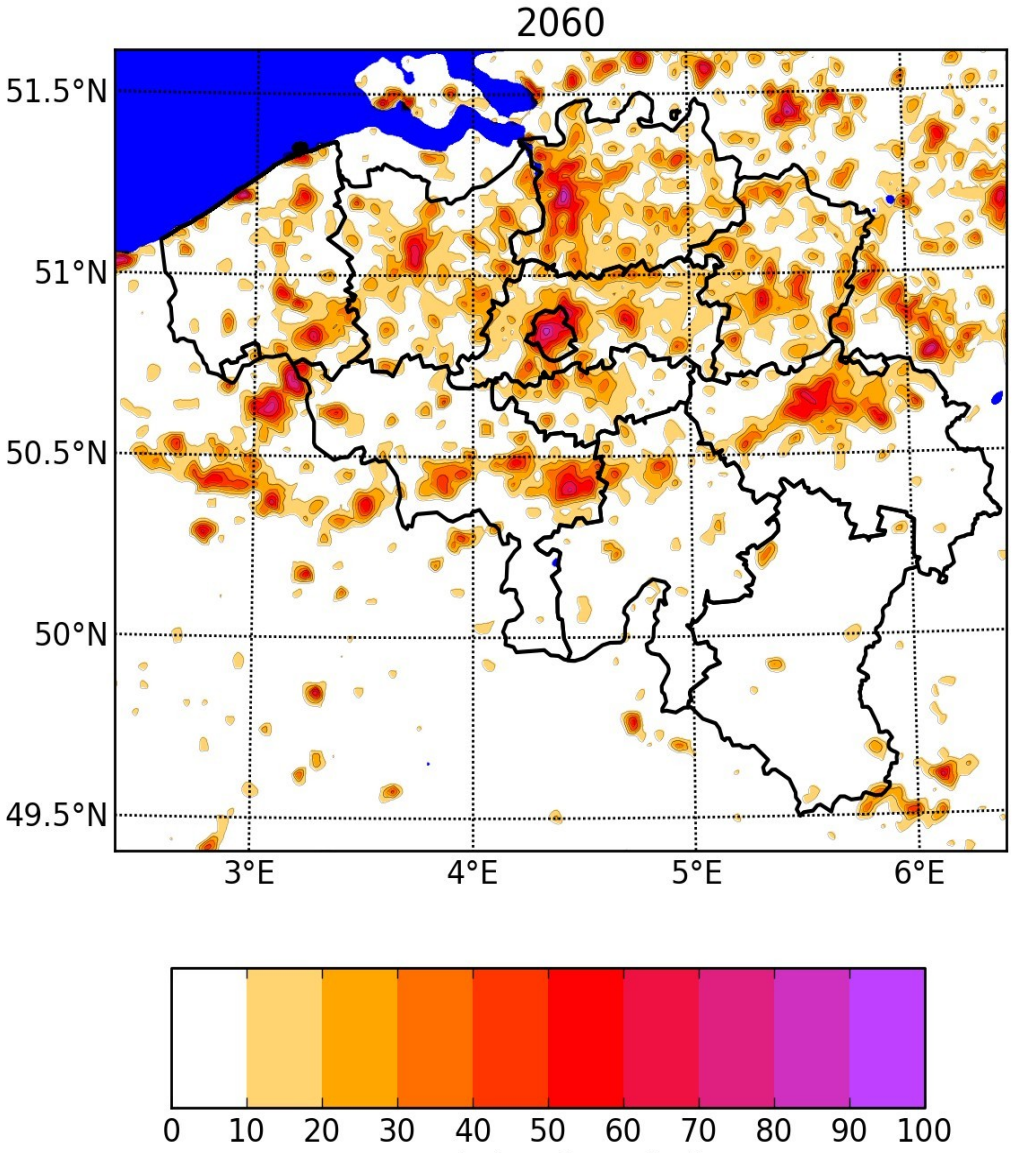
Output from
Ruimtemodel
Vlaanderen

Urban expansion



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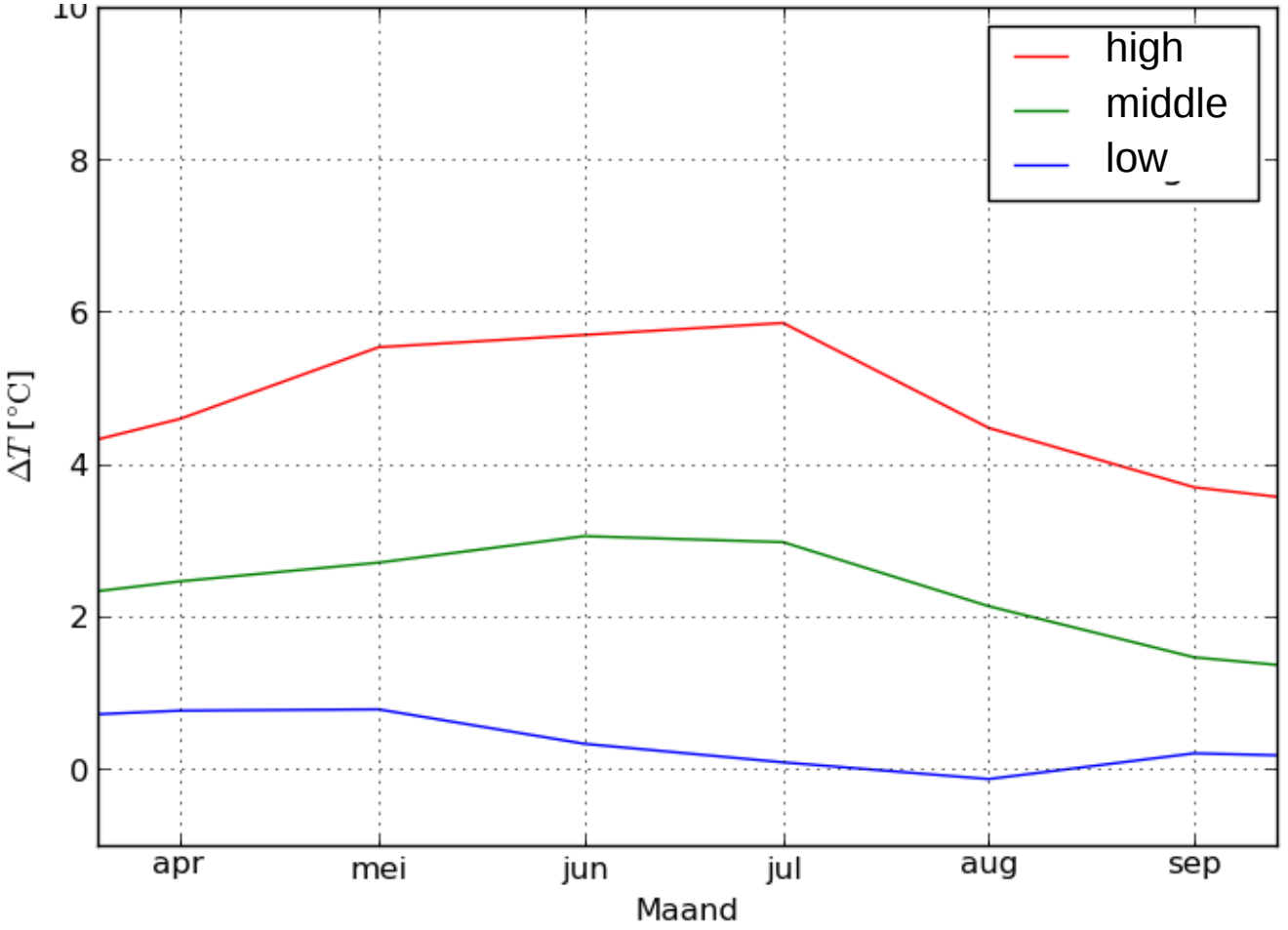
Output from Ruimtemodel Vlaanderen

BAU Urban expansion 2060

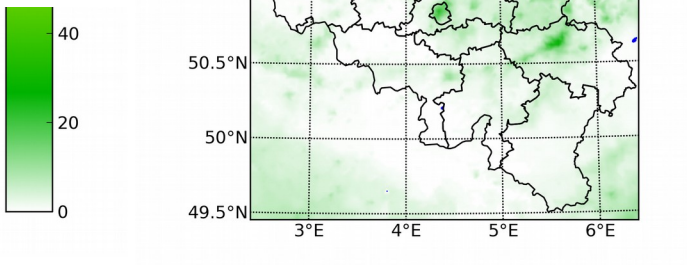
Climate change and uncertainty for Belgium (2000 → 2060)



ΔT approach → add monthly-mean temperature change to the high-resolution composites

Heat stress scenarios

Heat stress scenarios



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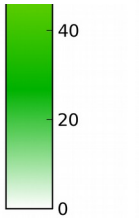

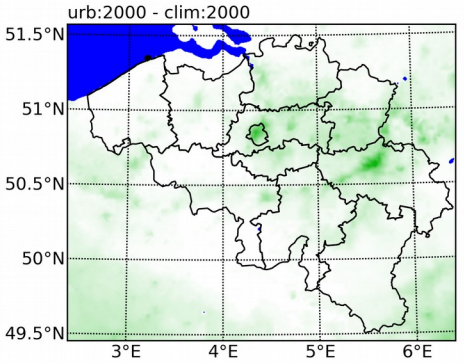

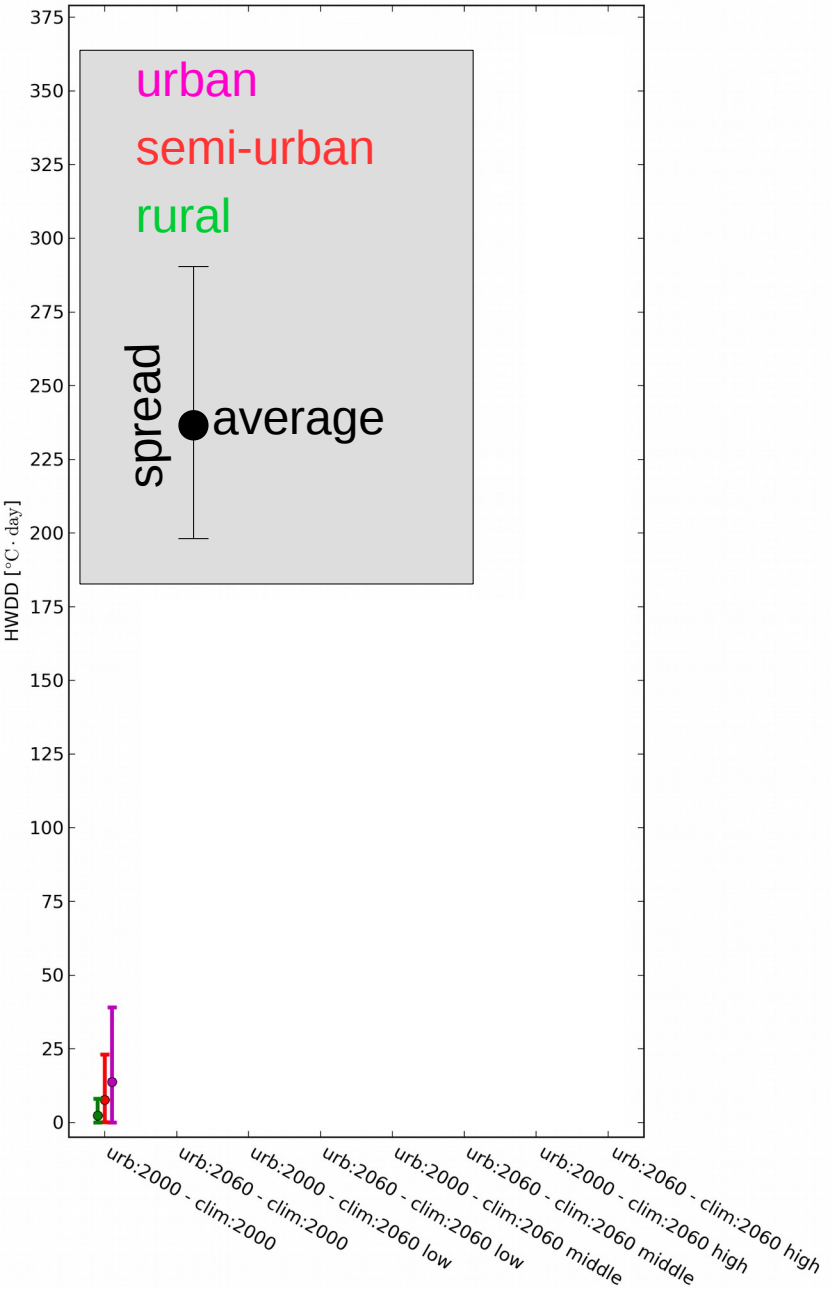

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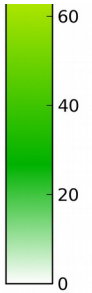

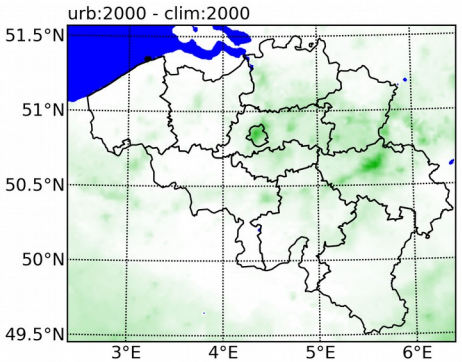

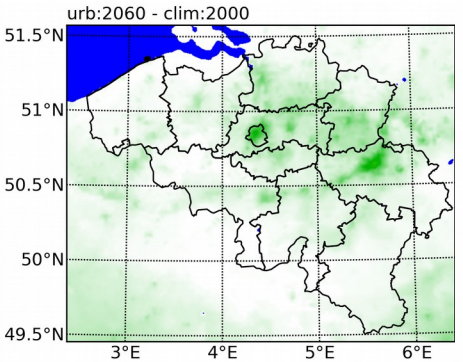

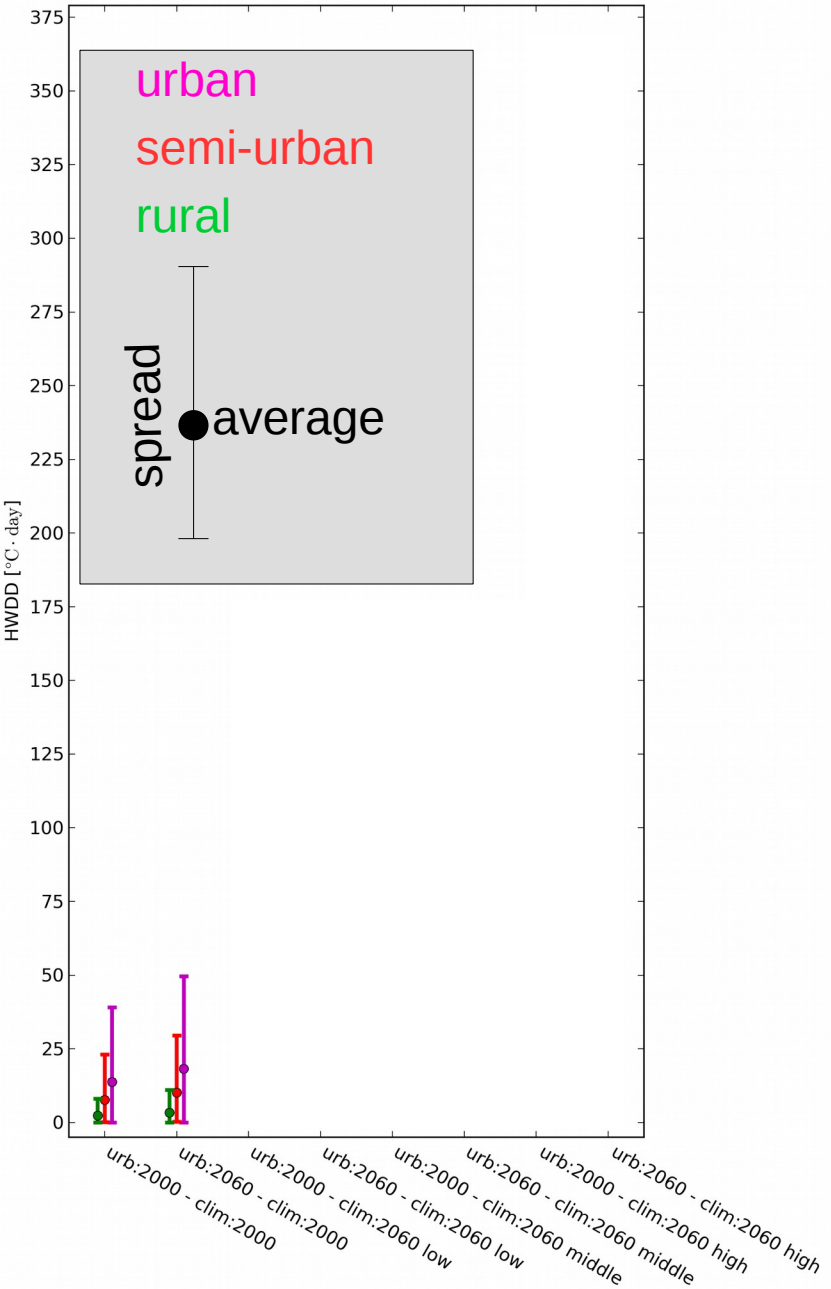

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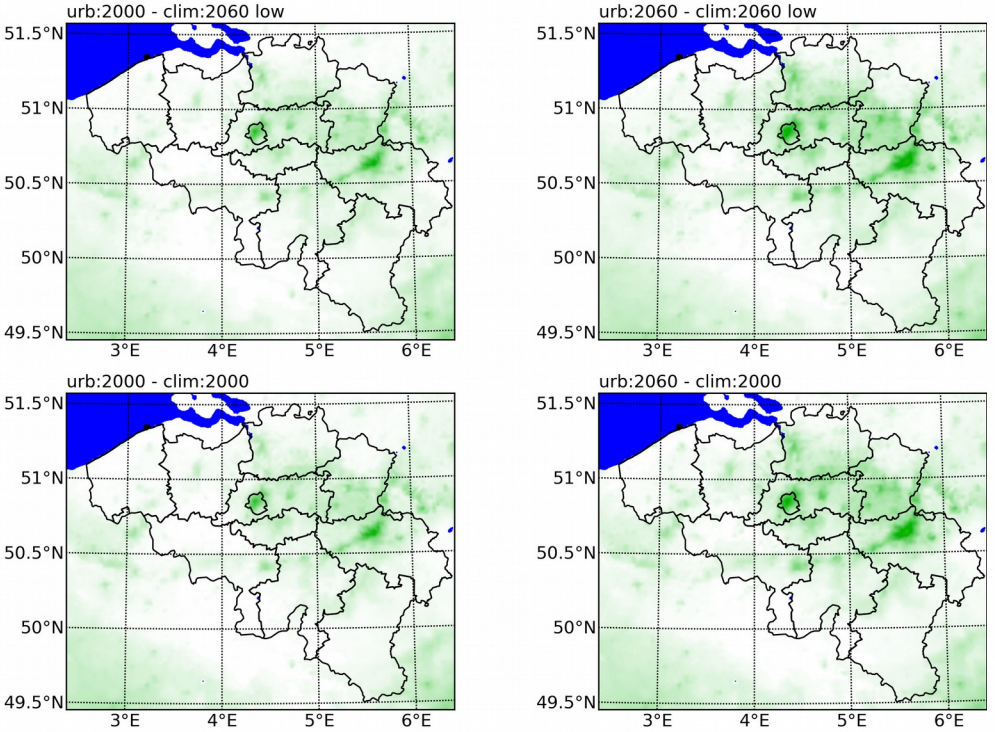

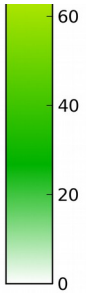

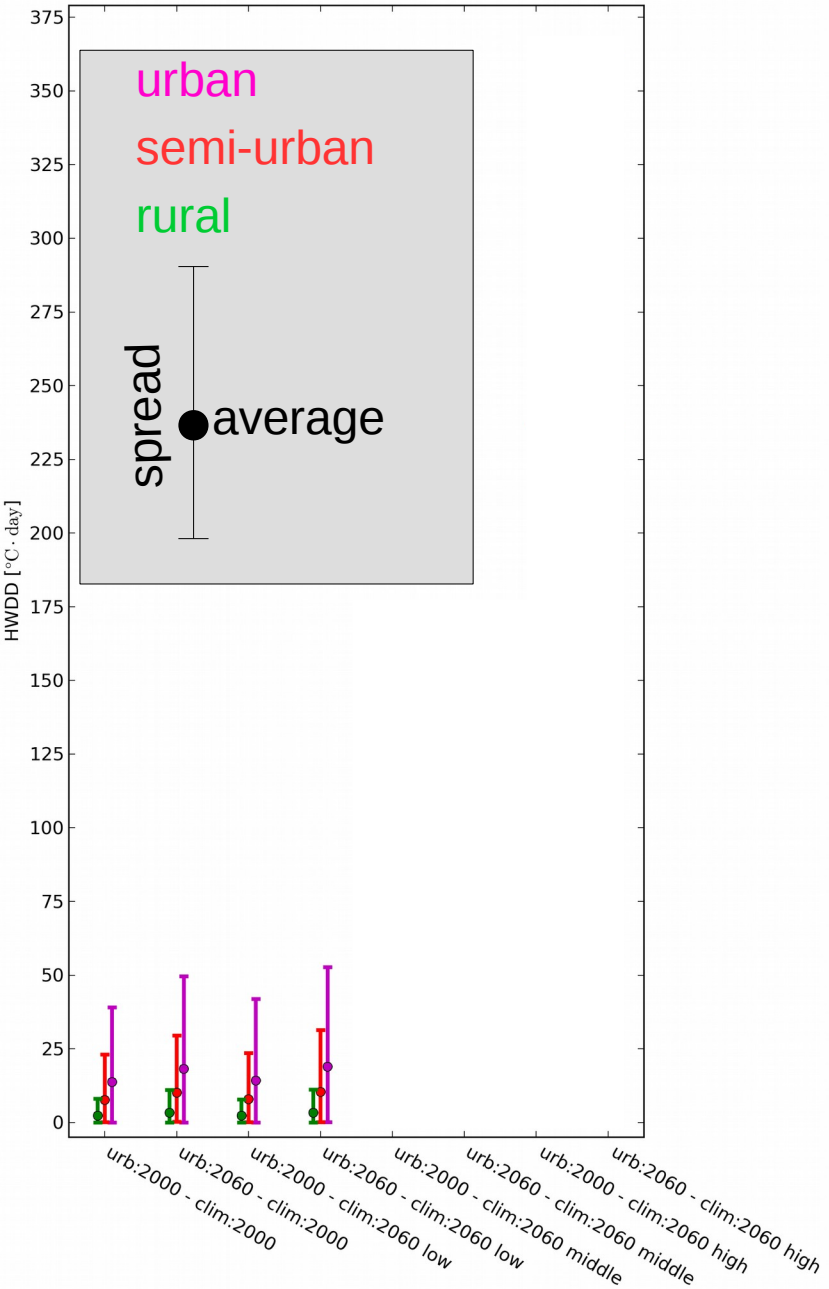

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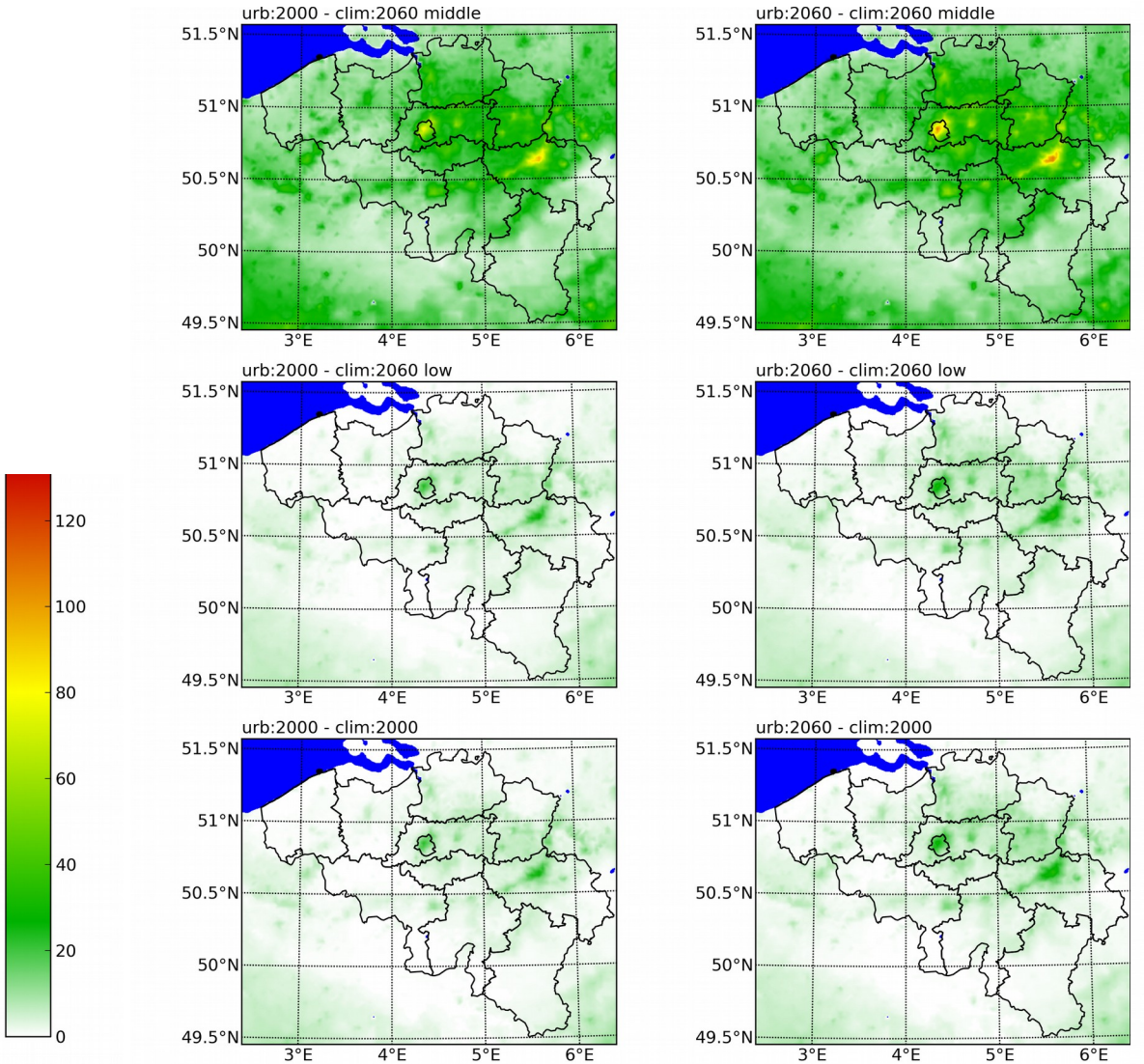
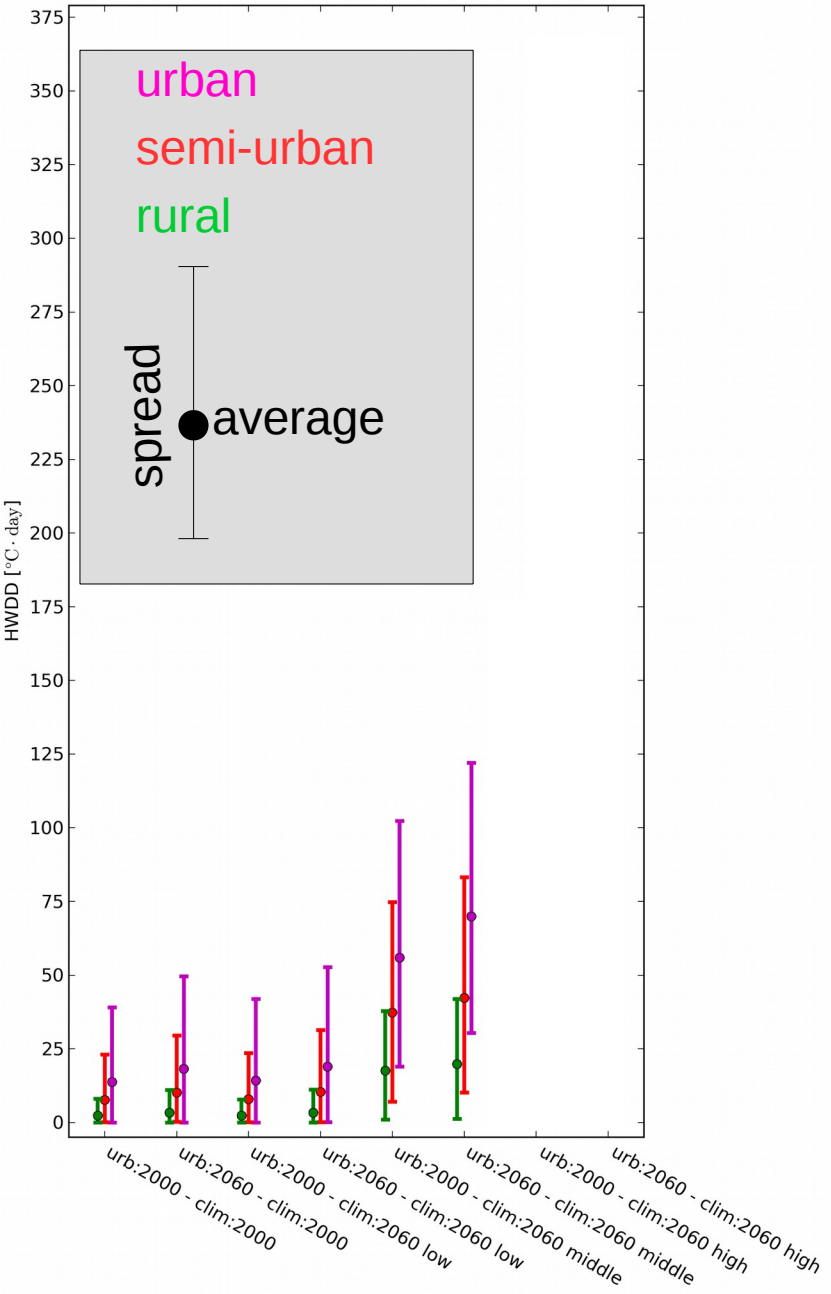
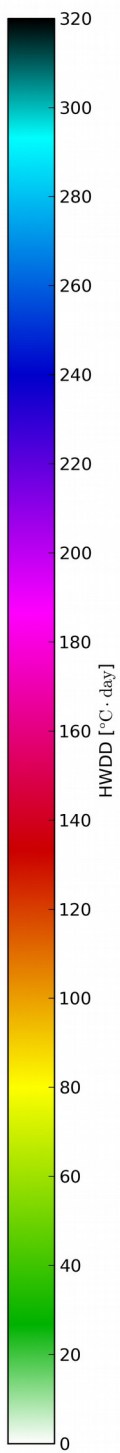
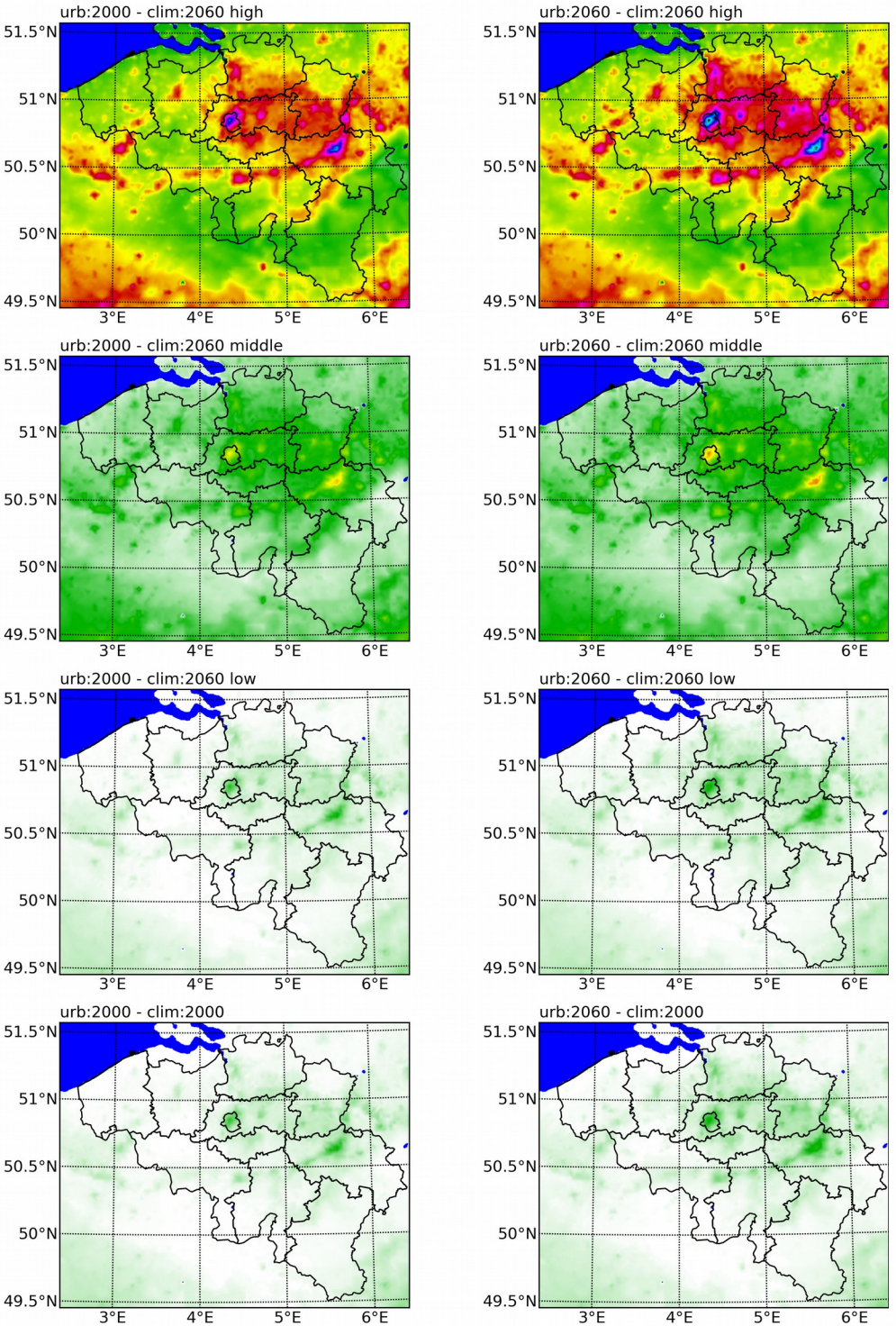
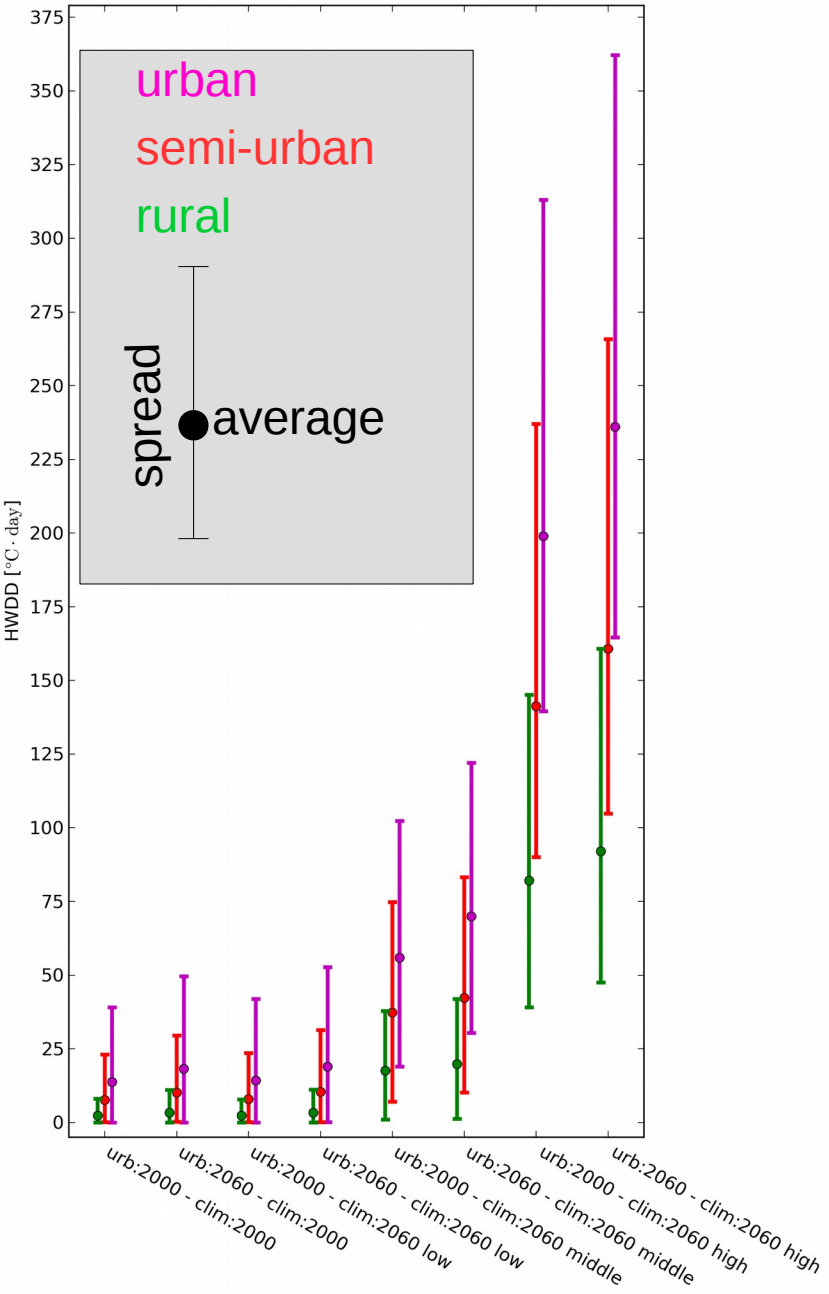




enarios

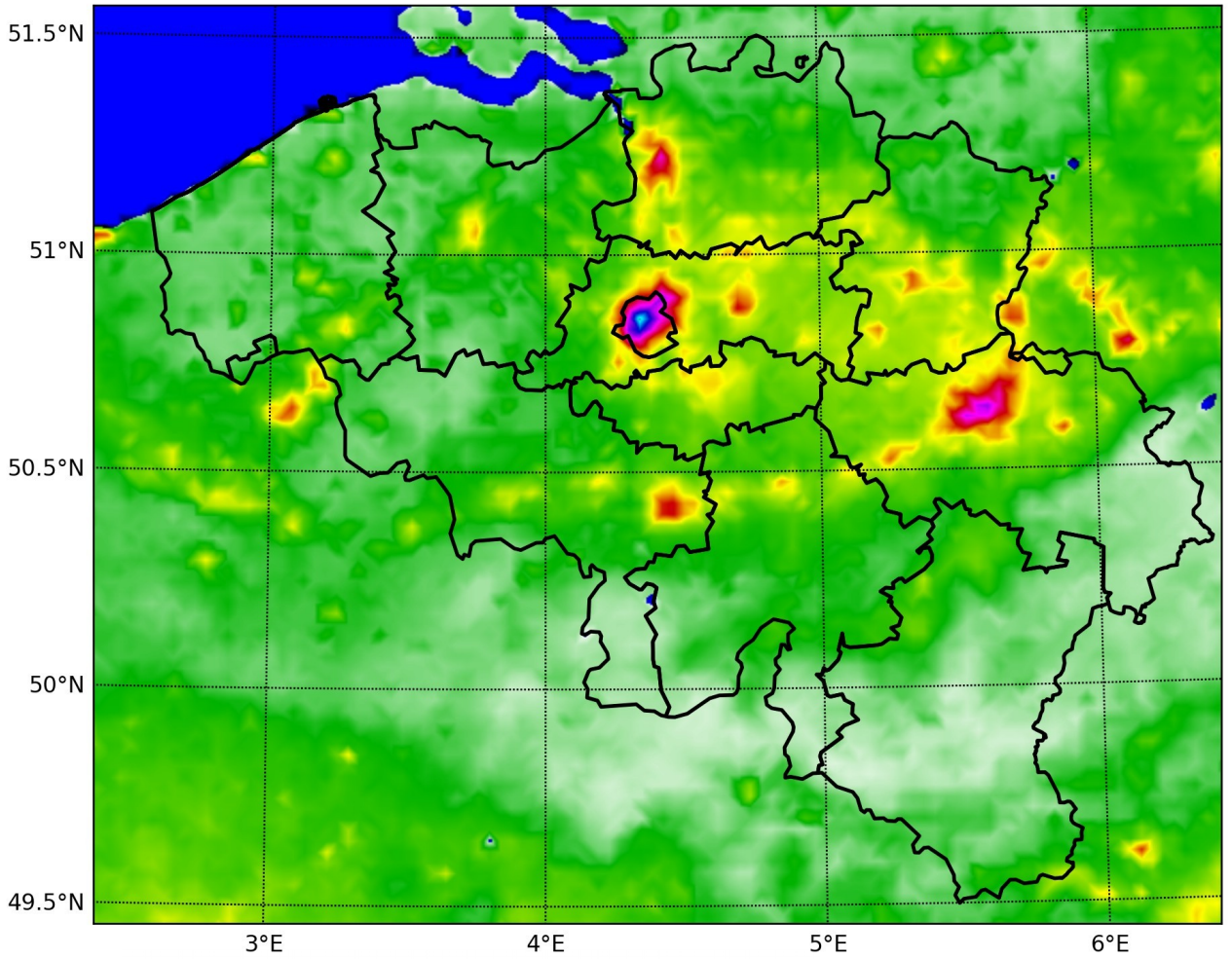

320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
HWDD [°C · day]


urb:2000 - clim:2060 high
urb:2060 - clim:2060 high
urb:2000 - clim:2060 middle
urb:2060 - clim:2060 middle
urb:2000 - clim:2060 low
urb:2060 - clim:2060 low
urb:2000 - clim:2000
urb:2060 - clim:2000
51.5°N
51°N
50.5°N
50°N
49.5°N
3°E
4°E
5°E
6°E


urban
semi-urban
rural
spread
average
HWDD [°C · day]
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
urb:2000 - clim:2000
urb:2060 - clim:2000
urb:2000 - clim:2060 low
urb:2060 - clim:2060 low
urb:2000 - clim:2060 middle
urb:2060 - clim:2060 middle
urb:2000 - clim:2060 high
urb:2060 - clim:2060 high

Conclusions

- Present-day heat stress in Belgium is primarily occuring in cities
- Increment of heatstress mainly originates from global climate change
- Cities are the hotspots of climate change: increment of heat stress is the largest in cities where it is already warmer
- Heat stress in city centres is further intensified by urban expansion



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