Urban effects on summertime air temperature in Germany under climate change

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Motivation

How do urban effects on air temperature change under climate change in Germany?

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Approaches:

- global and regional climate ensembles
  → robust predictions but no (sufficiently detailed) urban effects
- RCM simulations at urban scale / urban models
  → computationally expensive
  → either applied offline (e.g. Lemonsu et al. 2013) or online (e.g. Hamdi et al. 2014)

Reduction of computational demand of RCM simulations

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average projected monthly warming added to the boundary conditions from reanalysis
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Our approach:

- focus on summer time (JJA)
- analyse average conditions
- 3 driving CMIP5 GCMs (RCP 8.5): CNRM-CM5, HadGEM2-ES, MPI-ESM-LR

Definition of *average summer*

Average in terms of

- minimum, mean and maximum 2 m temperature percentiles averaged over Germany
- reference data: e.g. gridded observation dataset E-OBS (version 10.0)
- reference period: historical (1976–2005), future (2031–2060)

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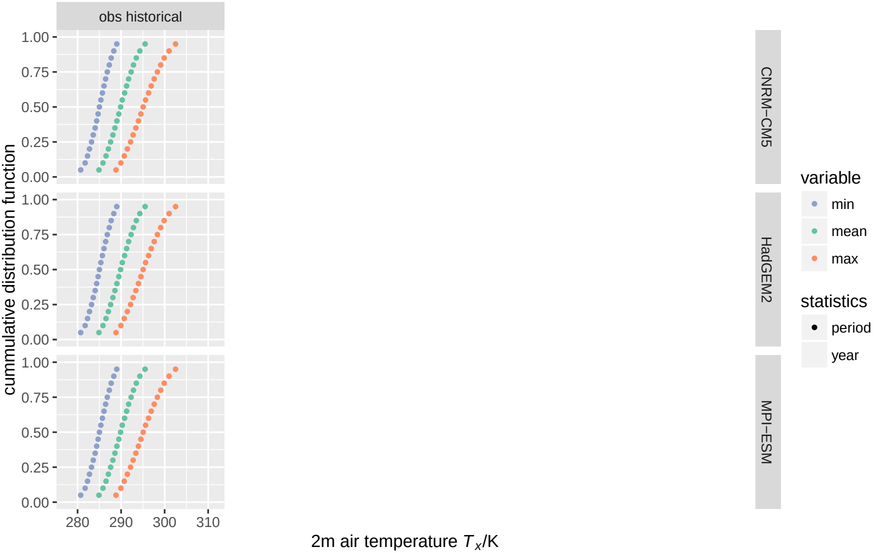
2. calculate same temperature percentile of GCMs for single years of reference period separately
3. select year for each GCM that minimizes average mean-square-deviation between percentiles of 1 und 2

Observation reference data: E-OBS (1976–2005)



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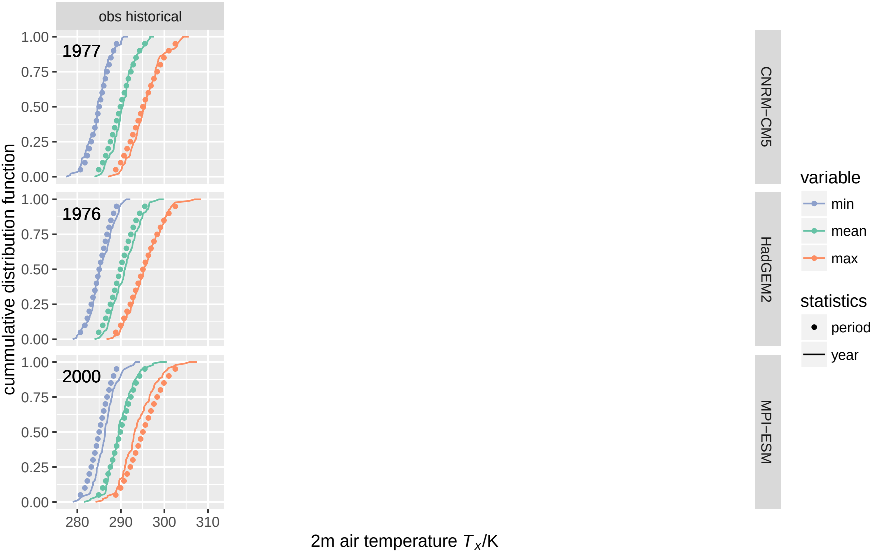

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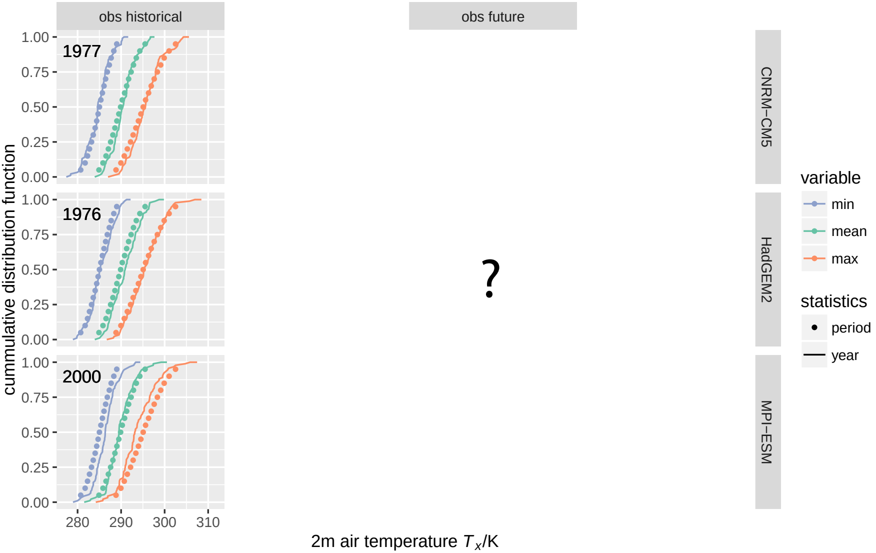
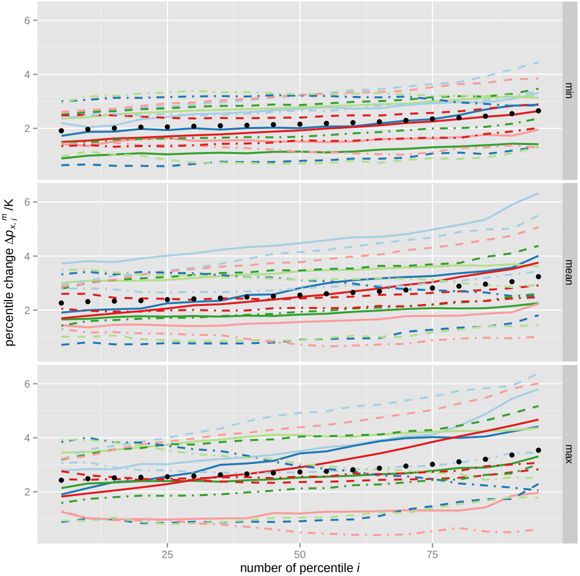


Climate change signal (CCS) 1976–2005 → 2031–2060

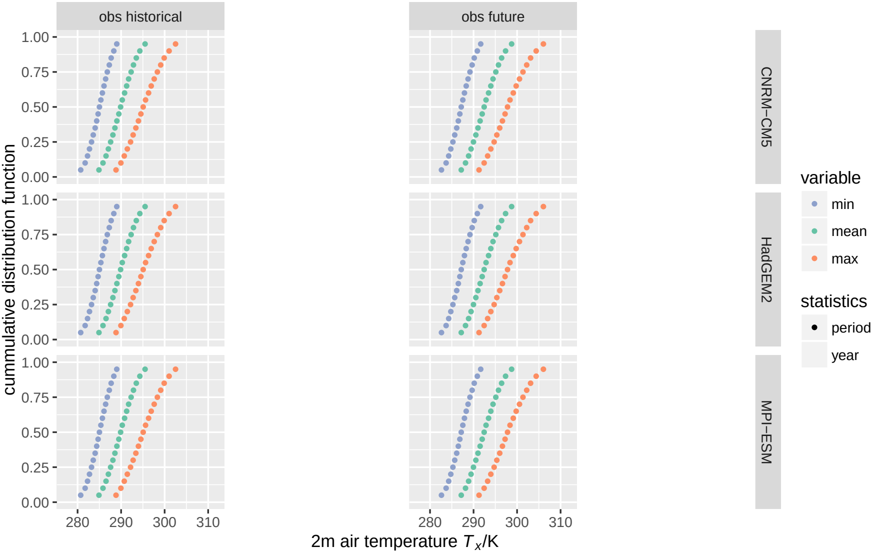


Climate change signal (CCS):

- 1976–2005 → 2031–2060
- percentile based
- 18 CMIP5 GCMs (lines)

ensemble average CCS (black dots) added to observation percentiles

E-OBS (1976–2005) + CCS(1976–2005 → 2031–2060)



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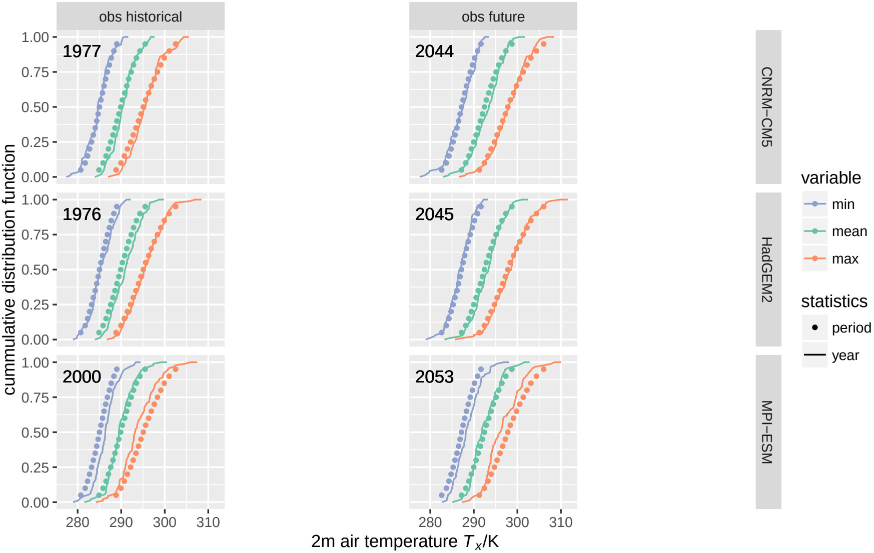
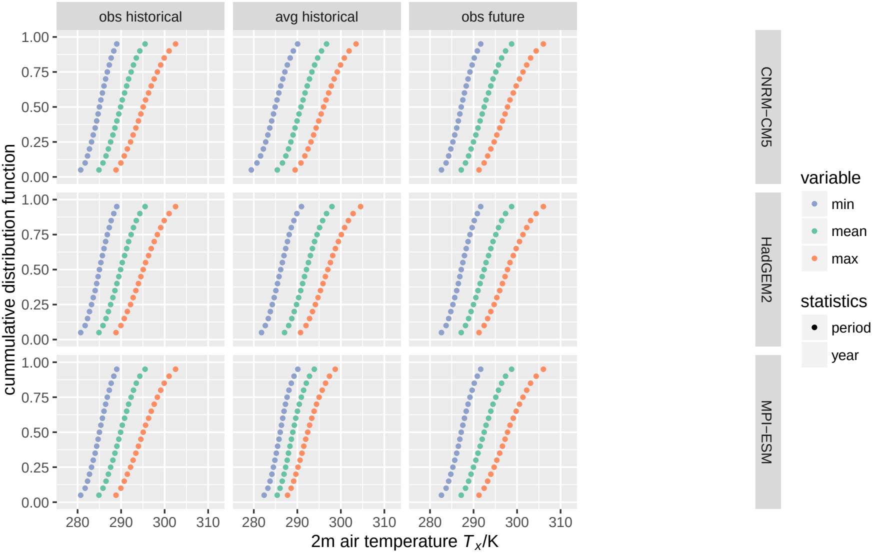
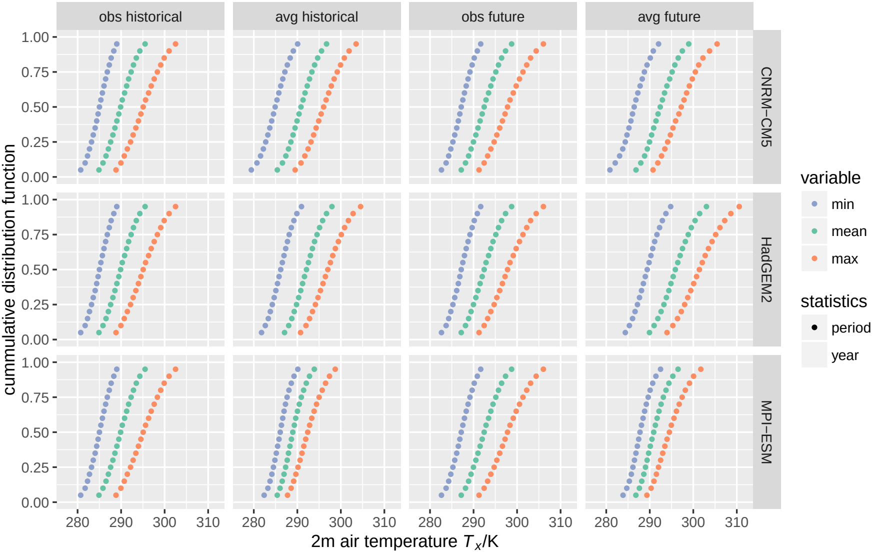


Average model reference data: historical (1976–2005)



Average model reference data: future (2031–2060)



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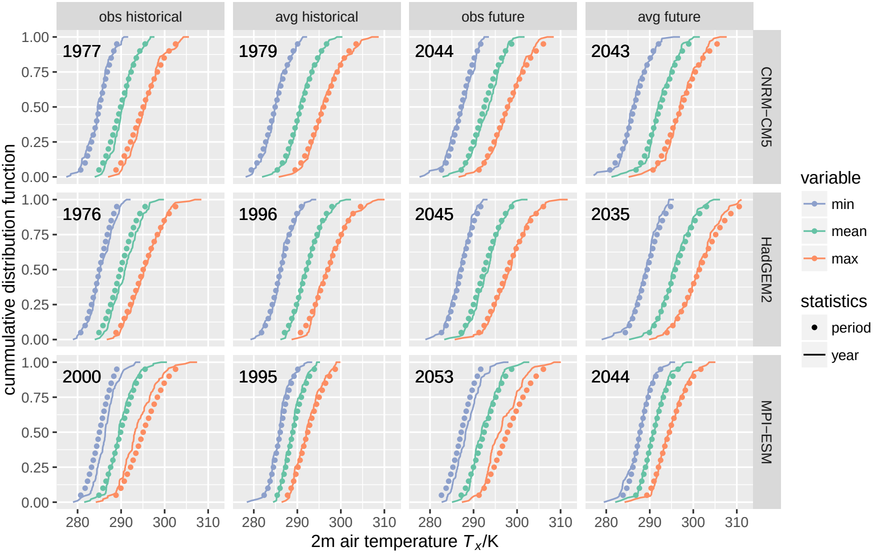
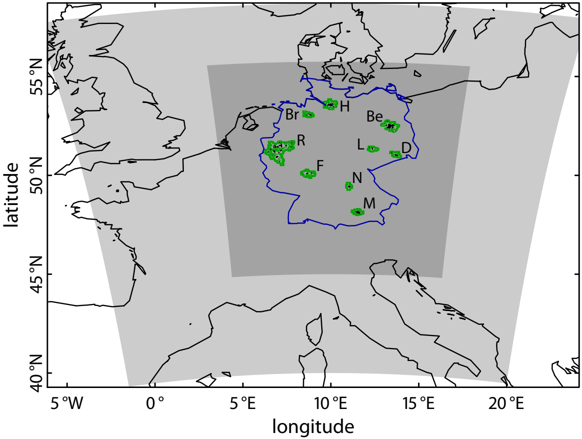


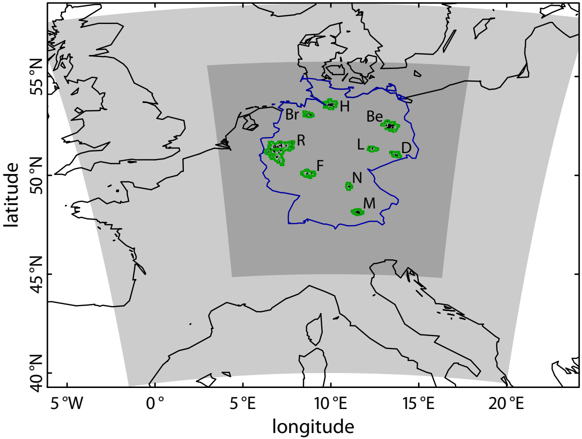
COSMO-CLM set-up

- Version 4.8_clm19
- Nesting steps: grid-spacing of 0.22°, 0.065° and 0.025°
- Finest nesting step:
  - Urban parametrization DCEP (Schubert et al. 2012)
  - 50 vertical levels



Urban parameters

Parameters from CORINE land-use data: e.g. urban fraction f_u



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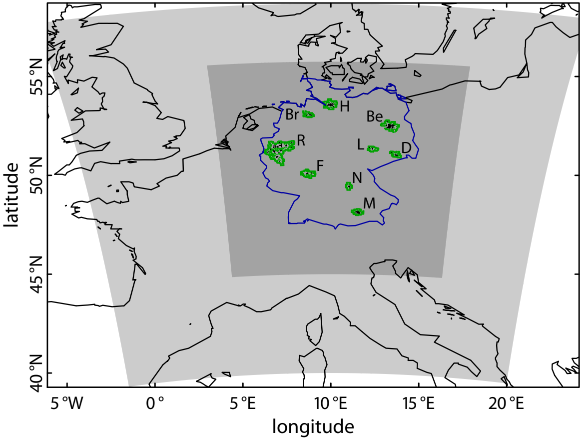
Parameters from CORINE land-use data: e.g. urban fraction f_u

Urban cluster ($f_u > 5\,\%$):

- urban core: $f_u > 50\,\%$
- rural reference area: boundary of cluster



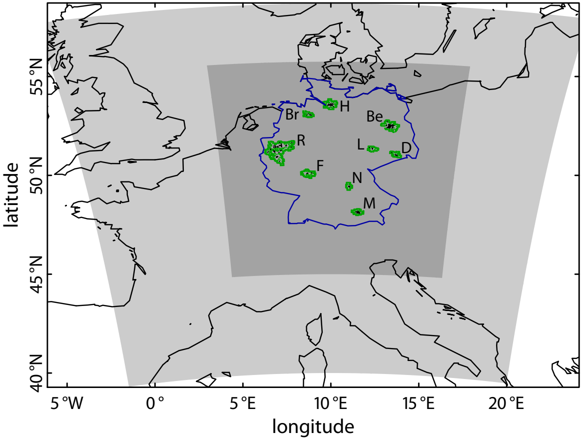
Definitions

- Average properties of *urban* core or *rural* reference area: e.g. 2 m temperature T_u or T_r
- Urban heat island intensity:

$$\Delta T_{u-r} = T_u - T_r$$

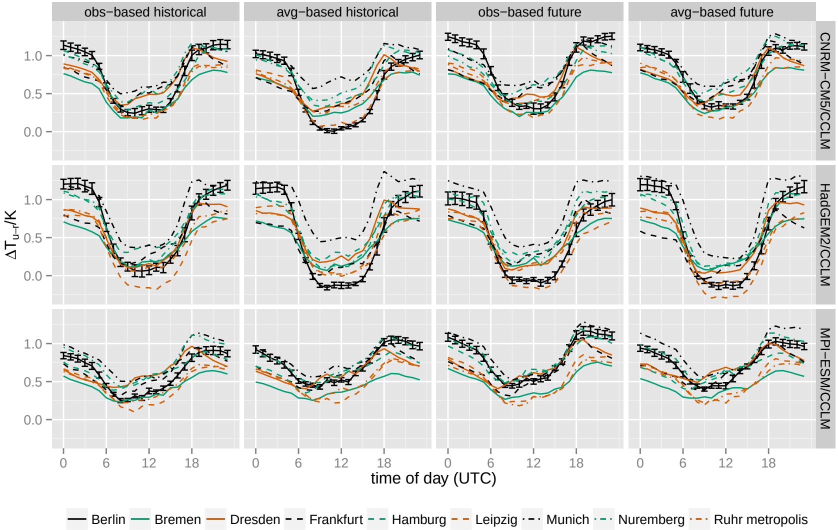
- Rural Bowen ratio:

$$\beta_r = H_r / \lambda E_r$$

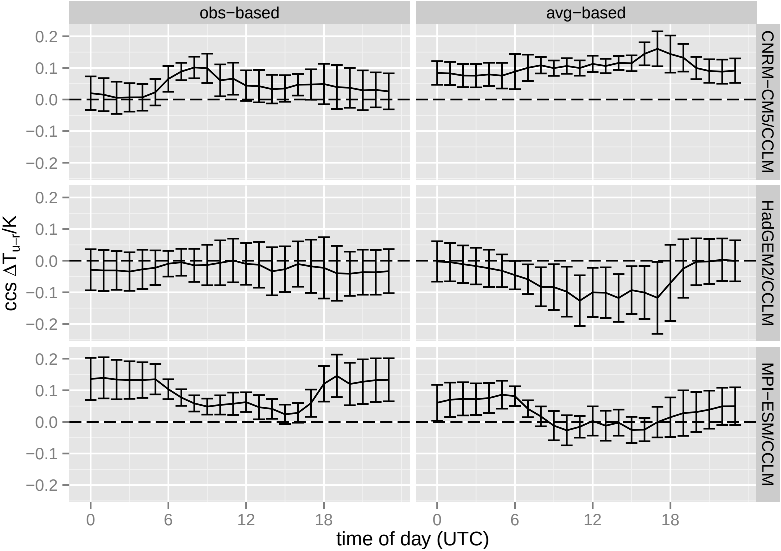


Uncertainty estimation: bootstrap; bars represent standard deviation of average of bootstrap samples

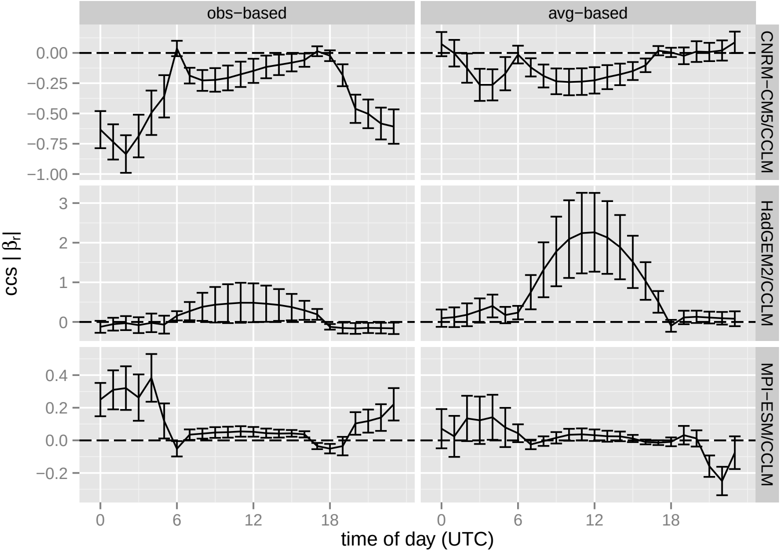
Urban heat island intensity



Climate change signal of urban heat island intensity



Climate change signal of rural Bowen ratio



Summary

- Topic: urban effects under climate change (1976–2005 to 2031–2060) of 9 largest German metropolitan areas
- Analysed single summers of three GCMs representing average summer conditions (in terms of observations and GCM conditions)
- City ensemble's summer mean hourly climate change signal of urban heat island intensity: −0.13 K to 0.16 K
- Importance of driving GCM: GCM determines characteristics of
  - urban heat island intensity
  - urban heat island climate change signal
  - surface energy fluxes
- Details in Grossman-Clarke et al. (2016). 'Urban effects on temperature in Germany under climate change'. In: International Journal of Climatology

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Thank you for your attention!

Literature

Früh, B., P. Becker, T. Deutschländer, J.-D. Hessel, M. Kossmann, I. Mieskes, J. Namyslo, M. Roos, U. Sievers, T. Steigerwald, H. Turau and U. Wienert (2011). 'Estimation of Climate-Change Impacts on the Urban Heat Load Using an Urban Climate Model and Regional Climate Projections'. In: *Journal of Applied Meteorology and Climatology* 50.1, pp. 167–184.

Grossman-Clarke, S., S. Schubert and D. Fenner (2016). 'Urban effects on temperature in Germany under climate change'. In: *International Journal of Climatology*. Pre-published.

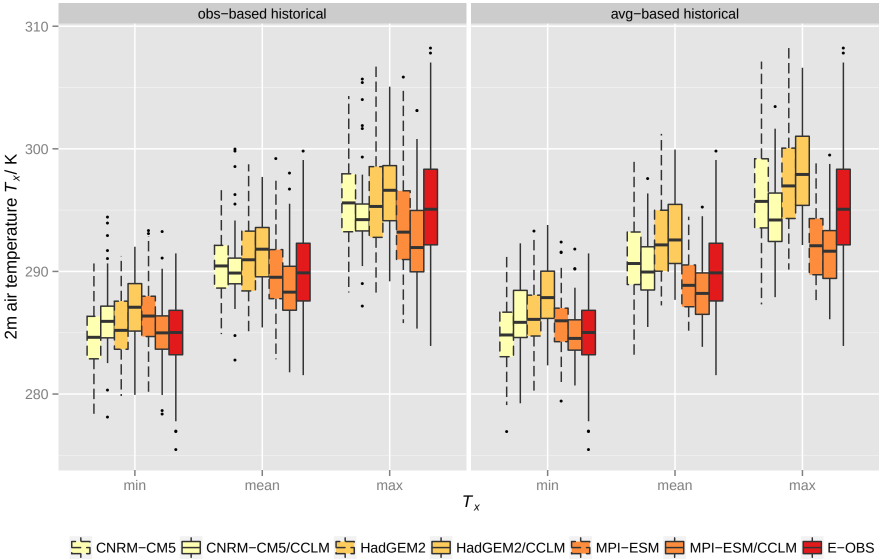
Hamdi, R., H. Van de Vyver, R. De Troch and P. Termonia (2014). 'Assessment of three dynamical urban climate downscaling methods: Brussels's future urban heat island under an A1B emission scenario'. In: *International Journal of Climatology* 34.4, pp. 978–999.

Kimura, F. and A. Kitoh (2007). *Downscaling by Pseudo Global Warning Method*. Research Institute for Humanity and Nature.

Lemonsu, A., R. Kounkou-Arnaud, J. Desplat, J.-L. Salagnac and V. Masson (2013). 'Evolution of the Parisian urban climate under a global changing climate'. English. In: *Climatic Change* 116.3-4, pp. 679–692.

Schubert, S., S. Grossman-Clarke and A. Martilli (2012). 'A Double-Canyon Radiation Scheme for Multi-Layer Urban Canopy Models'. In: *Boundary-Layer Meteorology* 145.3, pp. 439–468.

Temperature distribution of GCM and GCM/CCLM



Evaluation of 10 year simulation for Berlin