Urban effects on summertime air temperature in Germany under climate change

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COSMO/CLM/ART User Seminar 2016

Contents

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

Relevance without simulating 30 years historical and 30 years future for several GCMs?

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Pseudo global warming method (Kimura and Kitoh 2007):
average projected monthly warming added to the boundary conditions from reanalysis
Cuboid method (Früh et al. 2011):
linearly interpolate between idealized simulations that envelope possible urban weather

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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. observation E-OBS gridded dataset (version 10.0)
- reference period: historical (1976–2005), future (2031–2060)

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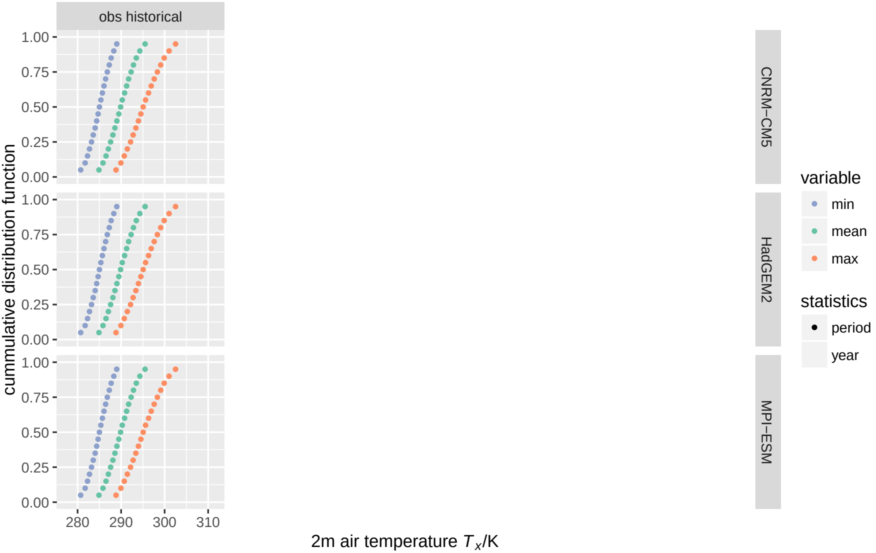
2. calculate same temperature percentile for each GCM during each year of reference period separately
3. select year for each GCM that minimizes average mean-square-deviation between percentiles of 1 und 2

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



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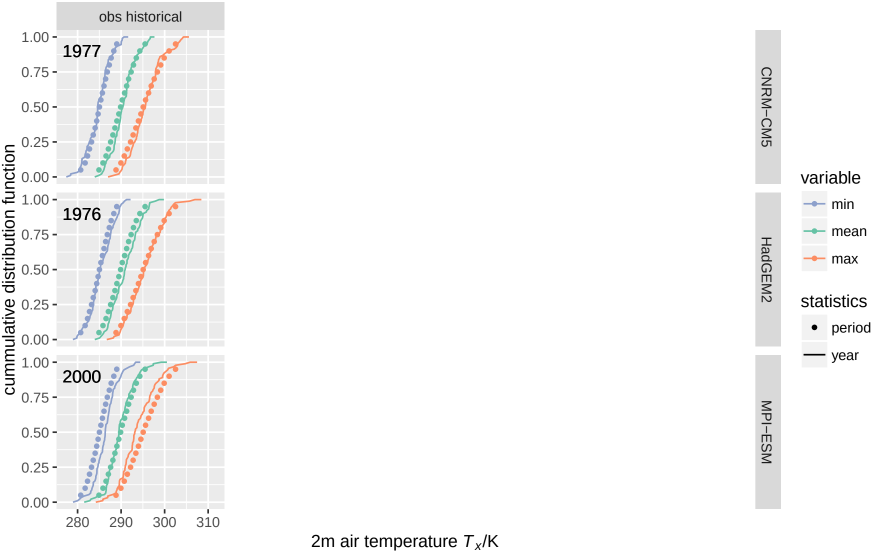

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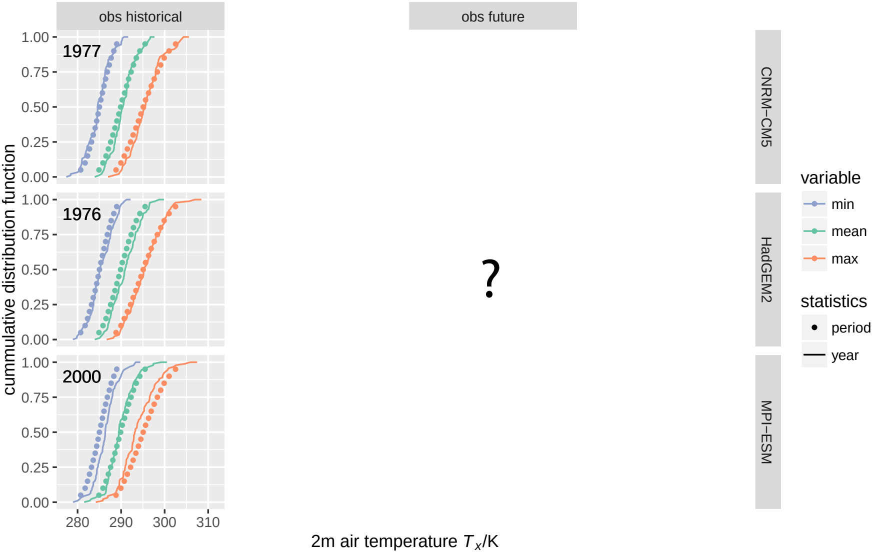
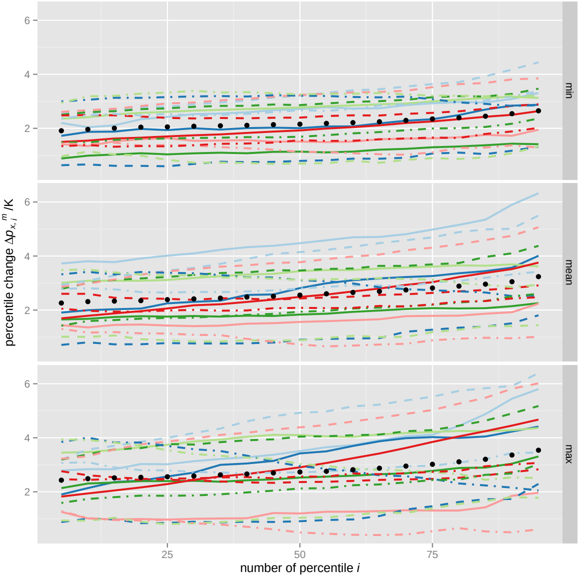


Climate change signal (CCS) 1976–2005 → 2031–2060

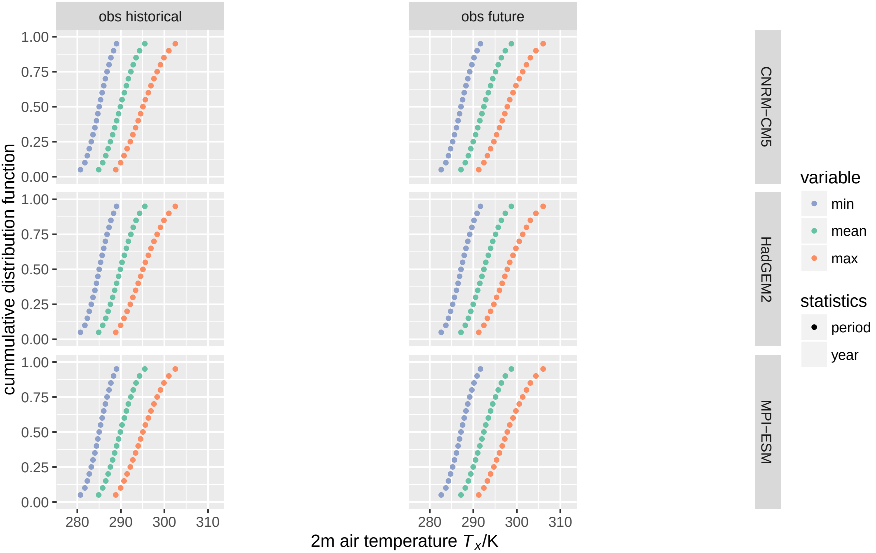


Climate change signal (CCS):

- 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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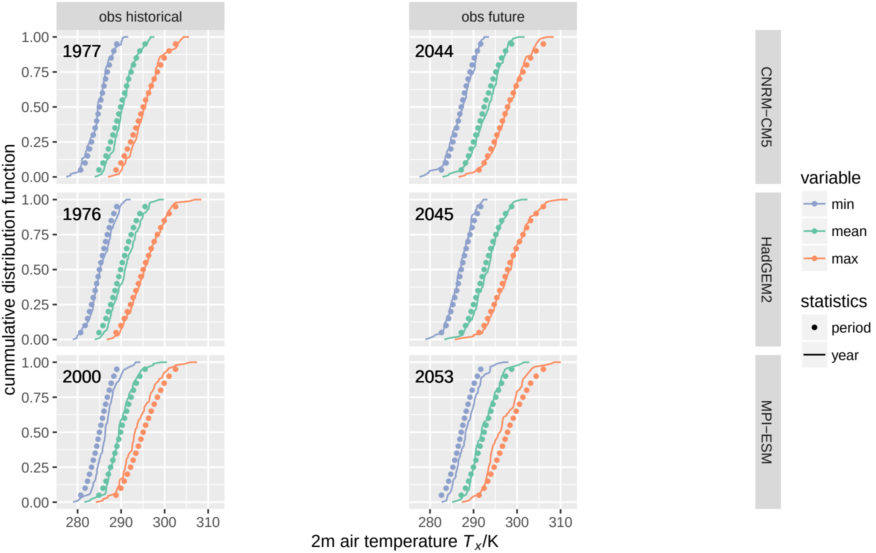
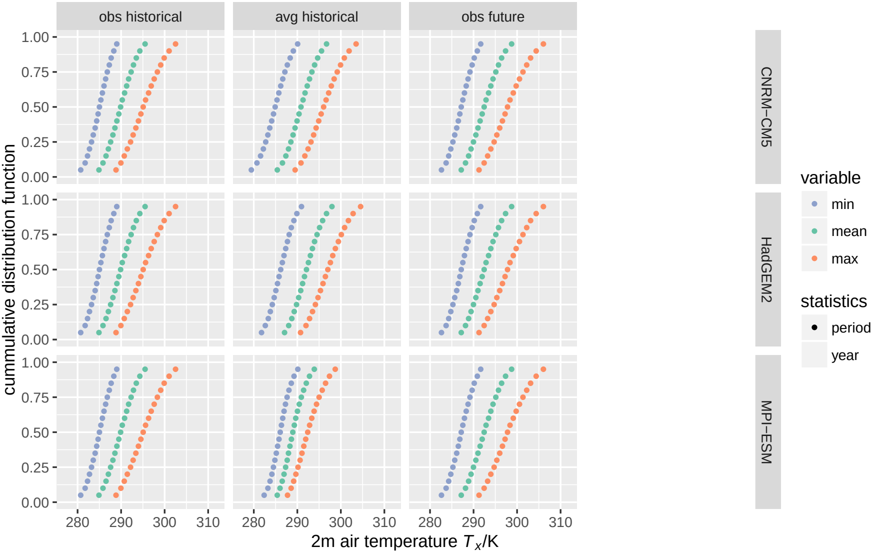
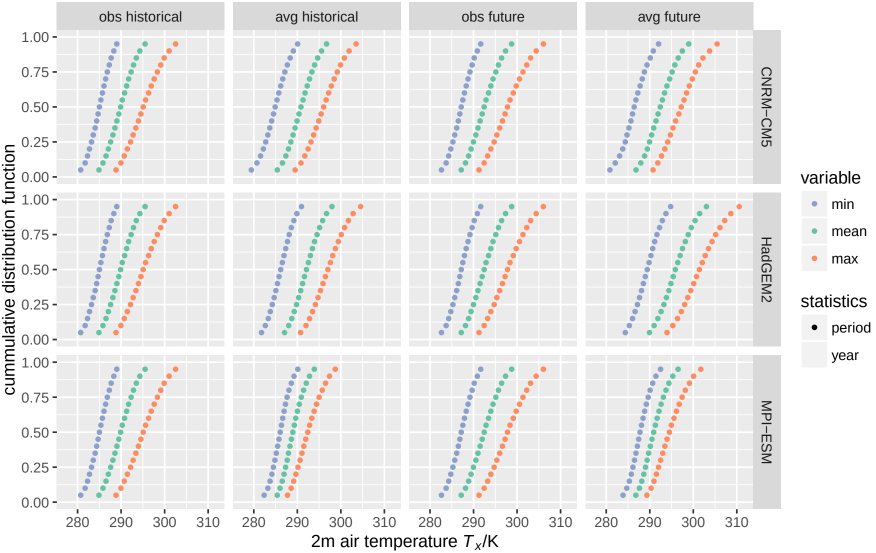


Average model reference data: historical (1976–2005)



Average model reference data: future (2031–2060)



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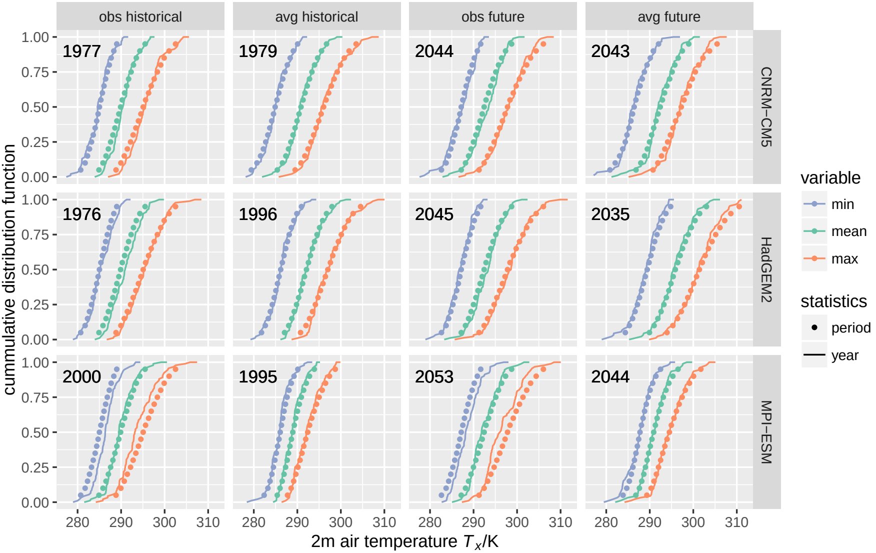
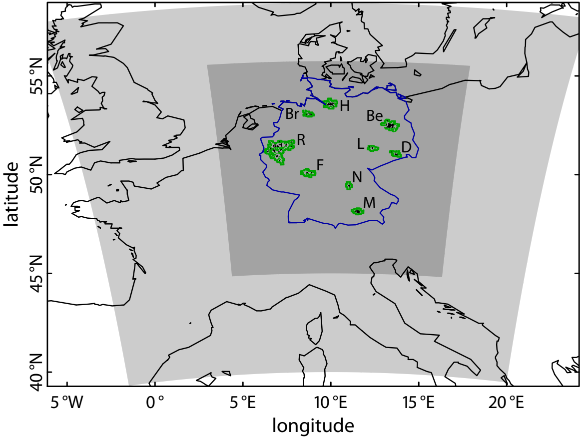


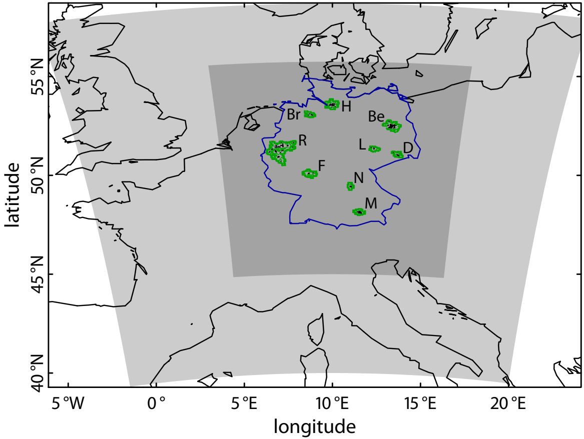
COSMO-CLM set-up

- 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

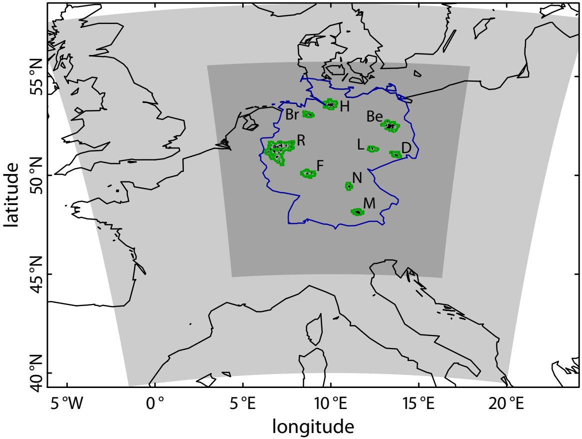


Urban parameters

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



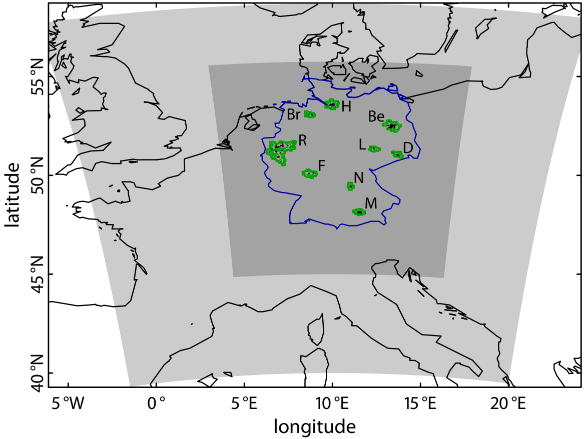
Definitions

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

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

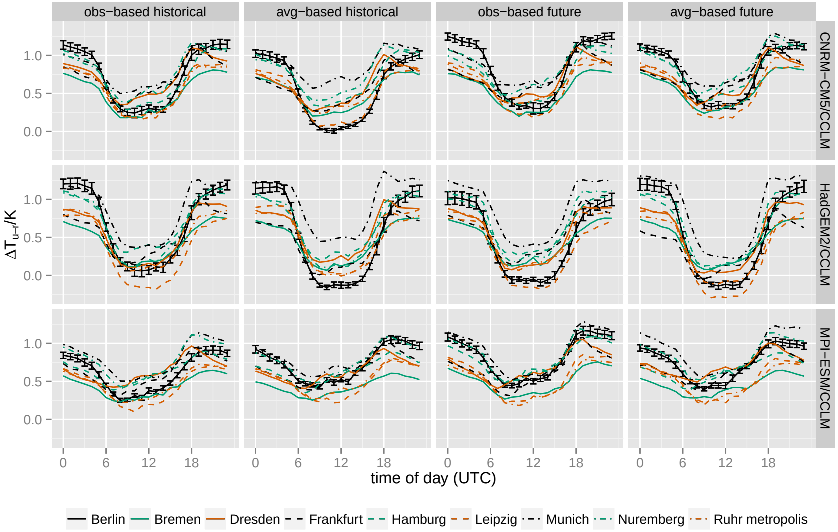
- Rural Bowen ratio:

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

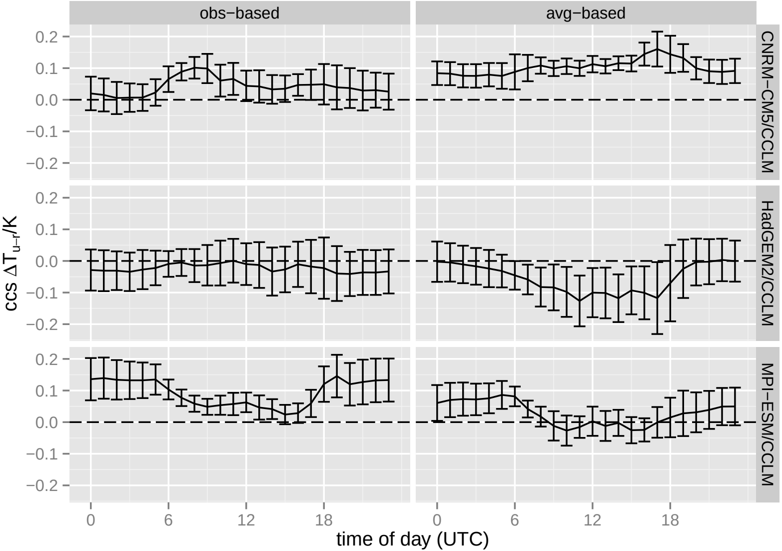


Error estimation: bootstrap; error bars represent standard deviation of average of bootstrap samples

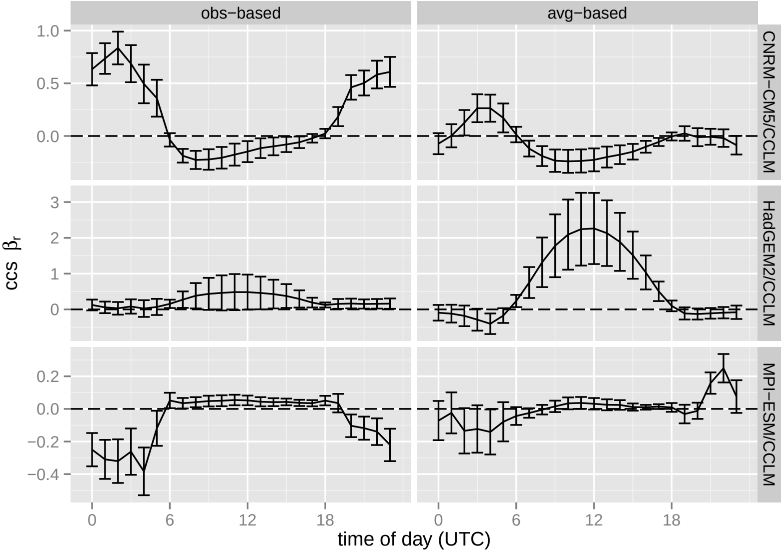
Urban heat island intensity



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 upcoming paper: Grossman-Clarke et al. (2016) in *International Journal of Climatology*

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Thank you for your attention!

Literature

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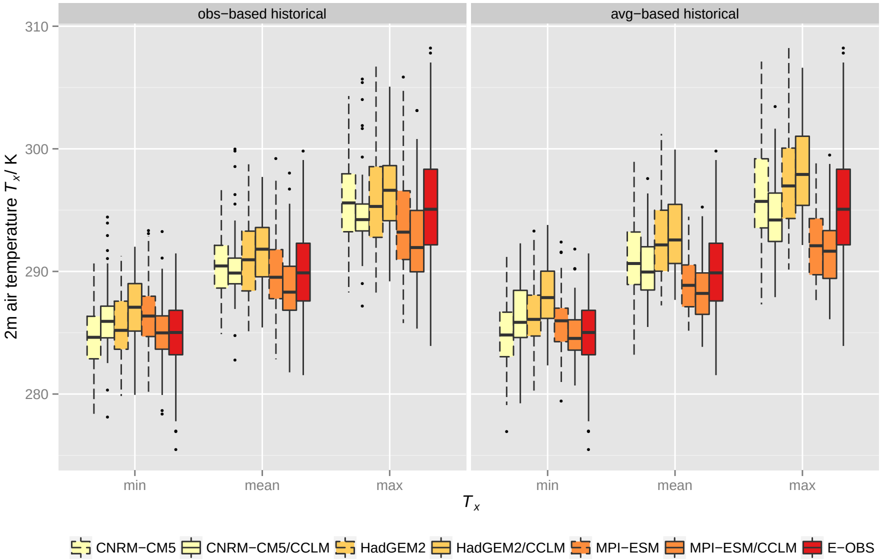
Kimura, F. and A. Kitoh (2007). *Downscaling by Pseudo Global Warning Method*. Research Institute for Humanity and Nature.

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