A double-canyon radiation scheme for urban canopy models

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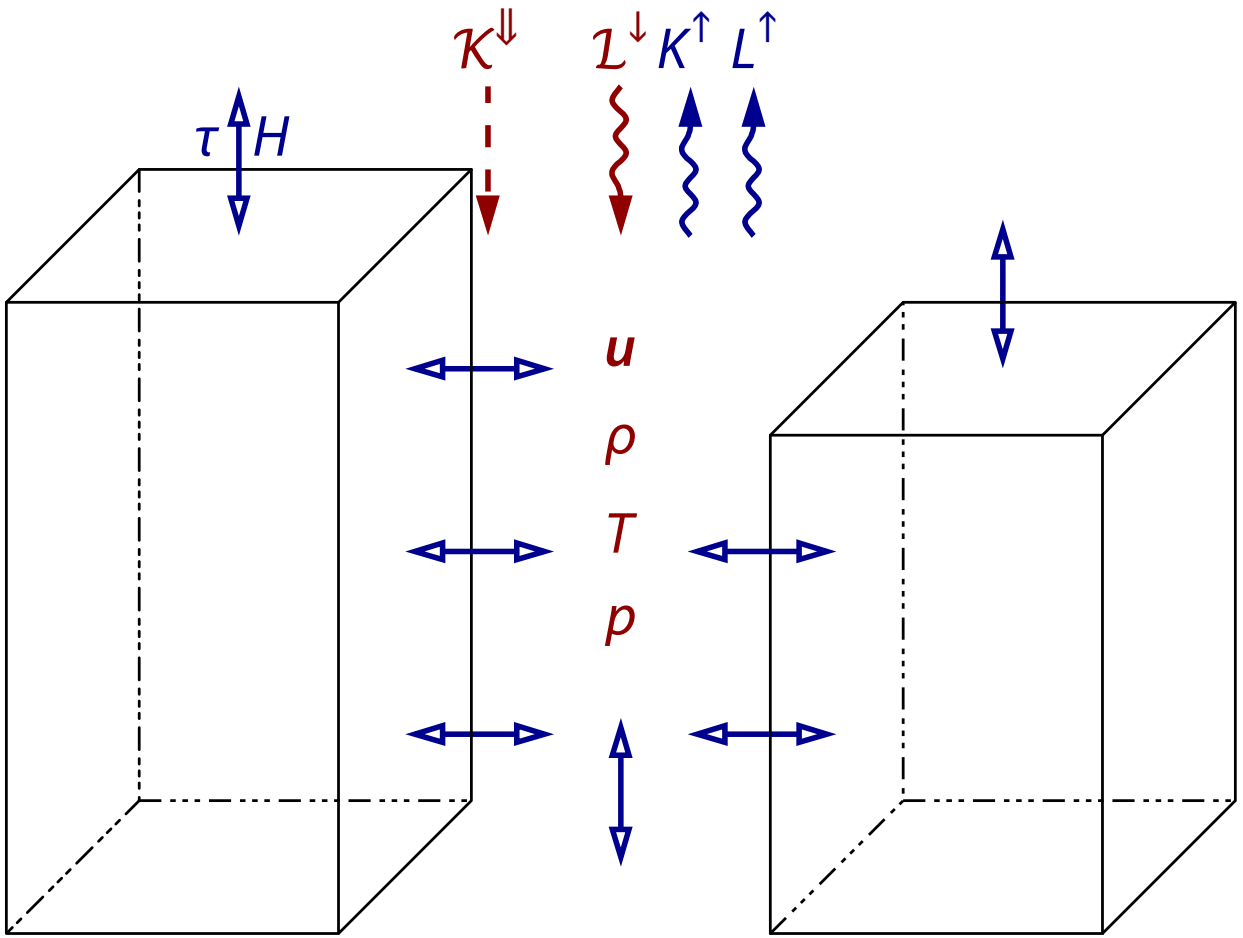
POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Contents

Contents

Building Effect Parametrization Model by Martilli et al.

Multilayer Street Canyon model



Input of BEP:

- $\mathcal{L}^{\downarrow}$: longwave rad. (down)
- $\mathcal{K}^{\Downarrow}$: shortwave rad (down)
- $\boldsymbol{u}$: wind velocity
- ρ: air density
- T: air temperature
- p: air pressure

Output of BEP:

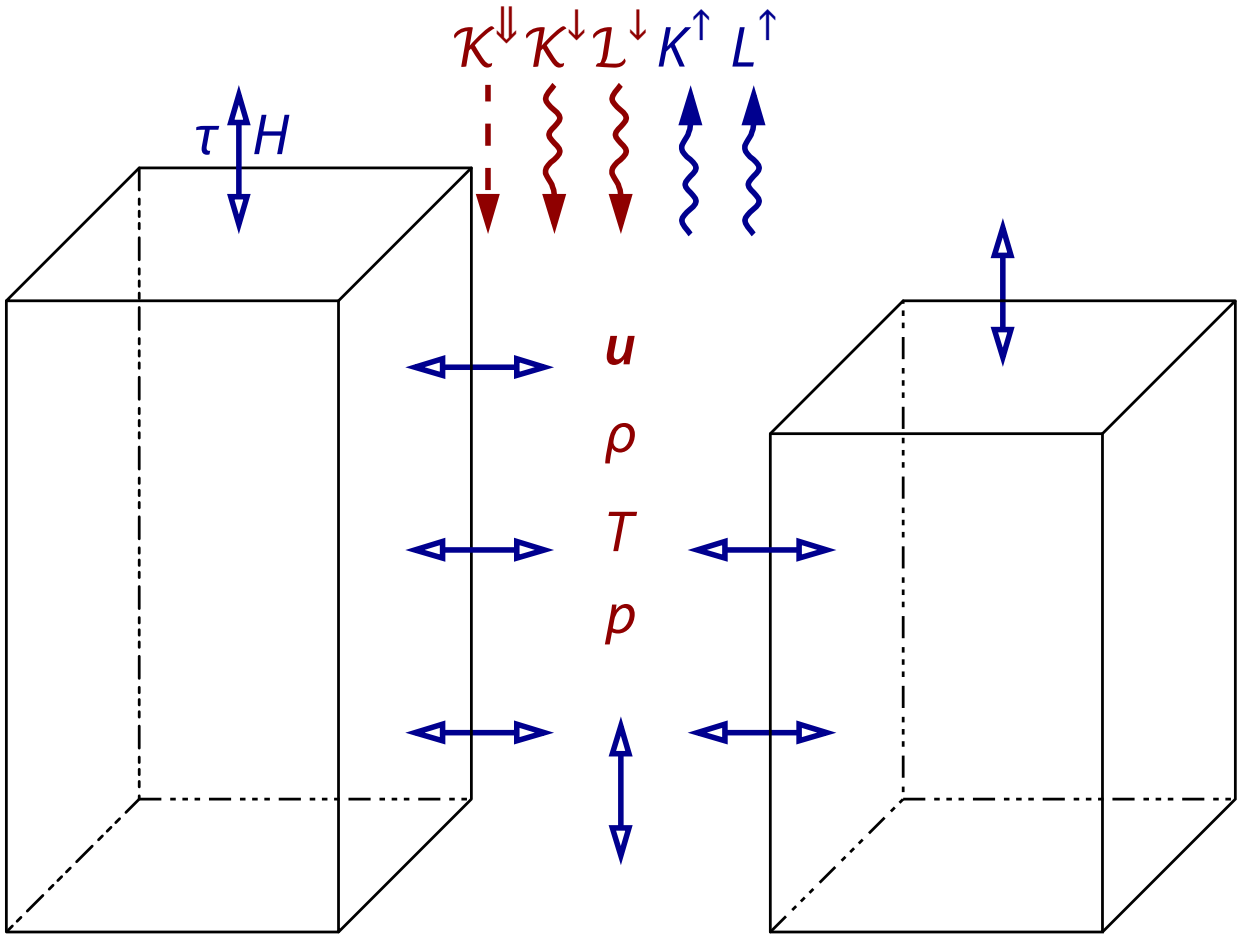
- $L^{\uparrow}$: longwave rad. (up)
- $K^{\uparrow}$: shortwave rad. (up)
- H: sensible heat flux
- τ: momentum flux

BEP by Martilli et al. (continued)

Issues in the radiation part of BEP

1. no differentiation between diffuse and direct shortwave radiation
2. energy balance of incoming and distributed radiation not closed
3. roofs do not interact with other urban surfaces, no shadow effects on roofs independent of roof height

1 Consider diffuse and direct solar radiation



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- τ: momentum flux

- diffuse solar radiation formulated analogously to diffuse longwave radiation
- separation of effective urban albedo for diffuse and direct radiation

2 Correction of incoming diffuse radiation

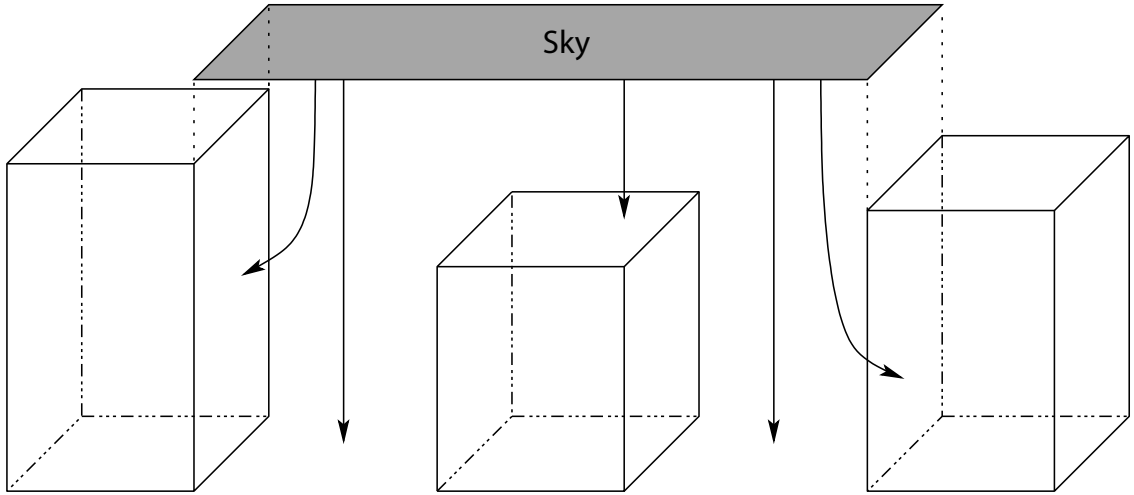
- reduce irradiance to fulfill energy conservation

- without correction
  - unphysical values of effective urban albedo $\alpha_{\mathrm{urb}} \equiv K^{\uparrow}/(\mathcal{K}^{\downarrow} + \mathcal{K}^{\Downarrow})$
  - underestimation of effective urban surface temperature

3 Double Canyon Effect Parametrization

extend the basic canyon element to include another canyon

- distribution of diffuse radiation using view factor formalism
- roofs do not receive the full diffuse sky radiation



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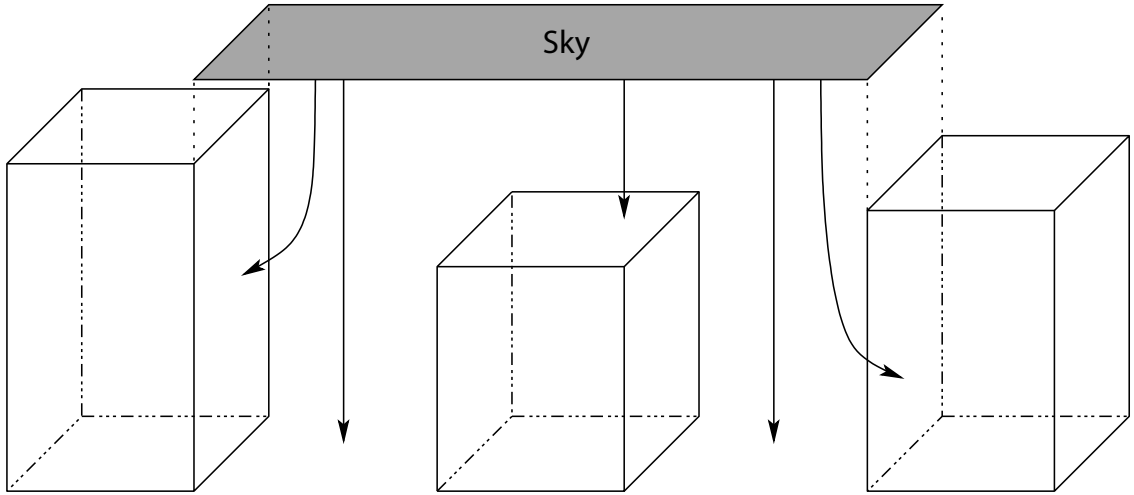
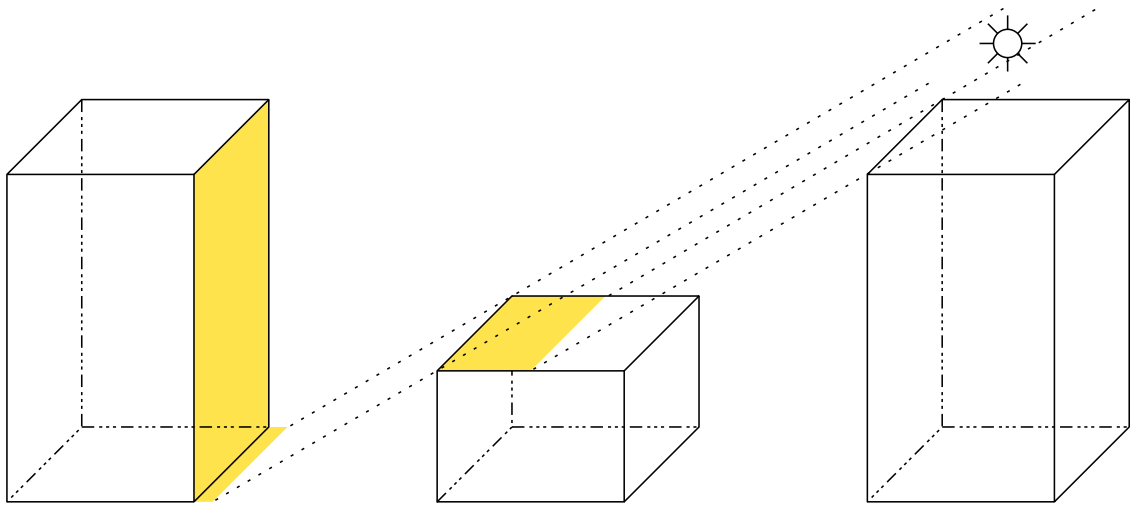
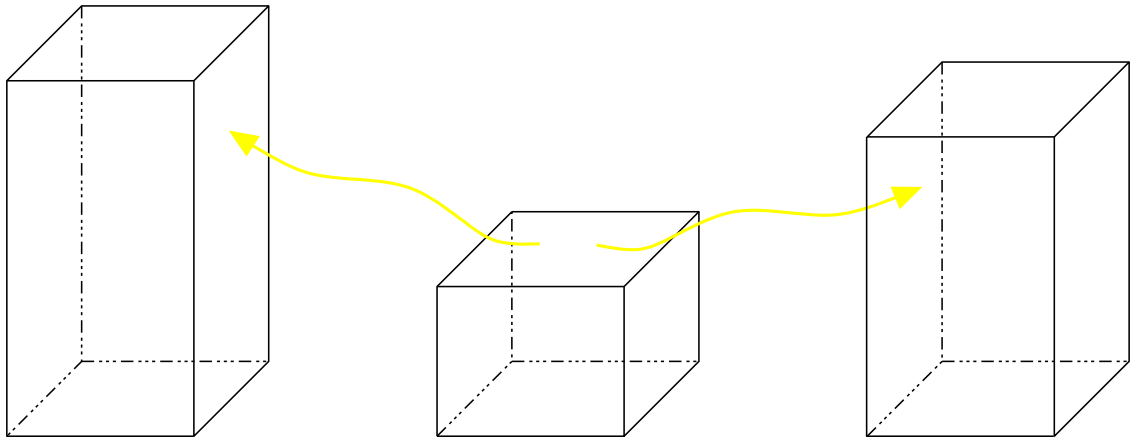


- calculation of received direct solar radiation depending on the position of the sun
- shadows on roofs possible

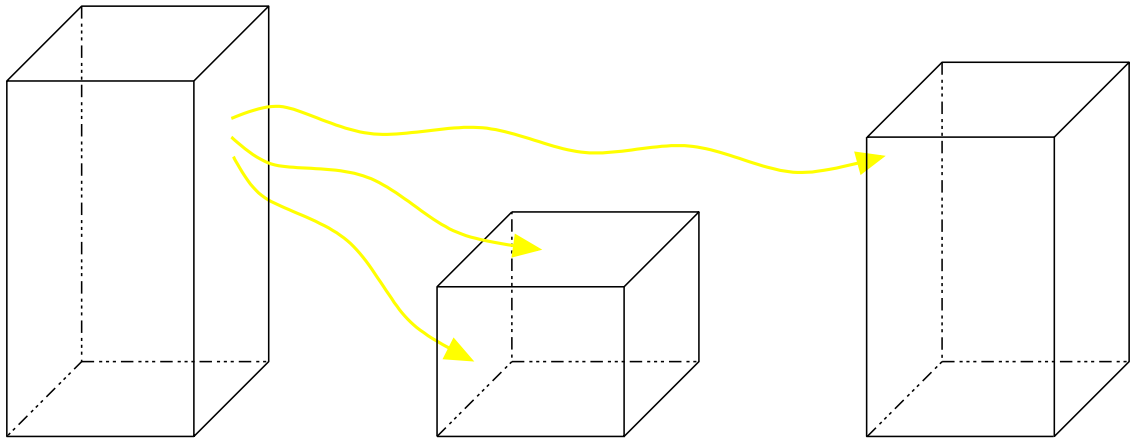


3 Double Canyon Effect Parametrization

radiative interaction of roofs with canyon



walls interact with “their” canyon and neighbouring canyon



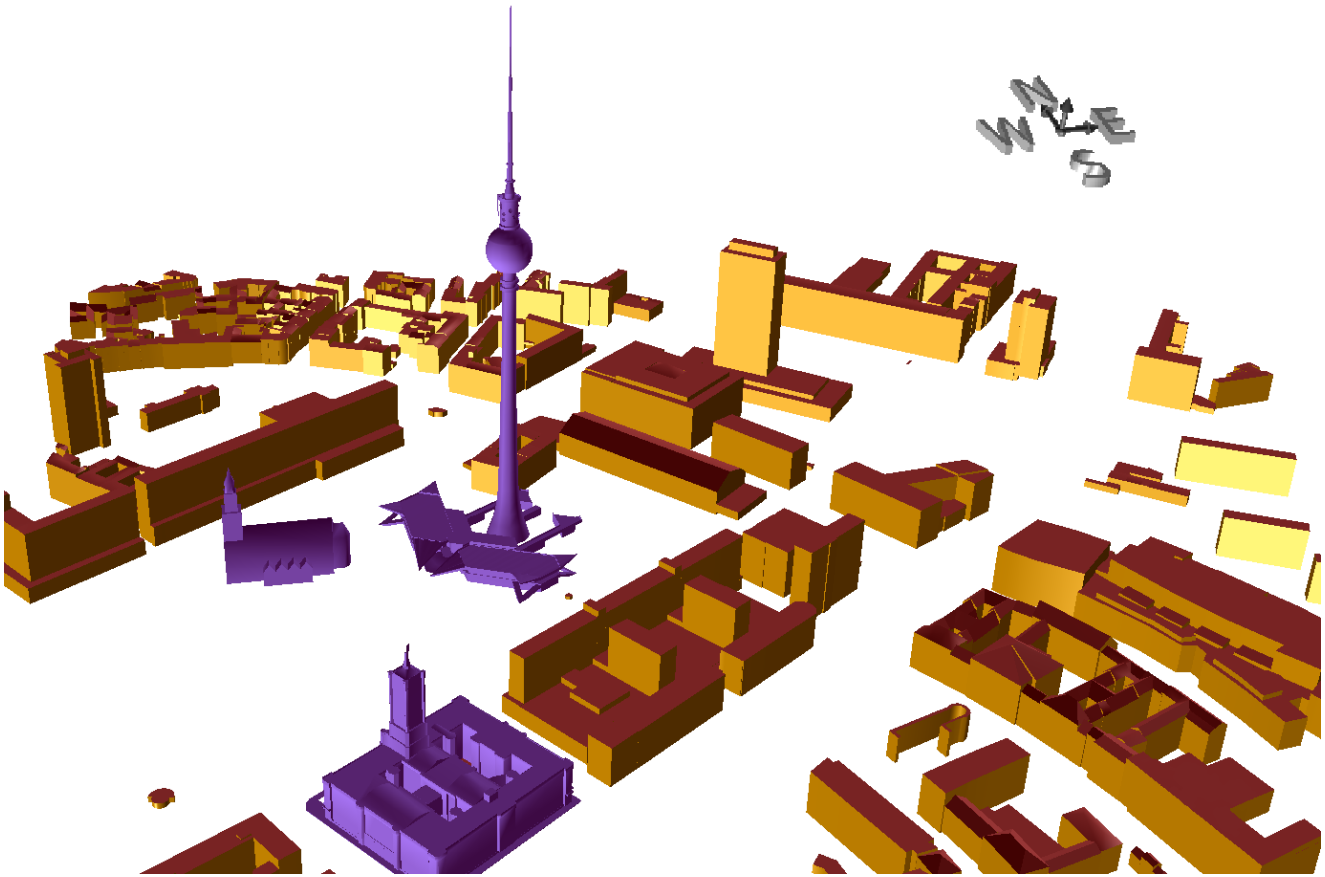
Summary of Sensitivity Analysis

- calculation of effective radiation parameters extended and corrected: albedo for diffuse and direct solar radiation, radiation temperature
- increased urban heat island effect compared to original formulation but without overestimation of incoming sky radiation
- most important for cities with hetereogenous distribution of building heights

Contents

Usage of morphological data

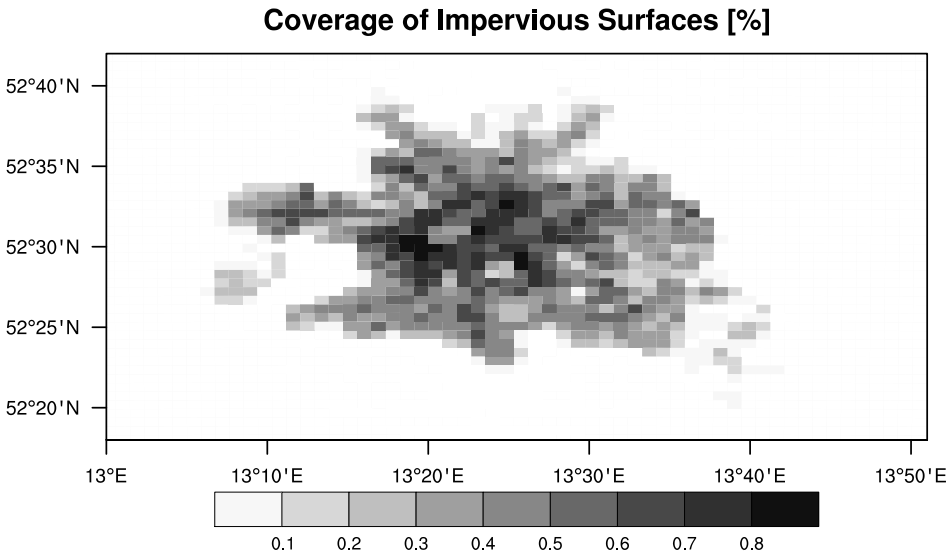
- for Berlin: highly detailed 3d data in CityGML[1] format available
- used to calculate morphological DCEP parameters

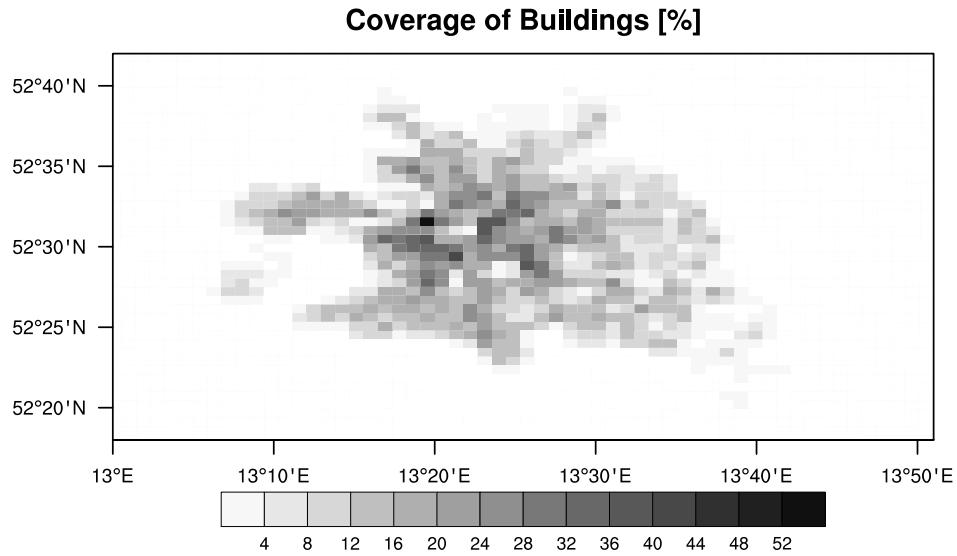


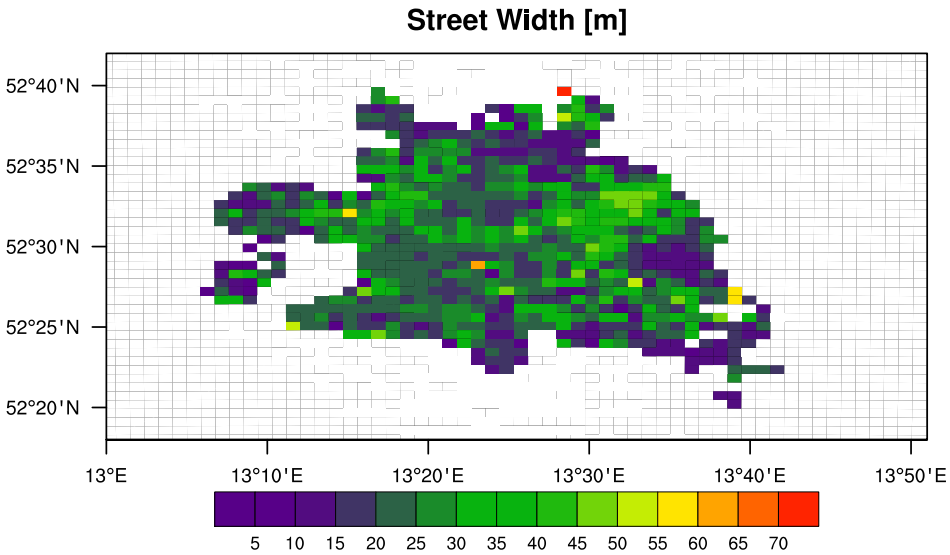
- buildings described by planar polygons
- polygons are differentiated into roof, wall and ground surfaces

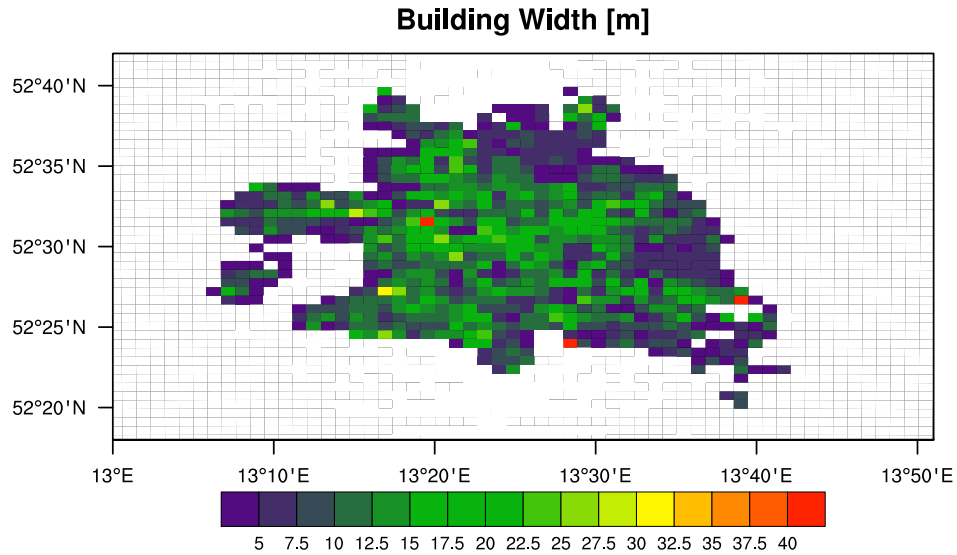
[1] OGC Standard: `http://www.opengeospatial.org/standards/citygml`

Results of conversion for Berlin (1 km resolution)

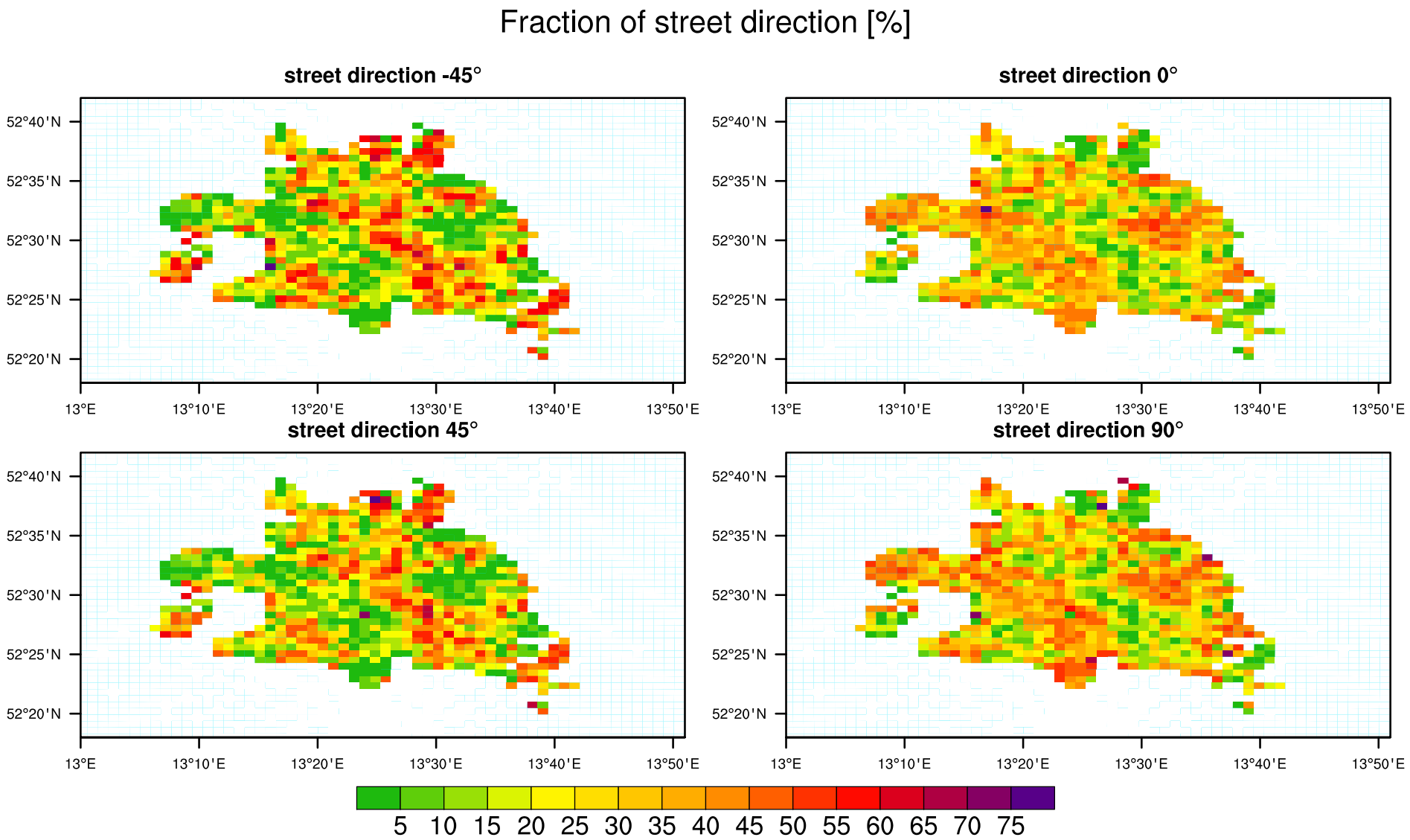








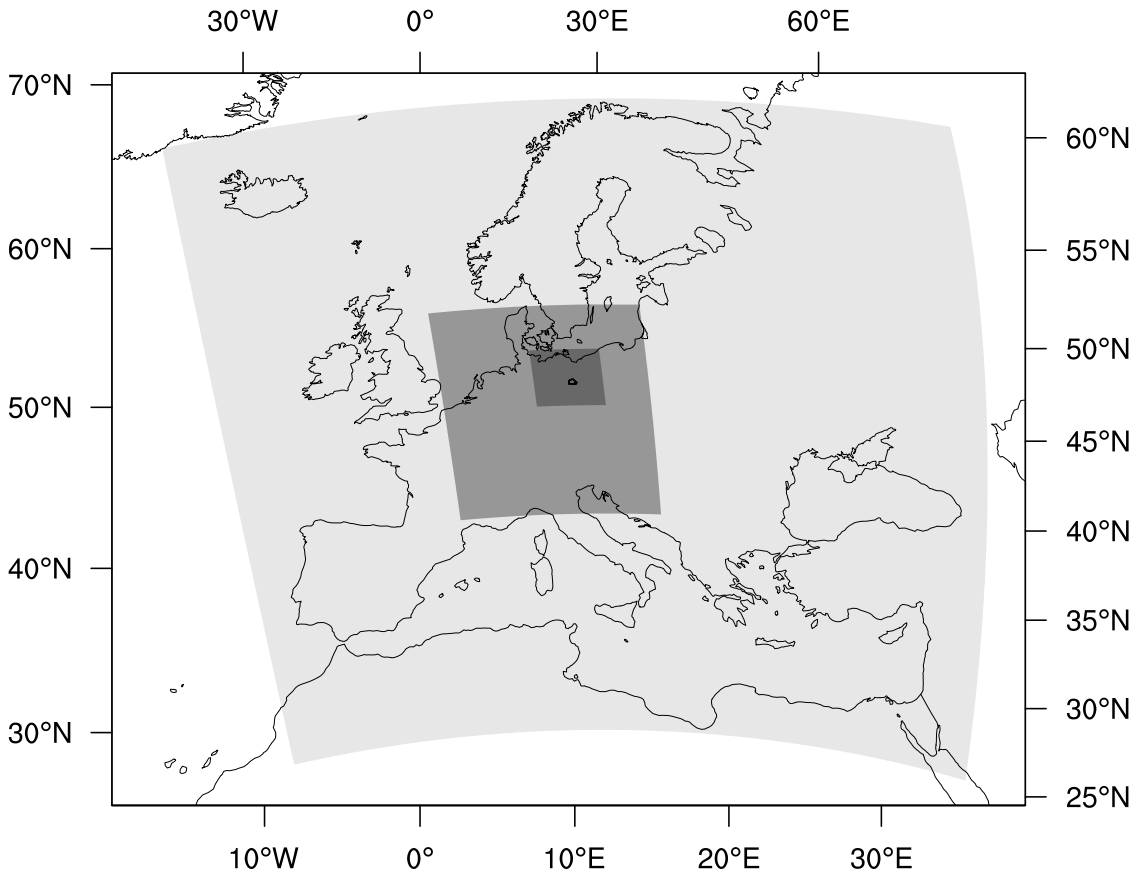
Further results: Weight of street directions



Simulation with COSMO-CLM

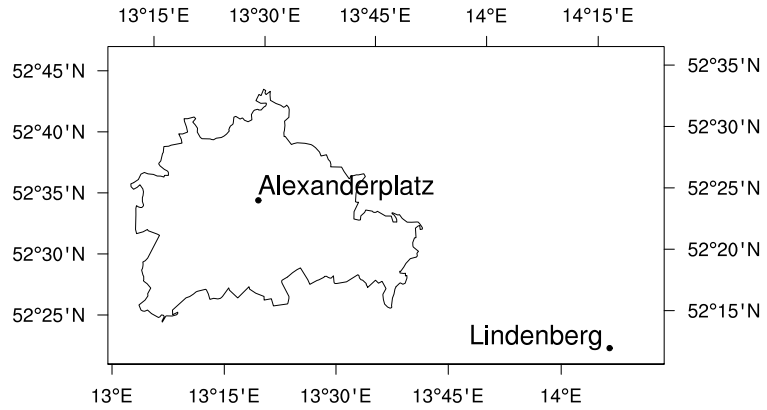
simulations starting 2002-08-14 00UTC with nesting steps:

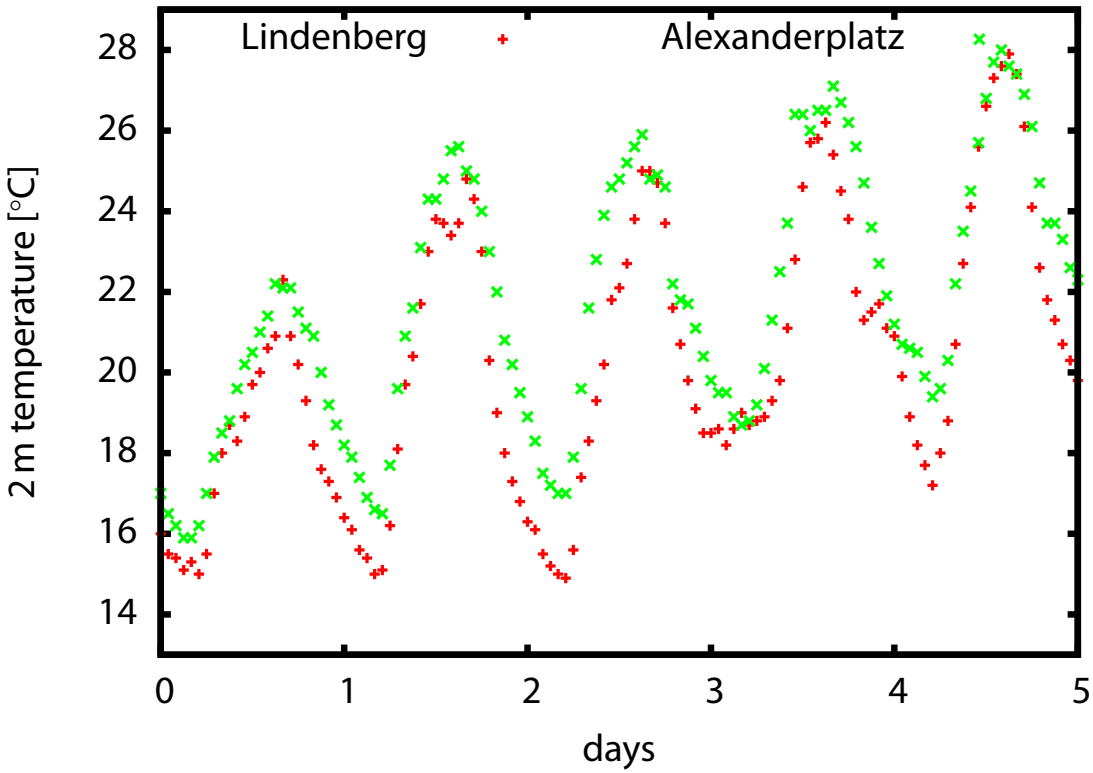
- 24 km resolution nested into ERA-Interim, soil water content from a simulation with spectral nudging starting in 1995
- 7.8 km resolution
- 2.8 km resolution with DCEP for the area of Berlin



Station data

urban station: Berlin-Alexanderplatz
rural station: Lindenberg
approx. 60 km apart



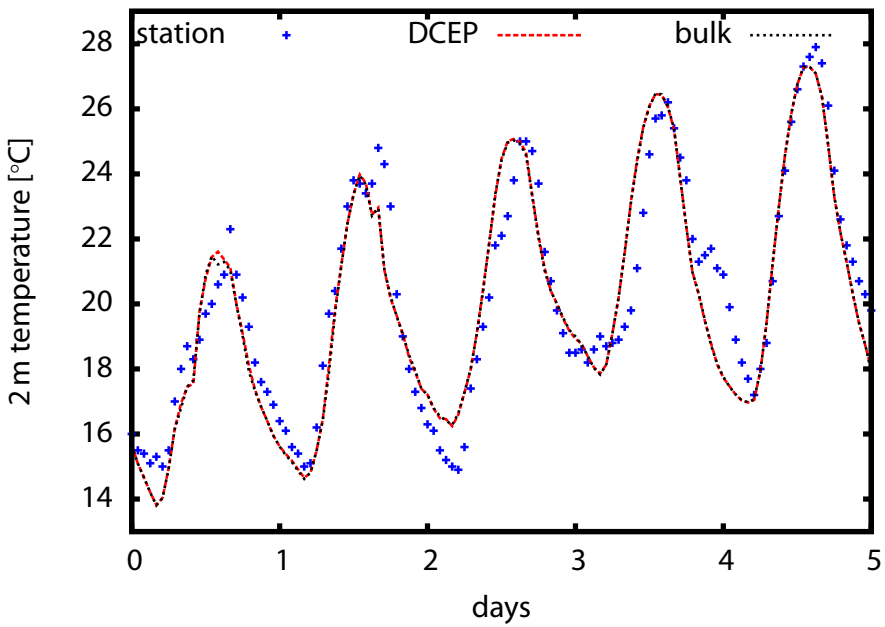


simulation period:
2002-08-14 00UTC –
2002-08-19 00UTC
(no precipitation)

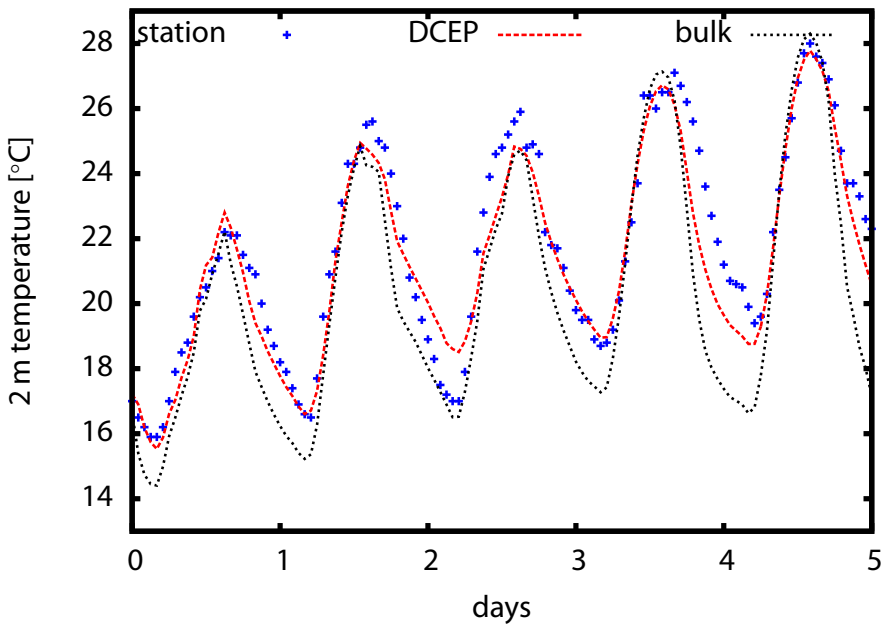
Model Results 2002-08-14 00UTC – 2002-08-19 00UTC

- comparison of station data with simulations (2.8 km resolution) with either urban module DCEP and bulk approach
- bulk approach: increased roughness length, lower vegetation fraction, lower leaf area index

Lindenberg

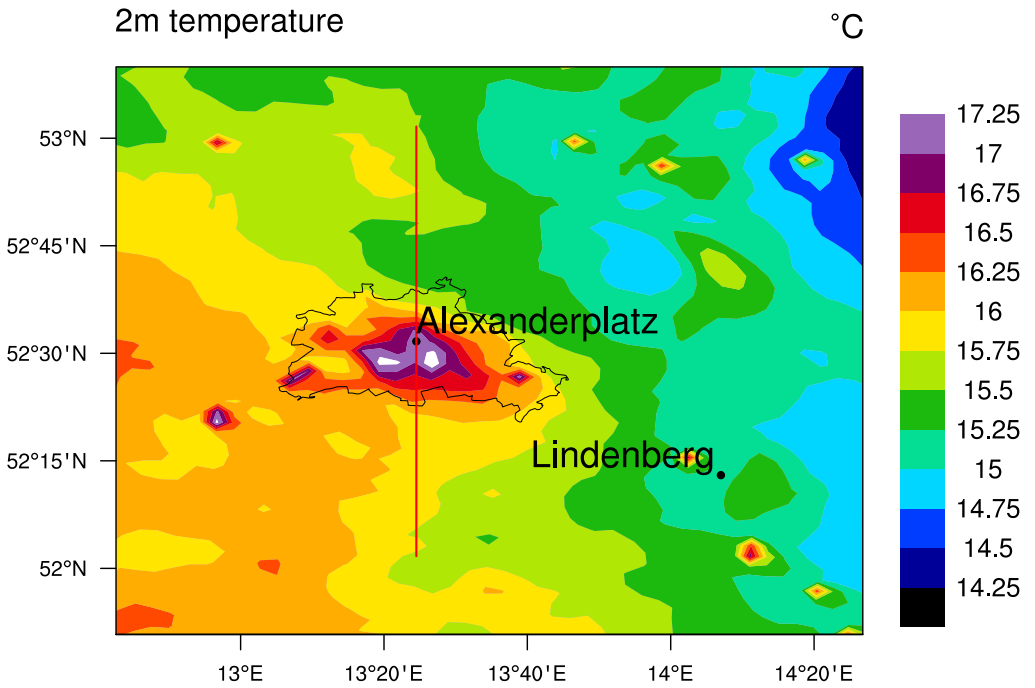


Berlin-Alexanderplatz

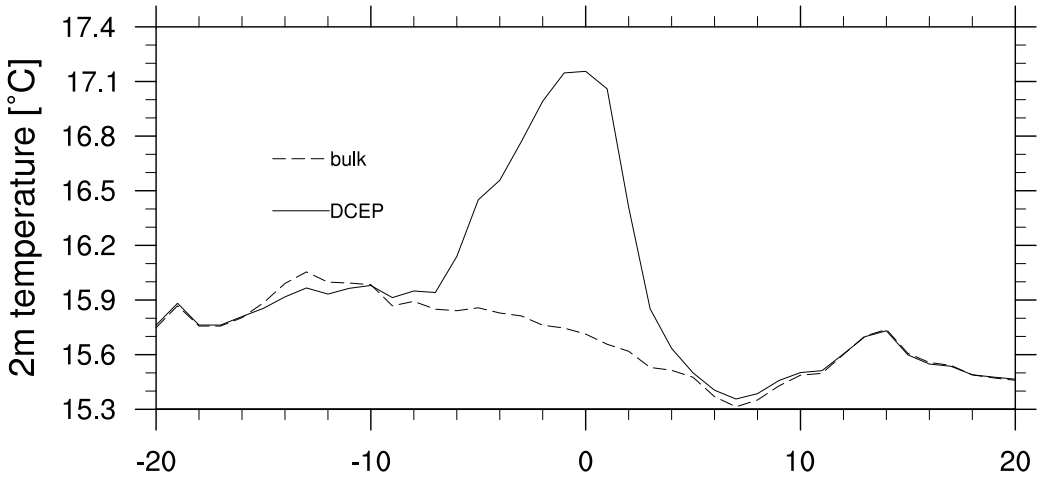


Urban Heat Island during the night 2002-08-15 02UTC

simulation with DCEP



2 m temperature along the red line with DCEP and bulk approach



Contents

Summary

- developed an urban radiation scheme which takes roof interaction into account
- use 3d building data to calculate urban input parameters; no guessing of building parameters when using land use data
- DCEP captures urban heat island well
- further plans:
  - comparison with other weather stations in Berlin (higher simulation resolution and exact station position)
  - application to other cities

Summary

- developed an urban radiation scheme which takes roof interaction into account
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  - comparison with other weather stations in Berlin (higher simulation resolution and exact station position)
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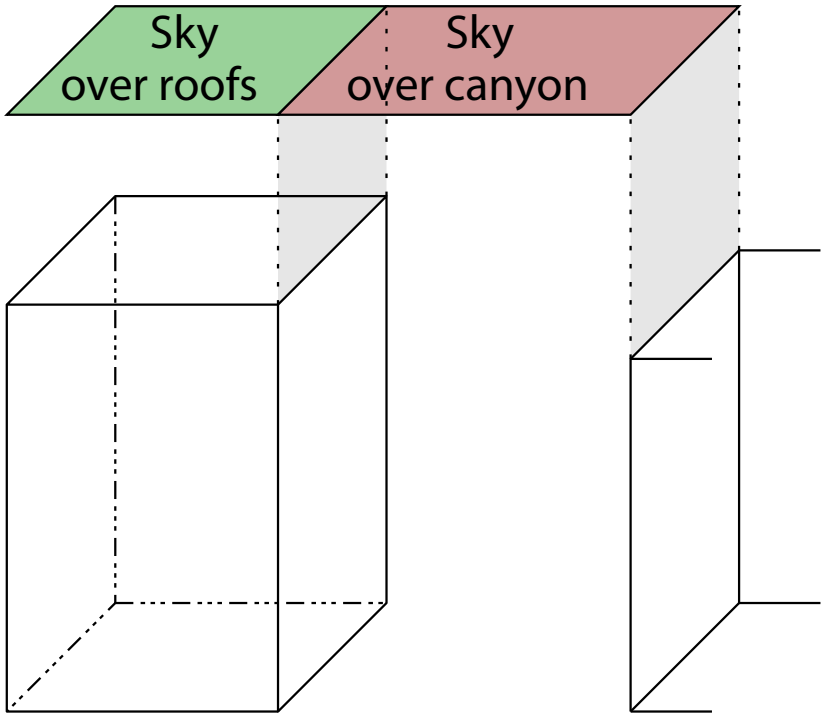
Thank you for your attention!

Any questions?

2 Where is the problem?

Distribution of incoming diffuse radiation from the sky

radiation from sky with R_{top} [Wm^{-2}]



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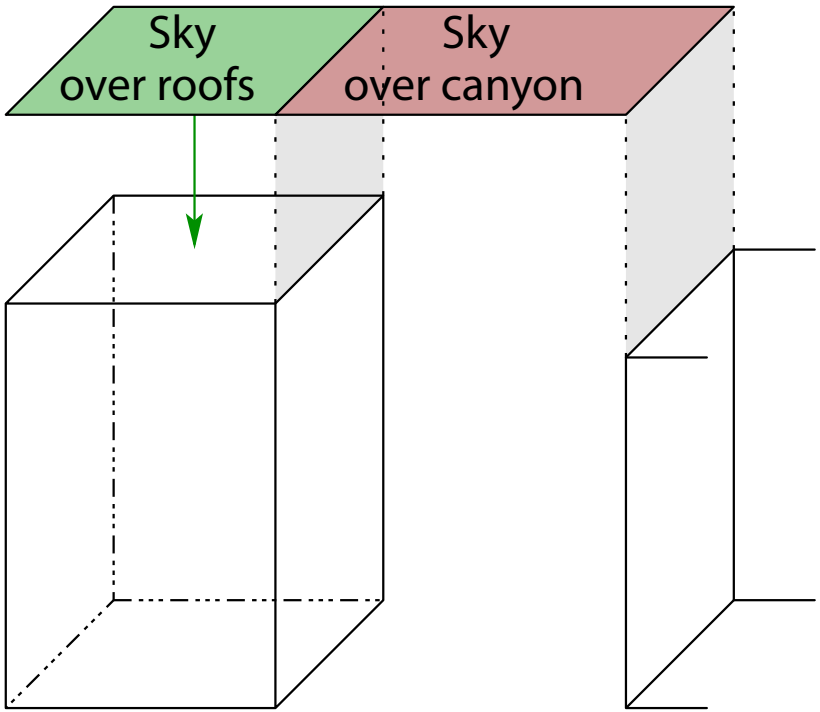

- roofs always get full radiation

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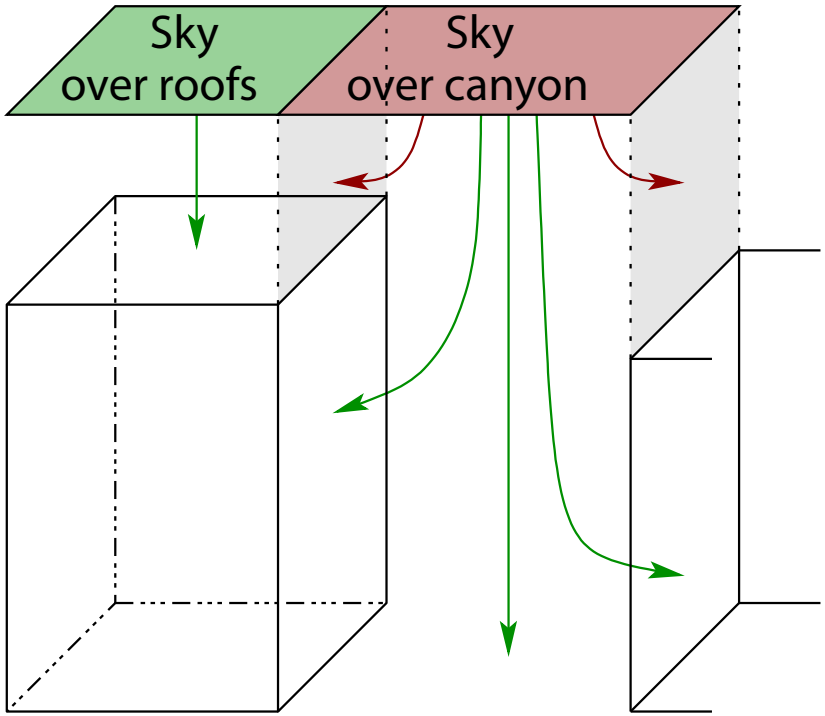

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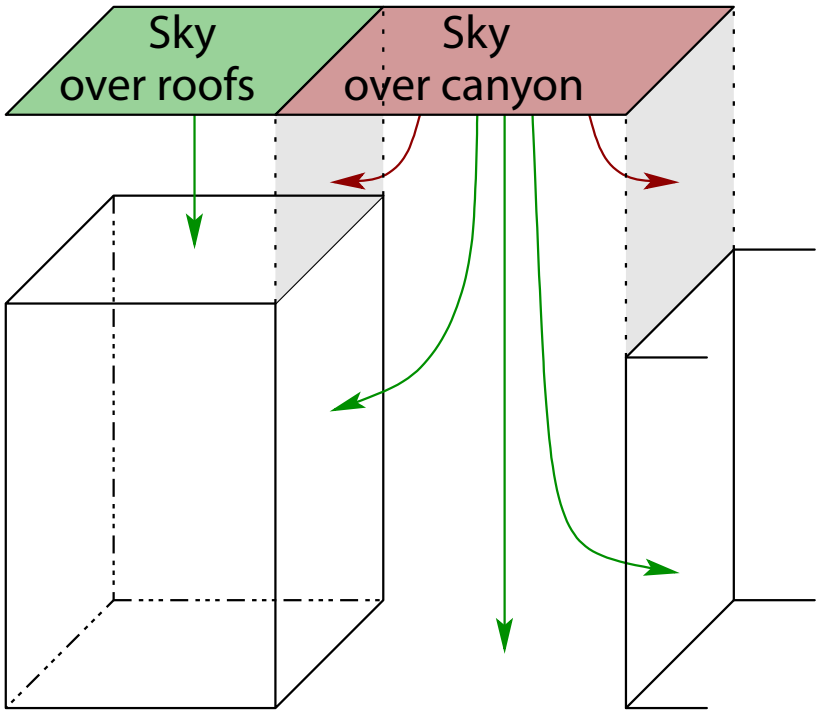
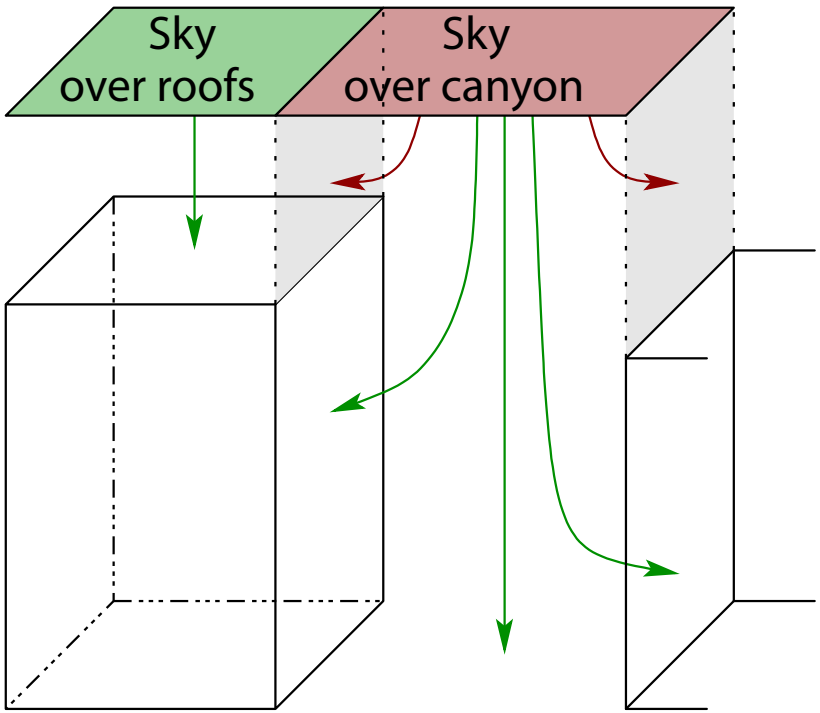


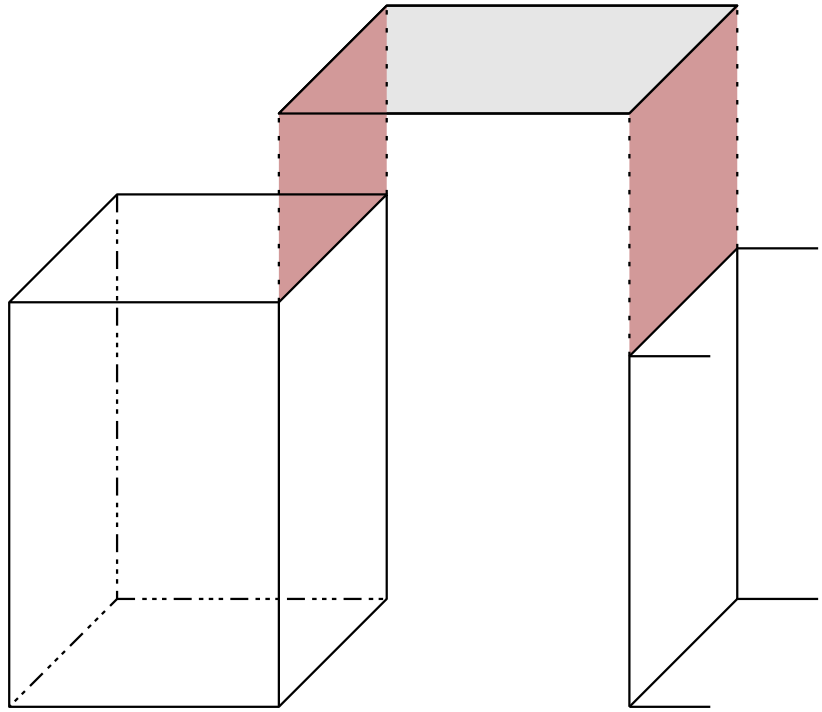
- roofs always get full radiation
- energy not accounted for where no walls present

2 Where is the problem?

Distribution of incoming diffuse radiation from the sky

radiation from sky with R_{top} [Wm^{-2}] from side with $R_{side} = R_{top}$





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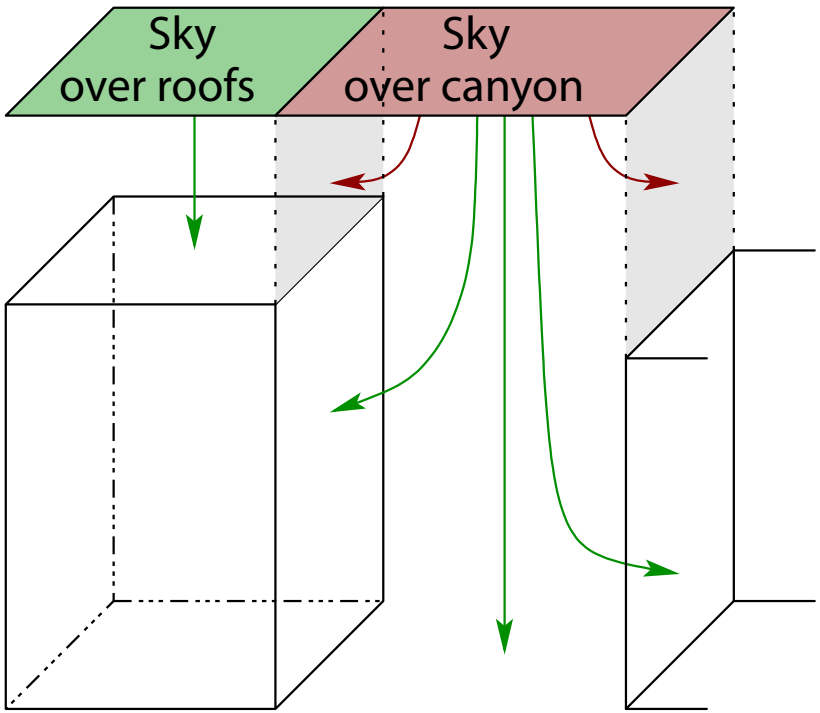

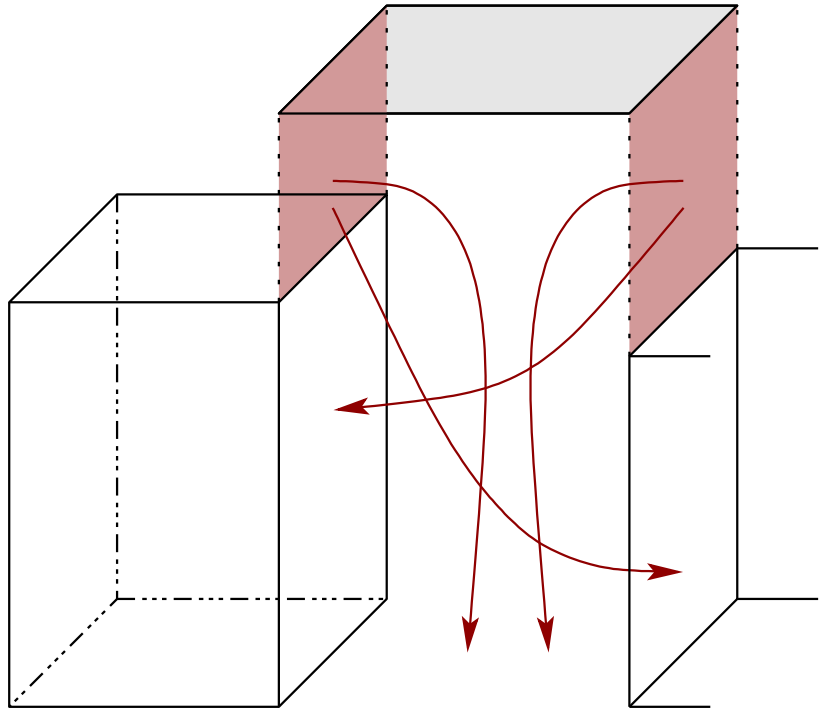

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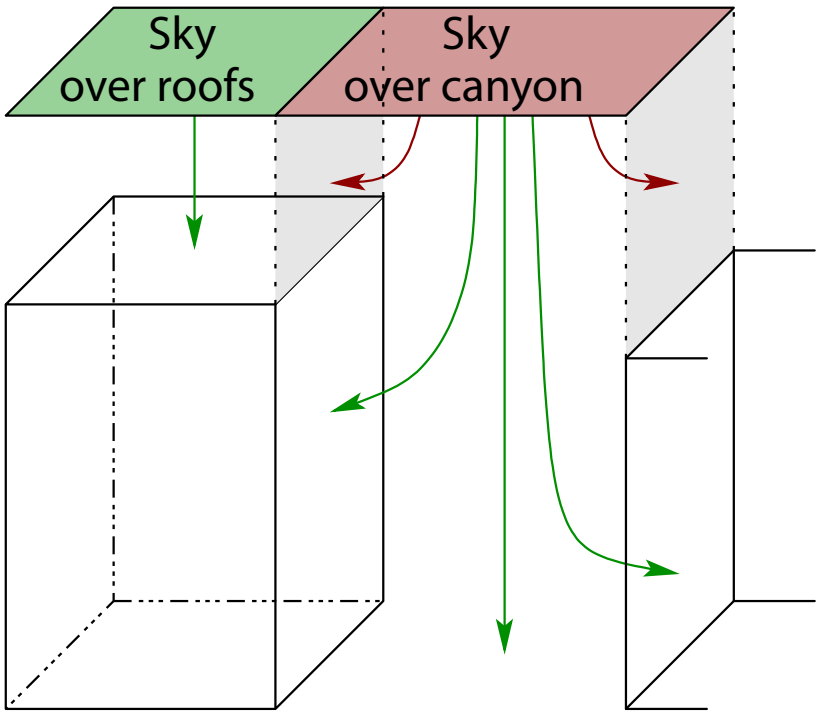

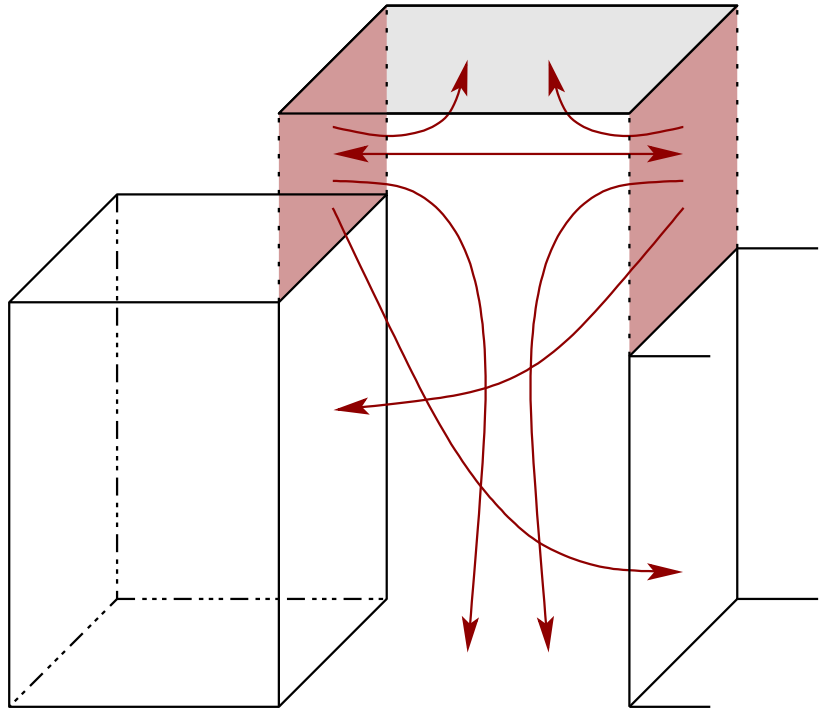

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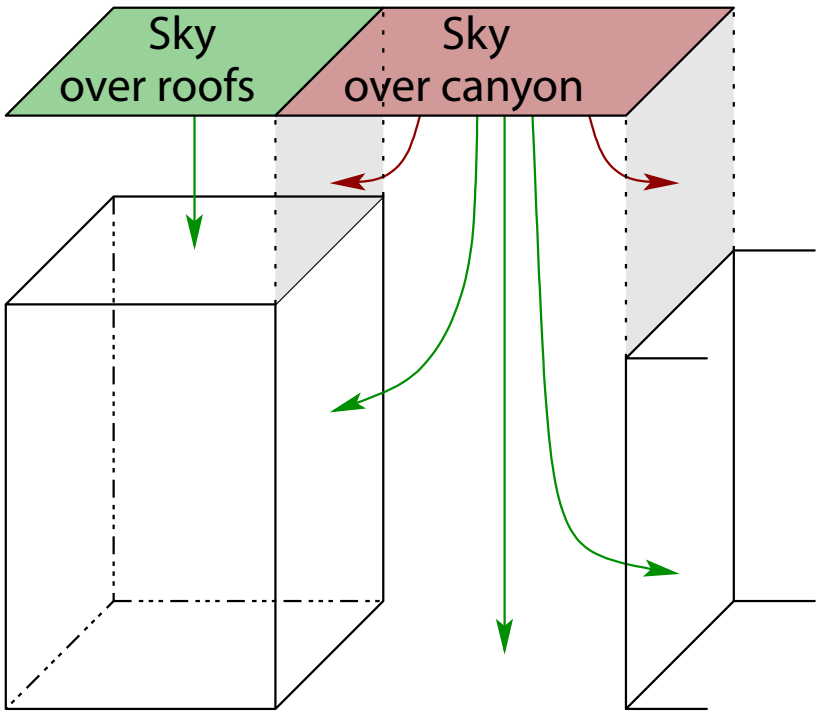

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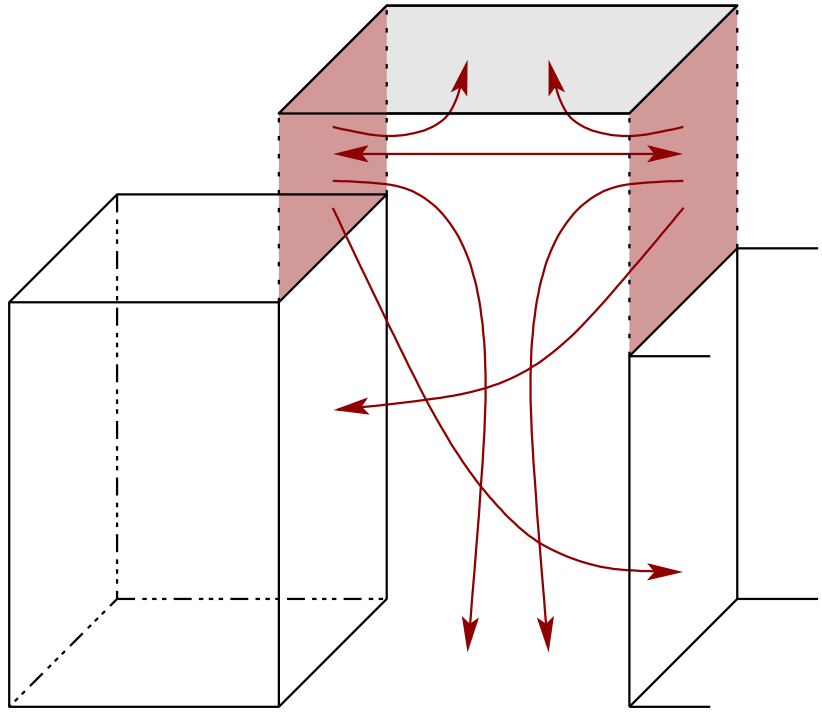
from side with $R_{side} = R_{top}$

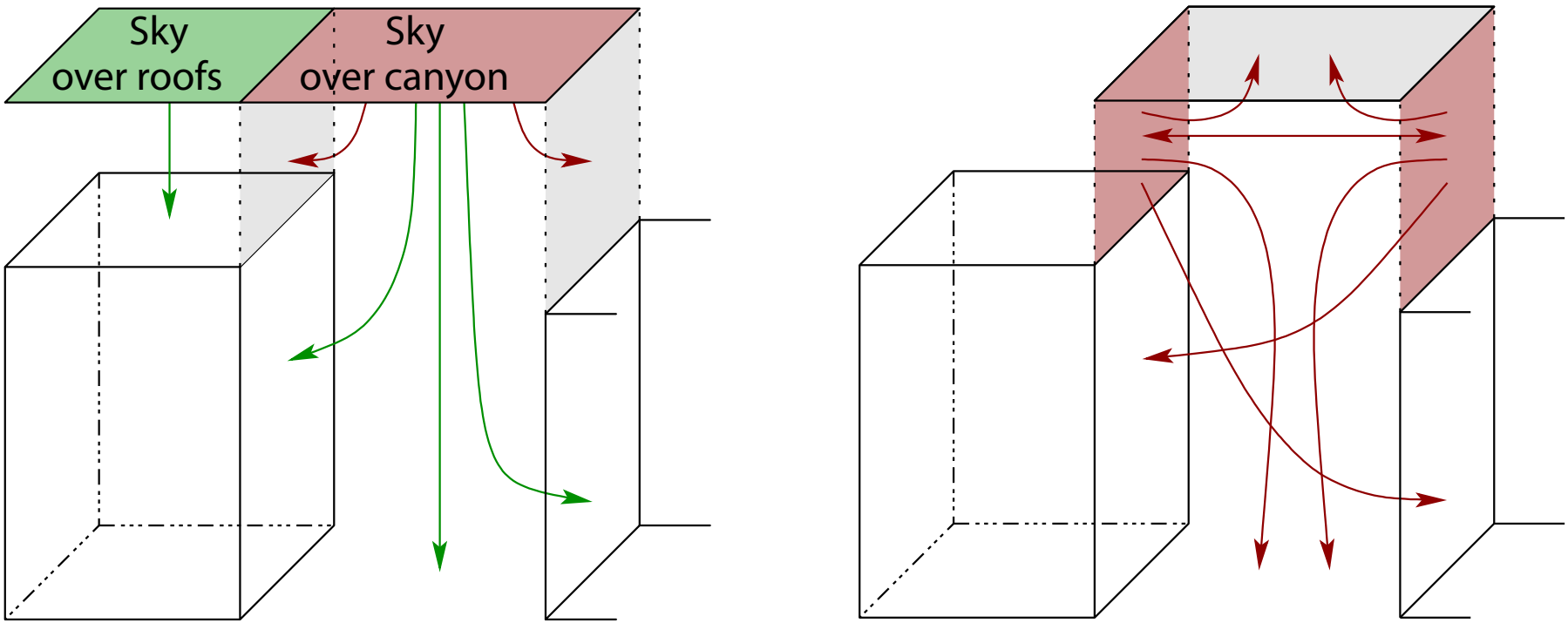


- in general, total calculated energy received by the canyon is larger than incoming energy

2 Our approach

Distribution of incoming diffuse radiation from the sky

radiation from sky with R_{top} [Wm^{-2}] from side with $R_{side} = cR_{top}$

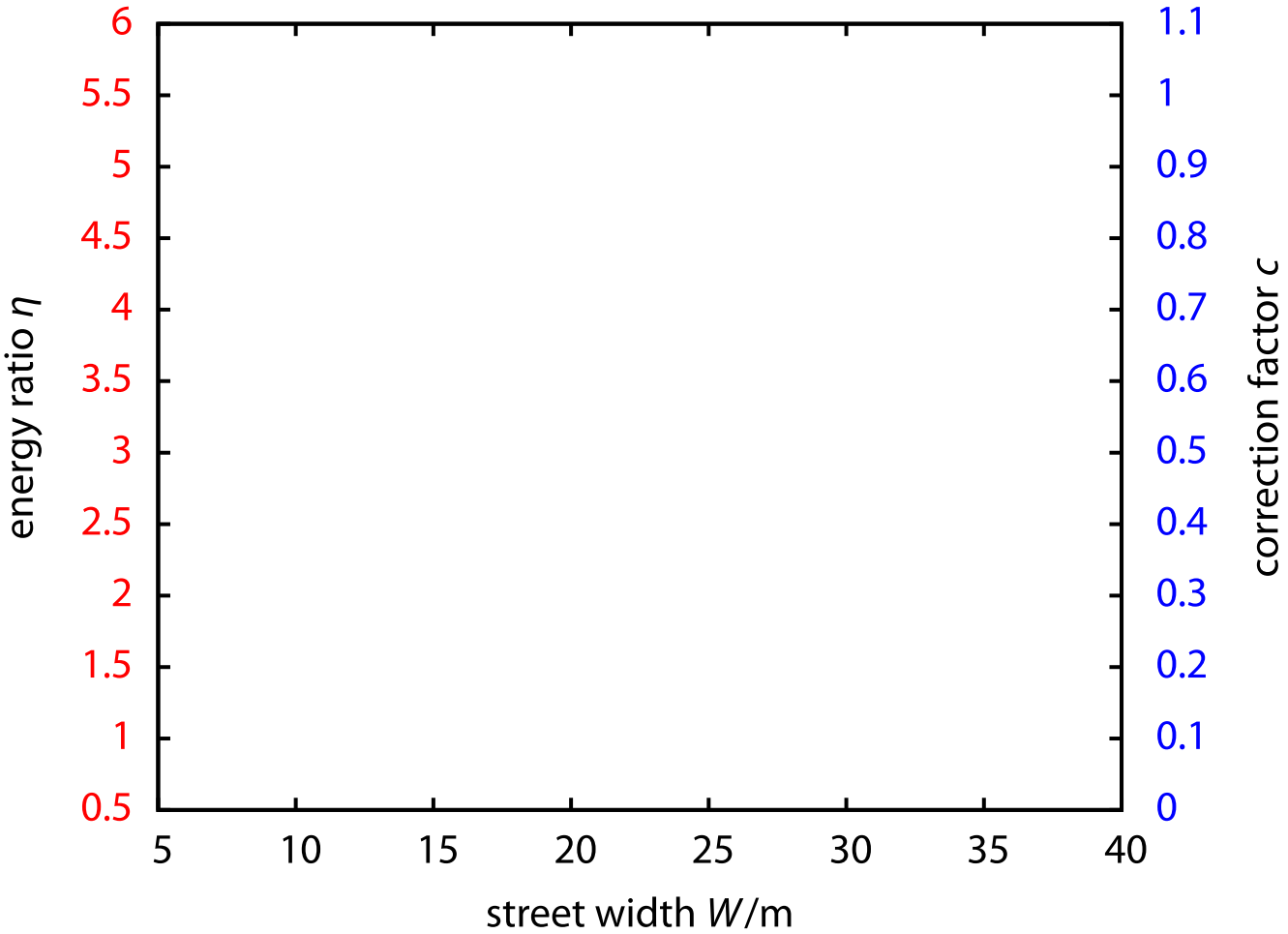


- scale irradiance from the side of the canyon with factor c to fulfill energy conservation
- c constant during runtime

Street width dependence of the distributed energy

- energy ratio η: ratio of incoming to in the canyon distributed energy
- η and correction factor c depend only on urban morphology parameters

different roof height distributions



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different roof height distributions:

γ^{max} 50 % at 0 m,
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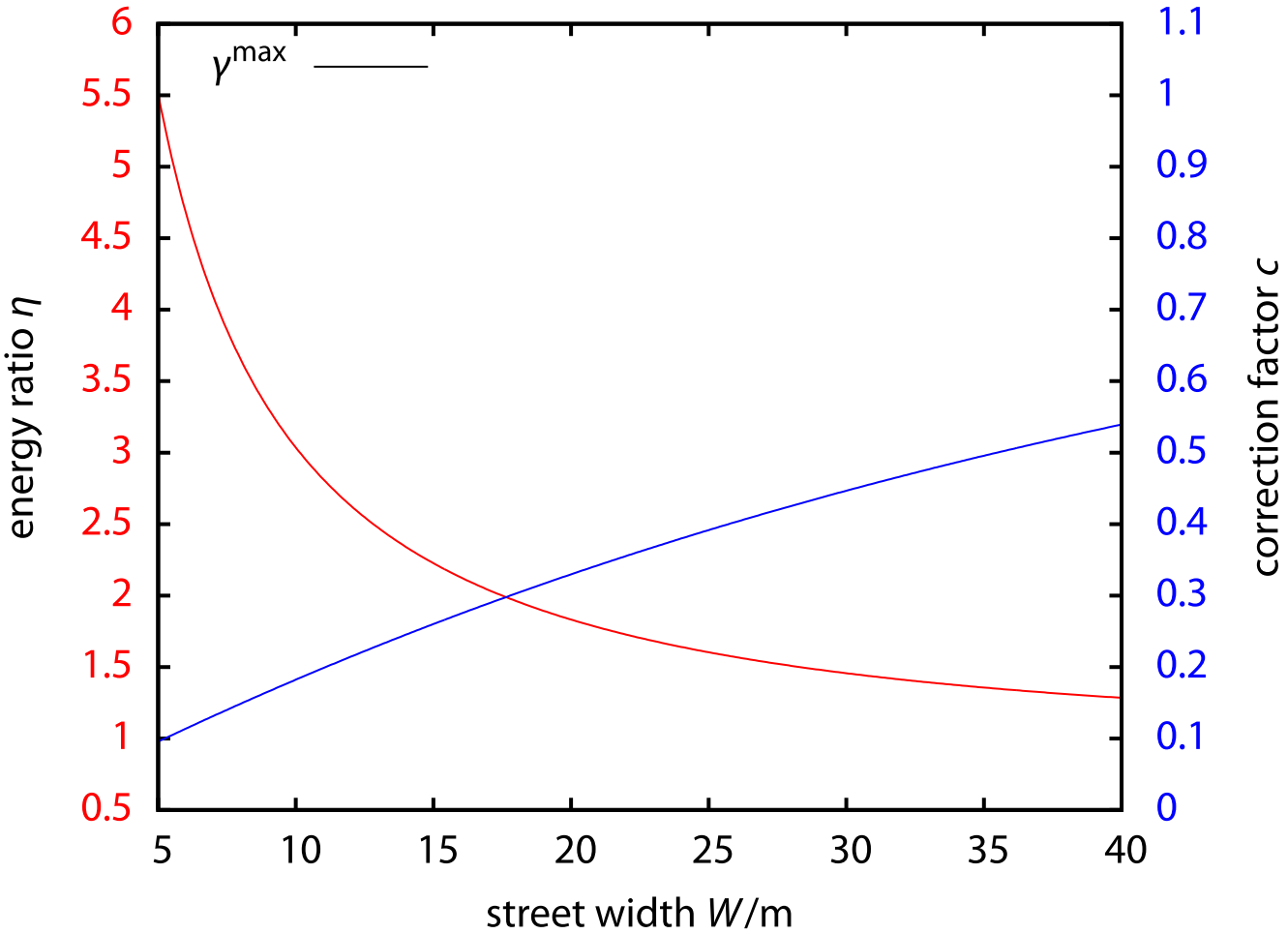

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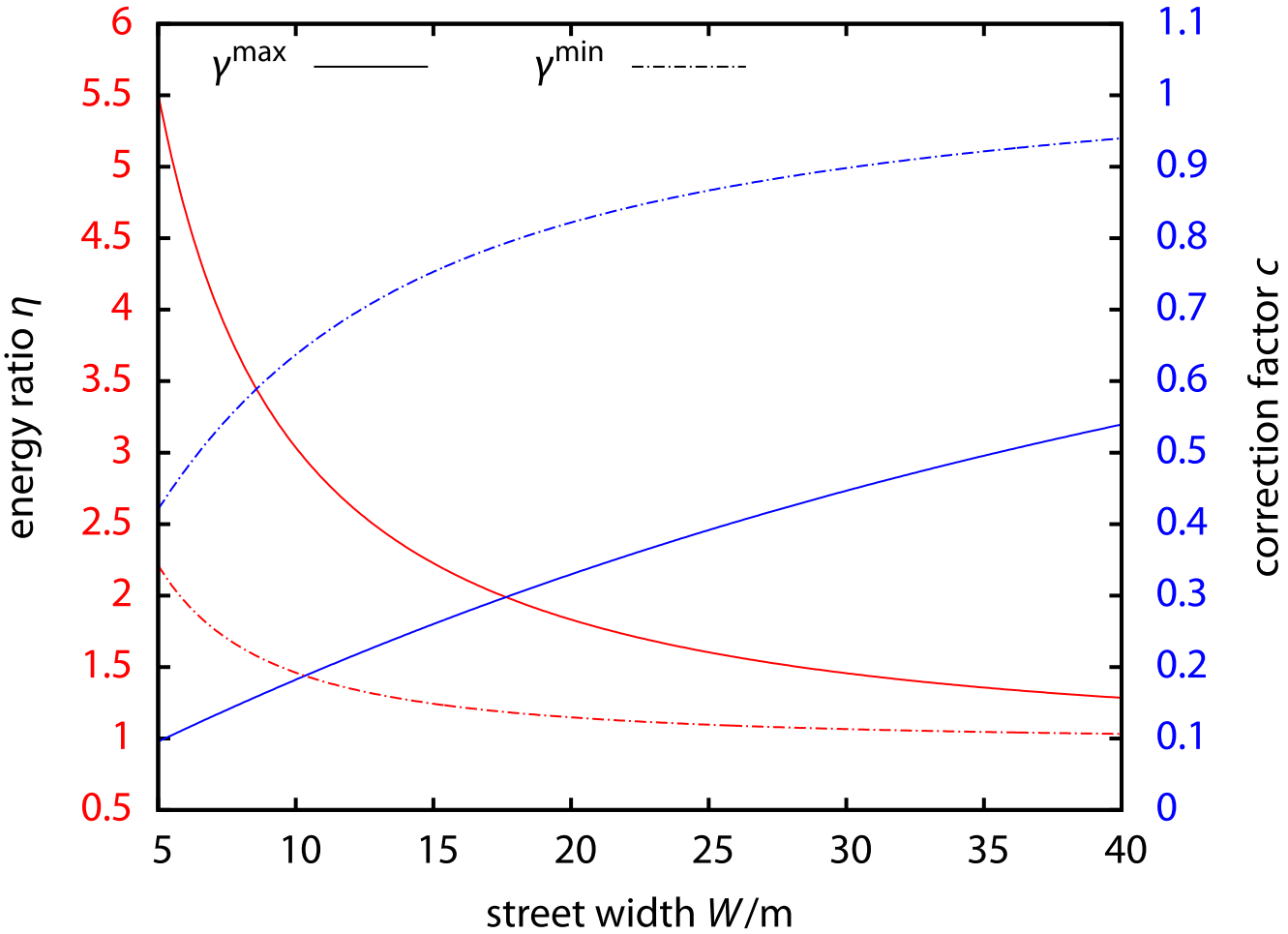

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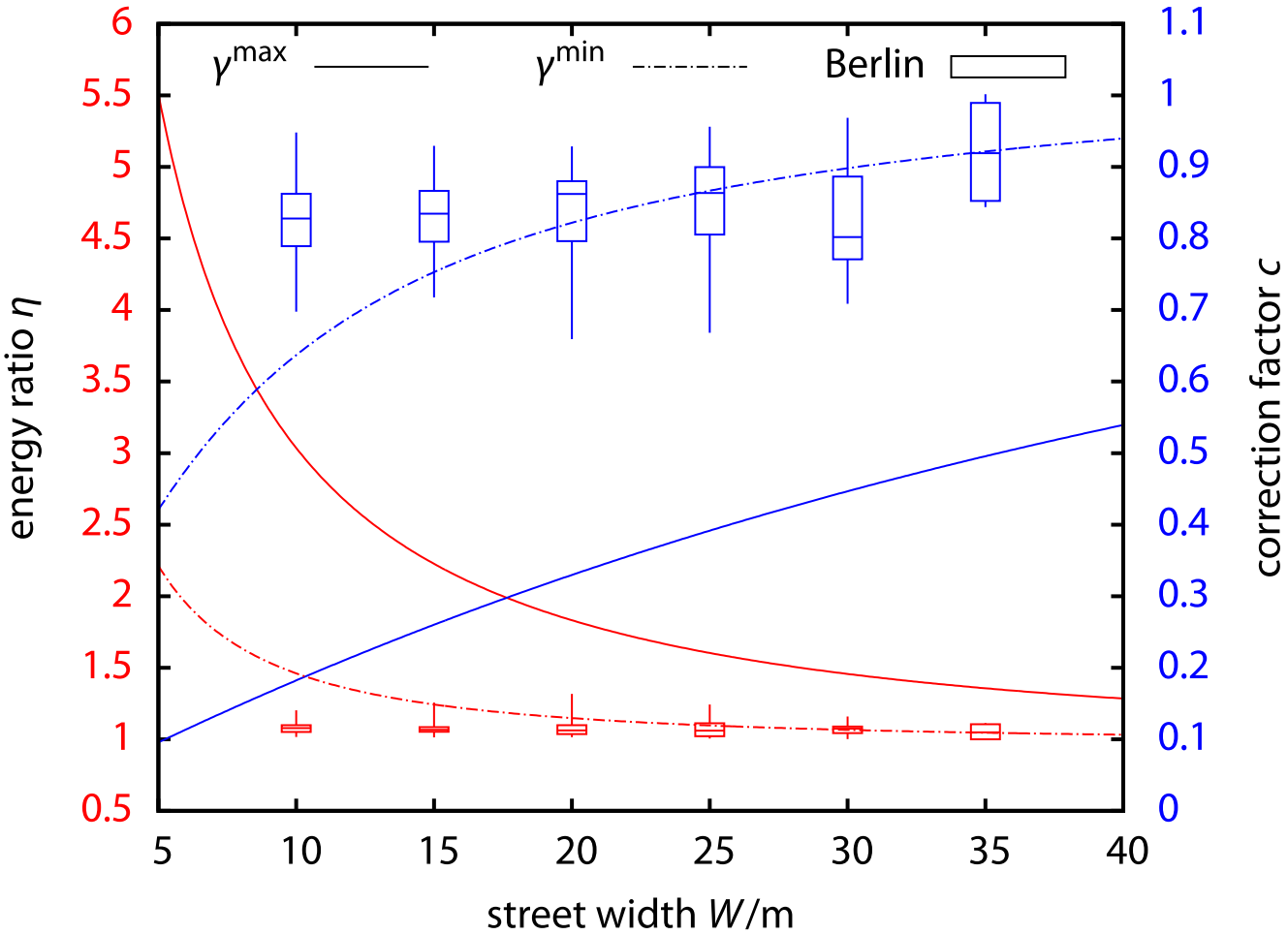
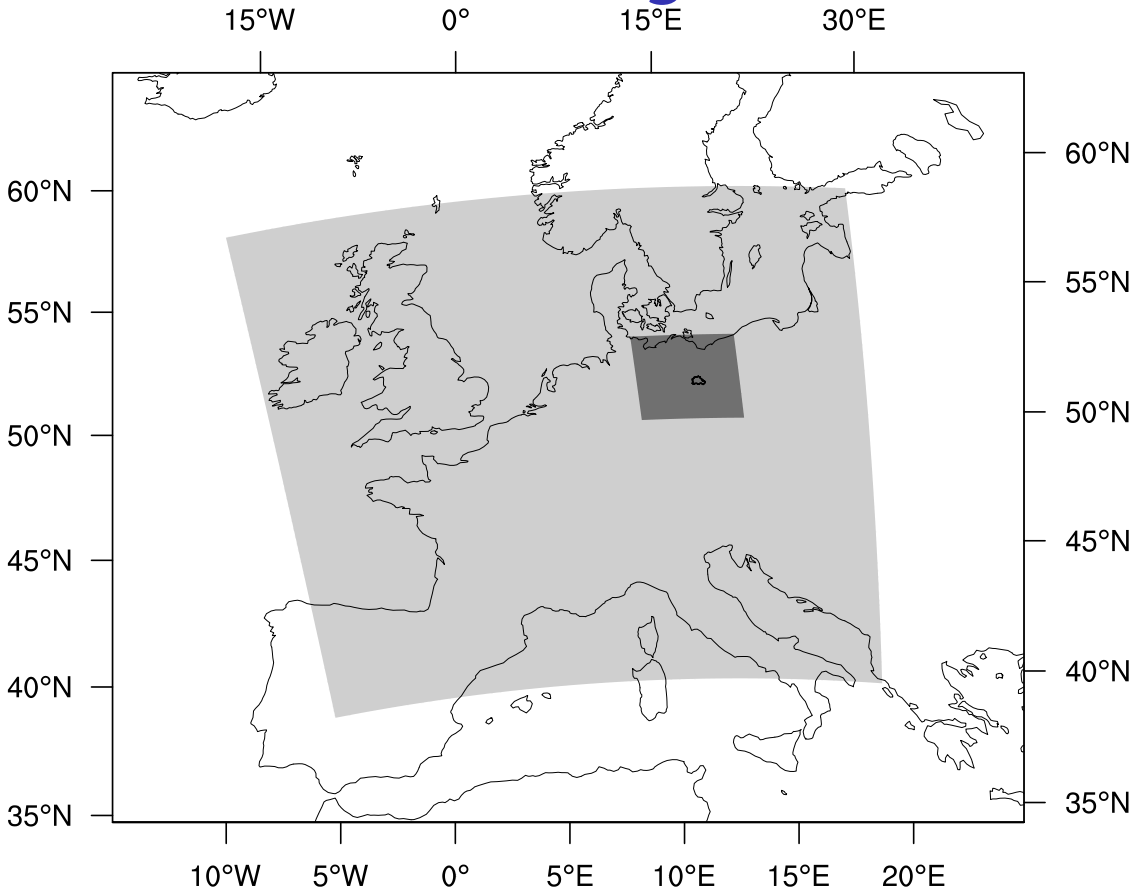
Berlin based on 3d building data of Berlin



Simulations with regional climate model CCLM



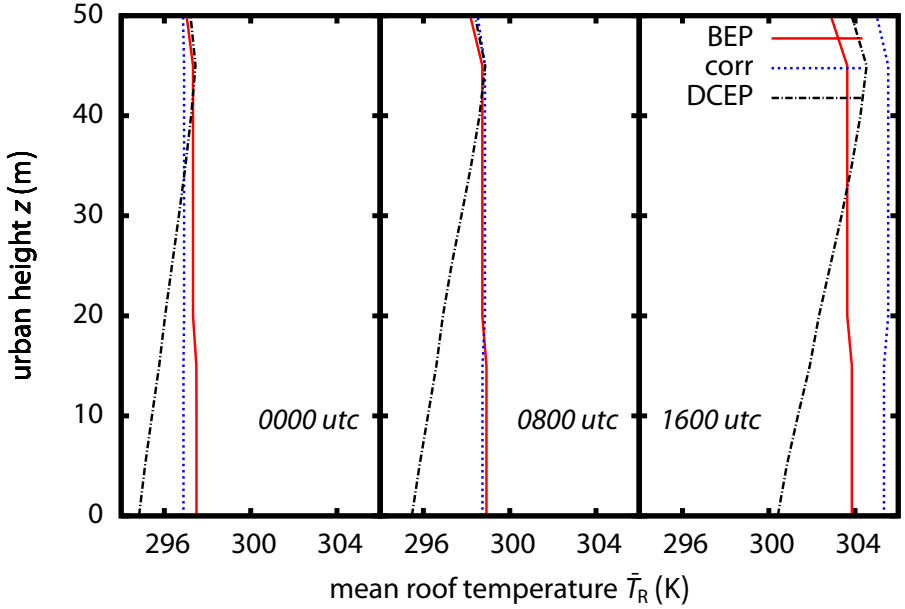
simulations starting 2003-08-01 00UTC with double nesting approach:

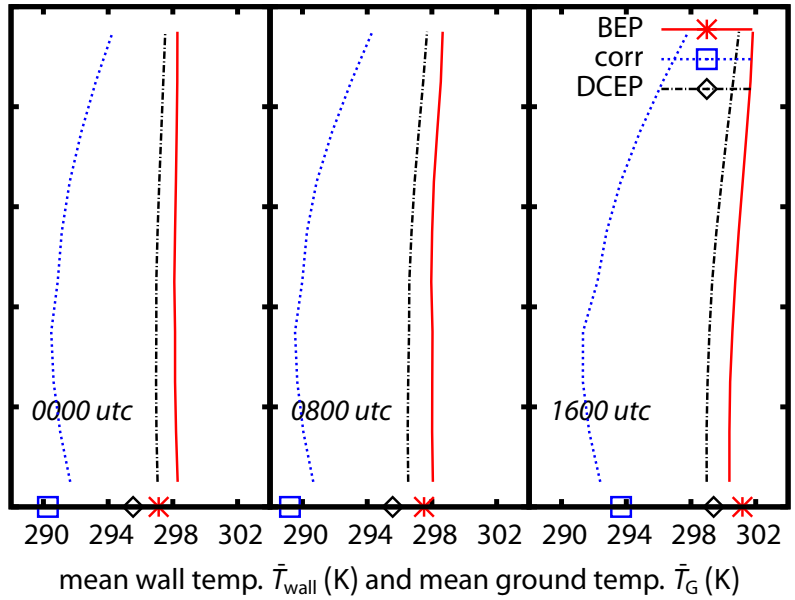
- 7.8 km resolution nested into ERA-Interim
- 2.8 km resolution with urban module for the area of Berlin, Germany

- urban module settings: urban fraction 1, street width 20 m, building width 10 m, height distribution γ^{max} or γ^{min}
- urban radiation scheme: “BEP” original but with (1), “corr” also (2), “DCEP” also (3)

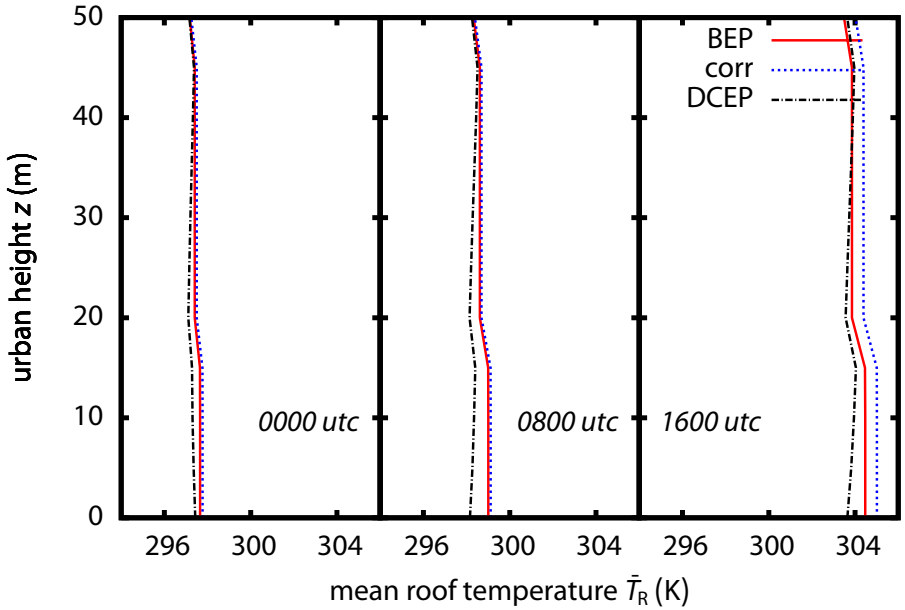
Urban surface temperatures

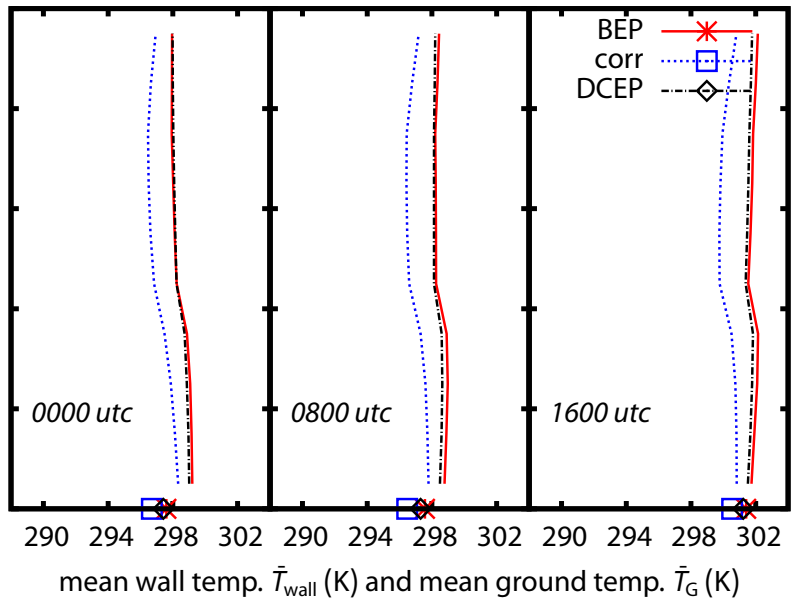
γ^{max}





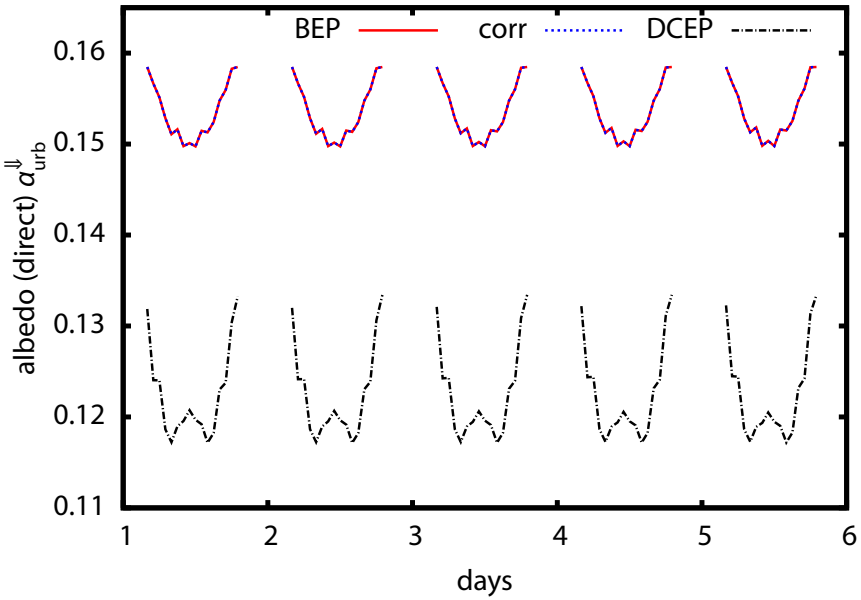
γ^{min}





Urban albedo

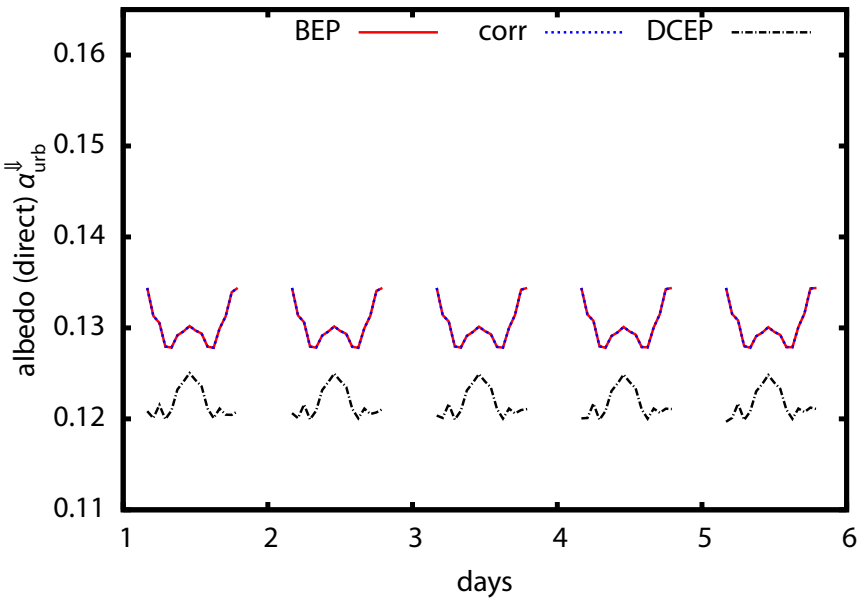
γ^{max}



albedo (diffuse) $\alpha^{\downarrow}_{urb}$

BEP	corr	DCEP
-0.34	0.15	0.12

γ^{min}

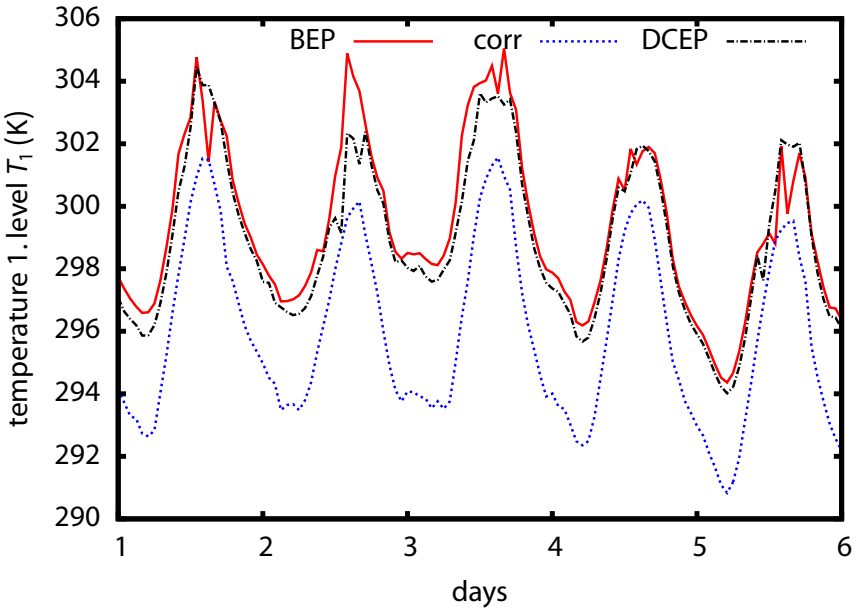


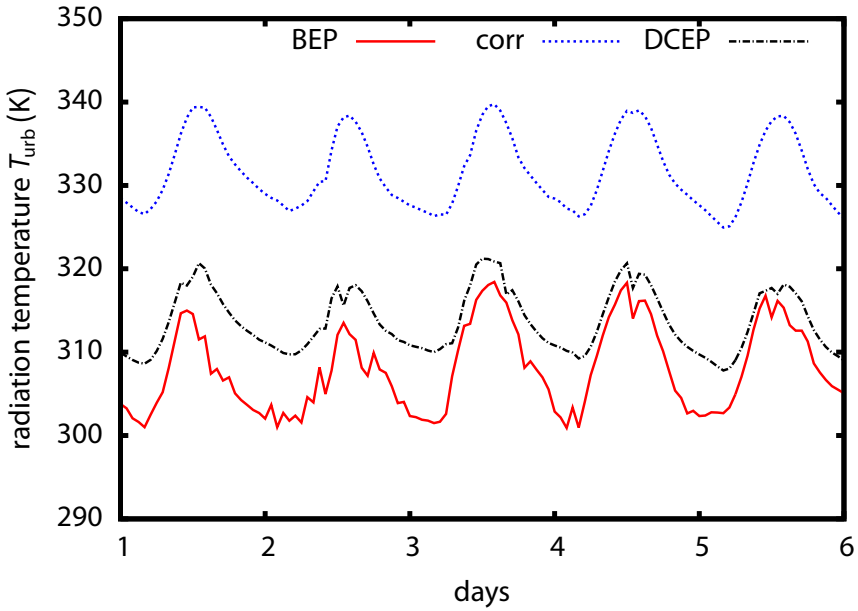
albedo (diffuse) $\alpha^{\downarrow}_{urb}$

BEP	corr	DCEP
0.04	0.13	0.12

Air and effective radiation temperatures

γ^{max}





γ^{min}