A double-canyon radiation scheme for urban canopy models

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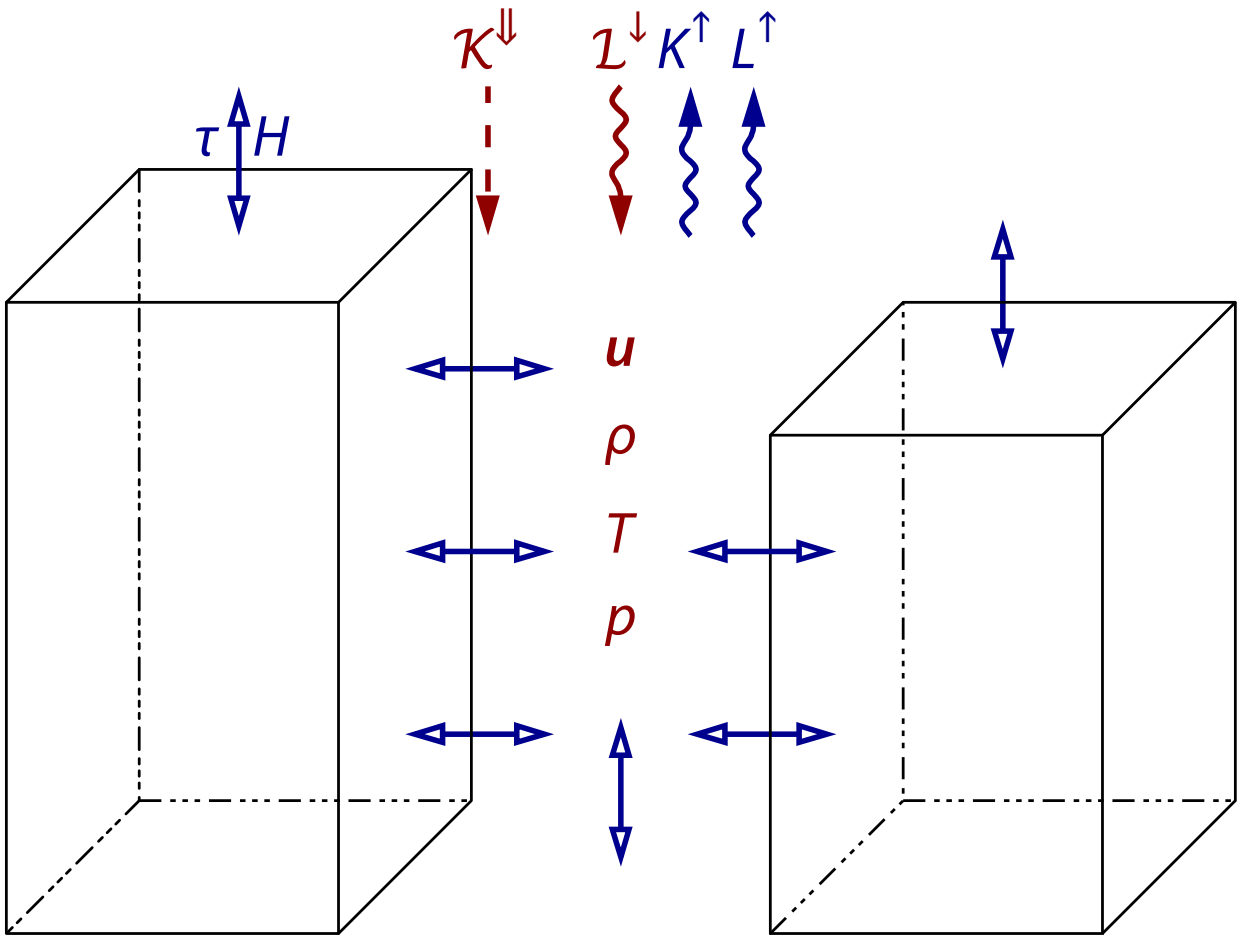
Contents

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:

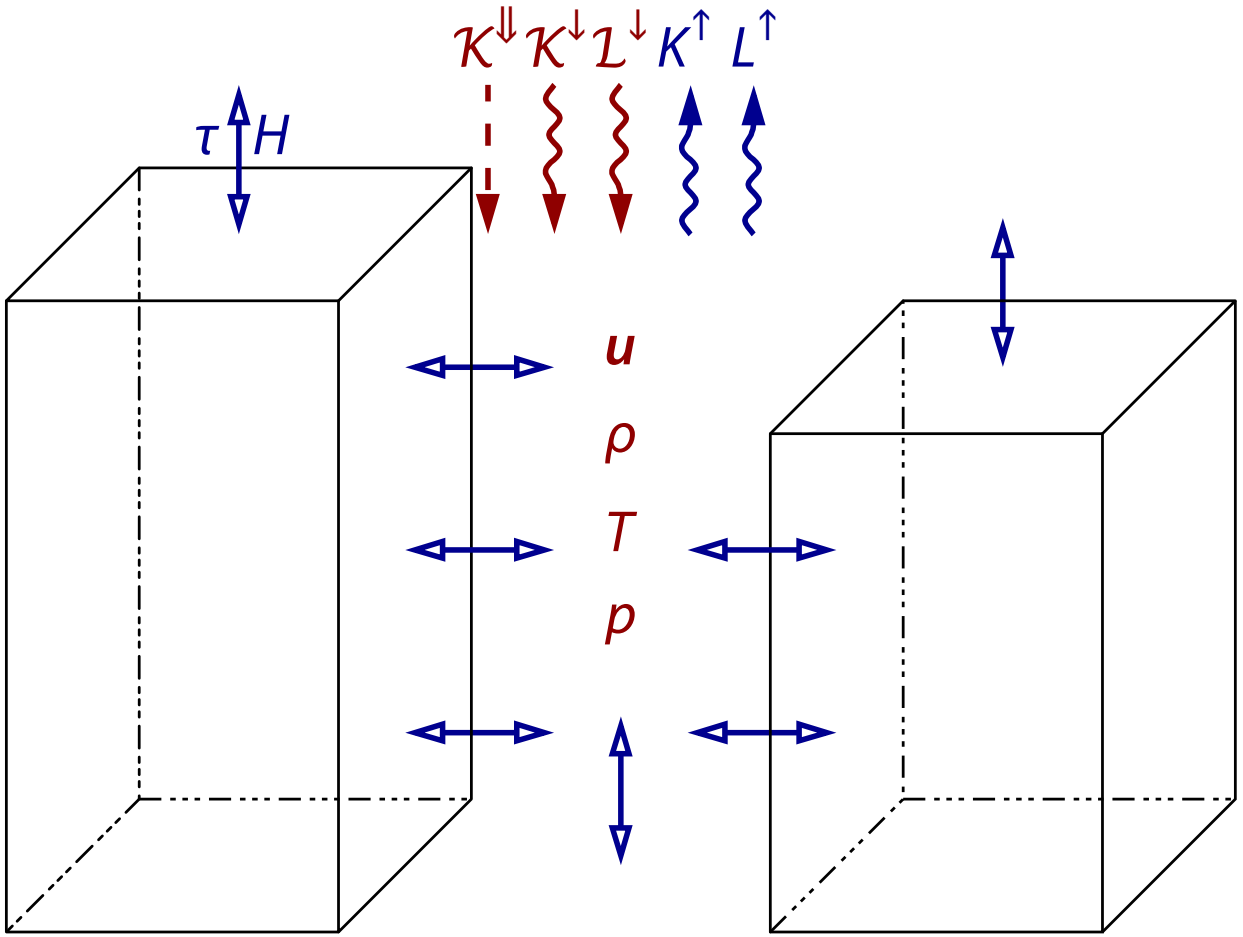
- $L^{\uparrow}$: longwave rad. (up)
- $K^{\uparrow}$: shortwave rad. (up)
- H: sensible heat flux
- τ: momentum flux

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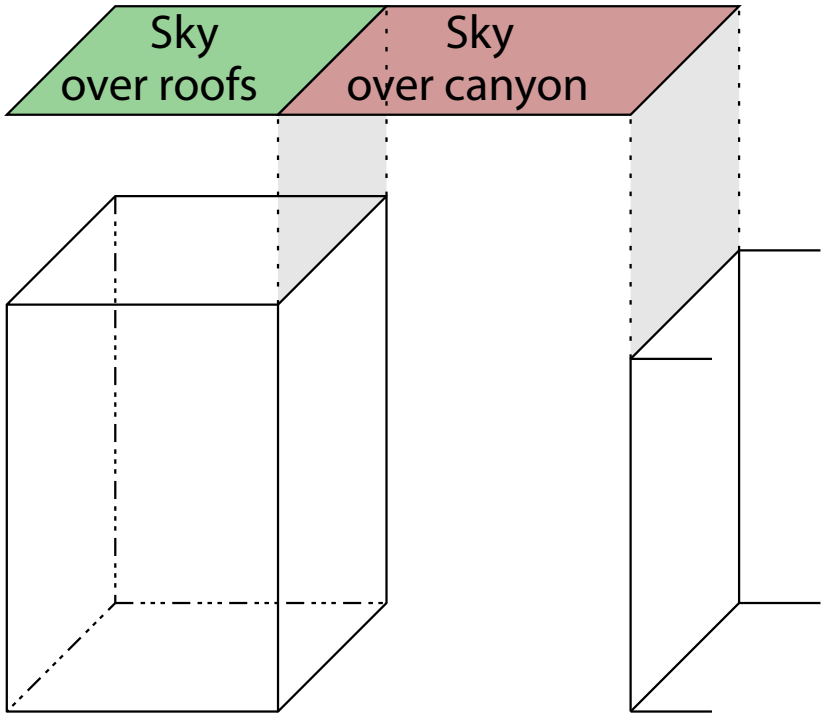
- diffuse solar radiation formulated analogously to diffuse longwave radiation
- separation of effective urban albedo for diffuse and direct radiation

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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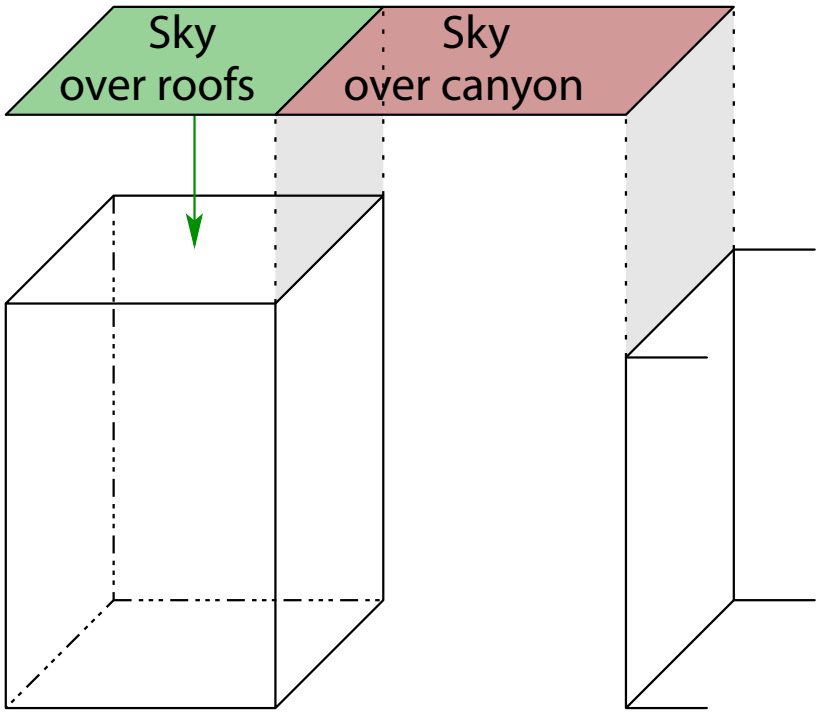

- roofs always get full radiation

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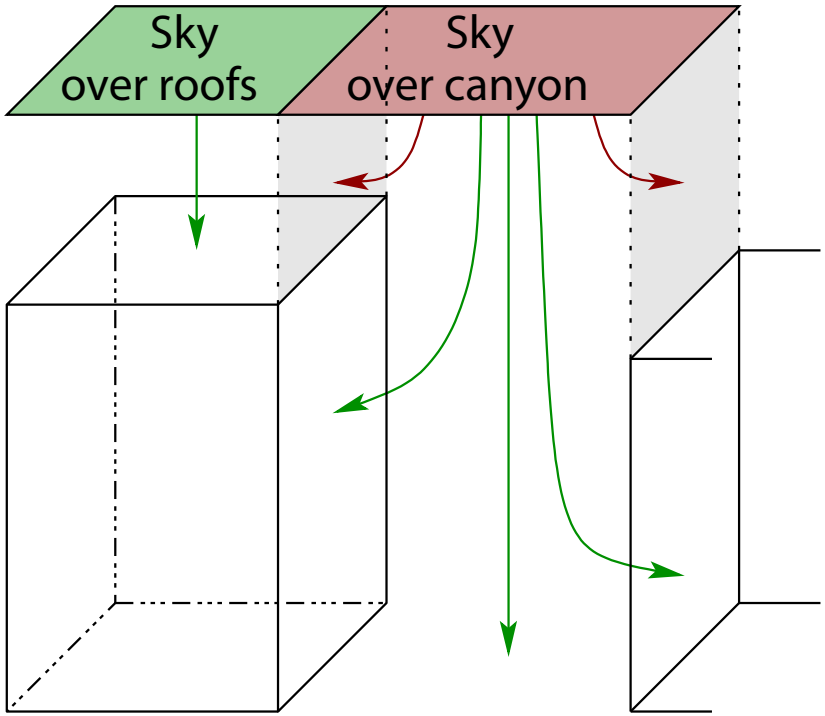

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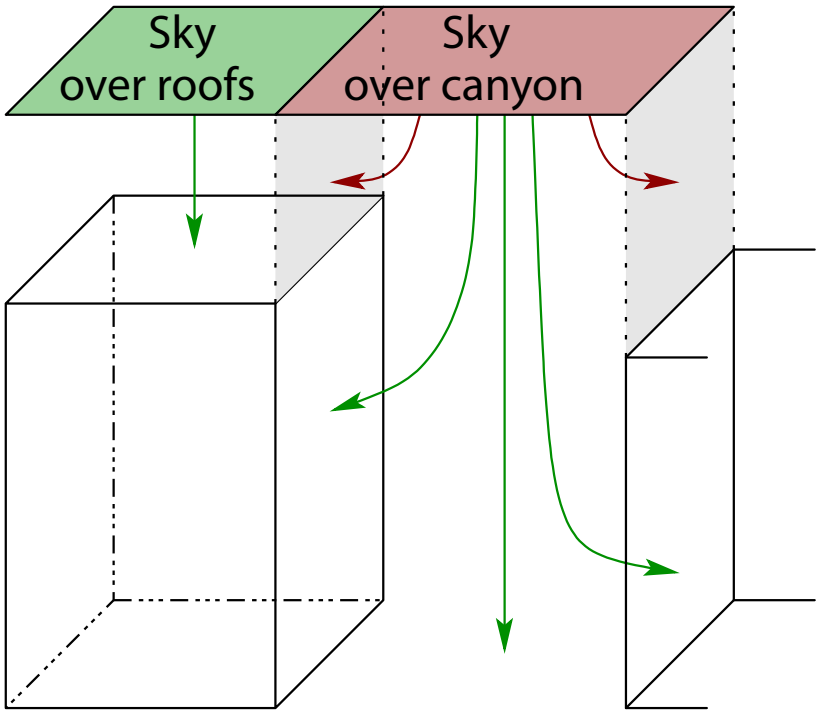
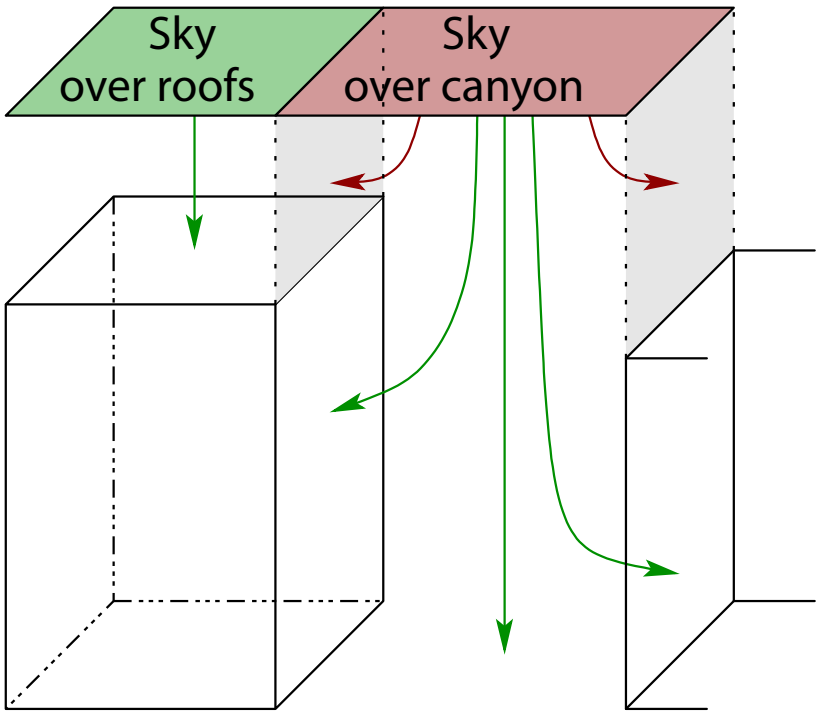


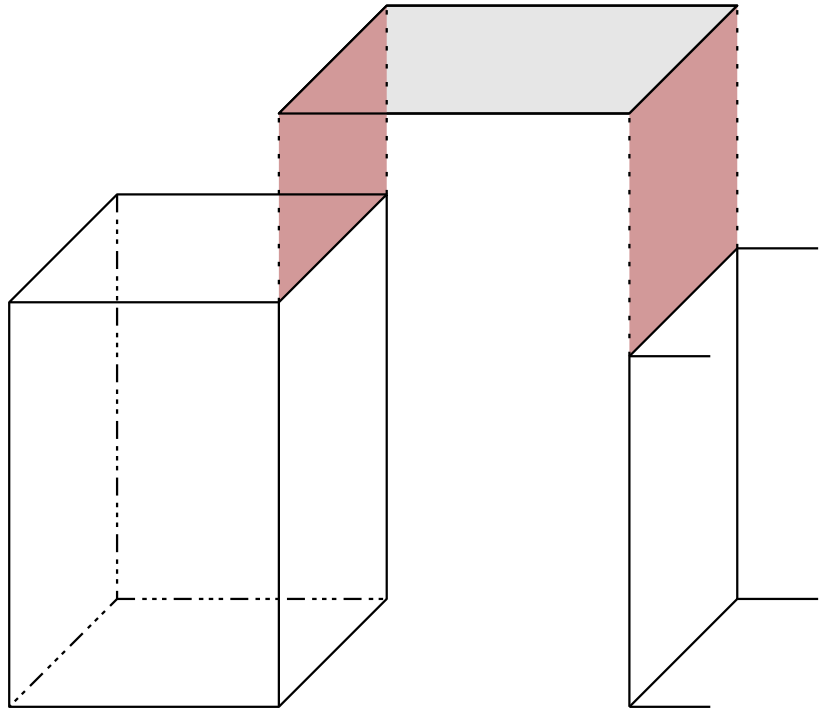
- roofs always get full radiation
- energy not accounted for where no walls present

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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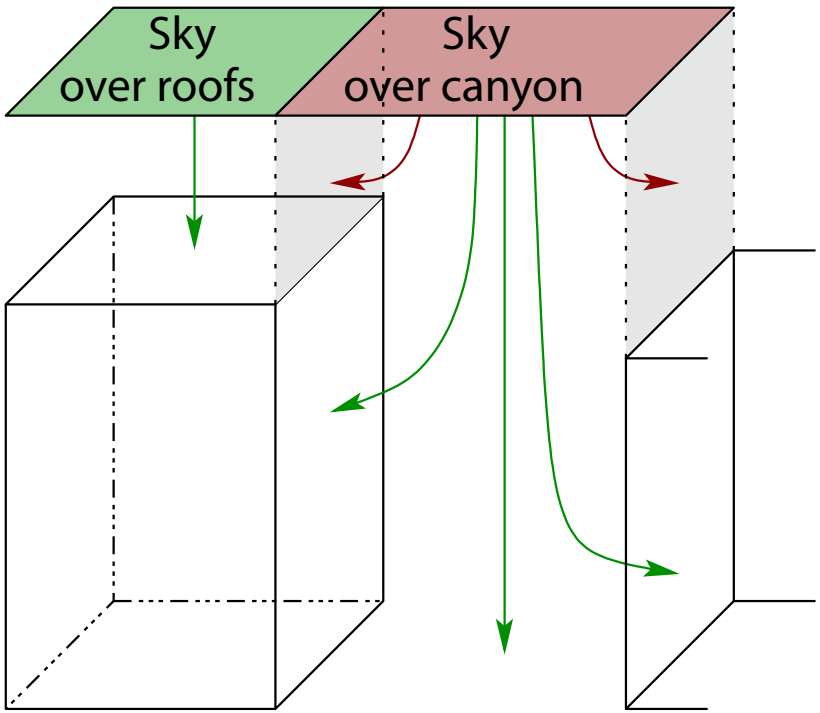

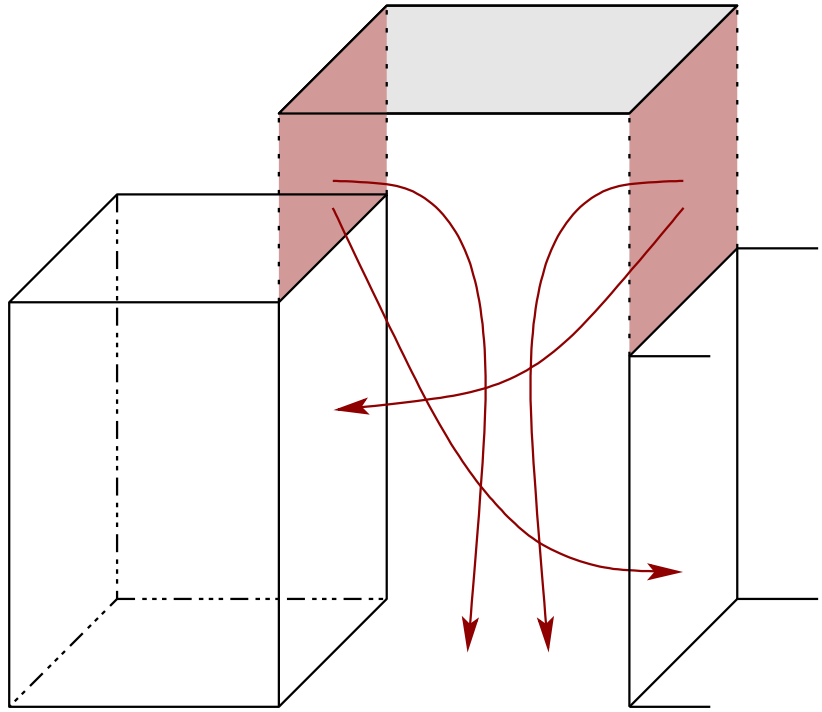

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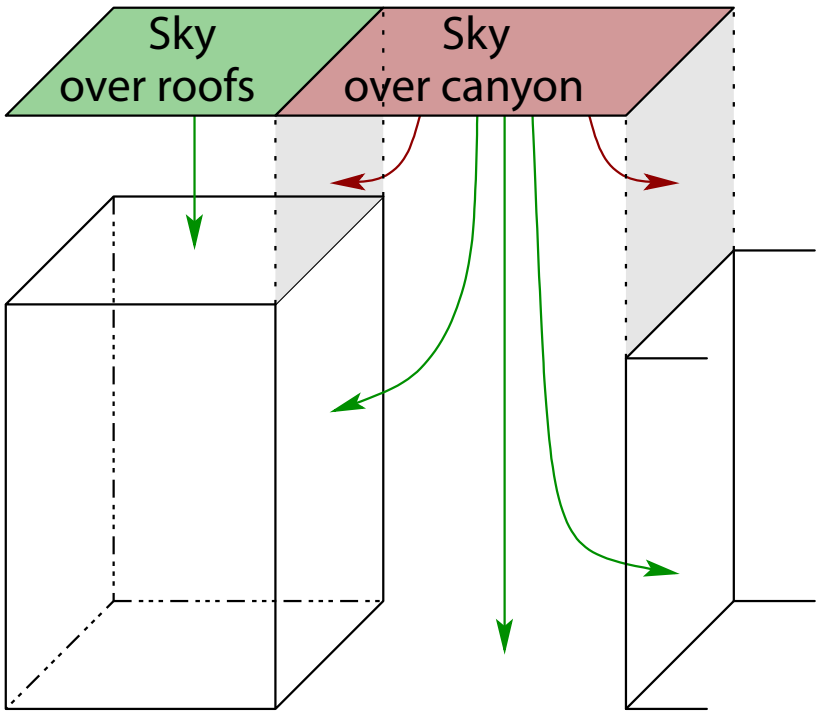

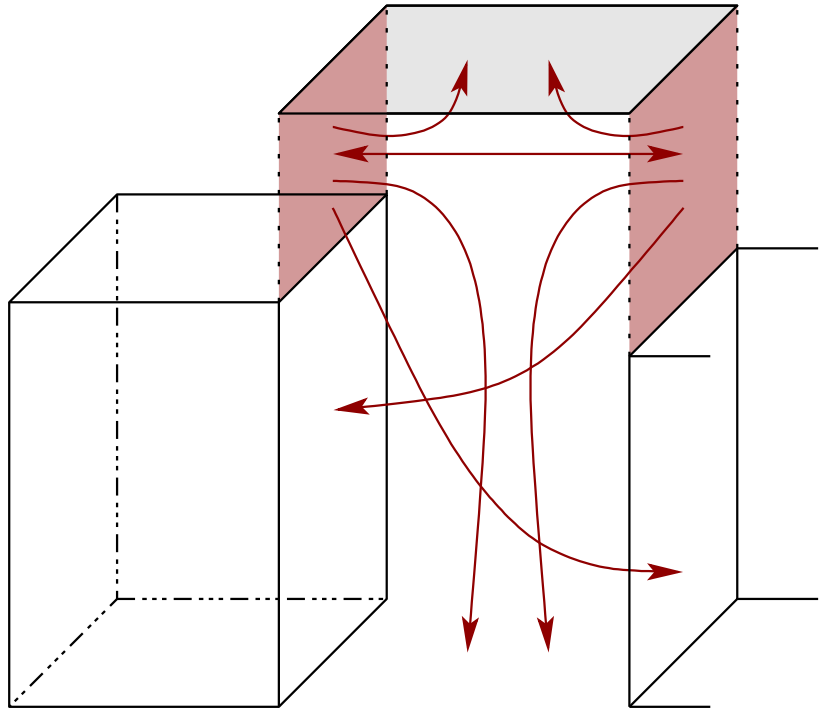

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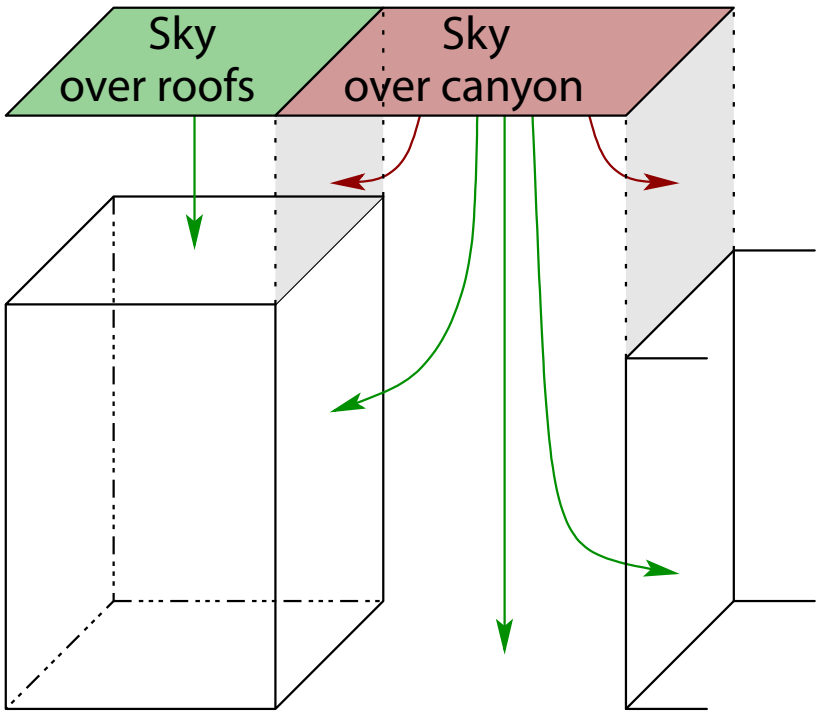

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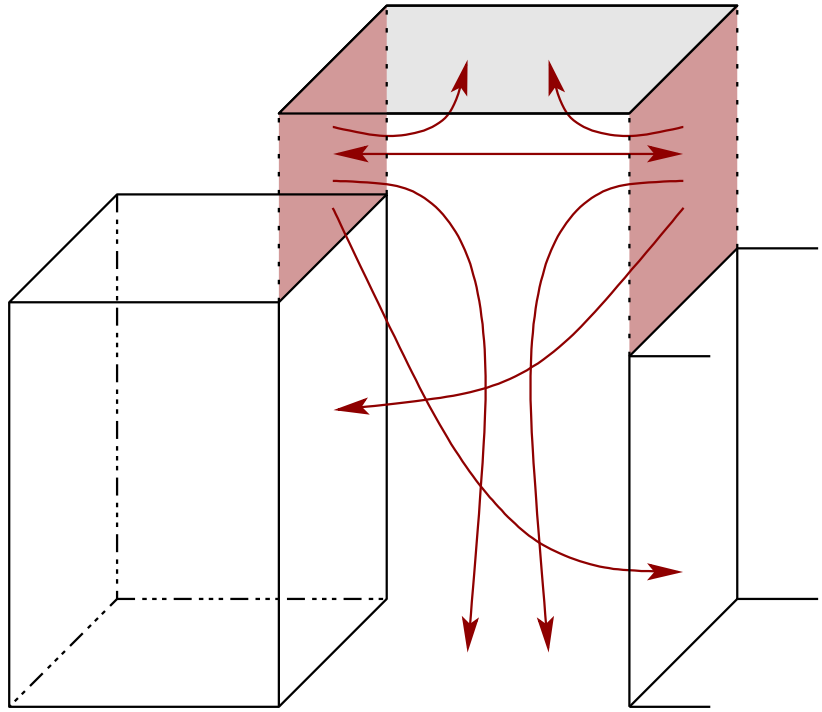
from side with $R_{side} = R_{top}$

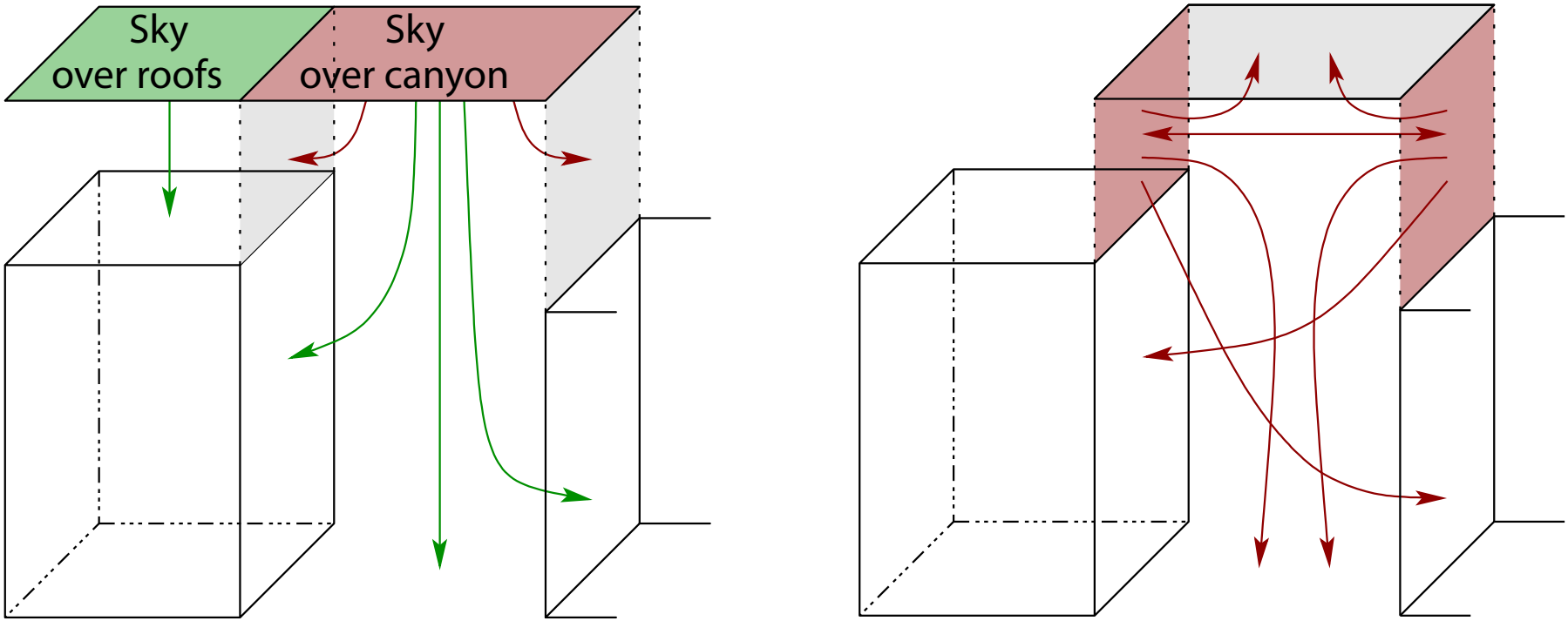


- in general, total calculated energy received by the canyon is larger than incoming energy

2 Our approach

Distribution of incoming diffuse radiation from the sky

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



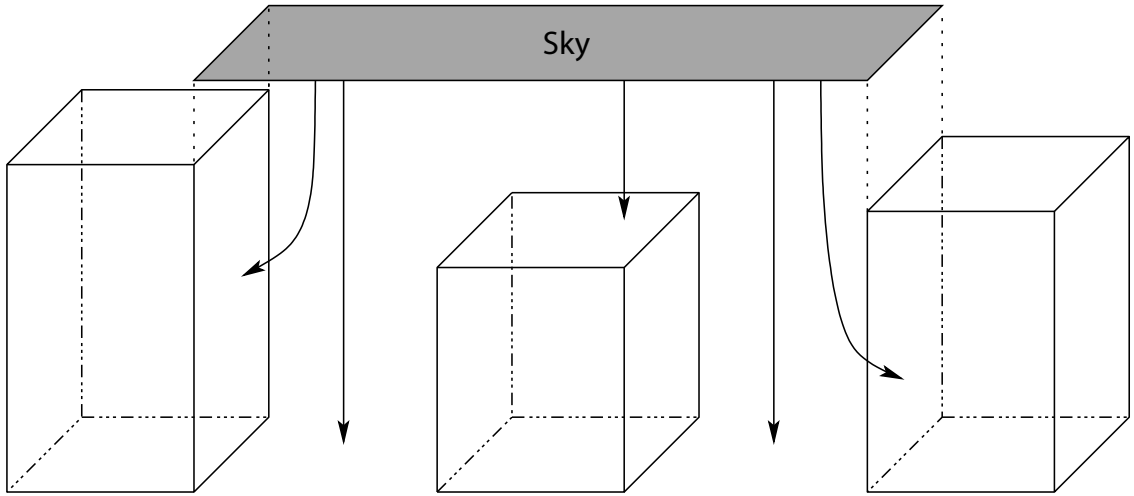
- scale irradiance from the side of the canyon with factor c to fulfill energy conservation
- c constant during runtime

3 Double Canyon Effect Parametrization

Distribution of radiation from the sky

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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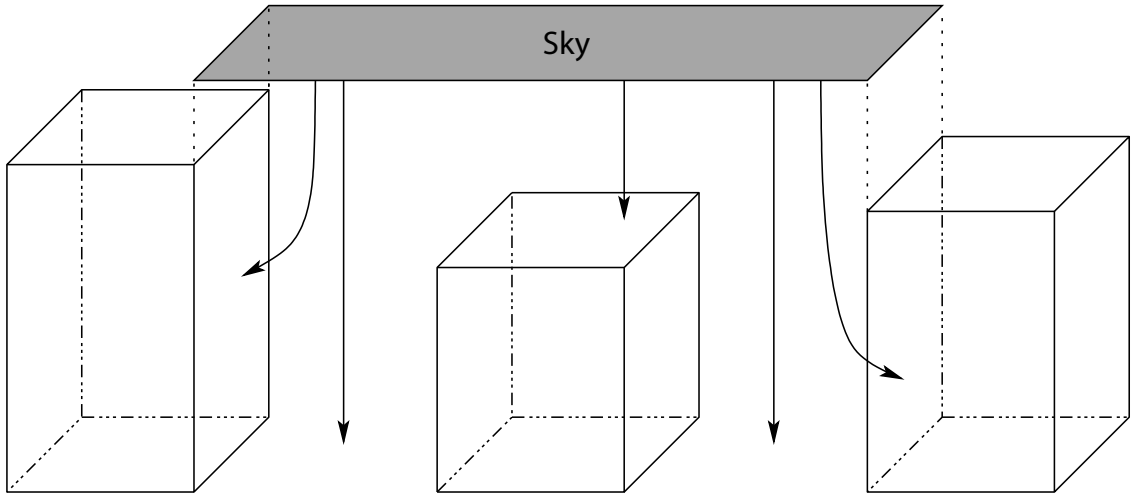
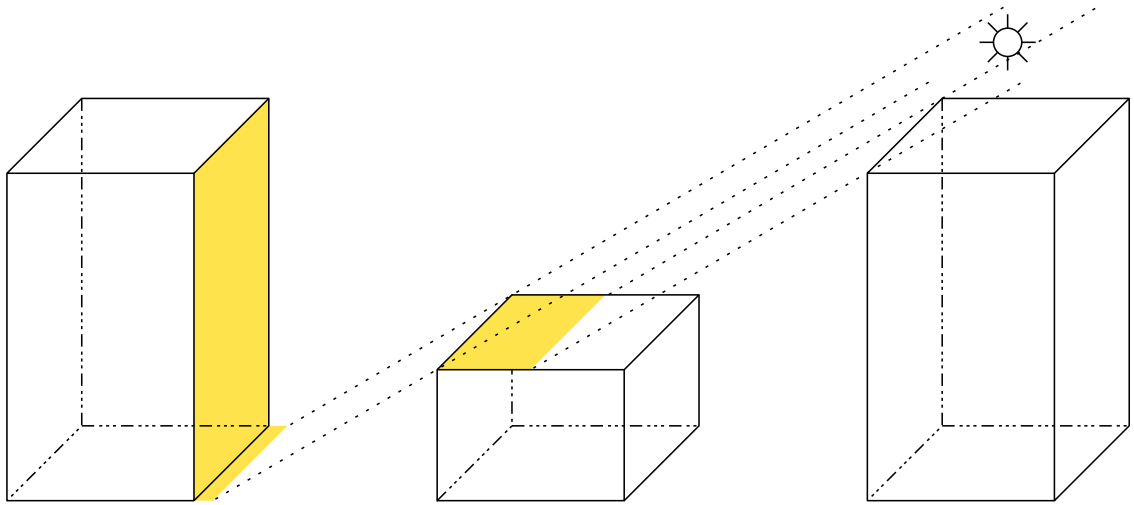


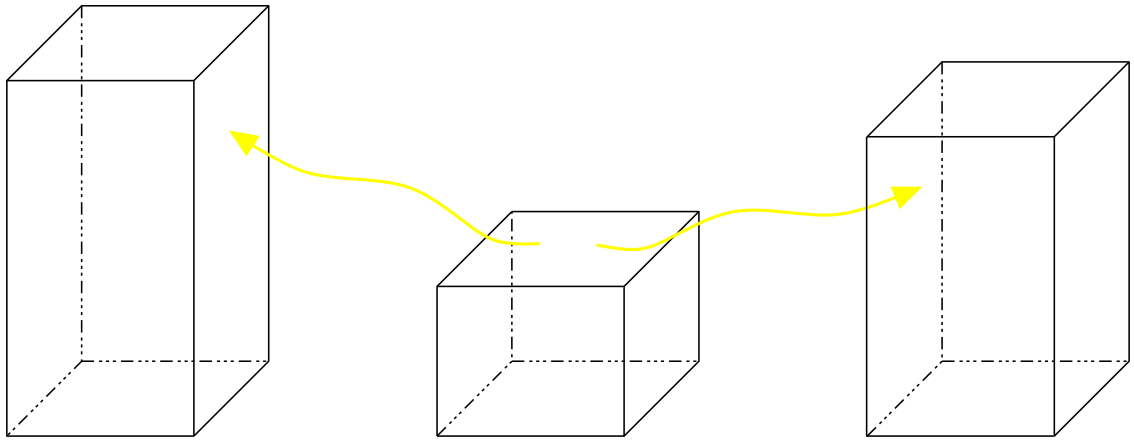
- calculation of received direct solar radiation depending on the position of the sun
- shadows on roofs possible



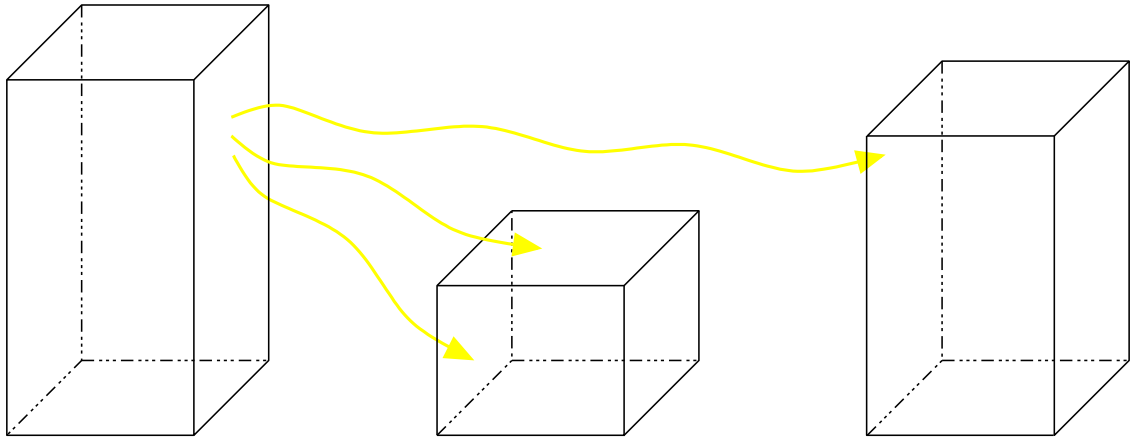
3 Double Canyon Effect Parametrization

Radiative interaction in the double canyon

radiative interaction of roofs with canyon



walls interact with “their” canyon and neighbouring canyon

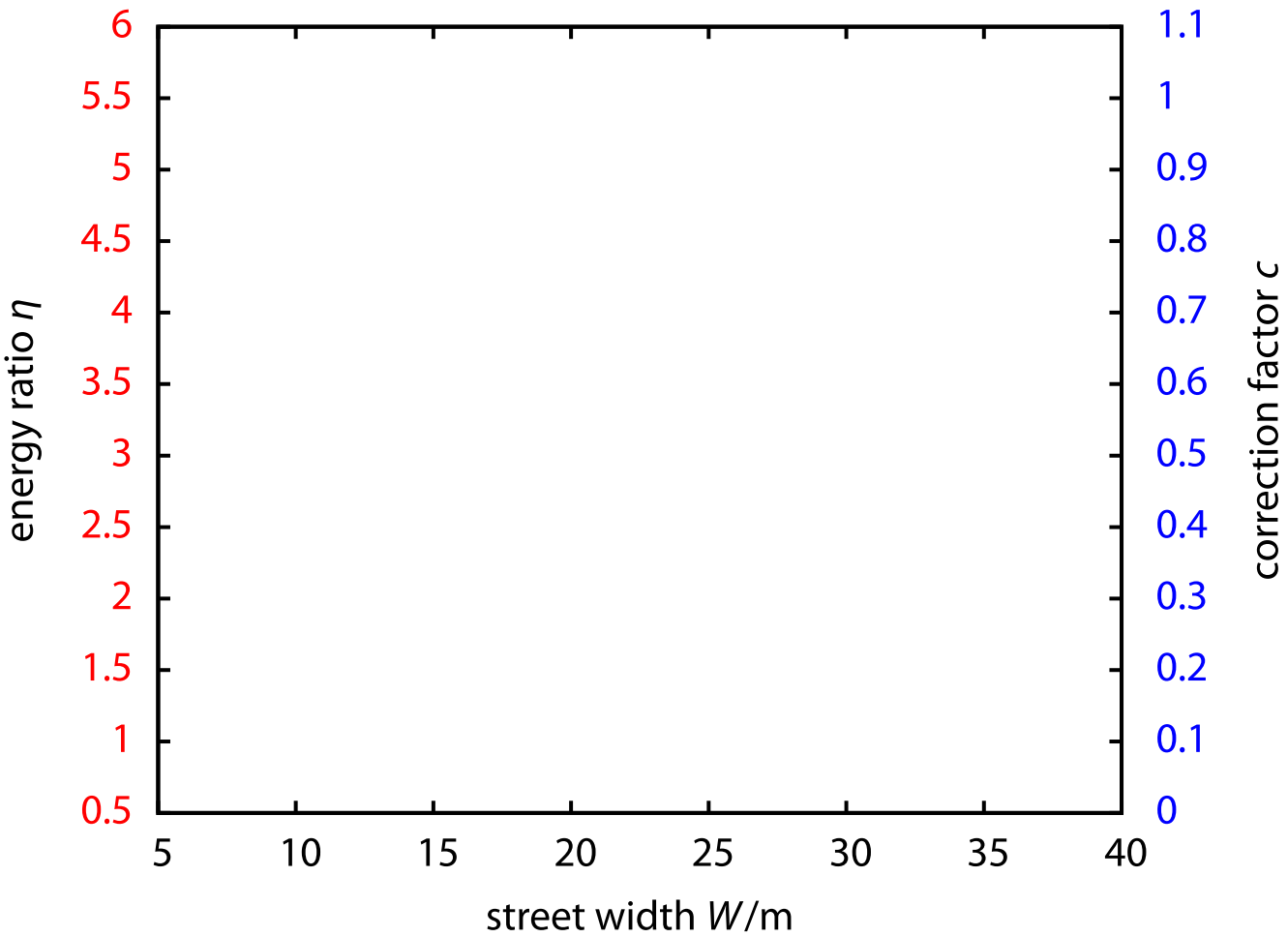


Contents

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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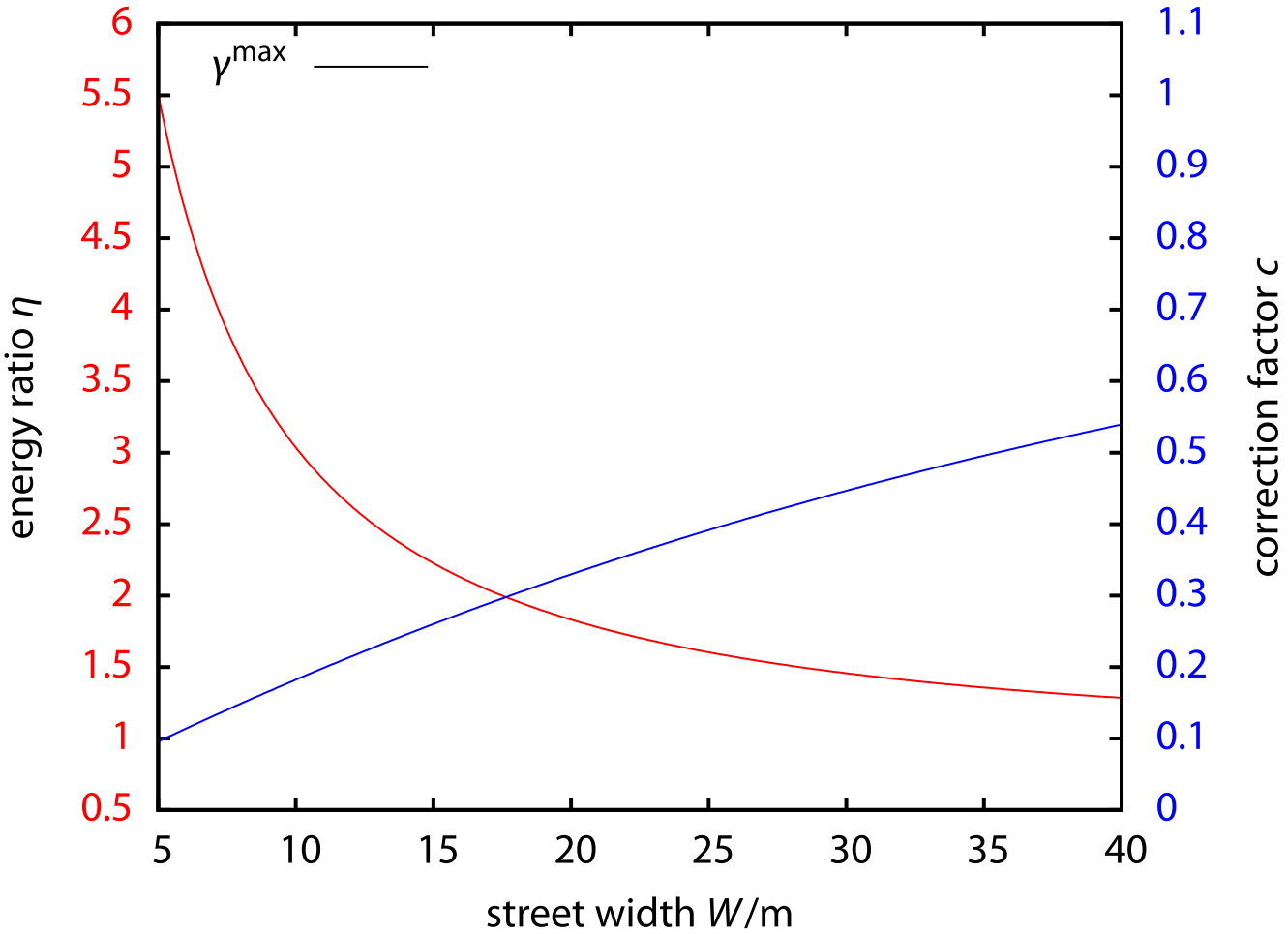
γ^{max} 50 % at 0 m,
50 % at 50 m



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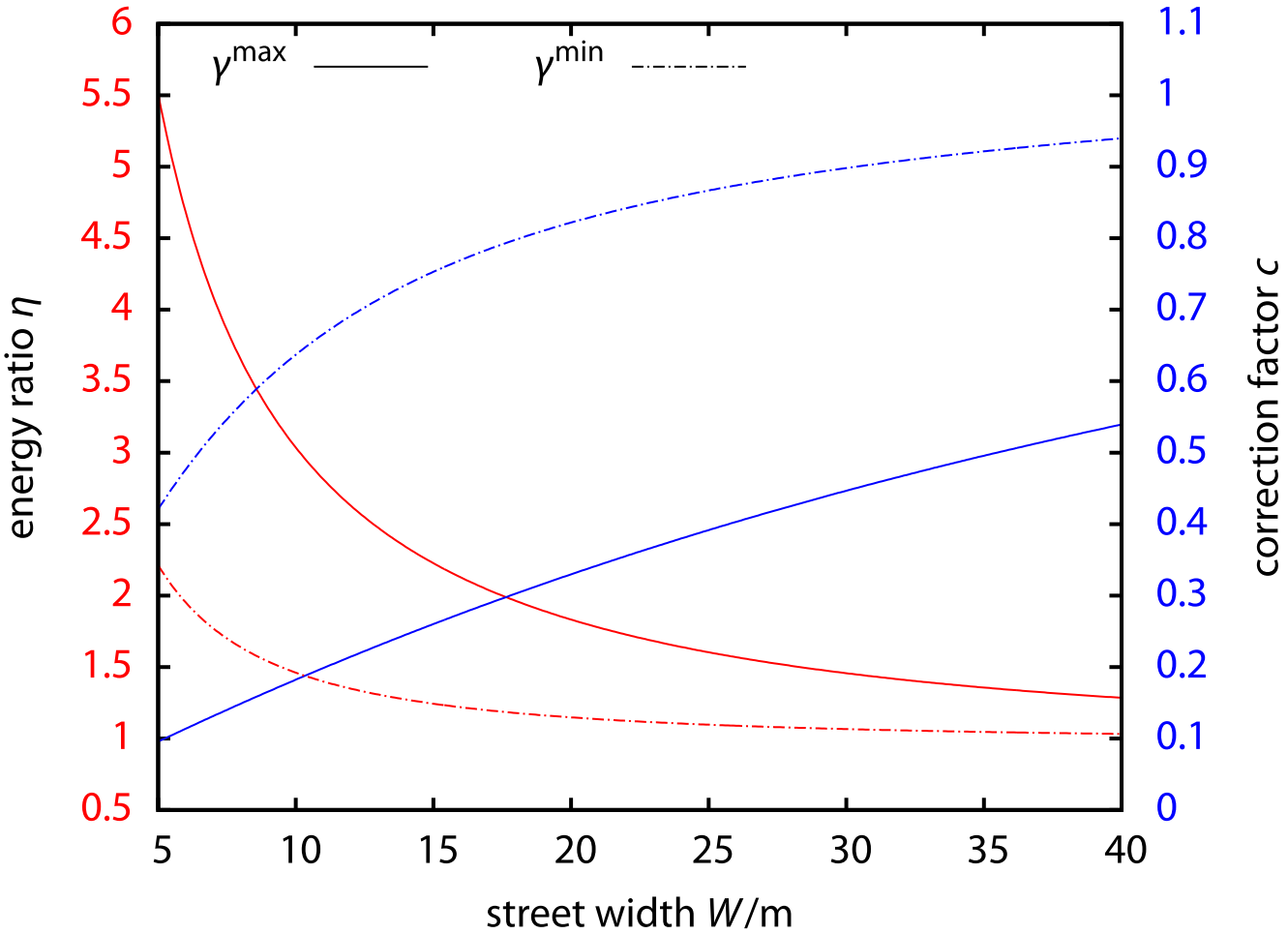

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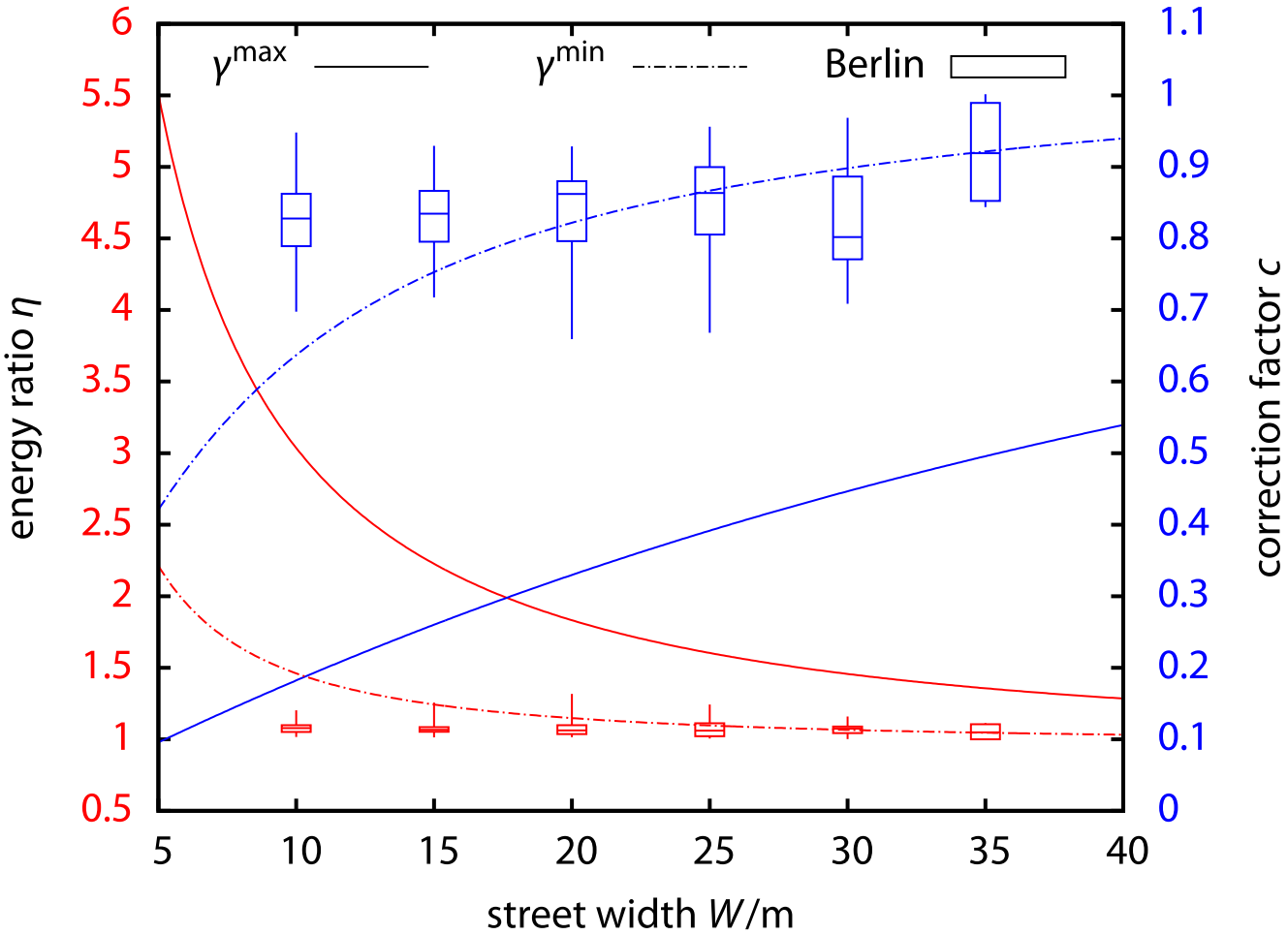
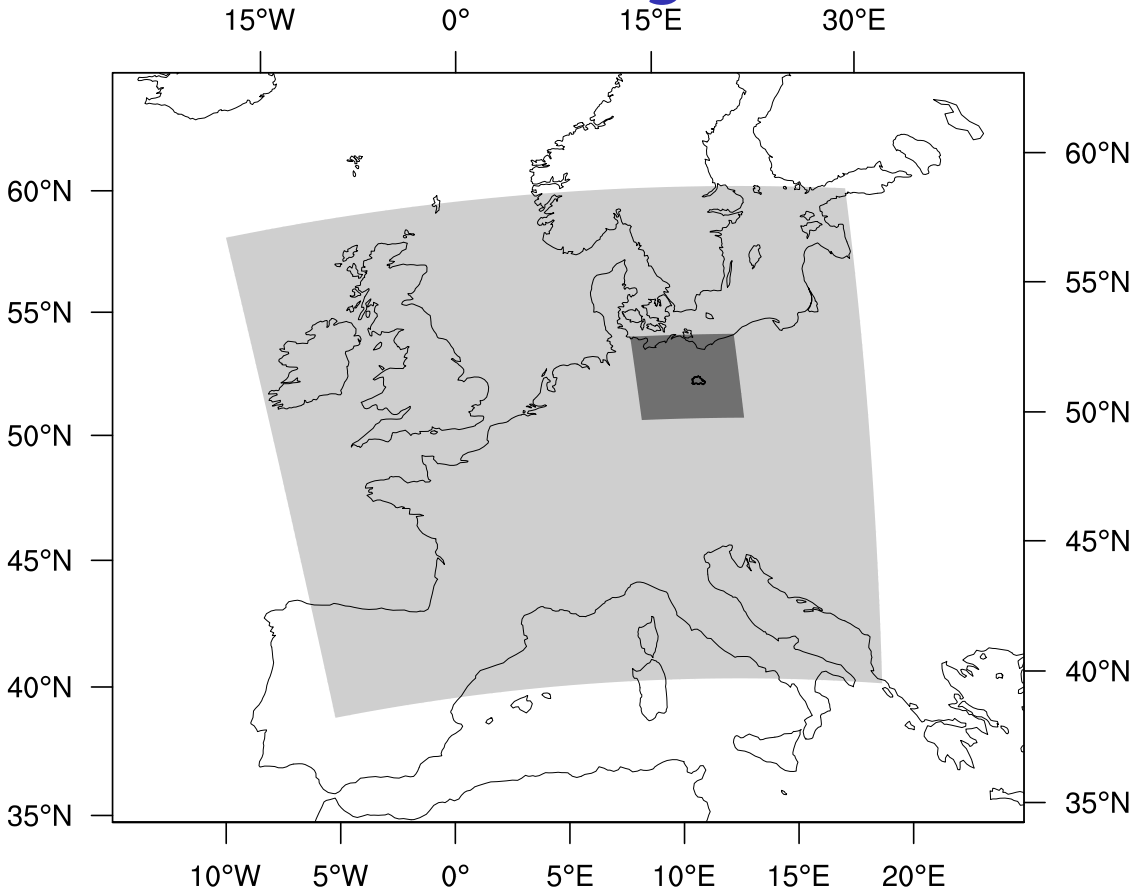
Berlin based on 3d building data of Berlin



Simulations with regional climate model CCLM



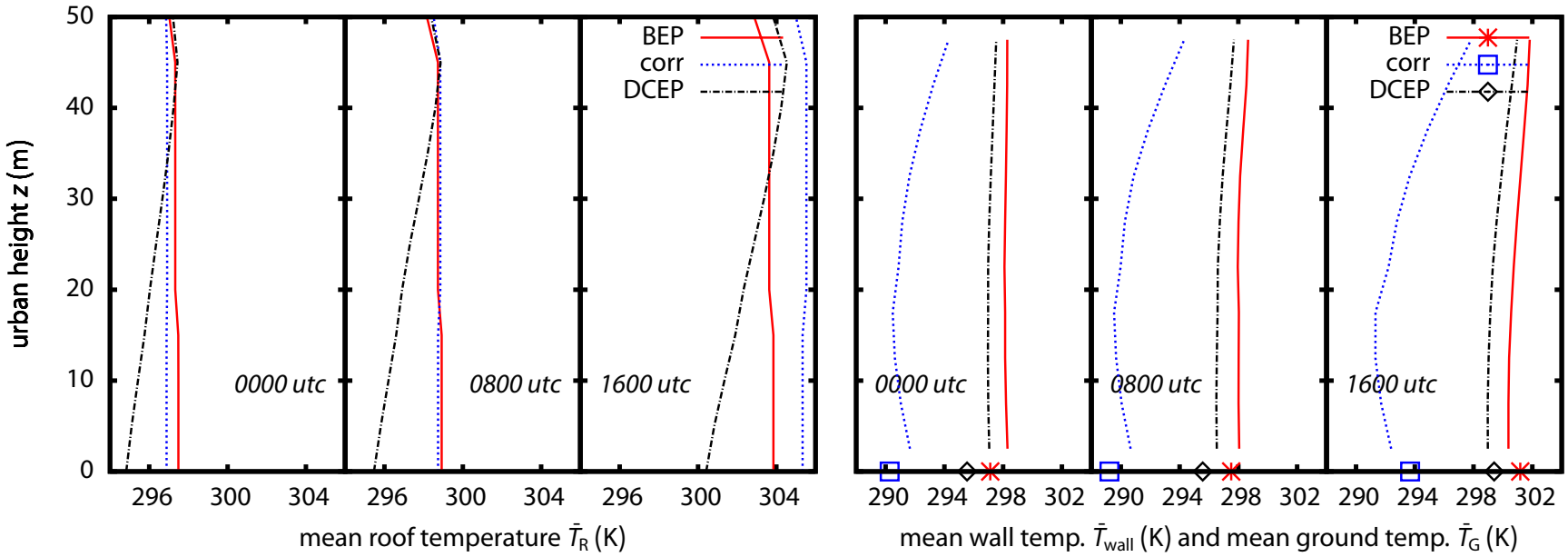
simulations starting 2003-08-01 00UTC with double nesting approach:

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

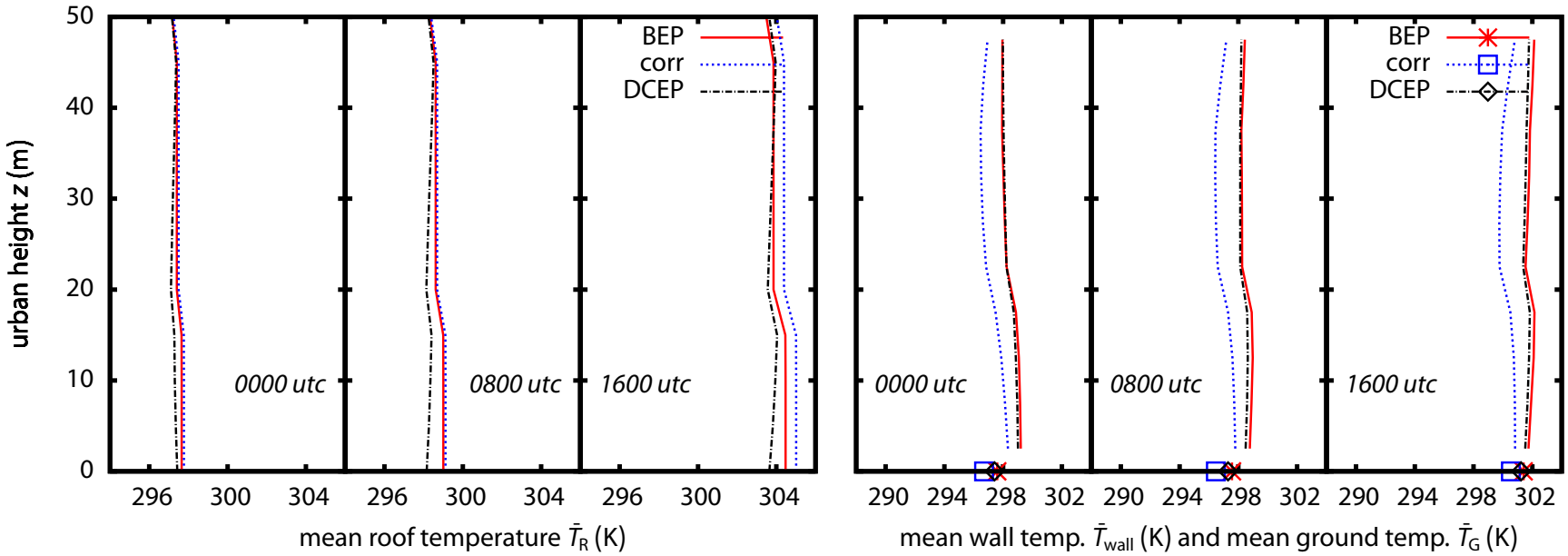
- urban module settings: urban fraction 1, street width 20 m, building width 10 m, height distribution γ^{max} or γ^{min}
- urban radiation scheme: “BEP” original but with (1), “corr” also (2), “DCEP” also (3)

Urban surface temperatures

γ^{max}

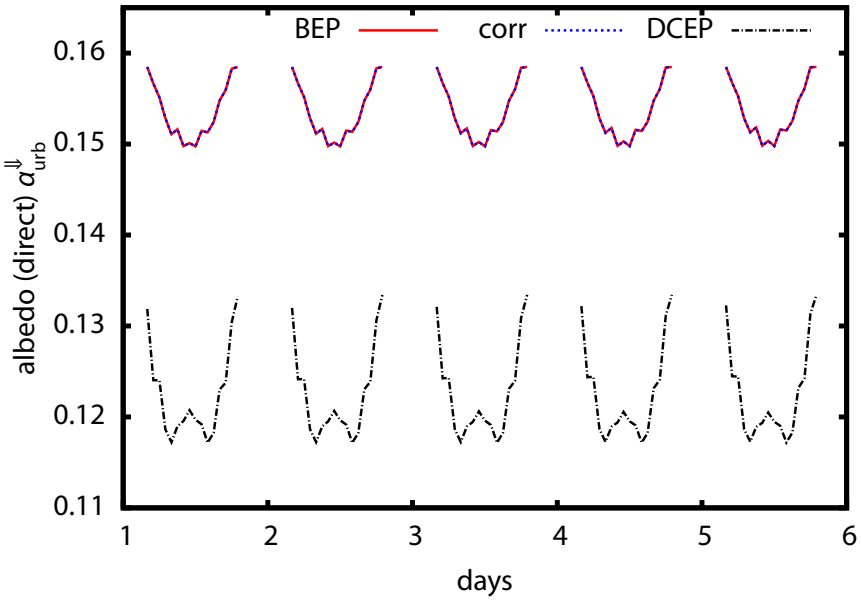


γ^{min}



Urban albedo

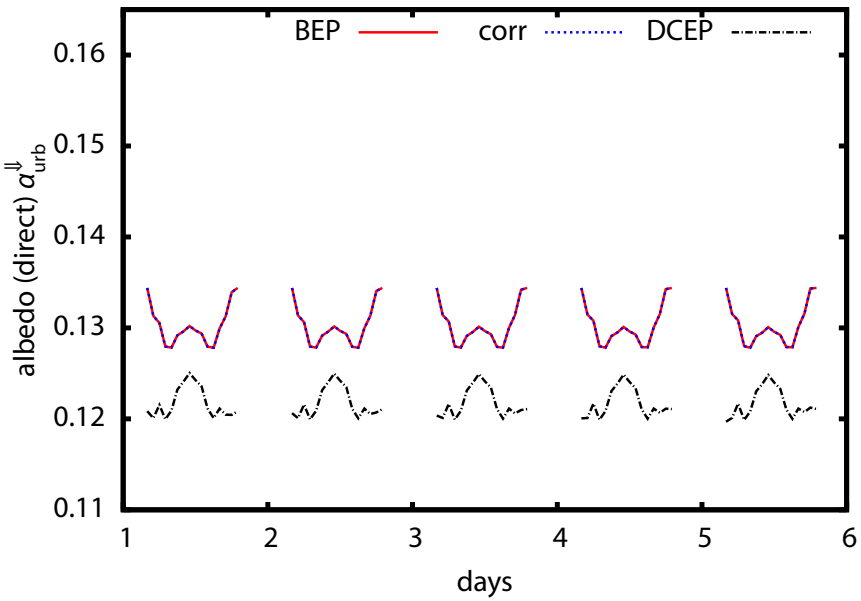
γ^{max}



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

BEP	corr	DCEP
-0.34	0.15	0.12

γ^{min}

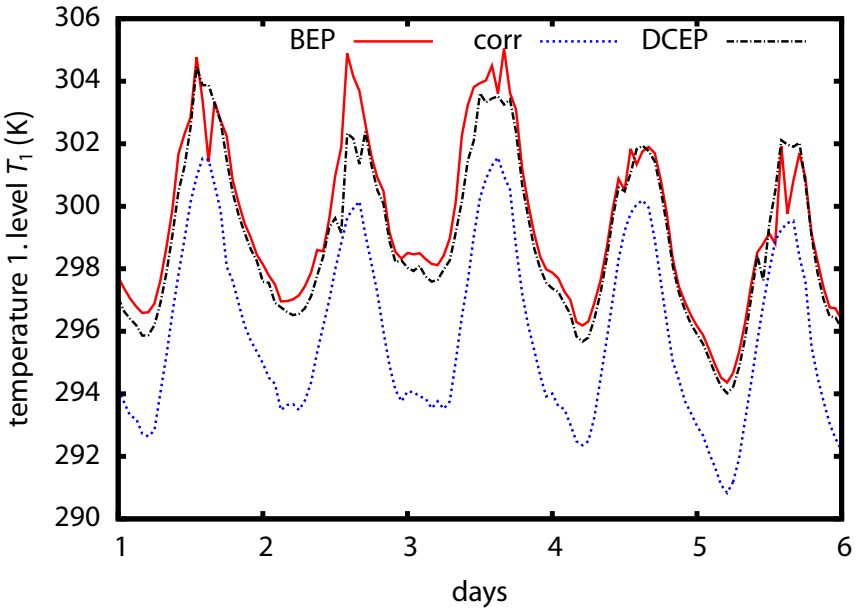


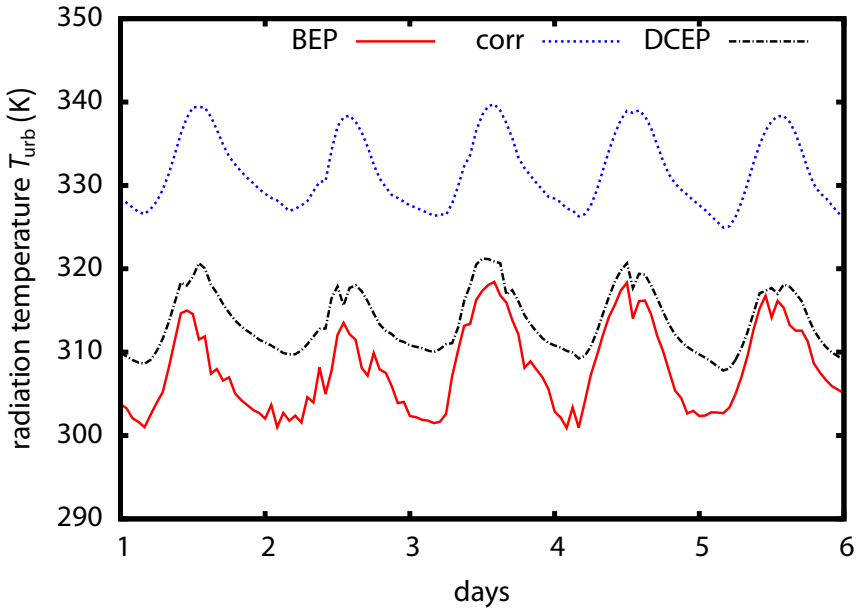
albedo (diffuse) $\alpha^{\downarrow}_{urb}$

BEP	corr	DCEP
0.04	0.13	0.12

Air and effective radiation temperatures

γ^{max}





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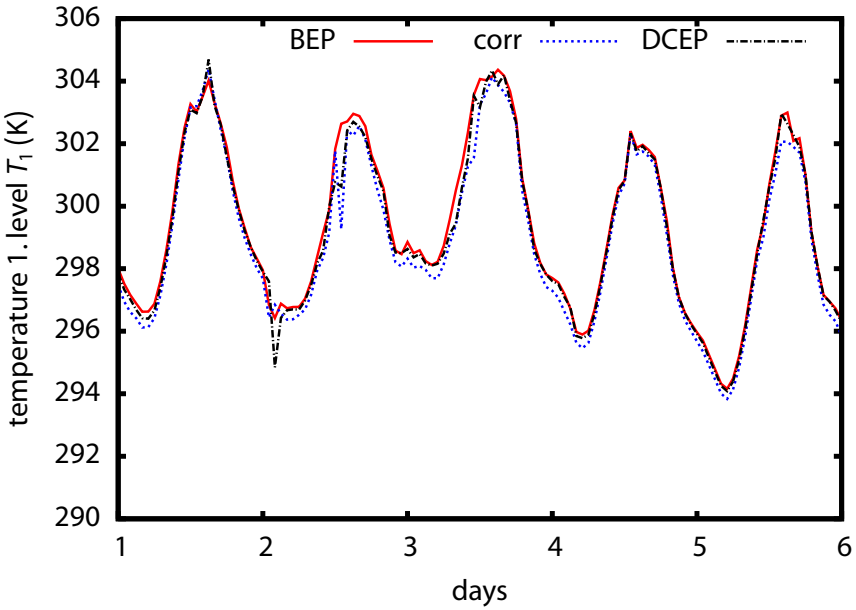

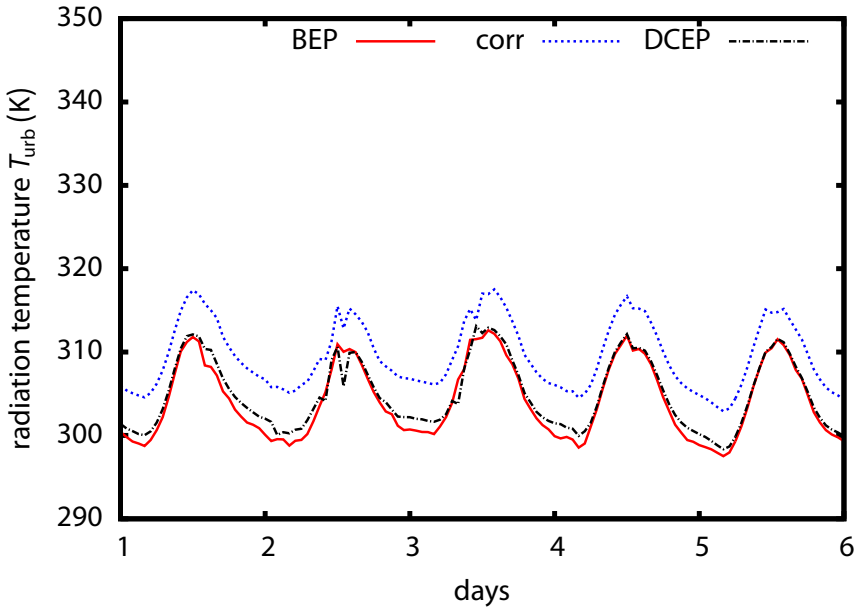

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- calculation of effective radiation parameters possible or corrected: albedo for diffuse and direct solar radiation, radiation temperature
- increased urban heat island effect compared to original formulation but without overestimation of incoming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

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Any questions?