An Urban Surface Parametrization Scheme and its Input Parameters

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POTSDAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH

P I K

Introduction
Growing Importance of Urban Centres in Weather and Climate Models

Tokyo

- size of urban areas growing
- resolution of weather and climate models increasing
- *but*: computation cost too high to incorporate every single building
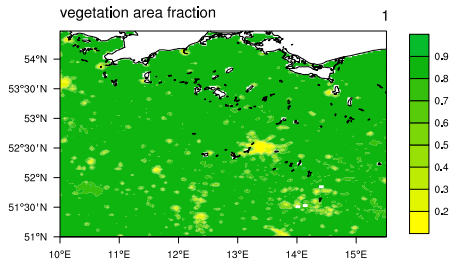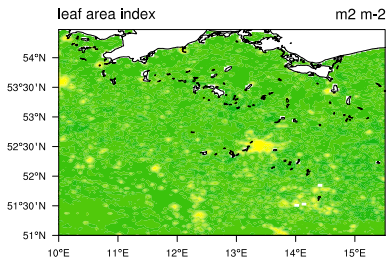 $\Rightarrow$ simplified model required
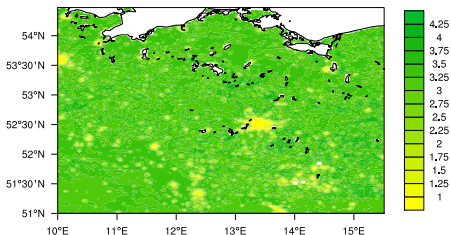
Contents

Contents

Urban regions in CCLM 4.8

Input parameters for Berlin

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Urban regions in CCLM 4.8
Need of Additional Parametrization

- main difference in urban centres: increased roughness length and reduced vegetation fraction
- not enough to model urban effects like
  ‣ radiation trapping
  ‣ heat storage in urban surfaces
  ‣ modified turbulent wind flow
  ‣ anthropogenic heat

  which result in Urban Heat Island

$\Rightarrow$ add additional urban surfaces with vertical and horizontal extent

Building **E**nergy **P**arametrization Model by Martilli et. al.

Street Canyon model

- B building width
- W street width
- D canyon length
- h height with probability $\gamma(h)$
- z_i height of level i

- **reduced sky visibility** and **reflections and emissions** from other urban surfaces (roofs, walls, roads)
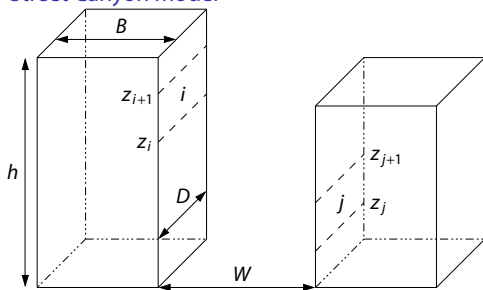
- **one dimensional heat diffusion** for every urban surface element

- **effects of urban surfaces on wind fields, temperature and TKE**

- **modified turbulent length scales**

- *no* anthropogenic heat

Building **E**nergy **P**arametrization Model by Martilli et. al.

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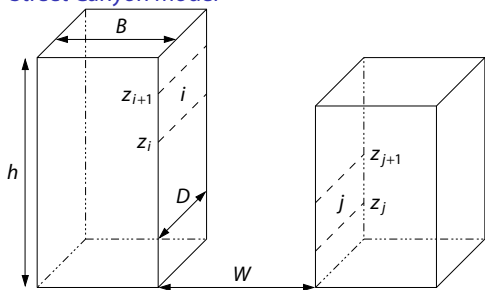- D canyon length
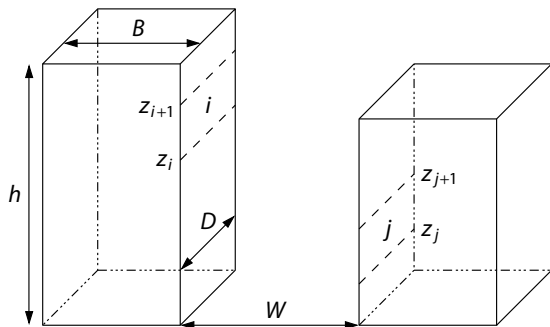- h height with probability $\gamma(h)$
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Longwave Radiation Budget

Example: ith element of west wall

west wall receives radiation from

- sky
- ground
- opposite wall

$$R_{\mathrm{W}i} = S\psi_{\mathrm{S}\to i} + \sum_{j=1}^{n} S\psi_{j\to i}(1-\Gamma_{j+1}) + \epsilon_{\mathrm{G}}\sigma T_{\mathrm{G}}^4\psi_{\mathrm{G}\to i} + (1-\epsilon_{\mathrm{G}})R_{\mathrm{G}}\psi_{\mathrm{G}\to i}$$

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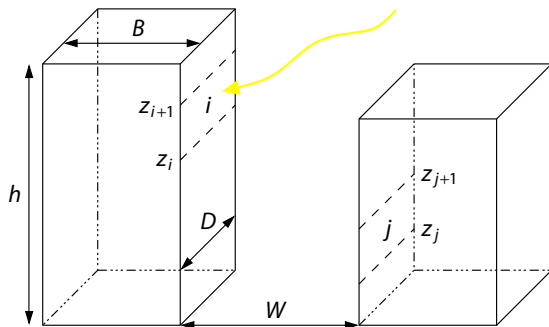west wall receives radiation
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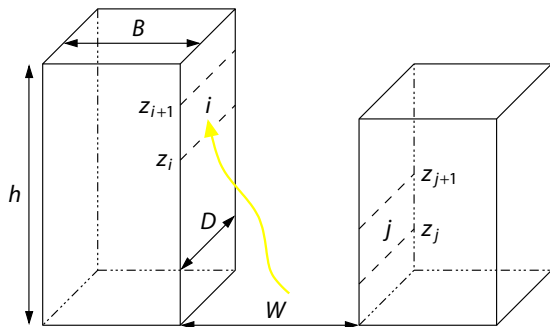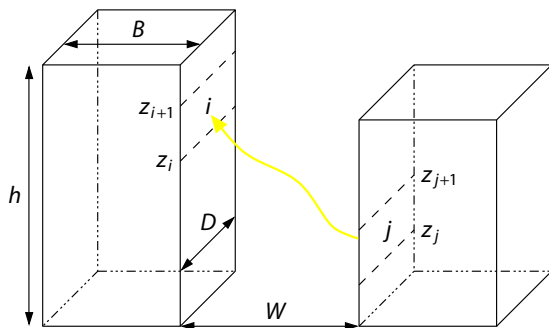west wall receives radiation
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Momentum and Heat Surface Fluxes

- horizontal surfaces (street and roofs): Formulation by Louis (1979)
  (standard bulk-transfer scheme of COSMO but only at the ground):

$$\vec{F}_M^h = -\rho C_M |\vec{v}_h| \vec{v}_h A_h\,, \quad \vec{v}_h = \begin{pmatrix} u \\ v \end{pmatrix}\,, \quad C_M = \frac{\kappa^2}{\ln^2 h/z_0} f_M(\mathrm{Ri_B}, h/z_0)$$

$$F_H^h = -\rho C_H |\vec{v}_h| \Delta T A_h\,, \qquad\qquad C_H = \frac{\kappa^2}{\ln^2 h/z_0} f_H(\mathrm{Ri_B}, h/z_0)$$

- vertical fluxes (walls): see e. g. Raupach (1991, 1992) and Clarke (1985)

$$\vec{F}_M^v = -\rho C |\vec{v}_{ort}| \vec{v}_{ort} A_v\,, \quad C = 0.4$$

$$F_H^v = -\frac{\eta}{\rho c_p} \Delta T A_v\,, \qquad \eta = 5.678\,\frac{\mathrm{W}}{\mathrm{m^2\,K}} \left[1.09 + 0.23 \left(\frac{|\vec{v}_h|/\mathrm{m\,s^{-1}}}{0.3048}\right)\right]$$

- instead of effective roughness length for model grid cell, different
  roughness lengths for roof, wall and road are applied

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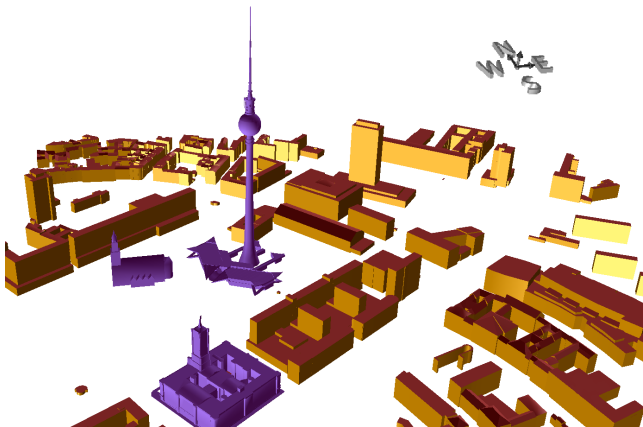$$\vec{F}_M^v = -\rho C |\vec{v}_{ort}| \vec{v}_{ort} A_v \,, \quad C = 0.4$$

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Usage of morphological data

- former studies mainly used land use classes, e. g. commercial and industrial, high/low-dense residential
- for Berlin: highly detailed 3d data in CityGML format available
- differentiated into roof, wall and ground surfaces

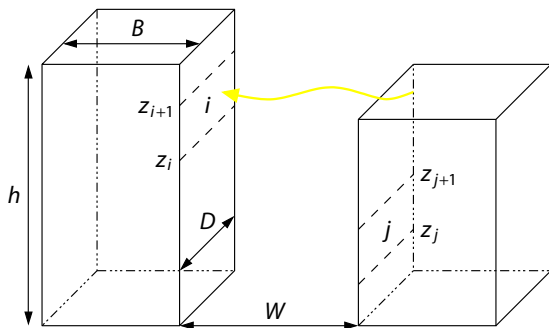rendered piece of 3d Berlin building data

Improvements and Corrections to BEP
Already Implemented

- usage of spatially resolved input data; employment of land use data still possible
- fixed a major and a minor bug in shadow calculation and radiation budget, resp.
- adjustments to total radiation budget used for calculation of effective emissivity, albedo and temperature
- minor correction for momentum and temperature flux due to vertical surfaces
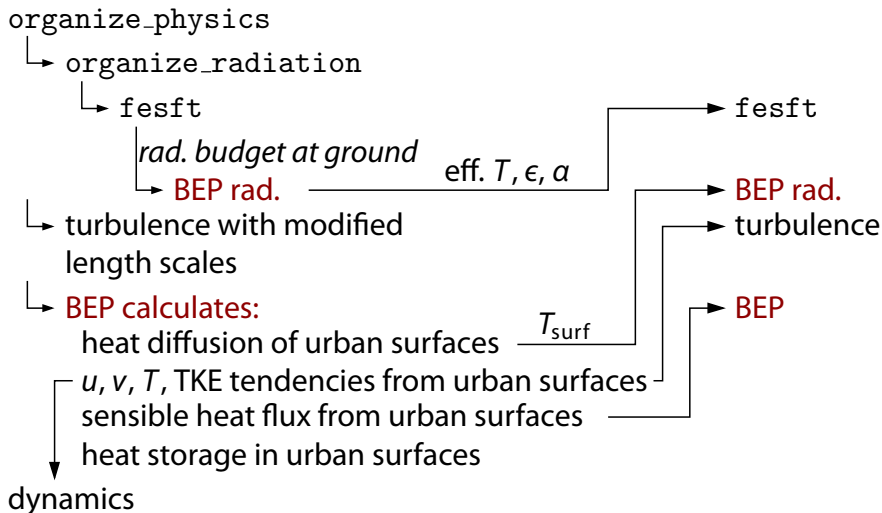- radiation budget's linear system of equations solved only once

Improvements and Corrections to BEP

Issues Under Investigation

- roof surfaces in radiation budget
- averaging of turbulent length scales
- precipitation

Flow Chart

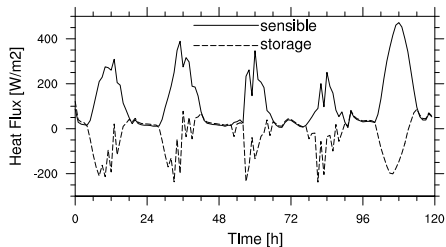**step *n***   **step *n* + 1**

```
organize_physics
  └─ organize_radiation
       └─ fesft                                                    ──────────►  fesft
            *rad. budget at ground*
            └─ BEP rad.  ───────────  eff. $T$, $\epsilon$, $\alpha$  ──────►  BEP rad.
  └─ turbulence with modified                                      ──────────►  turbulence
     length scales
  └─ BEP calculates:
       heat diffusion of urban surfaces   ── $T_{\mathrm{surf}}$ ──────────►  BEP
       *u*, *v*, *T*, TKE tendencies from urban surfaces ─┘
       sensible heat flux from urban surfaces ───────────────────┘
       heat storage in urban surfaces
dynamics
```

Contents

Time Development of Urban Values

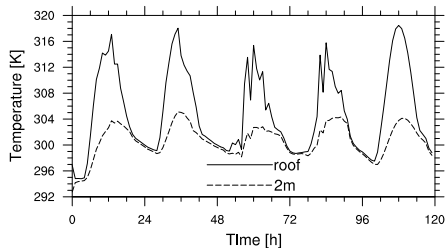## Centre of Berlin, starting 01.08.2003 00UTC

Time Development of Urban Values

Centre of Berlin, starting 01.08.2003 00UTC
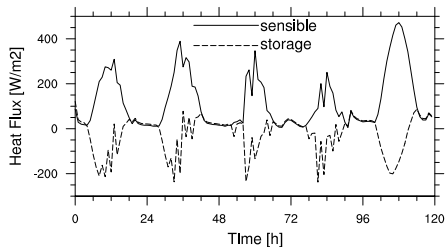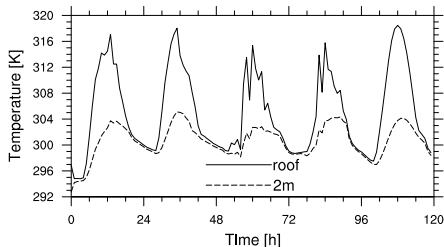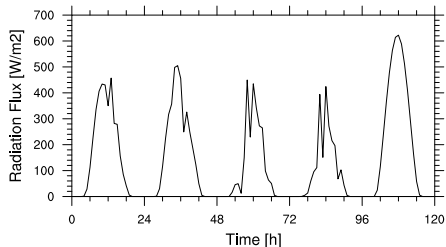

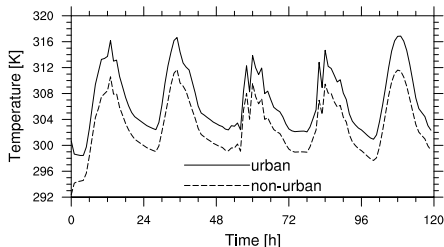Sensible Heat Flux and Storage Flux of Urban Surfaces

Roof Temperature and 2m Temperature

Net Downward Shortwave Radiation

Surface and Effective Urban Temperature

Thank You

We like to thank the city of Berlin for the supply of the 3d Berlin data as well as the European Union for supporting the creation of this data through the European Regional Development Fund.

Thank you for your attention!