Implementation, modification and testing of the Building Energy Parameterization Scheme (BEP)

S. Schubert[1]*, S. Grossman-Clarke[2], A. Martilli[3]

[1] Potsdam Institute for Climate Impact Research, [2] Arizona State University,[3] CIEMAT, Unidad de Contaminacion Atmosferice

*sebastian.schubert@pik-potsdam.de, Tel.: +49-(0)331-288-2592

The Building Energy Parameterization scheme (BEP, Martilli et al. 2002) was implemented in CLM to improve model performance in weather and climate simulations for urban areas. Furthermore, modifications were introduced in BEP's radiation scheme: (1) the radiative interactions of roofs with other urban canyon surface elements such as walls, roads and roofs and (2) closure of the radiative energy balance.

1. BEP and Implementation

1.1 Multilayer Street Canyon Model

Input of BEP:

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

Canyon Properties:

- B: building width
- W: street width
- D: canyon length

Output of BEP:

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

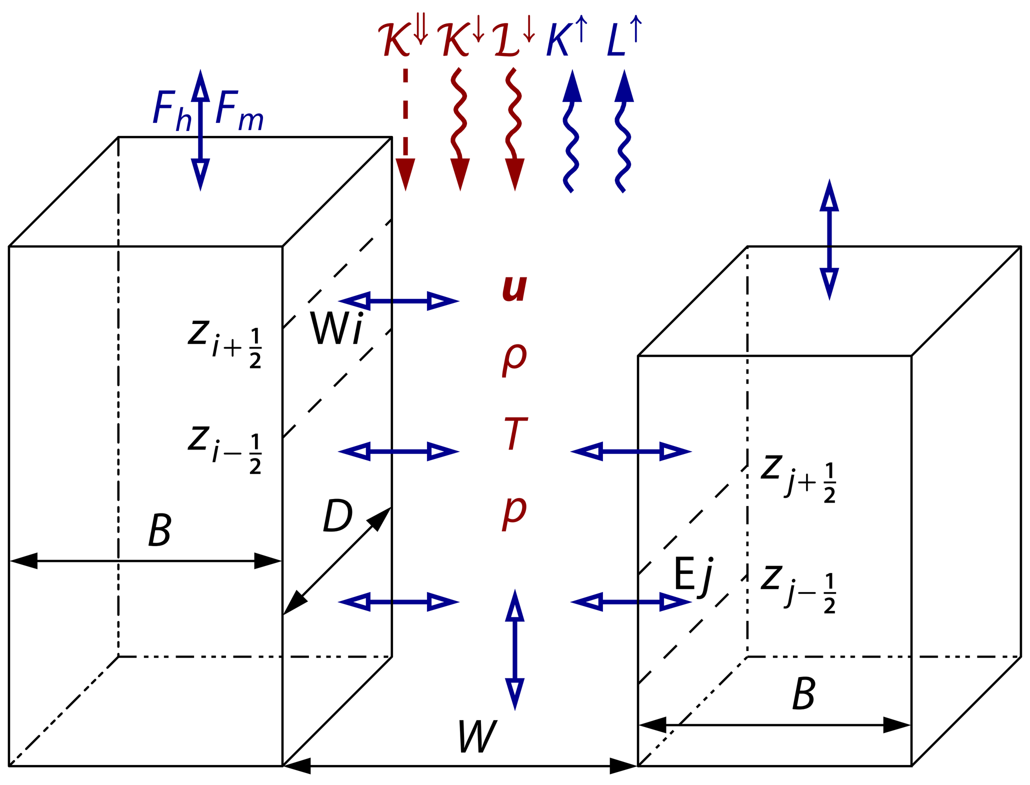


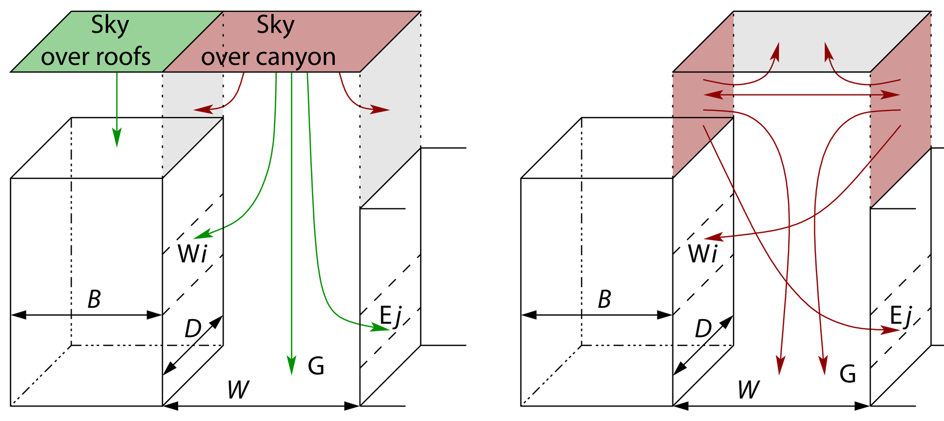
Figure 1: *Basic BEP morphology*

1.2 Implementation into CLM

- urban momentum and sensible fluxes included in wind and temperature tendency; replaced part of the turbulent diffusion flux
- additional TKE production due to urban fluxes; partly replaces TKE production due to turbulent diffusion flux
- averaging of turbulent length scales and effective height over surface
- calculation of effective urban radiative parameters and averaging with CLM's radiation parameters at the ground: effective surface radiation temperature, longwave emissivity, albedo for direct and diffuse radiation
- averaging of 2 m temperature
- modification of vegetation parameters and roughness length at urban sites (parameters are to represent vegetated surfaces there)
- input and output of urban fields (up to 7 dimensions)

2. BEP Modifications

In the original formulation, roof surfaces receive the full sky radiation whereas ground and wall surfaces receive diffuse radiation from the sky using the sky view formalism (fig. 2(a)). Energy that is received by side surfaces where no walls are present (grey surfaces in fig. 2(a)) is not accounted for. Instead, this area acts as a diffuse radiation source with the same flux density as from the top sky (fig. 2(b)). Each surface element inside the canyon receives radiation from both sources, the top sky and the areas where wall elements are not present. This leads to the problem that, in general, the total calculated amount of radiative energy received by the canyon is larger than the incoming radiation from CLM. Therefore, the energy ratio τ which is given by the energy distributed inside the street canyon divided by the radiation energy given by CLM is usually larger than 1. In order to solve that problem, a factor c is introduced in BEP which scales the radiative flux from the missing wall areas to ensure energy conservation.



(a) from the top (b) from the side

Figure 2: *Distribution of diffuse radiation inside the street canyon*

Figure 3 depicts the correction factor and the energy ratio τ for different fixed urban roof height distributions γ. Here, the urban height levels have been distributed with different probabilities between 0 m and 50 m. For example, γ^{max} is characterized by 50 % of the roofs at the lowest level and 50 % at the highest. The boxes are based on real data for the city of Berlin (fig. 5). In general, this means that depending on the street canyon geometry, more than 5 times the incoming energy from diffuse radiation can potentially be distributed inside the street canyon.

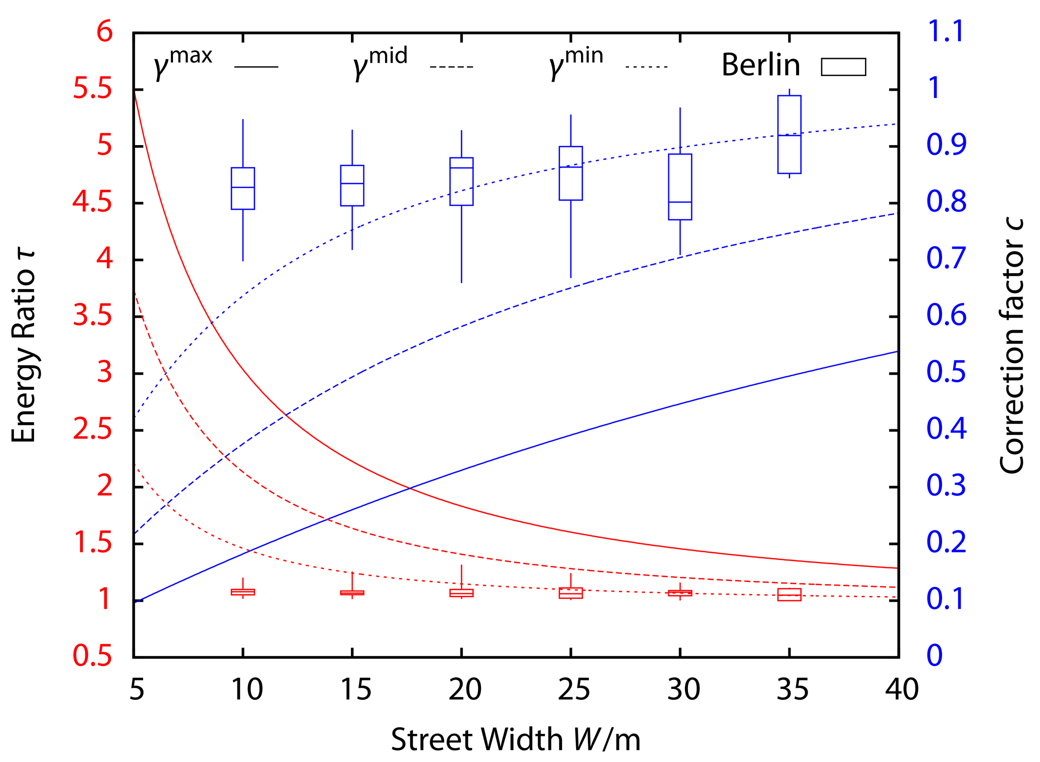


Figure 3: *Energy ratio τ and correction factor c dependence on the street width W. The curves are calculated for different height distributions γ and the boxes are based on data of the city of Berlin.*

Furthermore, the basic urban canyon has been extended (fig. 4) to include the interaction between roof surfaces with the other urban surfaces. With that, the radiation received by roof surfaces depends on the urban morphology.

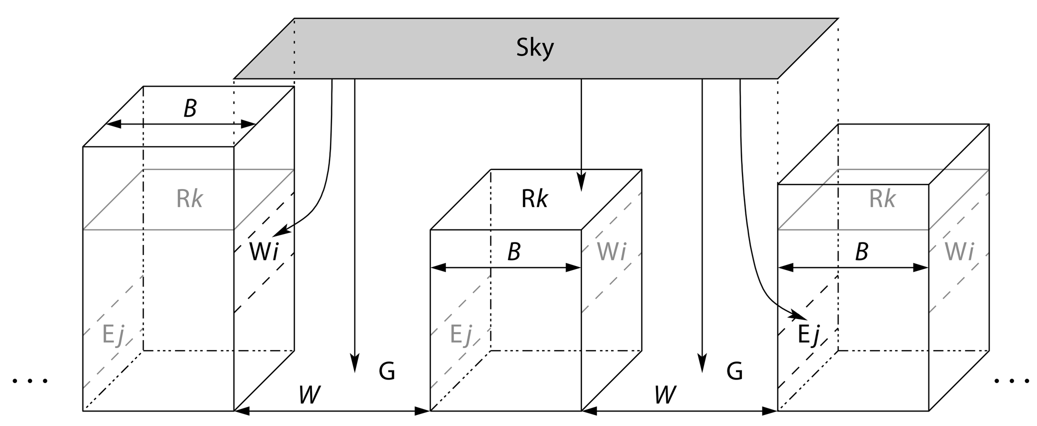


Figure 4: *Extended urban morphology to allow interaction of roofs with other urban surfaces and to represent sky radiation on roofs more realistically.*

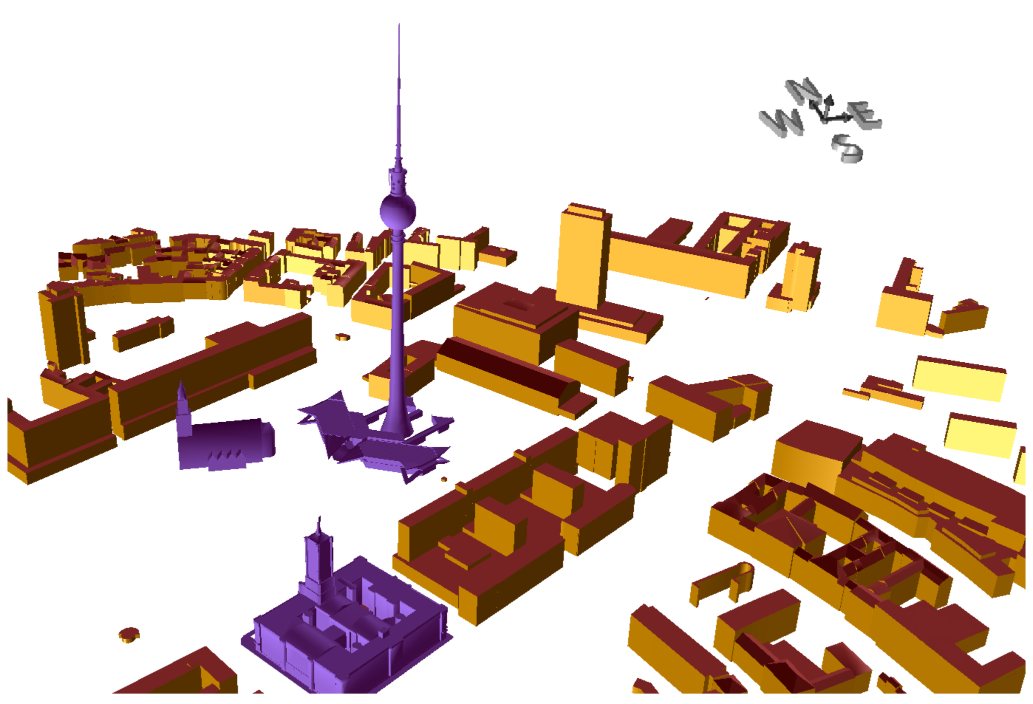


Figure 5: *Rendered example of the 3d data in CityGML format used to derive the urban parameters for Berlin*

3. Results

To evaluate the influence of the introduced changes, simulations with fixed street width $W = 20$ m, building width $B = 10$ m and γ^{max} but realistic urban fractions were conducted for the city of Berlin starting 2003-08-01 00UTC at an resolution of 2.8 km. Figure 6 shows the results for a grid cell at the centre of Berlin. The introduction of the correction factor reduces the air temperature T_1 of the level nearest to the ground. The first level is deep inside the urban canopy, where wall surfaces receive less radiation in the corrected version than in the original formulation and the extended version. In the latter, more radiation is received inside the canyon and, due to the inclusion of roofs into the radiation exchange, the energy is longer kept inside the urban canopy. In short, the radiation trapping effect is increased by this modification leading to a higher air temperature near the ground. Consequently, this leads to a *lower* radiation temperature T_{urb} and a lower albedo for direct radiation because less radiation is emitted back into the sky. A publication giving further detailed information is in preparation.

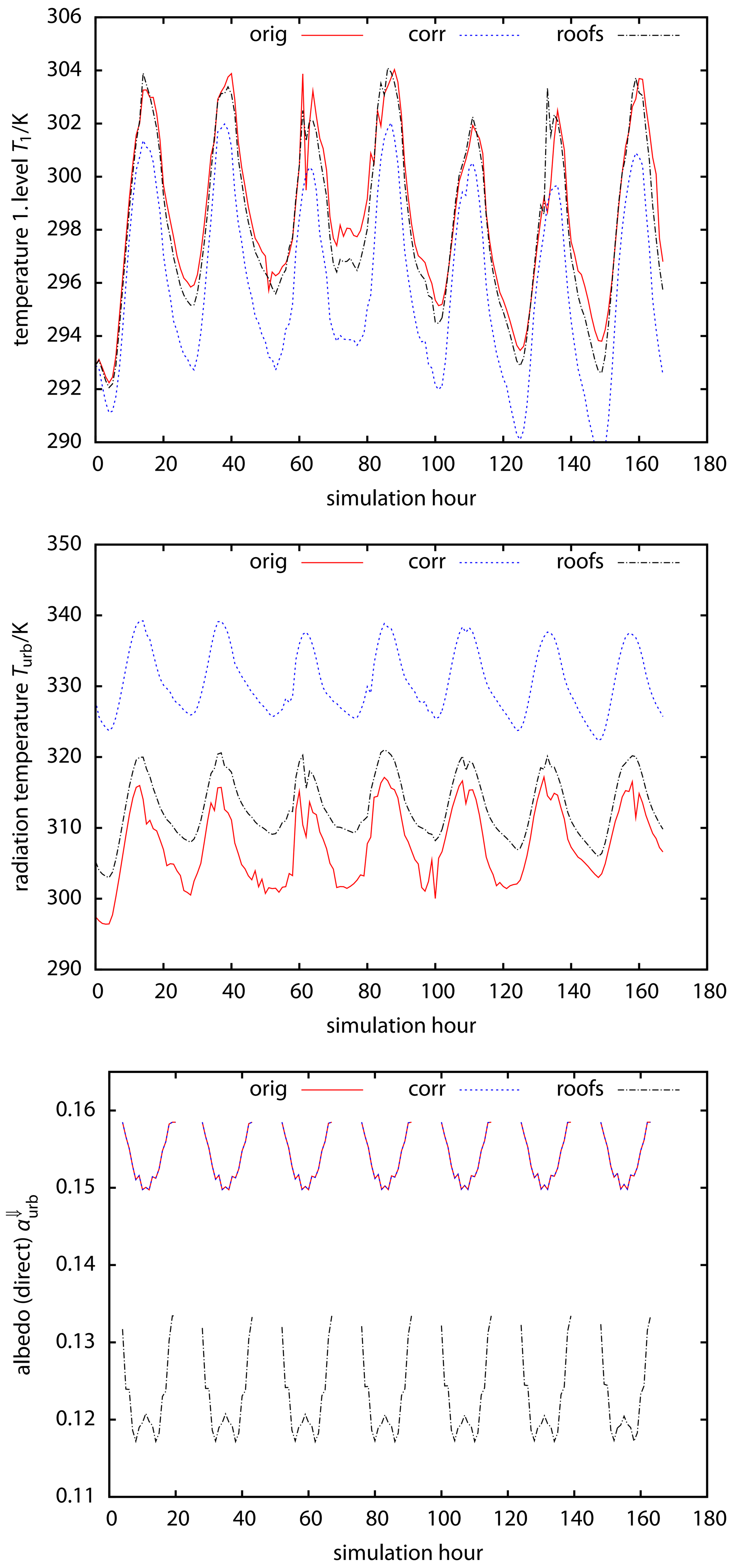


Figure 6: *Test run with BEP using original formulation, corrected radiation balance or extended morphology*

Figure 7 shows a comparison of air temperatures at the lowest main level (approx. 10 m) for simulations using the standard CLM bulk approach or BEP with the extended morphology and full set of spatially varying urban input parameters, respectively. Especially during night times, BEP produces higher temperatures creating the urban heat island effect. A complete validation of simulation results for Berlin and Basel, Swiss, will be done in the near future.

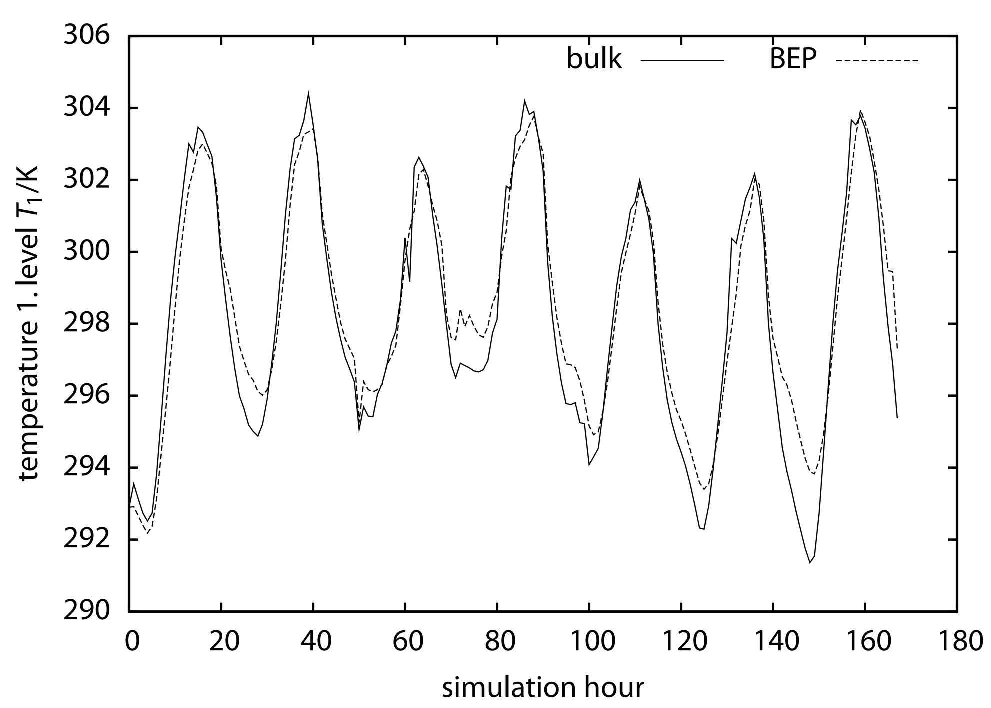


Figure 7: *Run of unmodified CLM and CLM with extended BEP and full set of spatially resolved urban input parameters for the centre of Berlin starting 2003-08-01 00UTC*