HUMBOLDT-UNIVERSITÄT ZU BERLIN

Radiative Transfer Model (RTM) in PALM-4U

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Why RTM is required?

Simulating urban area

Input :
Terrain data, Buildings, Vegetation,
Meteorology, etc.

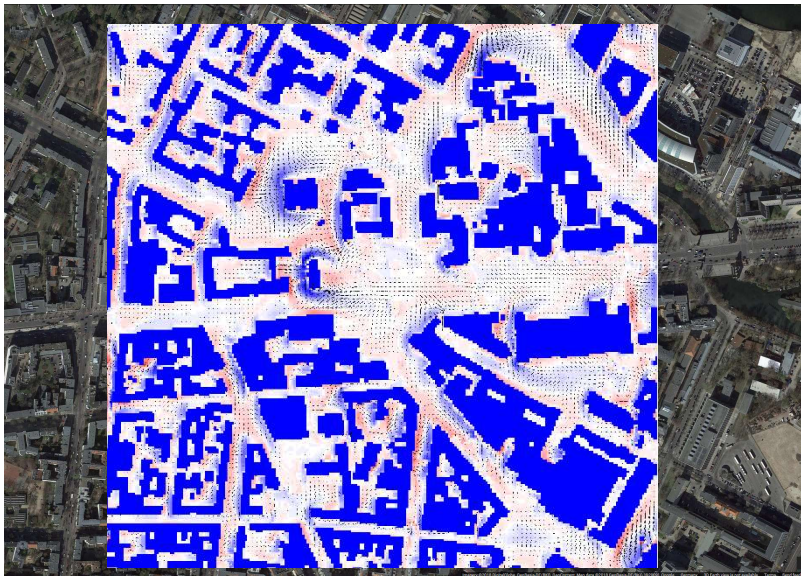
Output:
Wind field (u,v,w), Momentum fluxes, etc.

Application:
Dynamic effect of obstacles, Wind comfort,
Pollutant dispersion, etc.

What is missing?

Air temperature
Surface temperature
..
..

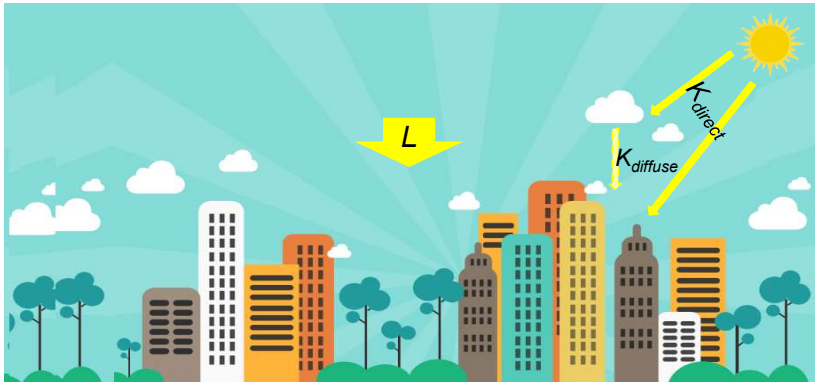
Solar radiation



Why RTM is required?

Radiation models

- Constant radiation
- Simple clear sky
- Rapid Radiation Transfer Model for Global Models (RRTMG)



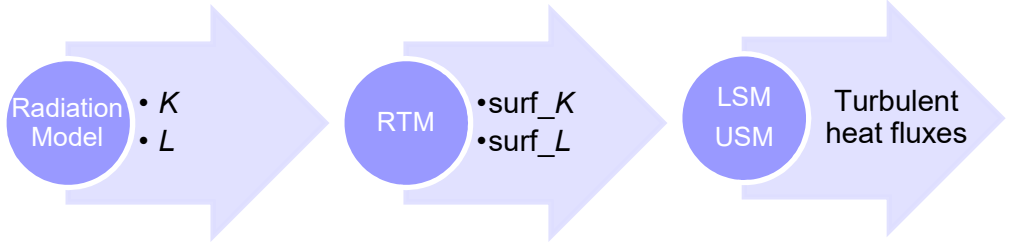
Urban Surfaces

- Natural (lawns, trees, etc.)
- Manufactured (buildings, roads, etc.) fabric

Surface models in PALM-4U

- Land Surface Model (LSM)
- Urban Surface Model (USM)



RTM basics

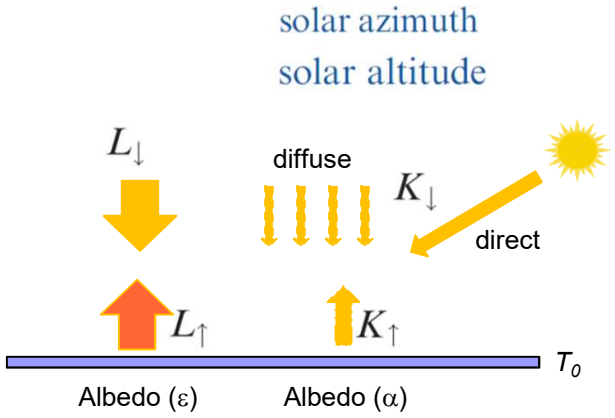
Radiation fluxes: First pass

- Direct SW radiation
- Diffuse SW radiation
- Diffuse LW radiation

$$Q^* = K^* + L^* = K_\downarrow - K_\uparrow + L_\downarrow - L_\uparrow$$

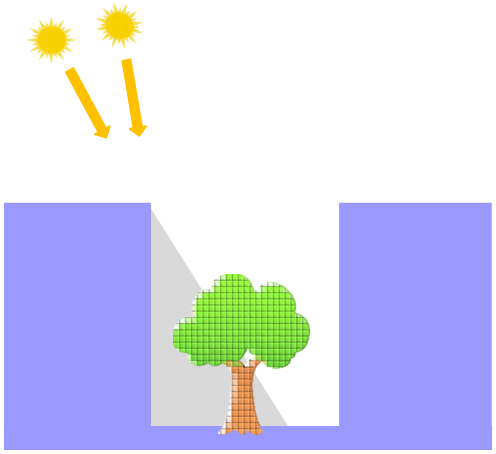
$$K_\uparrow = \alpha K_\downarrow$$

$$L_\uparrow = \varepsilon\sigma T_0^4 + (1-\varepsilon)L_\downarrow$$



Extra calculations

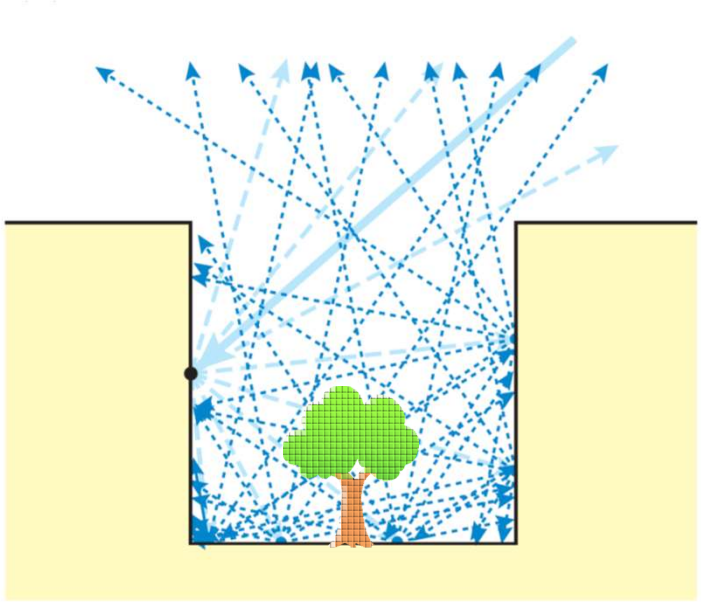
- Visibility (shadow)
- Sky View Factors *SVF* (*K* diffuse radiation + *L*)
- Transparency
- Plant canopy sink factors



RTM basics

Radiation fluxes: Second pass (reflections)

- Reflected SW radiation
- Reflected LW radiation
- Plant canopy absorption



Extra calculations

- Visibility (surface-surface)
- Shape View Factors *SVF*
- Transparency
- Plant canopy sink factors

Optimization

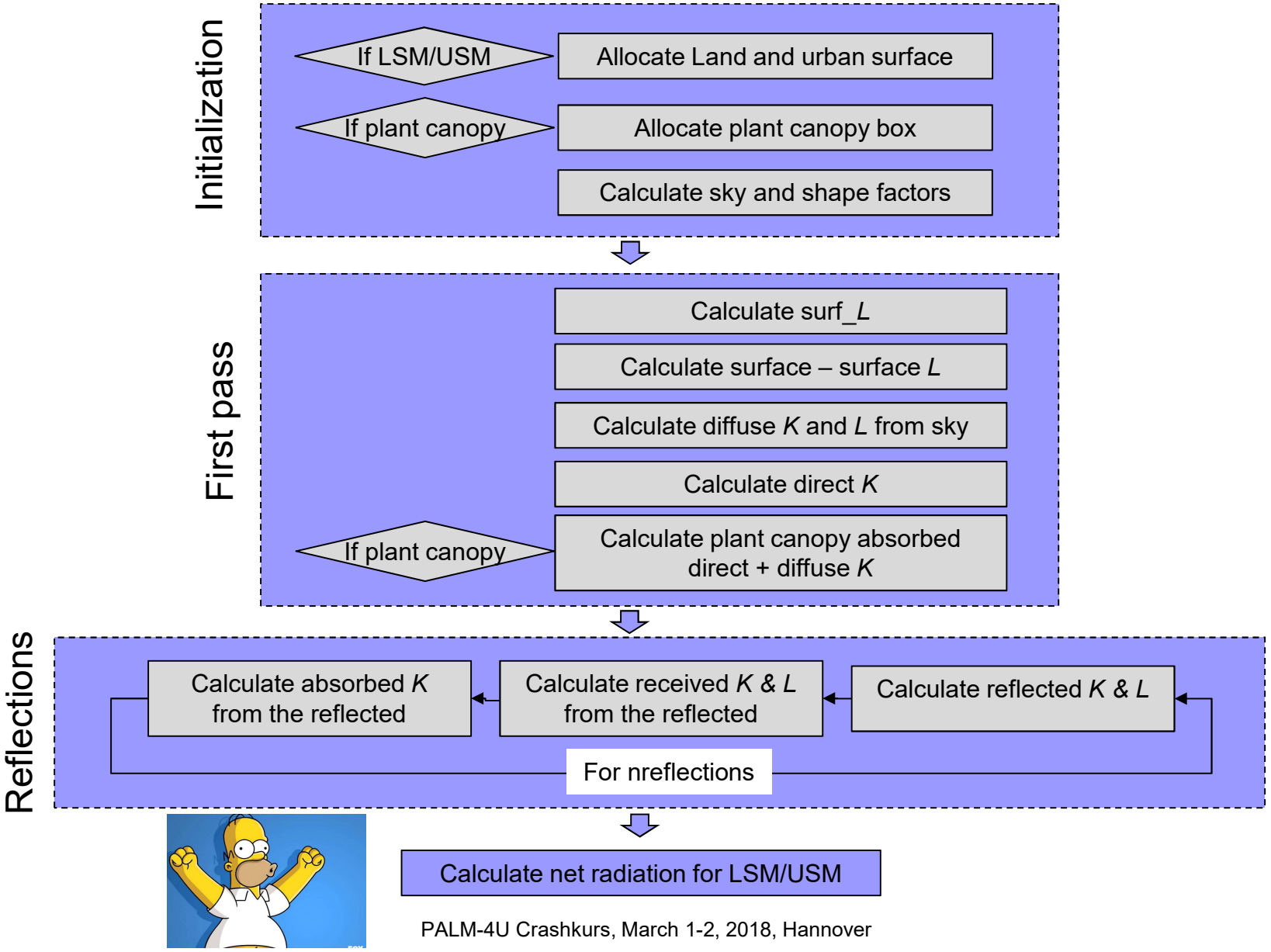
- Optimize raytracing: set maximum distance
- Optimize SVF values: neglect small values

RTM basics

Model limitations

- Absorption, emission, and scattering of radiation in the air within the urban canopy layer is NEGLECTED (fog, pollutants?)
- No treatment of reflective surfaces
- No plant-canopy evapotranspiration model surfaces are considered impervious to water
- The plant canopy is considered fully transparent longwave spectrum

Implementation of RMT in PALM-4U



Implementation of RMT in PALM-4U

Add-ons

- Radiation for atmospheric cells (Chemistry applications)
- Mean radiant temperature (MRT)
- Sky visibility (biometeorological studies)

How to use RTM with LSM/USM

NAMELIST: radiation_par

```
&radiation_par

    radiation_scheme = 'clear-sky',
    dt_radiation = 60.0,
    albedo = 0.2,
    albedo_type = 17,
    constant_albedo = .F.,
    nrefsteps = 9,
    surf_reflections = .T.,
    split_diffusion_radiation = .T.,
    average_radiation = .F.,
    write_svf_on_init = .T.,
    read_svf_on_init = .F.,
    max_raytracing_dist = 200.0,
    min_irrf_value = 0.000001,
    dist_max_svf = 500.0,
    atm_surfaces = .F.,
    surf_reflections = .T.,
/
```

albedo, albedo_type, albedo_lw_dir, albedo_lw_dif, albedo_sw_dir, albedo_sw_dif, constant_albedo, dt_radiation, emissivity, lw_radiation, net_radiation, radiation_scheme, skip_time_do_radiation, sw_radiation, unscheduled_radiation_calls, split_diffusion_radiation, read_svf_on_init, write_svf_on_init, max_raytracing_dist, min_irrf_value, nrefsteps, mrt_factors, rma_lad_raytrace, dist_max_svf, average_radiation, atm_surfaces, surf_reflections, svfnorm_report_thresh

Example

Domain	Ernst-Reuter-Platz, Berlin
Domain size	1000m x 1000m x 1000m
Resolution	4.0m x 4.0m x 2.0m
Buildings data*	Height, surface parameters, material parameters
Vegetation*	Street trees

Urban surface properties

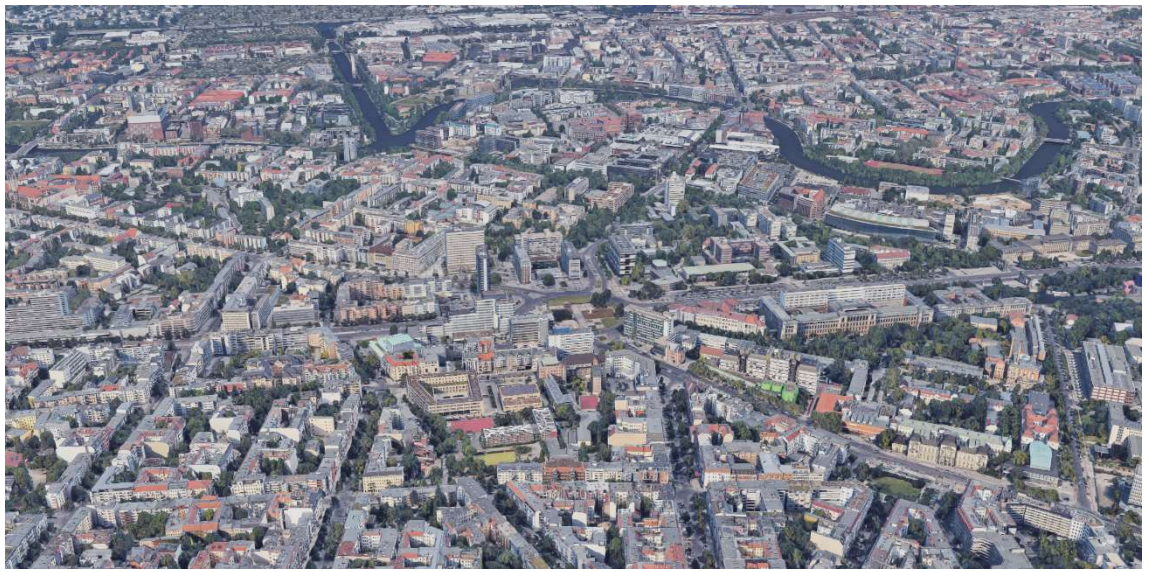
	albedo	emissivity
Land:	0.08	0.94
Walls:	0.20	0.90
Roof:	0.22	0.90

Vegetation (street trees)

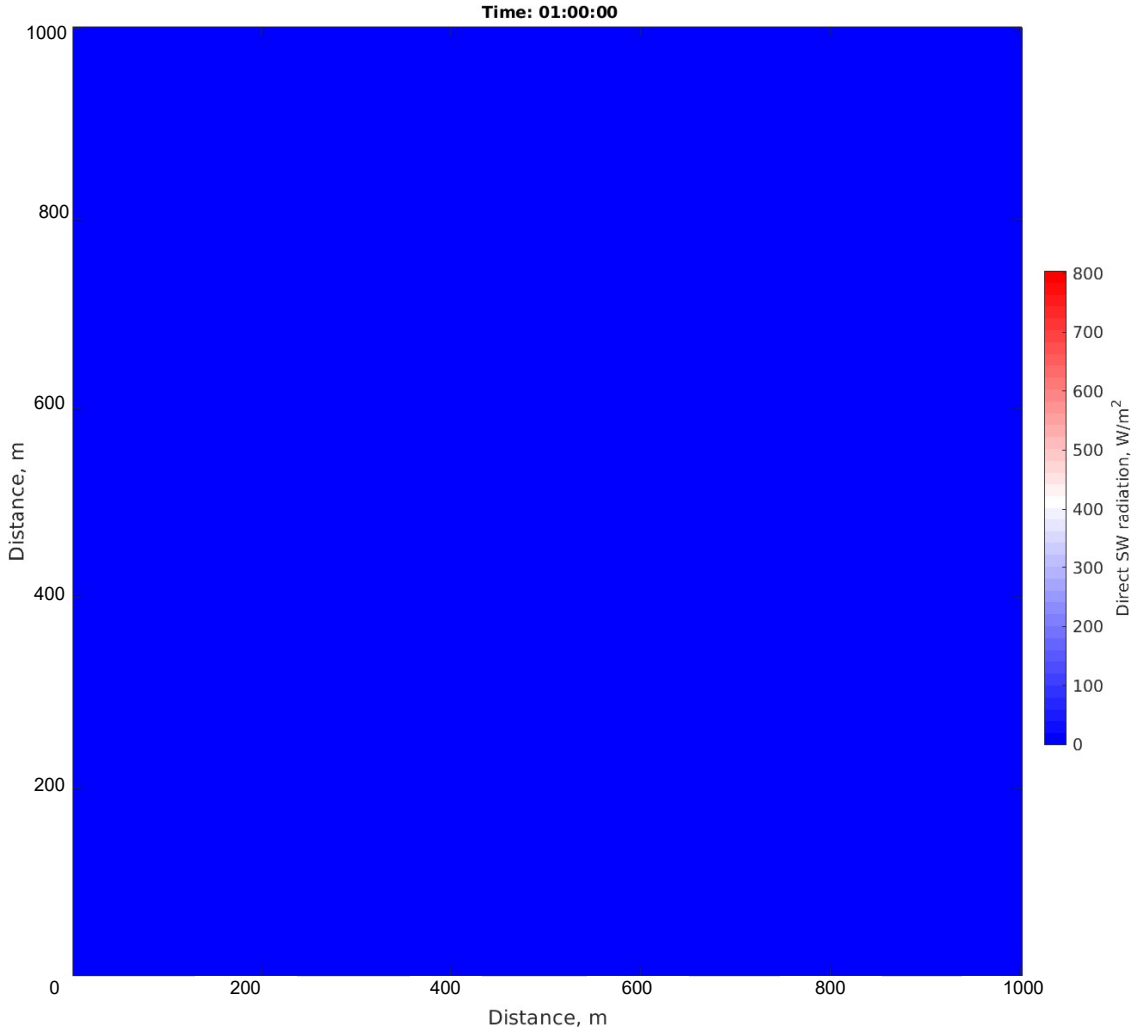
LAD distribution: Lalic and Mihailovic, 2004

$$L(z) = L_m \left(\frac{h - z_m}{h - z}\right)^n \exp\left[n\left(1 - \frac{h - z_m}{h - z}\right)\right]$$

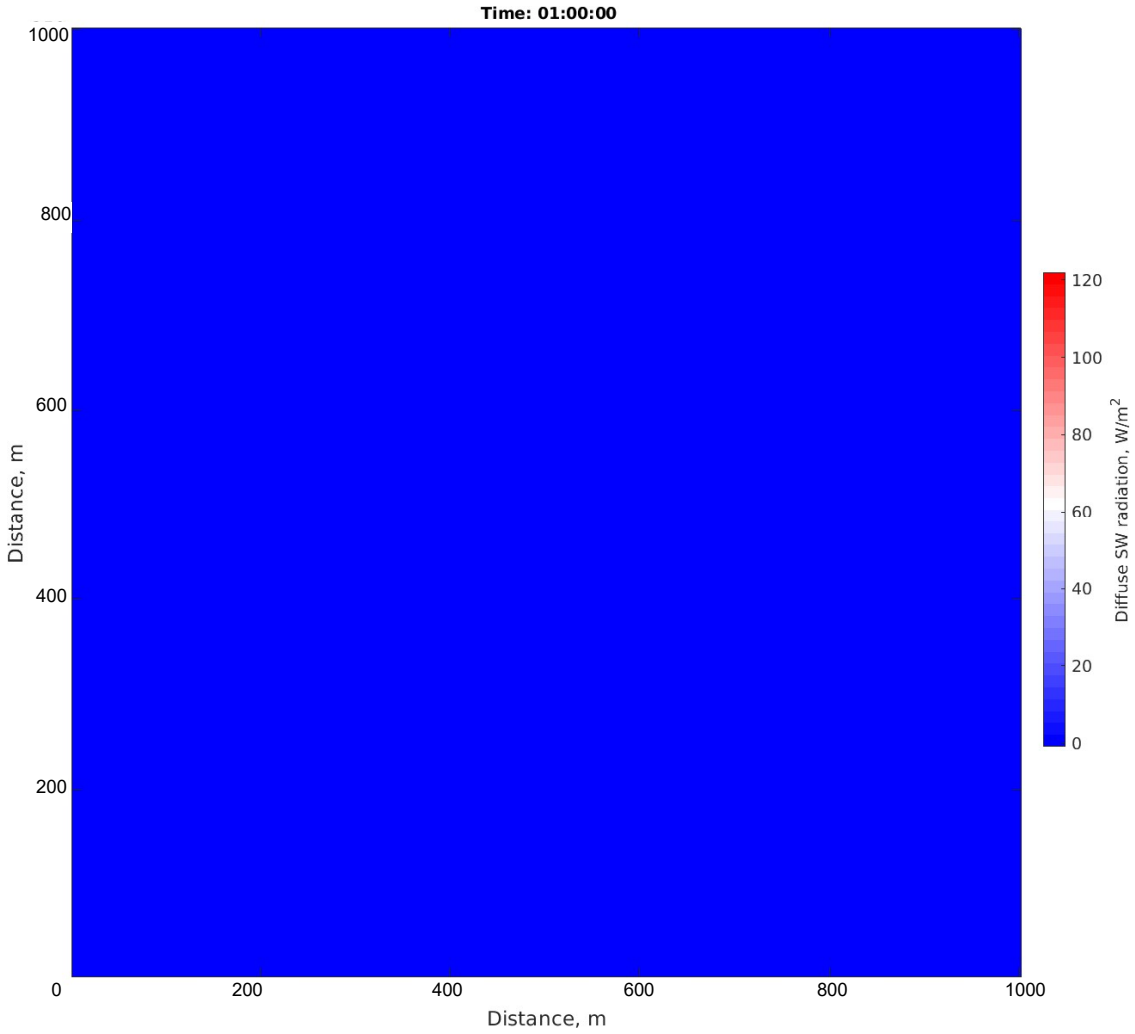
$$n = \begin{cases} 6 & 0 \le z < z_m \\ 0.5 & z_m \le z < h \end{cases}$$



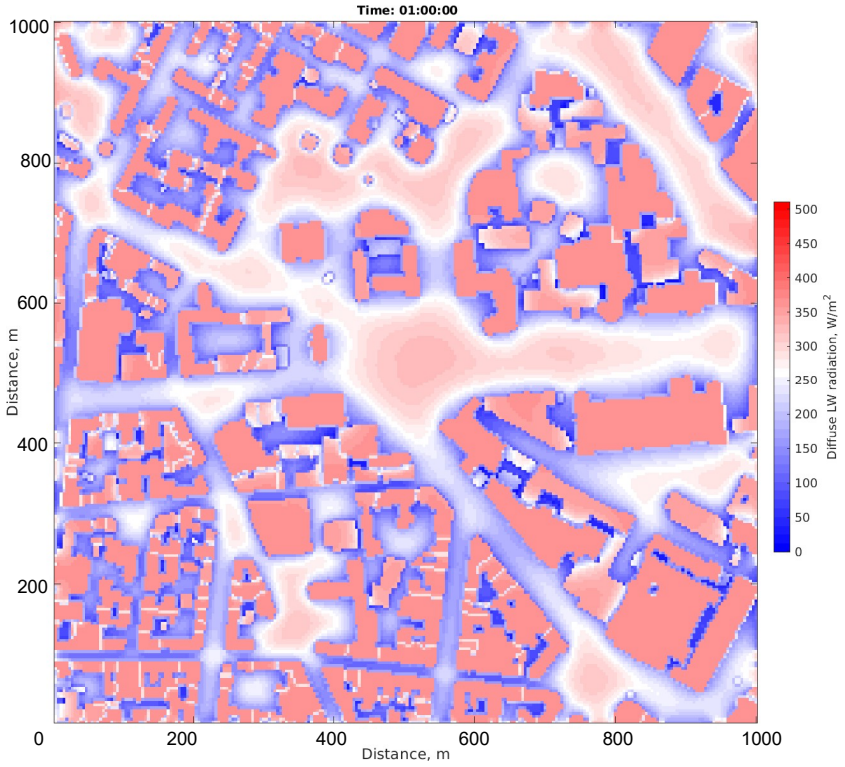
Example

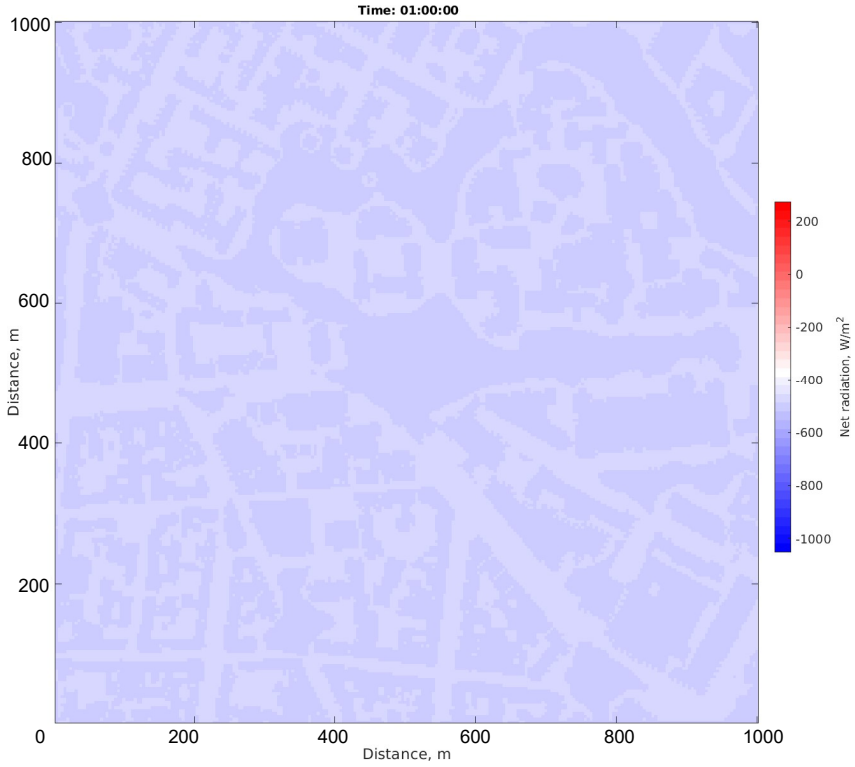

Time: 01:00:00
1000
800
600
400
200
0
Distance, m
0
200
400
600
800
1000
Distance, m
800
700
600
500
400
300
200
100
0
Direct SW radiation, W/m2

Example

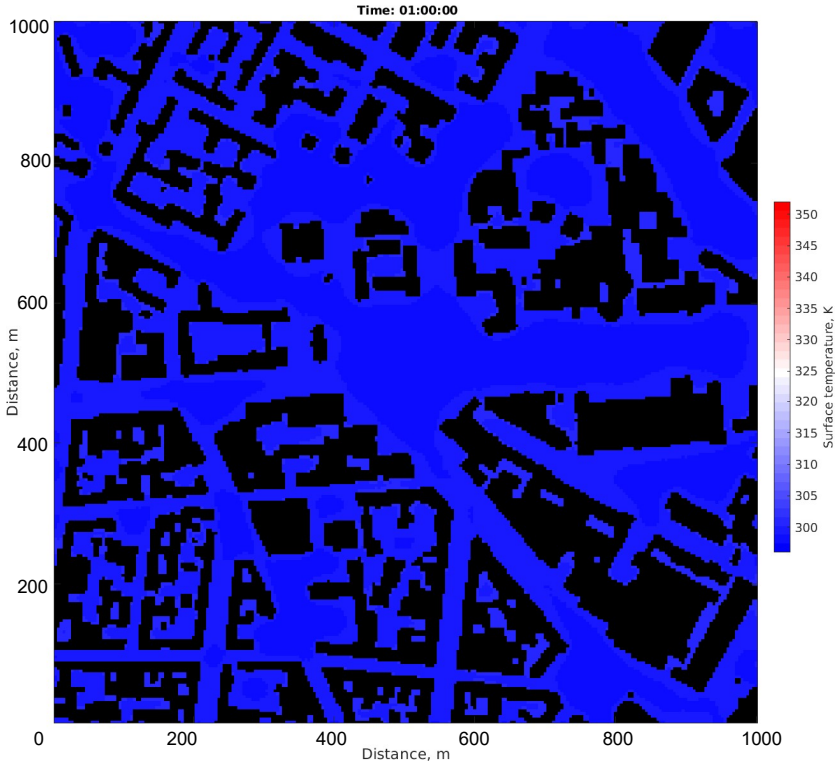

Time: 01:00:00
1000
800
600
400
200
0
Distance, m
0
200
400
600
800
1000
Distance, m
120
100
80
60
40
20
0
Diffuse SW radiation, W/m^2

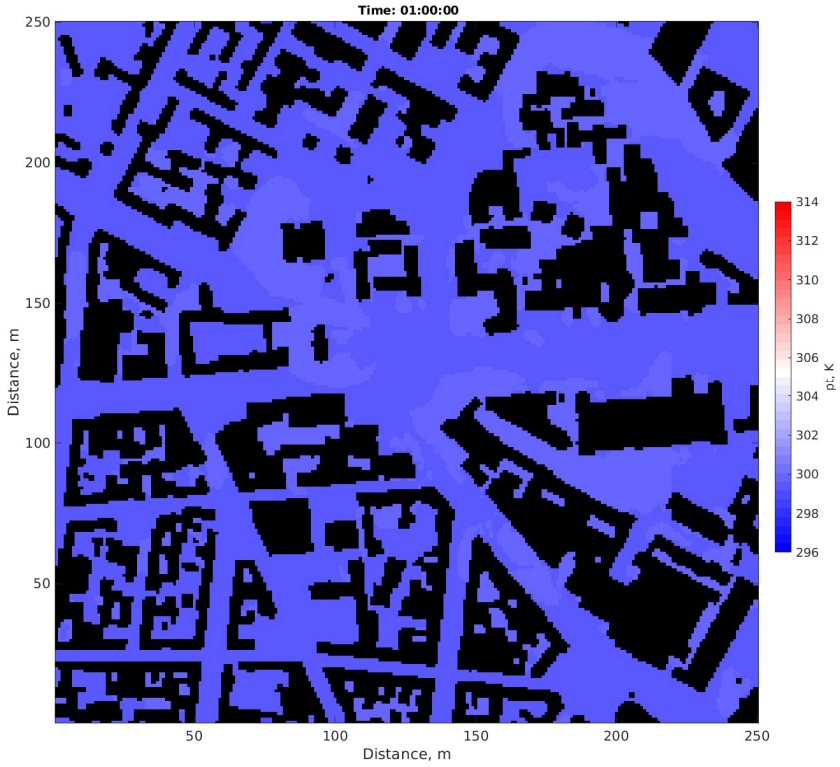
Example


Time: 01:00:00
Distance, m
Distance, m
Diffuse LW radiation, W/m²
0
200
400
600
800
1000
0
50
100
150
200
250
300
350
400
450
500


Time: 01:00:00
Distance, m
Distance, m
Net radiation, W/m²
0
200
400
600
800
1000
200
0
-200
-400
-600
-800
-1000

Example


Time: 01:00:00
Distance, m
Distance, m
Surface temperature, K


Time: 01:00:00
Distance, m
Distance, m
pt, K

Whey there is a Sun?! Well, probably to grow vegetables and to complicate our modeling parametrization.. ☺

Thanks!