Simulation of effects of trees on pollution dispersion and street canyon temperatures

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Motivation

- Simulation of processes inside the street canyons.
- In classical meteorological models these processes are parametrized.
- Model CLMM (Charles University Large-Eddy Microscale Model)
- It belongs to the category of the CFD (Computational Fluid Dynamics) models, used to model fluid flow in small scales.
- For UHI the model is adapted to account for trees, solar radiation and sensible and latent heat in complex geometries.

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Solar radiation

- Radiation balance on the building surfaces and on the trees.
- For direct radiation the shadows of the objects have to be computed.
- The existance of intersections of rays pointing to the sun with the 3D model is evaluated.
- Sky view factor evaluated using rays in random directions.

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Test case

- Inspired by the potential changes in the Legerova street.
- Planting of alleys.
- Concerns of impacts on air quality.
- Several variants of planting:
    - without any alley
    - 7 m trees on both sides
    - sparser 7 m trees on both sides
    - 7 m trees in the centreline
    - 17 m trees on both sides
- Leaf area density intentionally rather large $0.5\mathrm{m}^{-1}$

Simplifications

- Constant heat fluxes.
- Volume source of passive contaminant above the street surface.
- The PBL top height considered very high, the heat flux at the top of the domain computed from the average flux below.

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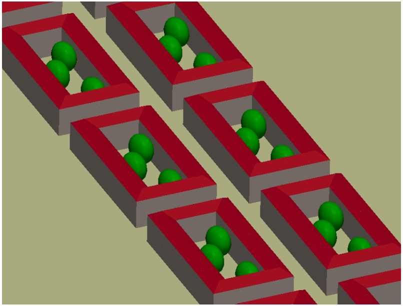
Other parameters

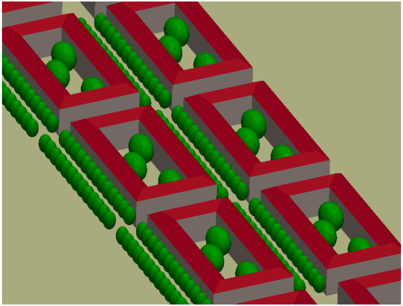
- The street oriented north-south.
- Direction and intensity of solar radiation corresponds to 14h local solar time at the end of June without clouds.
- SW wind with velocity 0.5 m/s at the height of 100 m.

Dimensions

- Street width 24 m, building height 26.5m.
- Computational domain $84 \times 130 \times 200$ m.
- Resolution $\Delta_g = 1$ m, i.e., 2.2 mil. points.
- One high resolution run at $\Delta_g = 0.5$ m to check the usability of the 1 m grid (17.5 mil. points).
- Periodic horizontal boundary conditions.
- Duration of the simulated flow 1 hour. Statistics from last 20 minutes.

Computational domain





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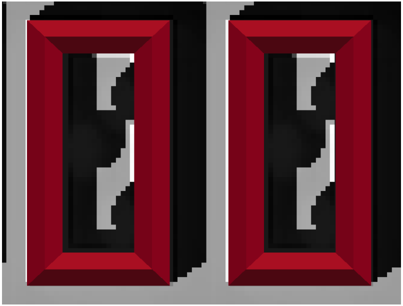
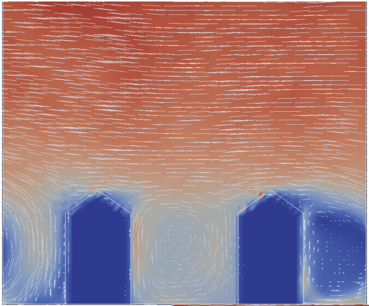
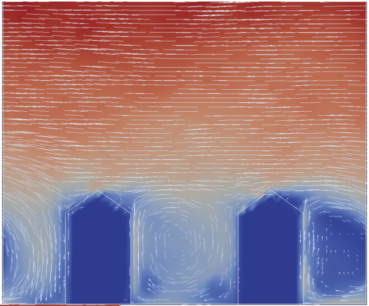
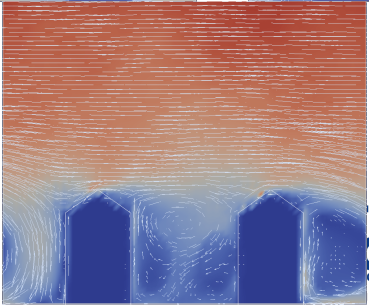
Ground heat fluxes - shadows



Air flow







Air temperature

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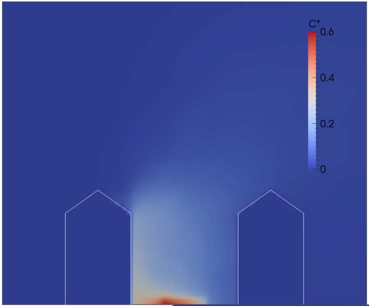
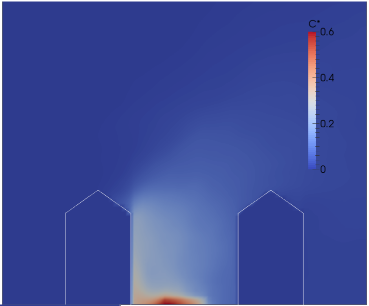
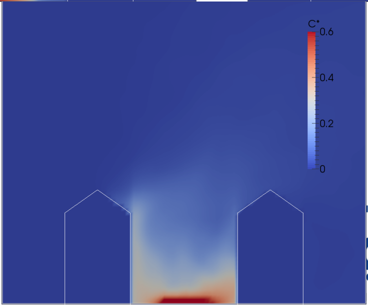
Concentrations







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Selected points

Concentration at 1.5 m from the wall in elevation 1.5 m

	western	eastern	average
no trees	0.33	0.07	0.20
base variant	0.35	0.08	0.21
sparser	0.32	0.08	0.20
street axis	0.42	0.08	0.25
large trees	0.32	0.39	0.35

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Complete sidewalks

Concentrations averaged over sidewalks in elevation 1.5 m

	western	eastern	average
no trees	0.35	0.10	0.23
base variant	0.38	0.12	0.25
sparser	0.36	0.13	0.24
street axis	0.41	0.11	0.26
large trees	0.35	0.33	0.34

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Selected points

Temperature difference from initial state in K at 1.5 m from the wall in elevation 1.5 m

	western	eastern	average
no trees	3.0	4.7	3.9
base variant	3.3	4.5	3.9
sparser	3.3	4.6	3.9
street axis	3.5	5.0	4.2
large trees	3.2	4.7	4.0

Differences are negligible due to strong mixing. Nighttime results can differ.

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Contaminant,large trees.

Temperature, large trees.

Conclusions

- Model extended by more complex parametrizations.
- Radiation still simplified.
- The effect of the trees on air temperature is small due to large mixing.
- The trees create an area of reduced direct solar radiation - affects PET.
- The adverse effect of the trees on air pollution is pronounced only for the large tree variant.
- The used LAD and the leaf drag coefficient are quite high and the concentration results should be on the "safe side".

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