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STREET-LEVEL ASSESSMENT OF URBAN SCENARIOS ON THERMAL COMFORT AND AIR QUALITY BY THE MEANS OF NEWLY DEVELOPED URBAN SURFACE MODEL FOR LES MODEL PALM

Jaroslav Resler[1,2], Pavel Krč[1,2], Michal Belda[1,2,4], Pavel Juruš[1,2], Nina Benešová[1,3], Ondřej Vlček[1,3], Daša Damašková[1,3], Kryštof Eben[1,2], Přemysl Derbek[1]

[1]Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic
[2]Institute of Computer Science, Czech Academy of Sciences, Czech Republic
[3]Czech Hydrometeorological Institute, Czech Republic
[4]Faculty of Mathematics and Physics, Charles University, Czech Republic

Abstract: Urban mitigation scenarios for the development area in Prague, Czech Republic were calculated by the LES model PALM extended with the urban surface model for radiation processes. Scenarios included the effect of tree planting and surface albedo adjustment on the surface temperature and NO_X concentrations during a summer heat wave episode. It was shown that positive effect (cooling) in temperature can be accompanied by the increase of NO_X concentration. Thus the impact of urban mitigation scenarios has to be carefully assessed from all relevant points of view.

***Key words:** Large Eddy Simulation, micro-scale modelling, climate change adaptation measures, air quality.*

INTRODUCTION

As more than a half of the human population resides in cities, the influence of urban environment on living conditions – mainly thermal comfort and air quality, gains more importance. One of the tasks in the Urban Adapt project (http://urbanadapt.cz/en), which this work was part of, was the evaluation of urban planning scenarios assessing the influence of urban buildings adaptations and changes of urban surface parameters and vegetation on pedestrian-level air quality and thermal comfort for citizens. Regarding these problems, CFD-LES models can be considered to be the most appropriate as they can predict the turbulent air flow with sufficient resolution over a very complex surface. Nevertheless, according to the authors' research at the beginning of the study there was no open source CFD-LES model that would be able to account for the realistic implementation of various processes inside an urban canopy. Therefore, it was decided to extend the existing LES model PALM (Maronga et al., 2015) with a submodel that explicitly describes energy exchanges in the urban environment, including some of the most important urban canopy mechanisms (Resler et al., 2017).

Urban planning scenarios were evaluated for the block of buildings encompassing the crossroads of Dělnická Street and Komunardů Street in Prague, Czech Republic (50.1032431N, 14.4499719E, https://goo.gl/maps/7HvsN5SYwYn). This area was selected in coordination with the Prague Institute of Planning and Development as a case study area for urban heat island adaptation and mitigation strategies. This particular area represents a typical residential area in a topographically flat part of the city of Prague with a combination of old and new buildings and a variety of other urban components (such as yards or parking spaces). The streets are oriented in a north-south (Komunardů St.) and west-east (Dělnická St.) direction and are roughly 20 and 16 m wide, respectively. The building heights alongside the streets range approximately from 10 to 25 m. The area does not contain much green vegetation and the majority of the trees is located in the yards. The neighbourhood in the extent of approximately 1 km^2 has similar characteristics as the study area. For the sensitivity tests were chosen days 2–3 July 2015 which represents the time of a heat wave episode in Central European area.

To obtain surface (albedo, emissivity, roughness length, thermal conductivity, and capacity of the skin layer) and volume (thermal capacity and volumetric thermal conductivity) input material parameters needed for the proper setting of the PALM model, a supplemental on-site data collection campaign was carried out and a detailed database of geospatial data was created. This includes information on wall, ground and roof materials and colours which was used to estimate surface and material properties.

Calculations were done for: 1) reference (current) state, 2) widen Dělnická Street with trees along pavements on both sides, 3) widen Dělnická Street with trees in its centre. Also a sensitivity study evaluating the effect of position of tree alley was performed – the alley was gradually moved from one side of the street to the opposite side. Another type of sensitivity studies estimated the impact of changed surface colours. Evaluated parameters were temperature, NO_X concentrations, mean radiant temperature (MRT), and physiologically equivalent temperature (PET). In this abstract a comparison of current state and widen Dělnická Street with tree alley in the middle with respect to temperature and NO_X concentration is presented as well as the impact of changed surface colours on temperature and NO_X.

Figure 1. Digital model of buildings in the modelling domain (in blue).

EFFECT OF TREE PLANTING

Results of two model runs are presented: current state and scenario with widen Dělnická Street with a tree alley in the middle (

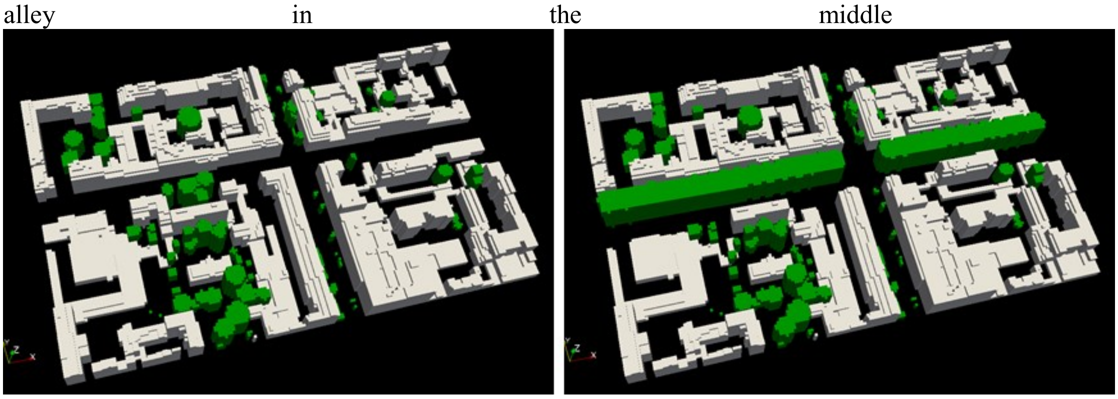

Figure 2).

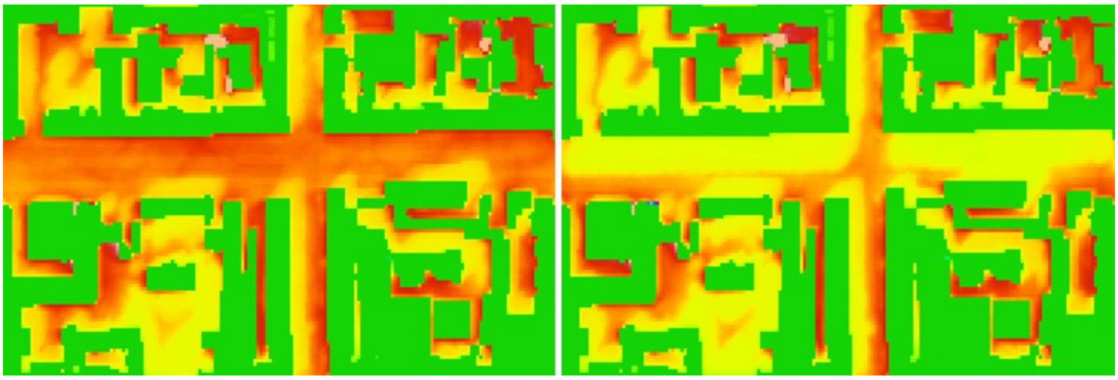

Figure 3 shows temperature in 1 m above the ground for 3 July 2015, 14:00 CET. It is clear that the trees cool the street significantly. Nevertheless the decision, which scenario is the best one is not clear when also other criteria are taken into account:

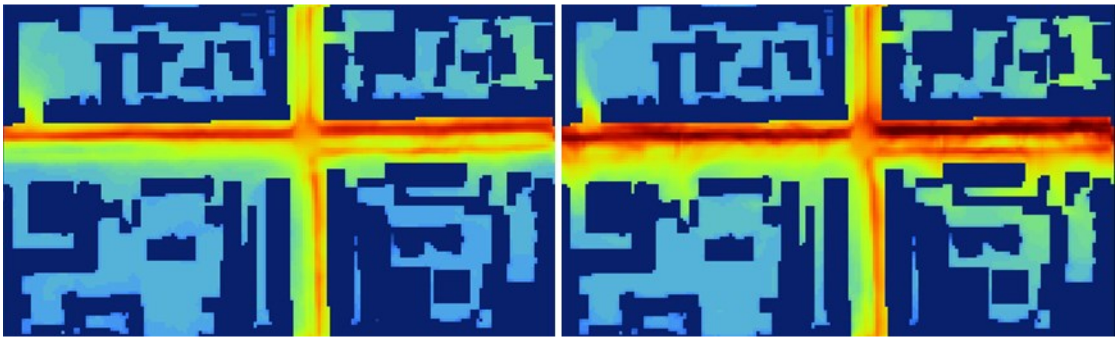

Figure 4 presents the increase of NO_X concentration for the same scenario.

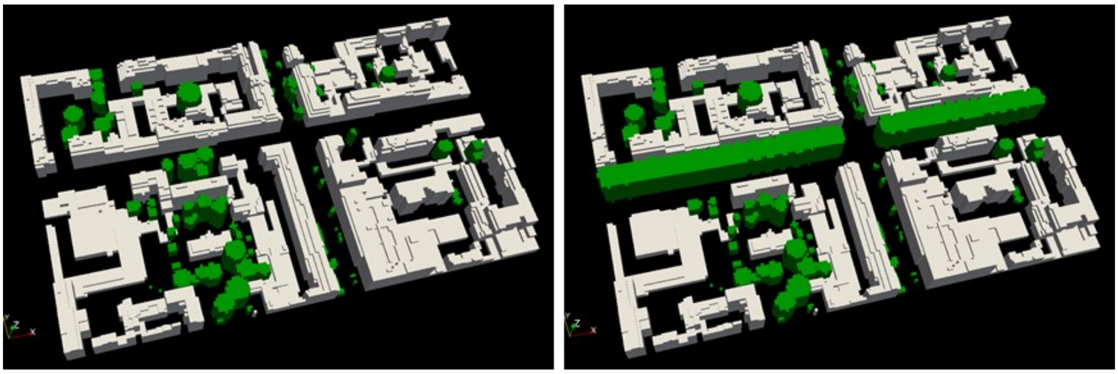

Figure 2. Modelling domain – current state (left) and widened Dělnická Street with the tree alley in the middle (right). Trees are coloured in green.

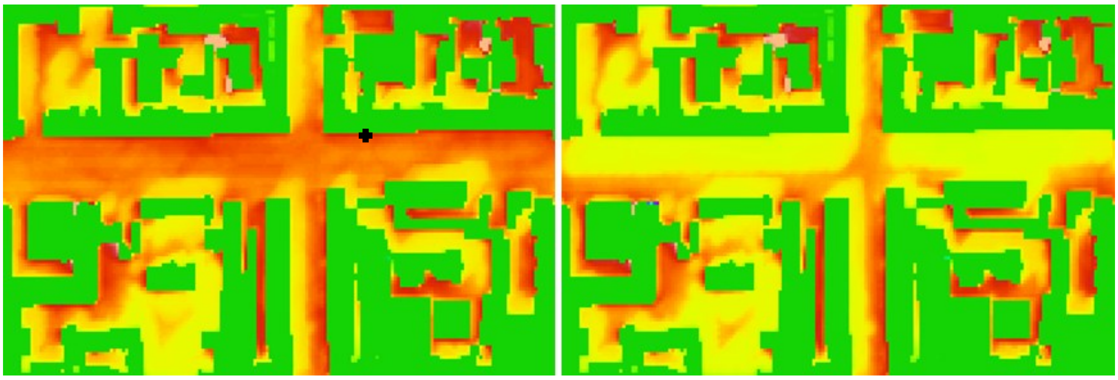

Figure 3. Air temperature at 1 m above the ground level for 3 July 2015, 14:00 CET – current state (left) and widened Dělnická Street with the tree alley in the middle (right). The cross is the point for which time series in **Figure 5** and **Figure 6** are displayed.

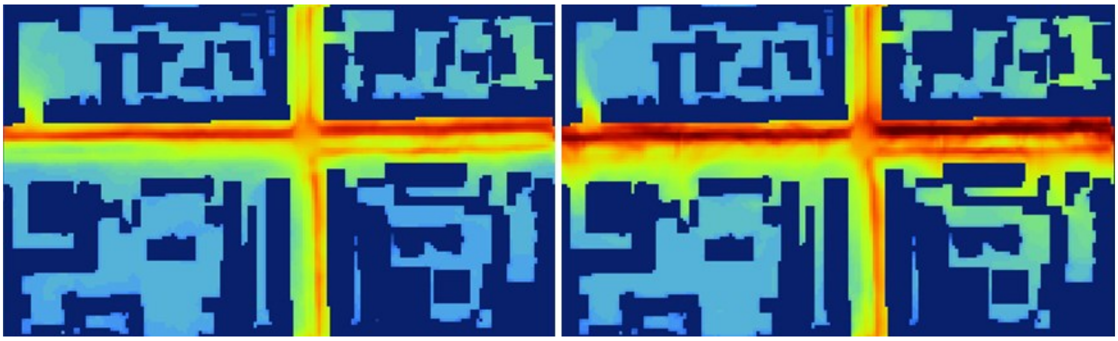

Figure 4. NO_X concentration at 1 m above the ground level for 3 July 2015, 14:00 CET – current state (left) and widened Dělnická Street with the tree alley in the middle (right).

ALBEDO SENSITIVITY TESTS

Results of the sensitivity runs modelling the effect of surface colour (albedo) are shown on **Figure 5** and **Figure 6**. It can be seen that air temperature is influenced mainly by the colour of horizontal surfaces. One possible reason is that most of the radiation is adsorbed by the dark street surface that subsequently warms the adjacent air. It is also possible to see that the positive effect (cooling) in air temperature is accompanied by the increase of NO_X concentrations.

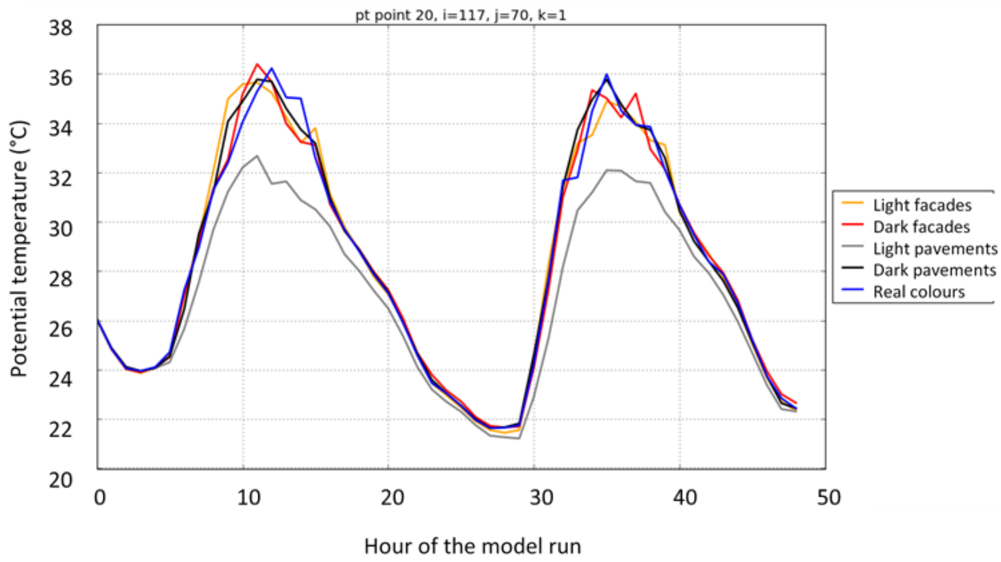

Figure 5. Influence of different surface albedo on the potential temperature concentrations at 1 m above the ground for point displayed on Fig. 3. 2 July 0:00 UTC to 4 July 2015 0:00 UTC. Real colours – real surface colours are used. Light/Dark facades – all facades have light/dark colour. Light/Dark pavements – all horizontal surfaces have light/dark colour.

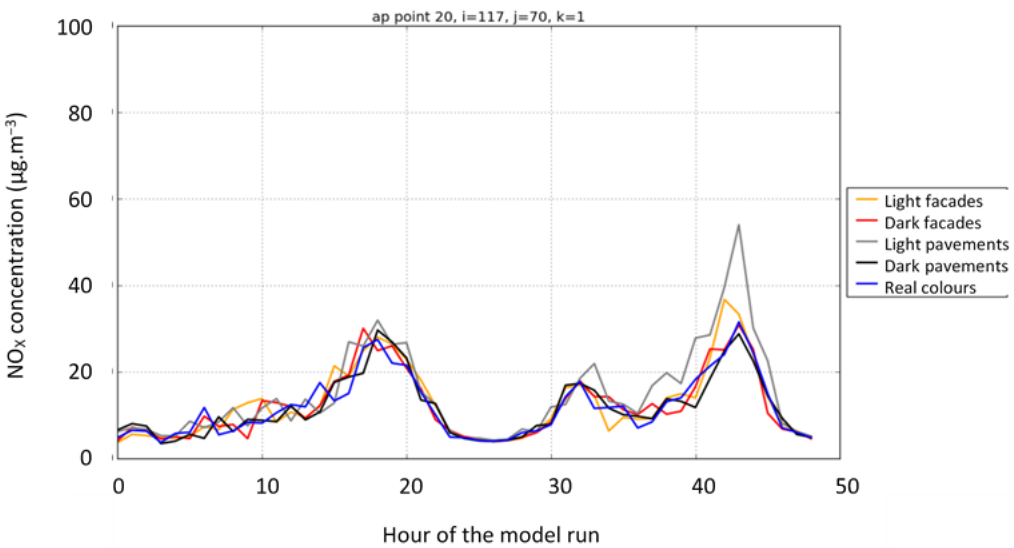

Figure 6. Influence of different surface albedo on NO_X concentrations at 1 m above the ground for point displayed on Fig. 3. 2 July 0:00 UTC to 4 July 2015 0:00 UTC. Real colours – real surface colours are used. Light/Dark facades – all facades have light/dark colour. Light/Dark pavements – all horizontal surfaces have light/dark colour.

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