Numerical analysis of the road traffic intensity influence on the urban heat island characteristics, case of Belgrade city, Serbia

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INTRODUCTION

Large fraction of the world's population living in cities. Rapid urbanization in cities and their inhabitants are key drivers of global environmental change. Not all of that influences is on global-scale climate, rather significant effects has on local microclimate in cities.

Based on the numerical model we performed case study simulations of air temperature and CO_2 in Belgrade city, Serbia. The numerical model has been validated by experimental measurement data.

Atmosphere above urban area is no transparent media, and the effective atmospheric emissivity is related to the concentration of the three atomic gasses, it is assumed that the variation of CO_2 is significant, which is the basic reason increased outside temperature in the urban environment. It is assumed that in the observed urban environment Belgrade city the prevailing contribution to the source of CO_2 is the urban traffic. For locations where no experimental measurement has been done the values of the pollutant was calculation by numerical simulation. This study has focused on investigation of the influence of road traffic intensity influence on the urban heat island characteristics, above all it is thought on outdoor temperature, using measurement and numerical simulation.

EXPERIMENTAL INVESTIGATION

The study site in this research work is the defensive city center of the city of Belgrade, Serbia, Fig. 1. For this location were measured air temperature, relative humidity, wind velocity and direction, temperature of the facade, grass and roads and global solar radiation, as well as number of vehicles per category, length of the road and average speed of the vehicle. The local meteorological mast has been installed on the roof of The College of Textile – Design Technology and Management (N44º48'37'', E20º28'42'').

Estimating the emission of the most important harmful substances emitting different categories of vehicles of measured traffic flow data was made using the COPERT software. For the selected urban locations, the measurement of the number of vehicles was done at seven crossroads and streets that intersect at that crossroads, Fig. 2. . The selected vehicles are categorized in one of 7 groups: Bicycle, Motorcycles, Passenger vehicle, Van, Bus, Easy truck and Heavy-duty truck.

Figure 1 .Urban structure of Belgrade Center

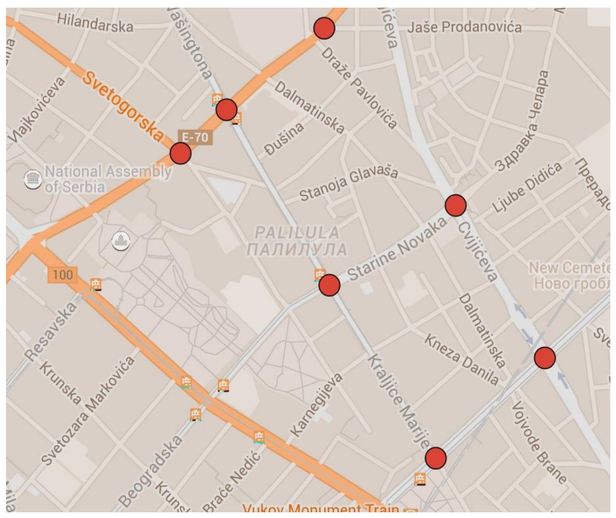


Figure 2. Location of measurement number of vehicles per category

CFD SIMULATIONS

The 3D model of selected urban area is presented on Fig. 3, green infrastructure (parks) is marked in green, the objects are marked in dark, the roads are marked in light, the swimming pool in blue, and the location where the local meteorological measurements were made is marked in red. Meteorological input data for numerical simulations were used obtained by experimental measurements, from a meteorological mast placed on the school building. Numerical simulations have been performed by PHOENICS computer code.

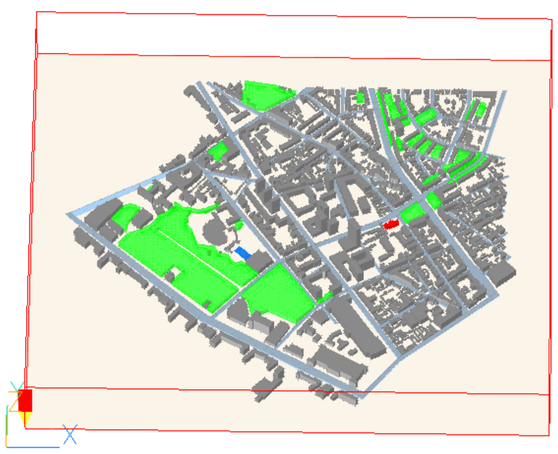


Figure 3. 3D solid model of Belgrade Center.

Computational domain and computational grid generation

A significant requirement for setting numerical boundary conditions is sufficient redirection of the distance from the boundary domain, in order to prepare an occasional flow in the domain. The main domain dimensions are: 1536 m in x-direction, 1425 m in y-direction, and 200 m in z-direction

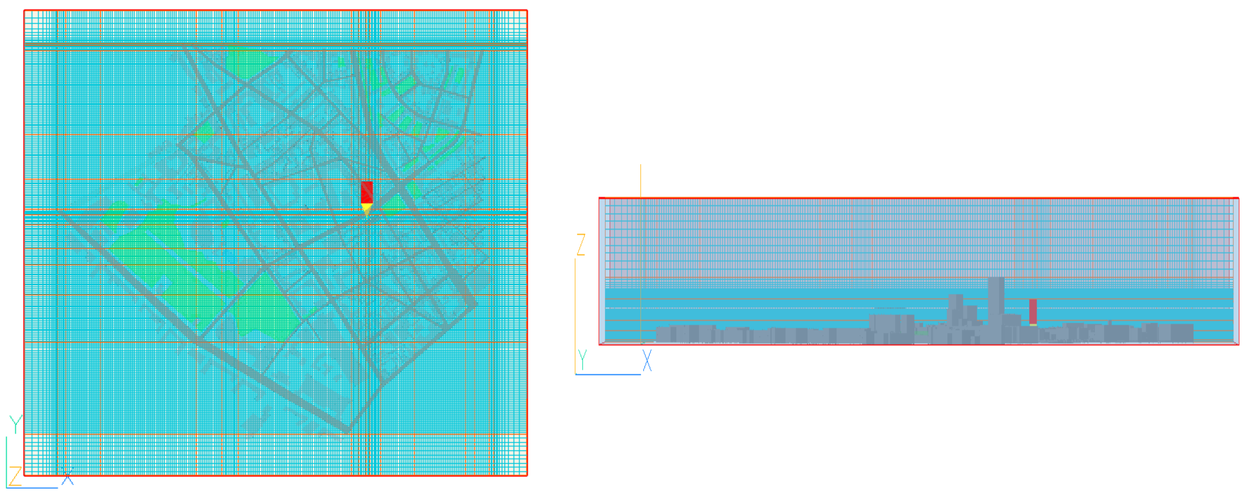


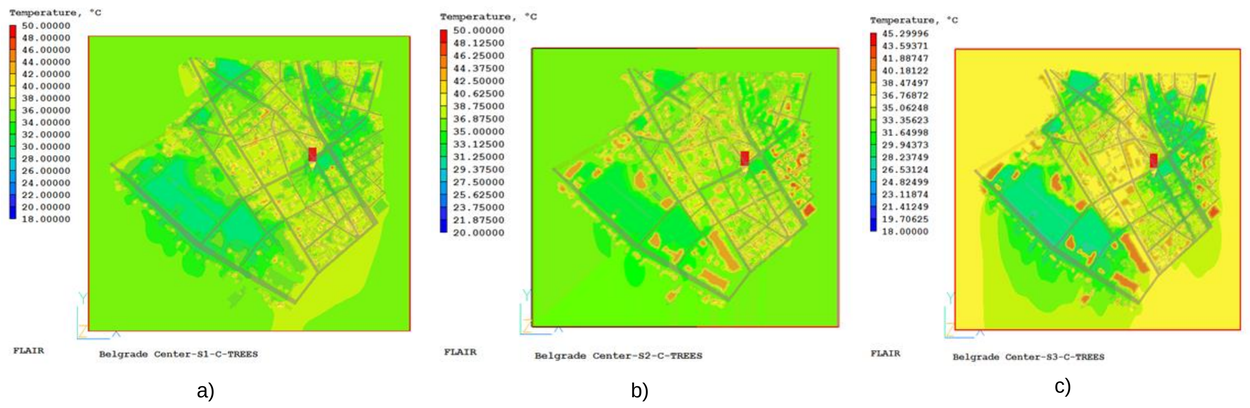
Figure 4. Finite volume grid of computational domain

RESULTS AND DISCUSSION

Numerical simulations were done for the warmest day in the measurement period. Input data of atmospheric parameters are taken from the measurement database depend of time of day.

Presents average values pollutants obtained by numerical simulation number of vehicles using computer software COPERT. In table are shown pollution values for crossroads and street where measurement of intensity of road traffic was done.

Time	8:00-9:00	14:00-15:00	18:00-19:00
Air temperature [ºC]	35.9	40.8	37.6
Relative humidity [%]	33.1	21.4	25.4
Atmosphere pressure [hPa]	1000.1	1000.3	999.8
Wind velocity (at 10 meters a.g.l.) [m/s]	1.1	2.8	3.1
Wind direction [degree]	300	330	322
Global solar radiation [W/m²]	410	794	217



a) b) c)

Figure 5. Ambient air temperature at a height of 1.8 meters a) morning, 08-09h b) afternoon, 14-15h and c) evenina. 18-19h

a) b) c)

Figure 6. CO_2 concentrations at a height of 1.8 meters a) morning, 08-09h b) afternoon, 14-15h and c) evening, 18-19h

CONCLUSION

Detailed three-dimensional simulations of air temperature and CO2 concentration distributions were performed for the Belgrade city center, Serbia to determine possible dependence of air temperature increase from the road traffic intensity.

- CFD simulations were performed for three different parts of the day;
- Ambient temperature is 1.5-3 °C higher in the areas near the streets with high traffic intensity;
- CO2 and NOx air pollutants are more affected by the increase in the air temperature in the city area compared with other air pollutants;
- This study showed that CFD simulations can be successfully utilized to predict outdoor air temperature in complex urban areas;
- This type of research can be significantly used in the planning and design of urban environments, as well as of smaller complexes within the larger urban environment;
- It is planned to further develop the current CFD model to include other important effects, such as the influence of other gaseous species with the greenhouse effect and health-hazardous components;
- The performed work offers a workflow that can be successfully used to develop and/or investigate different scenarios for energy consumption and outdoor thermal comfort.