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ASSESSING THE EFFECT OF VEGETATION LAYOUT ON AEROSOL PARTICLE CONCENTRATIONS WITHIN AN URBAN STREET CANYON USING LARGE-EDDY SIMULATIONS

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INTRODUCTION

The increase in computational resources creates a potential in utilizing high resolution air quality modelling to support urban planning. The possibility to solve the flow field and air quality related processes down to a one-meter scale and beyond allows the city planners and researchers to test the effects of different city planning scenarios on the very local air quality as well as wind and thermal comfort.

The large-eddy simulation (LES) is currently the most promising tool to study the local effects of different city planning scenarios on various environmental issues, such as air quality, wind and thermal comfort. Development of LES models has been active in recent years. One example is the PALM model system (Maronga et al., 2019), which incorporates various model components designed specifically for urban applications. These include, for example, a plant canopy model and a sectional aerosol model SALSA (Maronga et al., 2019; Kurppa et al., 2019).

The effect of urban vegetation on air quality has been found to be a two-fold question. Whilst in parks and open road configurations trees are effective in reducing pollutant concentrations by dry deposition to tree leaves, previous studies have shown that the decreased ventilation due to the aerodynamic effects of vegetation canopy seems to play a bigger role than the dry deposition in street canyons. An extensive review of the previous studies is available in Abhijith et al. (2017).

The study aims to combine high resolution flow modelling together with a sectional aerosol model SALSA to assess effects of different street vegetation configurations on local scale air quality. Simulations are conducted on a wide street canyon with high traffic rates for which six different street and vegetation configurations are considered. The analysis focuses on the pedestrian level number and mass concentrations, the differences in the particle size distributions and ventilation performance.

METHODS

The study area is described by a 50 to 58 meter wide and approximately 800 meter long street canyon surrounded by three to seven story buildings.

The simulations are conducted for six different street configurations, each with different vegetation layouts. Scenarios S0, S2A, S2B and S2C incorporated a 54-meter wide street canyon while scenario S1 used 58-meter wide and scenario S3 used a 50-meter wide street canyon. The vegetation configurations applied in each scenario are listed in Table 1. The simulations are performed for

Scenario	Tree rows	Tree species	Hedges
S0	0	-	-
S1	4	*Tilia* × *vulgaris*	-
S2A	3	*Tilia* × *vulgaris*	-
S2B	3	*Tilia* × *vulgaris*	Below outermost trees
S2C	3	*Tilia* × *vulgaris* (middle), *Sorbus intermedia* (outermost)	-
S3	2	*Tilia* × *vulgaris*	-

Table 1: The vegetation configurations used in the study. *Tilia* × *vulgaris* had a height of 15 meters, *Sorbus intermedia* 9 meters and hedges 0.75 meters.

two wind directions, 8° and 82° with respect to the street canyon. Moderate wind conditions and a neutral stratification are applied.

Traffic lanes are defined as pollutant source areas, covering 41-48% of the street canyon surface area. The emission factors used represented a high traffic rate (3660 vehicles per hour) with a vehicle fleet and technologies projected for year 2030. Moderate background concentration estimates are used as boundary conditions for the aerosol model.

The numerical approach used the PALM model system with a LES-LES self nesting approach. The simulations were initialized with a precursor run. A finer grid resolution (1 m horizontally and 0.75 m vertically) child domain of size 768 × 384 × 72 grid points is embedded in a coarser resolution (3 m in each direction) parent domain of size 384 × 192 × 64 grid points. The aerosol model is solved only for the child domain in order to reduce computational costs. Each simulation are run for 1 hr 10 mins and data only from the last 60 mins is used.

KEY FINDINGS

The key finding is that the vegetation increases pedestrian level PM10 mass concentrations within the street canyon compared to the vegetation-free case by 52% to 74%, depending on the scenario. The decrease in the street canyon ventilation is found to play more important role than the dry deposition of pollutants into vegetation. This is consistent with the majority of the previous studies (Abhijith et al., 2017).

For particle number concentrations this increase is significantly lower, from 7% to 18%. The dry deposition is more effective for smaller particles which dominate the particle number concentration. A decrease in particle number concentrations was observed for approximately sub-50 nm particles.

The best scenario and vegetation configuration in terms of air quality seems to depend on which measure is given the most weight. In terms of PM2.5 and PM10 concentrations, scenario S2C which incorporates a variable-height tree canopy disturbs the ventilation performance of the pollutants the least whilst in terms of smaller particles the scenarios with more vegetation content such as S1 and S2B show better performance.

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REFERENCES

Abhijith K.V., Kumar P., Gallagher J., McNabola A., Baldauf R., Pilla F., Broderick B, Di Sabatino S., Pulvirenti B. (2017) Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments – A review *Atmospheric Environment*, **162**, 71-86, doi:10.1016/j.atmosenv.2017.05.014

Kurppa M., Hellsten A., Roldin P., Kokkola H., Tonttila J., Auvinen M., Kent C., Kumar P., Maronga B., Järvi L. (2019) Implementation of the sectional aerosol module SALSA2.0 into the PALM model system 6.0: Model development and first evaluation *Geosci. Mod. Dev.*, **12**, 1403-1422, doi:10.5194/gmd-12-1403-2019

Maronga B., Banzhaf S., Burmeister C., et al. (2019) Overview of the PALM model system 6.0 *Geosci. Mod. Dev.*, doi:10.5194/gmd-2019-103