

Urban greening and air quality: A modelling investigation into the effect of trees on photochemical pollution in a street canyon

Supervisor: Dr Xiaoming Cai (XC), Prof Rob MacKenzie (ARMK), Dr William Bloss (WJB) GEES

Project description: Global climate change and worldwide urbanization challenge quality of life with regard to comfortable climate and good air quality. Risks associated with extreme weather in cities, such as heat waves, are projected to increase with global climate change; world population of urban residents (currently above 50%) is also projected to increase sharply in this century. One of the emerging ideas to mitigate the effects of climate change is urban greening, e.g. by planting more trees along streets. However this may reduce the ventilation of air pollutants below the tree canopy (MacKenzie et al. 2010; Pugh et al. 2012) and may worsen air quality at the street level. The effects of street trees on urban climate and air quality have been little studied, because direct simulation of flow through and around trees is difficult. *This project aims to quantify the effects of trees on the street canyon flow, and dispersion and chemical reactions of air pollutants using the powerful large-eddy simulation (LES) methodology which reveals the detailed turbulent and photochemical processes involved.* The project will address the following issues: (i) how the ventilation is affected by a combination of building geometry, tree characteristics, and wind condition; (ii) how the altered ventilation by trees perturbs the escape of road traffic emissions and the penetration of above-roof background pollution; (iii) how the altered ventilation and trees' shadows affect photochemical reactions and pollutant concentrations; and (iv) whether it is feasible to derive a parameterization scheme for the users of the research outcome. A comprehensive dataset from wind-tunnel experiments will be used to evaluate the model performance. The results of the project can be used as guidance for assessing the mitigation strategy of urban greening and the parameterization scheme can be implemented in box models as well as meso-scale models.

Approach: The research team at University of Birmingham has developed for the first time a large-eddy simulation code that resolves large turbulent eddies carrying photo-chemically reactive plumes inside a street canyon (Cai et al. 2008; Bright et al. 2013). Fig. 1 shows a few examples of simulated concentration field of a scalar in street canyons with various street widths. In this proposal, the code will be modified to consider trees. The wind-tunnel data (Gromke & Ruck 2007) will be used to evaluate the new code. After the evaluation, simulations will be conducted for a list of combination of following variables: building geometry (different canyon aspect ratio), tree characteristics (location of leaves; leaf density varying with season and tree type), wind condition (different wind speed & direction), and emissions (either the emissions inside the canyon or the background pollution above the building roofs). The quantities to be assessed are: mean wind and pollutant concentration pattern, turbulence quantities, and exchange velocity at the roof level.

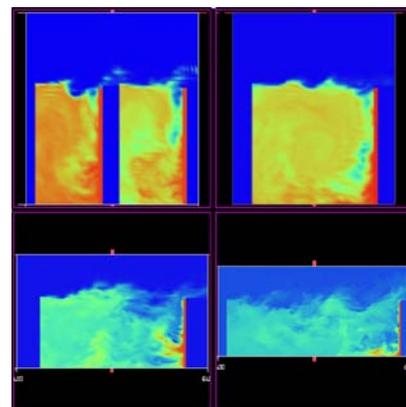


Fig. 1 Simulated flow & dispersion in street canyons with various street widths from the large-eddy simulation model at Birmingham.

Training: The goal of this project is to train the student to become a mature researcher with the expertise and skills in the areas of large-eddy simulation, turbulence & dispersion modelling, and urban air quality. The University's IT Services provide subject specific training, e.g. UNIX, parallel computation, computing languages (Matlab, R, and FORTRAN).

References

- Bright, V., W.J. Bloss and X.-M. Cai, 2013, Urban street canyons: coupling dynamics, chemistry and atmospheric pre-processing, *Atmospheric Environment*, **68**, 127-142.
- Cai, X. M., J. F. Barlow, and S. E. Belcher, 2008: Dispersion and transfer of passive scalars in and above street canyons - Large-eddy simulations. *Atmospheric Environment*, **42**, 5885-5895.
- Gromke, C., and B. Ruck, 2007: Influence of trees on the dispersion of pollutants in an urban street canyon - Experimental investigation of the flow and concentration field. *Atmospheric Environment*, **41**, 3287-3302.
- MacKenzie, R., T. Pugh, and C. Rogers, 2010: Sustainable cities: seeing past the trees. *Nature*, **468**, 765-765.
- Pugh, T. A. M., A. R. MacKenzie, J. D. Whyatt, and C. N. Hewitt, 2012: Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. *Environ. Sci. Technol.*, **46**, 7692-7699

Applicants should apply via

<http://www.birmingham.ac.uk/postgraduate/courses/research/gees/environmental-health-risk-mgt.aspx> where they should click on 'Apply now' and choose the option 'PhD in Department of Division of Environmental Health and Risk Management' and give the PhD title in the 'Funding details' section of the online application.