Scenario DOCTORAL TRAINING PARTNERSHIP
NERC SCIENCE OF THE ENVIRONMENT

Developing an urban canopy model for improved weather forecasts in cities

Lead Supervisor: Janet F. Barlow, University of Reading, Department of Meteorology
Email: J.f.barlow@reading.ac.uk

Co-supervisors: Omduth Coceal (UoR), o.coceal@reading.ac.uk; Matteo Carpentieri (UoS), m.carpentieri@surrey.ac.uk, Martin Best, Humphrey Lean (UK Met Office)

Most of the world's population now experiences an urban version of weather extremes and climate change. Accurate forecasting of weather and air quality in cities relies on correctly representing the physics of turbulent exchange between the surface and the overlying atmosphere. Each building produces a complex flow but by treating their effect collectively as an "urban canopy", relatively simple models can be formulated. The problem lies in understanding how urban heterogeneity affects flow processes: how does the heat flux change from tall vs small buildings? What if sun heats one side of the street and not the other? Does a single tall building dominate surface drag?

This project will explore flow processes around buildings to develop an urban canopy model suitable for numerical weather prediction. The project would adapt a modelling approach developed for vegetation canopies for application to urban canopies [1]. New wind-tunnel experiments would be done to investigate flows for more realistic heated building layouts.

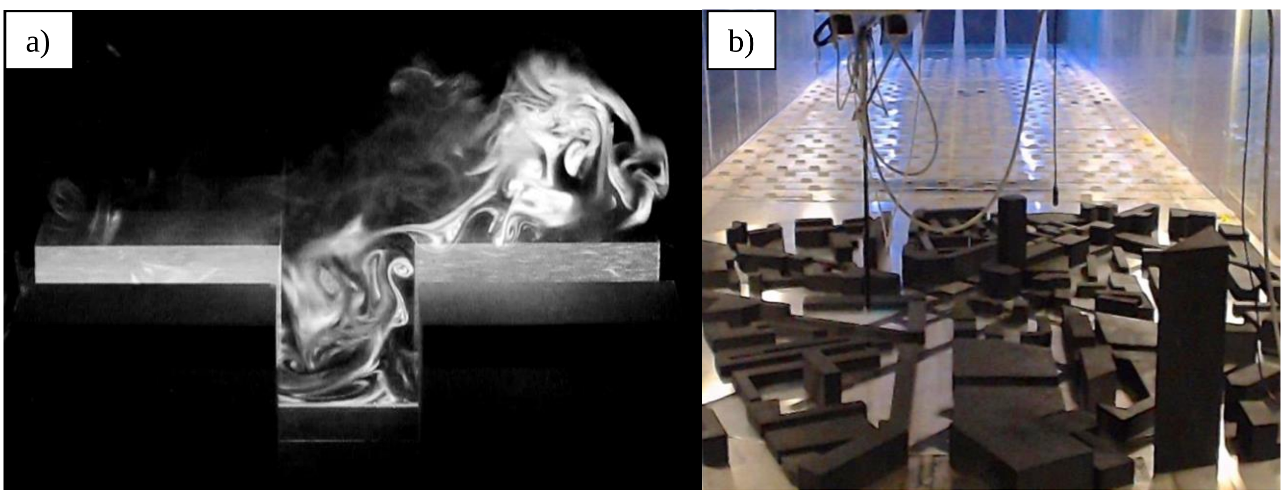

Figure shows a) smoke flow visualization of turbulence over buildings b) wind-tunnel model of an area of central London at the EnFlo laboratory – spires and blocks upstream of model determine inlet conditions.

This project has a CASE award from the UK Met Office. The current urban surface scheme (MORUSES) in the Unified Model is coupled to the model at a single level: effectively, the buildings are flat. Urban areas contain increasingly large buildings that can occupy a significant fraction of the boundary layer, for which a single, surface prediction is inadequate and ill-defined. A key part of the Met Office urban modelling strategy is thus to develop a vertically distributed scheme that captures momentum and scalar exchange throughout the depth of the urban canopy. For the first time this will allow "within-street" forecasts of wind, temperature, pollution, etc.

MORUSES was developed to represent urban canopy heat fluxes in a simplified way [2]. The concept behind the scheme is based on a 2D street canyon, consisting of building wake and “non-wake” areas of the flow [3]. The turbulent exchange scheme within MORUSES was developed for a neutral flow regime and validated using wind-tunnel modelling of heat fluxes from street canyons. Moving from a 2D to a 3D framework is a necessary step to modelling real urban areas.

Wind-tunnel experiments with heated buildings would be done at EnFlo at the University of Surrey. Model facets – streets, walls, roofs – would be heated and heat fluxes measured using fast response sensors. By heating the models to relatively low temperatures in moderate flows, heat acts as a passive scalar. The objective would be to explore the impact of different configurations (3D building layout, heating patterns) on turbulent exchange. This methodology was already used to study vegetation canopies and street canyons. Heating the models to higher temperatures addresses the regime where heat is an active scalar [4]. Wind-tunnel inlet conditions can also be varied to simulate convective and stable boundary layers above the buildings.

Training opportunities:
This project is in collaboration with the Met Office, the UK’s national weather service. The student will spend at least three months at the Met Office in Exeter during the project, in addition to regular interaction with the MO@Reading group. In addition, the student will spend some time doing experiments at EnFlo at the University of Surrey, a unique wind-tunnel facility in the UK and one of the few atmospheric boundary layer wind-tunnels in the world.

Student profile:
The student should have a background in physical or mathematical sciences, or engineering. Strong mathematical and computational skills are required as well as basic experience in experimentation and data analysis. Knowledge of environmental science and/or advanced experimental skills are an advantage.

Funding particulars:
This project has a CASE award with the UK Met Office

References:
[1] Coceal, O. and Belcher, S. E. (2004) A canopy model of mean winds through urban areas. Quarterly Journal of the Royal Meteorological Society, 130 (599),1349-1372
[2] Porson, A., Clark, P.A., Harman, I.N., Best, M.J. and Belcher, S.E. (2010) Implementation of a new urban energy budget scheme in the MetUM. Part I: Description and idealized simulations. Quarterly Journal of the Royal Meteorological Society, 136, 1514-1529
[3] Barlow, J.F., Harman, I.N. and Belcher, S.E. (2004) Scalar fluxes from urban street canyons. Part I: Laboratory simulation, Boundary Layer Meteorology, 113(3), 369-385
[4] Marucci, D. and Carpentieri, M. (2019) Effect of local and upwind stratification on flow and dispersion inside and above a bi-dimensional street canyon, Building and Environment, 156, 74-88

http://www.reading.ac.uk/nercdtp