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Modelling the urban atmospheric environment

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Background

UWERN has identified urban meteorology as one of its priority areas that responds to several scientific themes identified by NERC. Consequently UWERN has formulated a strategy for delivery of the science required (see www.met.reading.ac.uk/~bl_met/urban). It is motivated by the following applications:

- Urban meteorology and its interaction with larger scale meteorology
- Urban air quality and the dispersion of pollutants in urban areas
- Emergency response to fires and to releases of toxic material
- Wind loading on engineering structures
- Urban climatology
- Urban sustainable development

Large-scale numerical weather prediction models, such as the Met Office's Unified Model, cannot be used to compute flows at the smallest scales, such as those within city streets or even neighbourhoods. This situation will persist into the foreseeable future. On the other hand, engineering-type computational fluid dynamics (CFD) models, typified by those embodied in codes marketed by a number of well-known CFD companies and those being developed in Universities, are designed for small scale fluid flows, but have not been constructed with meteorological applications in mind. Although CFD models have become increasingly sophisticated in terms of numerical methods, mesh structures, etc., so that in principle they can be used to compute flows around assemblages of buildings, they cannot yet be run with appropriate meteorological boundary conditions. There is an absence of models needed to compute small-scale flows in urban areas with realistic meteorology.

The Proposal

This proposal aims to develop a system, called here the *urban CFD code*, that will model numerically the urban atmospheric environment and address these applications. The modelling system would complement a parallel strategy for observations of the urban atmospheric environment. The initial goal is to produce a research tool, but we recognise that there is scope here to produce the basis of a forecasting system.

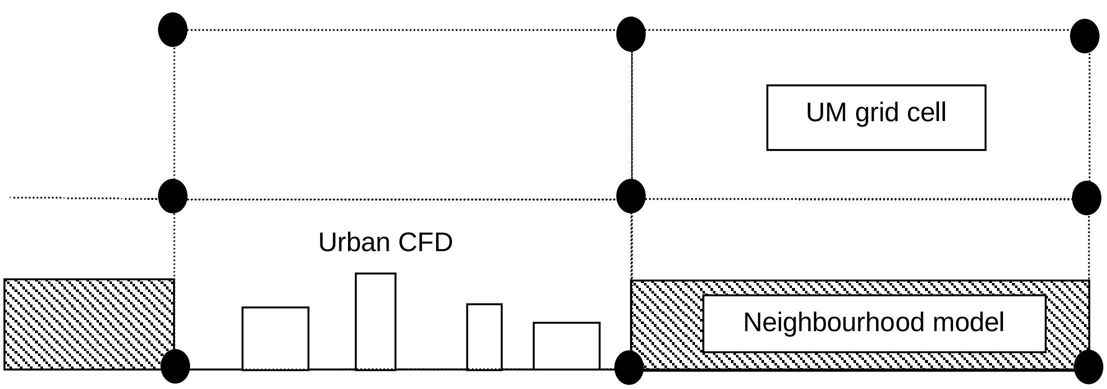
The applications drive the scientific components that need to be represented in the modelling system, namely

- Transport and mixing processes (for mass, momentum, energy, moisture) within the urban canopy
- Exchange between the urban canopy and the boundary layer flow above
- Forcing from upwind and above by non-stationary meteorology

- Resolution down to the building scale (1m) and up to the mesoscale (~5 km)
- Boundary conditions that can resolve fine scale geometry
- A range of turbulence models ranging from closure models to large eddy simulation
- Dispersion of pollutants and effects on air pollution
- Capability to calculate a back-trajectories

These are ambitious requirements. Nevertheless, we believe they can be met by combining expertise from the meteorology and engineering CFD communities within academe and industry. This project will complement the activities of the UWERN microscale modelling project, which is being designed to interface with an urban code.

The proposal is to couple initially the microscale code and then, later, the Met Office Unified Model with an engineering CFD code that will be used to compute the details of the flow around individual buildings. Figure 1 shows a schematic of the coupling. The urban CFD code will sit below the larger scale model. One might hope that this could eventually be the Unified Model but, more likely, an intermediate-scale region might have to be modelled separately. This could be the new microscale model under development. The urban CFD code will receive upper boundary conditions from the larger scale meteorological model. One-way coupling between the two models is currently envisaged for the meteorology. By completion of the project, it is anticipated that all the surface flow at scales smaller than the UM scale (i.e. 1-2km) could be computed using an appropriate combination of the urban CFD code and, probably, some form of intermediate-scale model.



Overall challenges

The authors bring to this proposal a unique combination of experience in

- Meteorology
- Thermofluid mechanics
- Model development and use
- Regulatory awareness
- CFD development and use
- Formalised scientific evaluation of models
- City scale, neighbourhood scale and street scale modelling activities

Also, and importantly, the consortium brings a wealth of observational experience and data. Extensive measurements of street flow in York, Birmingham, Salford and London, a detailed collection of relevant wind tunnel data, current intensive emission pathway observations in DAPPLE are but a brief summary of the available data, which would form part of the project.

Implementation plan

We propose that the modelling system be developed as a partnership between the academic community (via UWERN), the Met Office, and the Engineering CFD community. We perceive benefits to all. The increased resources ensure that this ambitious project has critical mass. We propose to develop a partnership with a commercial CFD vendor and to explore options to obtain financial support and resources from them. The following possibilities for support will be investigated:

- UWERN: initially funds for a workshop, following the strategic review a PDRA and a student;
- CFD Vendor: CFD code, resources for code development, and CASE sponsorship or other financial support;
- Met Office: Unified model support, resources via JCMM, CASE sponsorship

Specific steps to be accomplished

The goals in the short term, which will feed into the NCAS strategic review, are a scoping procedure which will

- Enter detailed discussions with CFD code vendors
- Hold a workshop funded by UWERN attended by academic and industrial experts to
  - Establish simulation test cases and date for comparison
  - Establish veracity of commercial and academic CFD codes and best methods and accuracy that can be expected from simulations.
- Seek consensus on best numerical methods

The deliverable from this activity will be a clear consensus on the way forward in developing the urban CFD code, in addition to the scientific results obtained in the scoping procedure.

In the medium term, when collaboration has been agreed with a commercial CFD vendor, the aims are to develop the system itself, namely

- Streamline commercial CFD code for this application
- Determine method for deriving boundary conditions from larger-scale model
- Establish range of turbulence models
- Determine approach for validation with a view to incorporating observations
- Establish Quality Assurance and Best Practice procedures

Deliverables

The deliverables from this activity will be

- An urban CFD code, which has an interface to a larger scale model.
- A workshop reports that analyse approaches and validation strategies
- A set of documented test cases
- A full model description, quality assurance and application best practice