EPSRC Grand Challenge: Future Cities
Managing Air for Green Inner Cities (MAGIC)

MAGIC CIRCLE

MAGIC Circular 1 December 2017

Summary

This first year has focused on recruiting a team of highly talented post-doctoral research associates (PDRAs). I am pleased to report that we have now filled all but one of the positions and details of the PDRAs is given below. We have also identified a test site for a monitoring campaign to be carried out next year, and we are currently carrying out a series of modelling studies to support this work.

This first circular provides an update on the activities within MAGIC, including information on the personnel and the research being undertaken.

Appointments

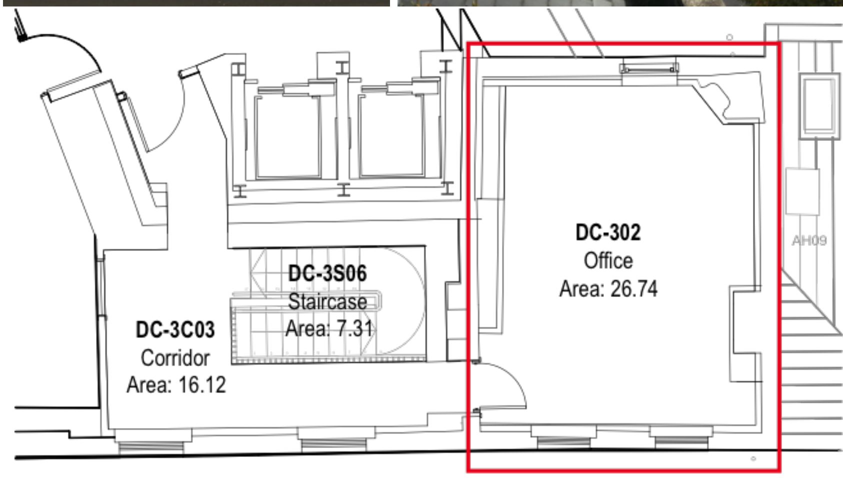
The following appointments (duration in person months) have been made. Initial appointments are for 24 months duration, and those indicated with (12) are funded 50% with other related projects.

- Cambridge (4):
  - Building ventilation (DAMTP/CUED): Megan Davies Wykes (24)
  - Building energy performance (DAMTP/Arch): Jiyun Song (12)
  - Sensor deployment (Chemistry): Shiwei Fan (24)
  - ATHAM Fluidity (Geography): James O'Neill (12)
- Imperial (2):
  - Fluidity development: Fangxin Fang (36)
  - Data assimilation and sensor optimisation: David Fairburn (24)
  - Building modelling (ICL/CAM): Laetitia Mottet (12)
  - Reduced order modelling: Dunhui Xiao (Travis) (6)
  - Street canyon modelling: Currently advertised
- Surrey (1):
  - Wind tunnel and numerical modelling: William Lin (24)

Brief bios of the postdocs are given below.

Test site

We have chosen a naturally ventilated third-floor office building owned by one of our partners, London South Bank University. It is located adjacent to the busy London Road, and has windows opening onto the road and a further window at the rear opening on to a cleaner, quiet courtyard. The office has the possibility of both single-sided and cross ventilation, and has significant internal gains associated with occupants and computers. We plan to start monitoring the interior and exterior conditions next spring.



Monitoring

A set of low-cost and portable monitoring units is under design by Shiwei Fan for the field test. The unit will measure trace gases of CO and CO2, temperature, humidity, and pressure. The unit is battery powered to ensure portability and hassle-free installation. Low-power microcontroller and electronics are chosen for long time operation. Before deployment, each unit will be calibrated with standard instruments. Along with advanced algorithms, the unit can operate accurately and stably under a wide range of conditions. It is planned to make a total of 20 monitoring units to cover the interior and exterior of the building.

Computational Modelling

Fluidity

Initial work by James O'Neill has involved bringing the LES model ATHAM-FLUIDITY up to date with FLUIDITY, which forms the model's dynamical core. This has now been completed, and the model will soon be released as an open-source code through GitHub. Simplified street canyon simulations (neutral stratification, incompressible flow, periodic boundary conditions) have also been performed as a precursor to more complex urban canopy simulations in the near-future.

Laetitia Mottet is using FLUIDITY software and the associated pre-processor (GMSH) to set up simulation cases for the Enflo (University of Surrey) wind tunnel tests for different conditions, as well as generating the geometries for two real campuses: (i) the LSBU test case and (ii) the Zhejiang University campus. More specifically:
(a) Ridged Roofs: inclusion of ridged roofs on buildings - in order to assess effect on pressure and velocity variation and vertical mixing, as well as tracer dispersion.
(b) Turbulent Inlets: inclusion of a turbulent inlet and determination of optimal synthetic eddy generation parameters as per the Jarrin *et al.* model.
(c) Real Geometries: conversion of real AutoCAD drawings for the (1) LSBU site and (ii) Zhejang University campus into corresponding 3D shapefiles that are required for the mesh generation.
(d) Terreno software: cnsuring Terreno software runs smoothly with the shape files of the geometries of interest (LSBU site and Zhejang University campus) and can generate the corresponding appropriate meshes.
(e) Thermal effect: including thermal effect to study the heat island effect. Possible buildings: Walkie talkie building and LSBU site.
(f) Indoor/outdoor modelling: developing preliminary simulations for outdoor/indoor modelling for the Liubo building in Zhejang University (data have been already collected by Chinese colleagues). EnergyPlus software will be also used to have the building energy consumption.

Reduced order modelling and data assimilation
David Fairburn will research advanced techniques for data assimilation, sensor optimization and reduced order modelling for urban flow and air pollution problems. Specifically he will be working with the FLUIDITY unstructured mesh modelling platform and the development of ensemble data assimilation methods. At first this will involve idealized twin experiments assimilating pseudo-observations, which are quick to run and easy to validate. There is then scope to assimilate real observations from wind tunnel simulations and urban sensors. The techniques will then be applied to real observations, first from the controlled environment of a wind tunnel and then from full scale.

Dunhui Xiao has been developing rapid reduced order models of a given neighbourhood and is working on linking these models together to produce a larger scale city model.

Laboratory modelling

Megan Davies Wykes will investigate the ventilation of a room subject to both wind and buoyancy forcing. The experiments will be conducted using a model room with a heated floor, within a water tunnel. These experiments will be used to create reduced order models for the state of the interior of the room and the exchange between the room and exterior, given some external conditions and internal forcing.

Wind tunnel modelling

Wind tunnel research in Surrey's meteorological wind tunnel by William Lin will concentrate on a number of case studies as well as process investigations. Initial work will follow-on from a previous collaboration with ICL in studying flow and dispersion in relatively simple geometrical conditions, comprising no more than a few buildings. Output will provide further test cases for Fluidity modelling, guide the development of more advanced urban modelling in the CERC ADMS-URBAN model, and help understand the impact of multiple, but individually small, emissions associated with building services (heating, cooling and ventilation). This phase of the research will also provide a test-bed for the more advanced experimental techniques that will be required during the MAGIC project. Preparation for the first MAGIC case study in London Road will run simultaneously with the initial experiments. This will involve design and manufacture of the wind tunnel model (or models) and the development of the test strategy.

Data returned from these studies will include detailed mappings of flow and concentration fields, including turbulent mass fluxes, in neutral flow conditions. This provides a basic understanding of local flow and dispersion behaviour, and built on this is the subsequent more advanced work with, for example, multiple sensors to provide test cases for data-assimilation studies (see above), effects of atmospheric stability, traffic movement, and so on.

Work in China

Within the MAGIC project Fangxin Fang has been working directly the Institute of Atmospheric Physics (IAP) and on air pollution modelling and applications to China. She has incorporated the IAP chemistry model into Fluidity and setup 3D Chemical modelling test cases; 4)

We are currently exploring the development of a large consortium between four universities within China on Fluidity and new air pollution modelling. In addition two of our PDRAs are funded 50% on a closely related project LoHCool led by Alan Short and Peter Guthrie. A description of this project is given below.

LoHCool

The project Low carbon climate-responsive Heating and Cooling of Cities, LoHCool, is one of four EPSRC/NSFC funded Low Carbon Cities projects, focusing on 'Delivering economic and energy-efficient heating and cooling to city areas of different population densities and climates'. It will attempt to solve the conundrum of offering greater winter and summer comfort in a continental climate zone while mitigating what would be a carbon penalty of prodigious proportions. It concentrates on recovering value from the existing building stock in the very challenging Hot Summer-Cold Winter region of China, some 3.4 billion square metres occupied by some 550 million citizens. It is a highly cross-disciplinary project now further enhanced by collaboration with MAGIC. It involves engineers, building scientists, atmospheric scientists, architects and behavioural researchers in China and the UK, measuring real performance in existing type buildings in Chinese cities to investigate the use of passive and active systems for re-engineering familiar type buildings. It aims to enable the much desired improvements in living conditions and comfort levels within buildings through developing a keen understanding of the current heating and cooling technologies and practices in buildings by monitoring, surveying and measuring people's comfort and capturing this understanding through developing systems modelling including energy simulations. Dominant building types have been identified in two cities, Chongqing and Hangzhou. LoHCool will test them in the current climate, 'current' extreme events, future climates and will estimate the carbon implications and cost of widespread implementation. MAGIC is adopting the LoHCool test buildings as one of its own case studies and the detailed modelling of airflow around and within the test buildings, set in their complex urban landscapes, will greatly enhance LoHCool’s understanding and outcomes and enable some commentary on the implications of the adaptation recommendations about air quality, as well as energy and carbon performance. Findings for the existing stock are likely to be equally applicable to new-build, which in many ways is a simpler prospect.

Website

The MAGIC website (www.magic-air.uk) is currently being updated. Please visit the site for future news and information

Next partners meeting

We propose to hold the next meeting in February 2017. A doodle poll will be circulated soon with possible dates.

MAGIC postdocs

Megan Davies Wykes

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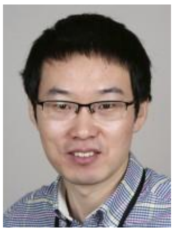
Megan did her PhD in turbulent stratified mixing at the Department of Applied Mathematics and Theoretical Physics, University of Cambridge. She then moved to the Courant Institute, New York University as a Fulbright Scholar to study the feedback between shape and flow when objects dissolve in a fluid. Megan has research interests that span turbulent mixing, buoyancy-driven flows and fluid-structure interaction. As part of MAGIC, Megan will be performing laboratory experiments to derive reduced order models that link the external high-resolution simulations with the interior conditions of ventilated spaces.

Shiwei Fan



shiweifan@gmail.com

Shiwei obtained his PhD from Cranfield University in 2014. His thesis focused on development of instrumentations and their application on characterisation of multiphase flow. Subsequently, he joined Schlumberger Gould Research Centre (SGR) as a post-doc researcher. At SGR, he worked on a variety of techniques for downhole production logging, subsea pipeline monitoring, and surface multiphase flow metering. He is developing sensors and instruments for air quality monitoring and model validation.

William Lin

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Will is a Canadian researcher who was introduced to the topics of urban flow and dispersion while enrolled in Rob Macdonald's senior undergraduate course on air pollution at the University of Waterloo. He completed his PhD at Western University with a research focus on loading of a power transmission line by storm winds. As a postdoc, he has been involved with commissioning a new buildiwilliamelin@gmail.comng energy lab at Purdue

University, the study of the spread of virus by cough bioaerosols, and the analysis of tornado wind field data.

Laetitia Mottet

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Laetitia has an engineering degree specialized in energy and thermal science delivered in 2012 by Polytech'Nantes (France). Between October 2012 and February 2016, I did my PhD at the Intitut de Mécanique des Fluides de Toulouse (France) under the supervision of Dr. Marc Prat. I have developed numerical models to study capillary evaporators of two-phase loops (systems used to manage the thermal control of electronic devices).
My position is jointly funded by MAGIC and LoHCool project.

James O'Neill

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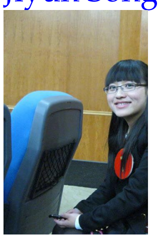
I am interested in the development and application of high-resolution large-eddy-simulation (LES) models for the simulation of atmospheric flows. I studied Mathematics with Engineering at undergraduate level at the University of Nottingham, going on to complete a masters in Applied Meteorology and Climatology at the University of Birmingham. I then worked at an environmental consultancy at Cambridge Environmental Research Consultants for two years, developing atmospheric dispersion modelling software. I returned to the University of Birmingham to complete my PhD, where I worked on developing a new subgrid-scale model for LES of neutral atmospheric flows. I am working on the MAGIC project, as well as a project looking at coastal flooding events.

Jiyun Song



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Jiyun will get her Ph.D. degree in Civil, Environmental and Sustainable Engineering from Arizona State University in December 2016 and will join the MAGIC project in University of Cambridge in January 2017. She obtained her Bachelor's and Master's degree in Hydrology and Water Resources from Wuhan University, China. Her research interests cover urban microclimate, urban land-atmosphere interactions, urban boundary layer meteorology, climate modelling, and hydrological modelling. Before joining the MAGIC project, she made significant contributions to several projects sponsored by U.S. National Science Foundation, U.S. Army Research Office, Central Arizona-Phoenix Long-Term Ecological Research, and the National Natural Science Foundation of China. In addition, she is an active member of American Meteorological Society (AMS), American Geophysical Union (AGU) and International Association for Urban Climate (IAUC).

Dunhui Xiao

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Dunhui did his PhD in reduced order modelling at the Department of Earth Science and Engineering, Imperial College London. Then he worked as a research associate at AMCG, ESE, Imperial College. Dunhui has research interests that span reduced order modelling of ocean problems, fluids-solids coupling problems, multiphase problems, machine learning and decision making system. As part of MAGIC, Dunhui will be developing a sub-domain reduced order model technology for city-wide big computational domain problems.

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