MAGIC

Envisaging a world with greener cities

Partners Meeting

PDRA slides

24/03/17

UNIVERSITY OF CAMBRIDGE

Imperial College London

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MAGIC Partners Meeting

24 March 2017
Downing College
James O’Neill (PDRA)

UNIVERSITY OF CAMBRIDGE

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My Background

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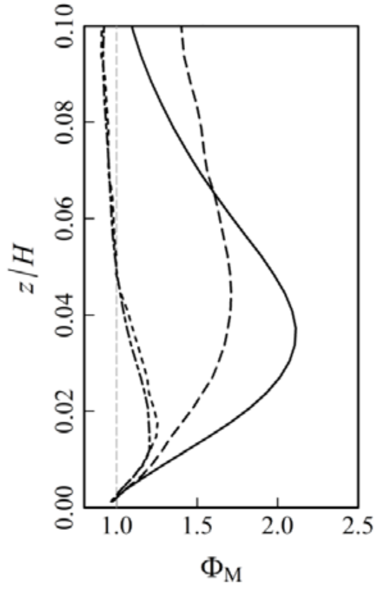
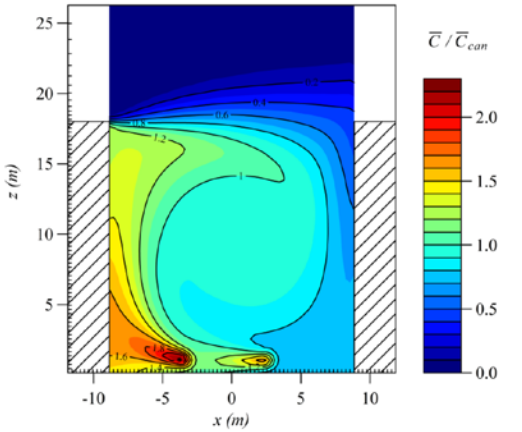
- 2005-2009 – Mathematics with Engineering BSc (University of Nottingham)
- 2009-2010 – Applied Meteorology and Climatology MSc (University of Birmingham)
- 2010-2012 – Cambridge Environmental Research Consultants (ADMS Software developer)
- 2012-2016 – PhD in Meteorology (UoB) on “A new stochastic backscatter model for large-eddy simulation of neutral atmospheric flows”
- 2016-present – Postdoctoral Researcher (University of Cambridge)





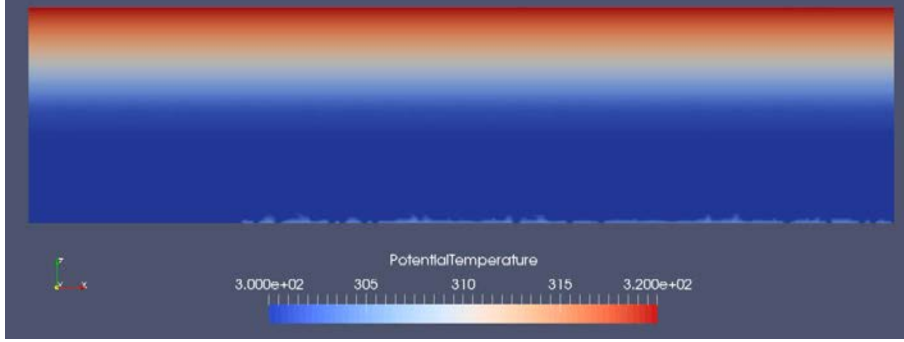
pearl

Preparing for Extreme And Rare events in coastaL regions

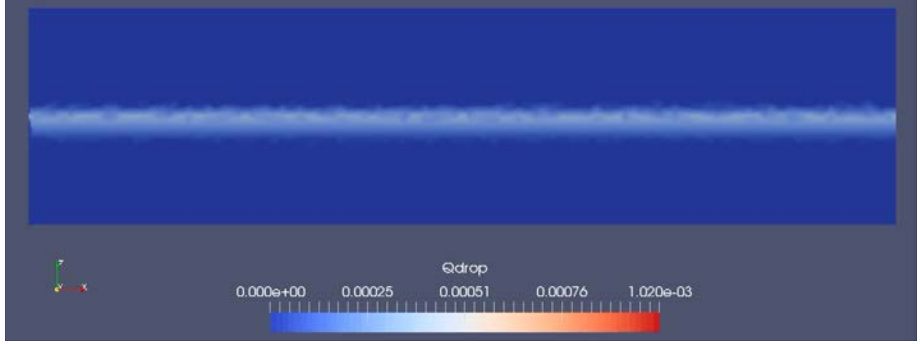
My Role in MAGIC

- Development of ATHAM-Fluidity:
  - A sister model of Fluidity (same dynamic core) with additional parameterisations specifically designed for atmospheric simulations (ATHAM)
  - Fully compressible, nonhydrostatic
  - Uses a mixed continuous/discontinuous finite element discretisation, shown to be highly suited to atmospheric modelling
  - Designed to run at large-eddy simulation scales to capture most important turbulence structures
  - Unstructured adaptive tetrahedral mesh that can dynamically concentrate resolution where it is most needed whilst coarsening in other regions (like Fluidity)

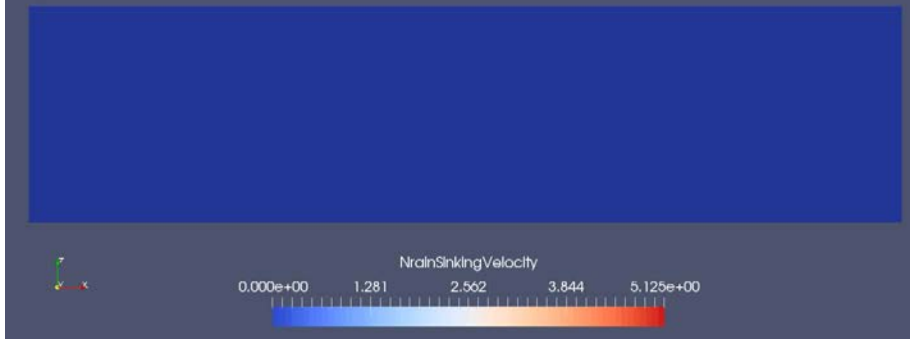
Potential temperature (K)



Mass concentration of cloud droplets (g/kg)



Rain (sinking velocity m/s)



My Objectives

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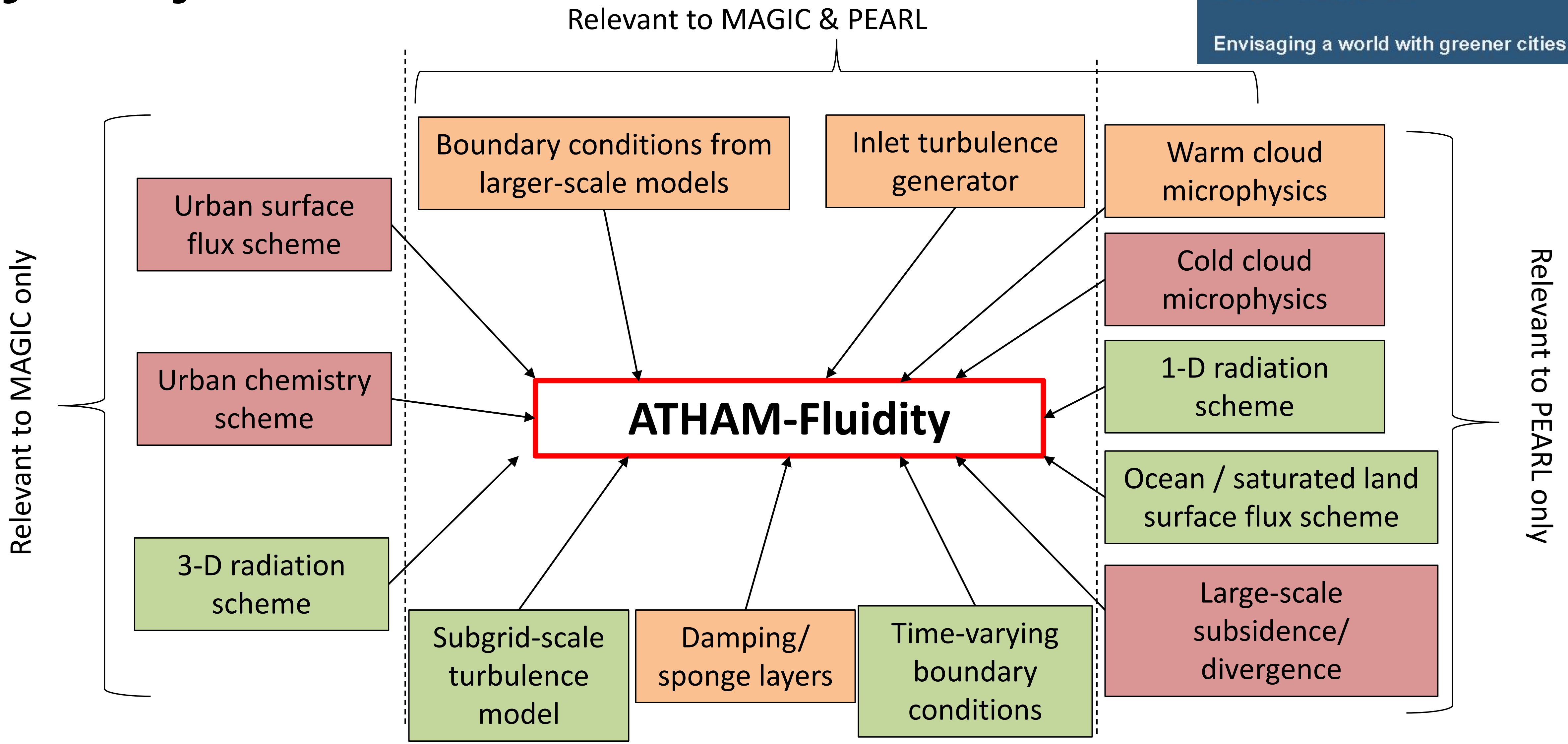

MAGIC Partner Meeting

24th March 2017

Laetitia Mottet

POLYTECH NANTES
École d'ingénieurs de l'université de Nantes

Engineering degree (2012) in
Thermal and energy sciences

PhD student (2016) in
Group of expertise on porous media
"Heat and mass transfer within the capillary evaporator of a two-phase loop"
(supervised by Dr. Marc Prat and funded by CNES and Airbus Defence and Space)

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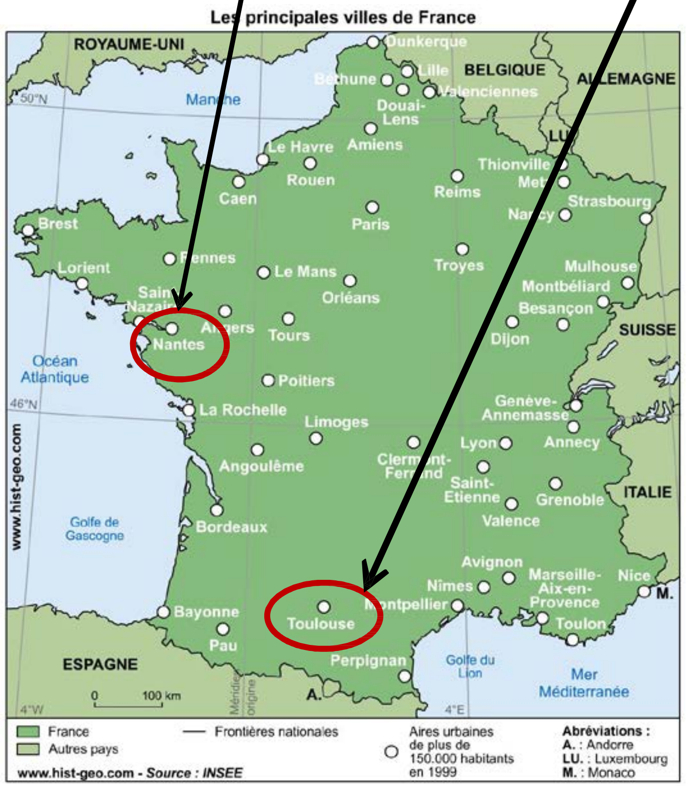
LoHCool
Low-carbon climate-responsive heating & cooling of cities

University of Cambridge,
Department of Architecture -
since Oct 2016 - (Prof. Alan Short)



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Imperial College London, Department of Earth Science and Engineering - since Oct 2016 - (Prof. Christopher Pain)

Main objective for MAGIC project:
Building modelling

Geometry of the case study area

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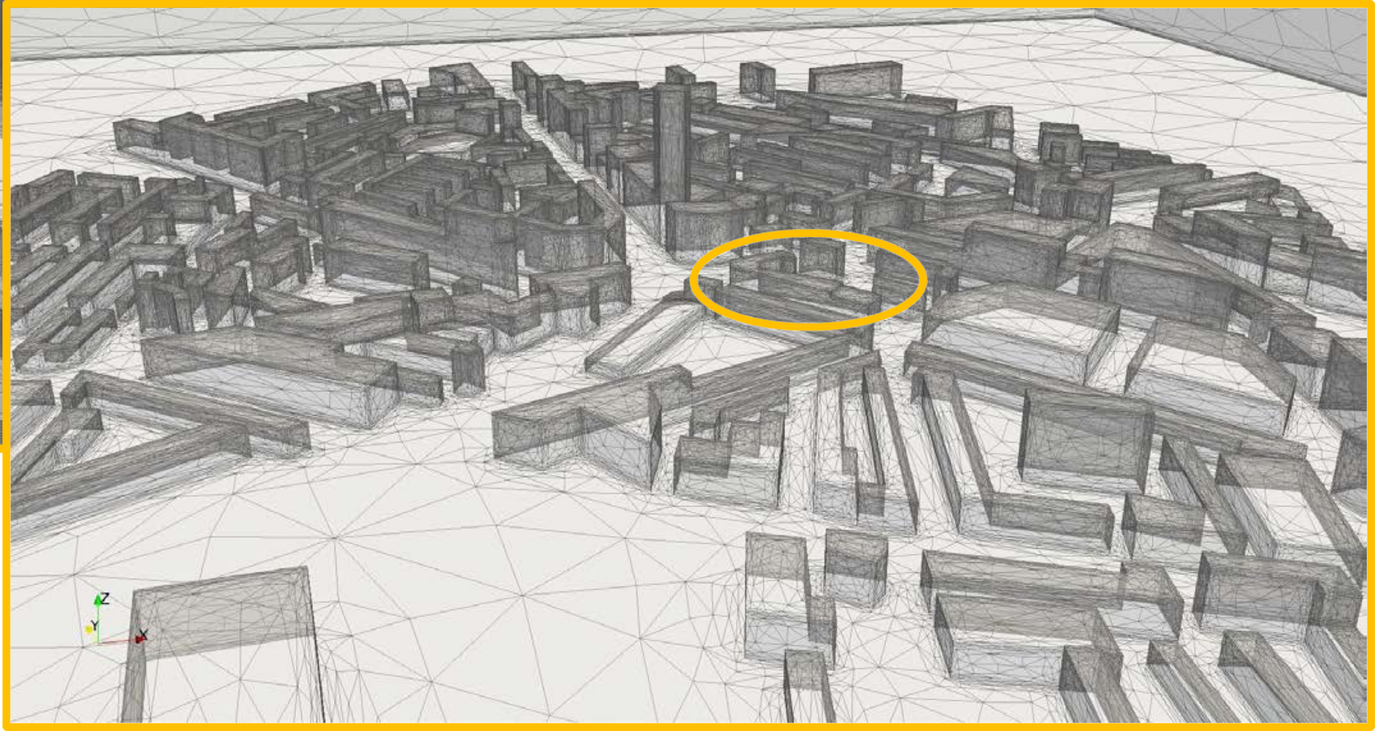
Diameter of the area: 1km

Real geometry



Simplified geometry
(wind tunnel geometry)

Fluidity - application to the simplified geometry

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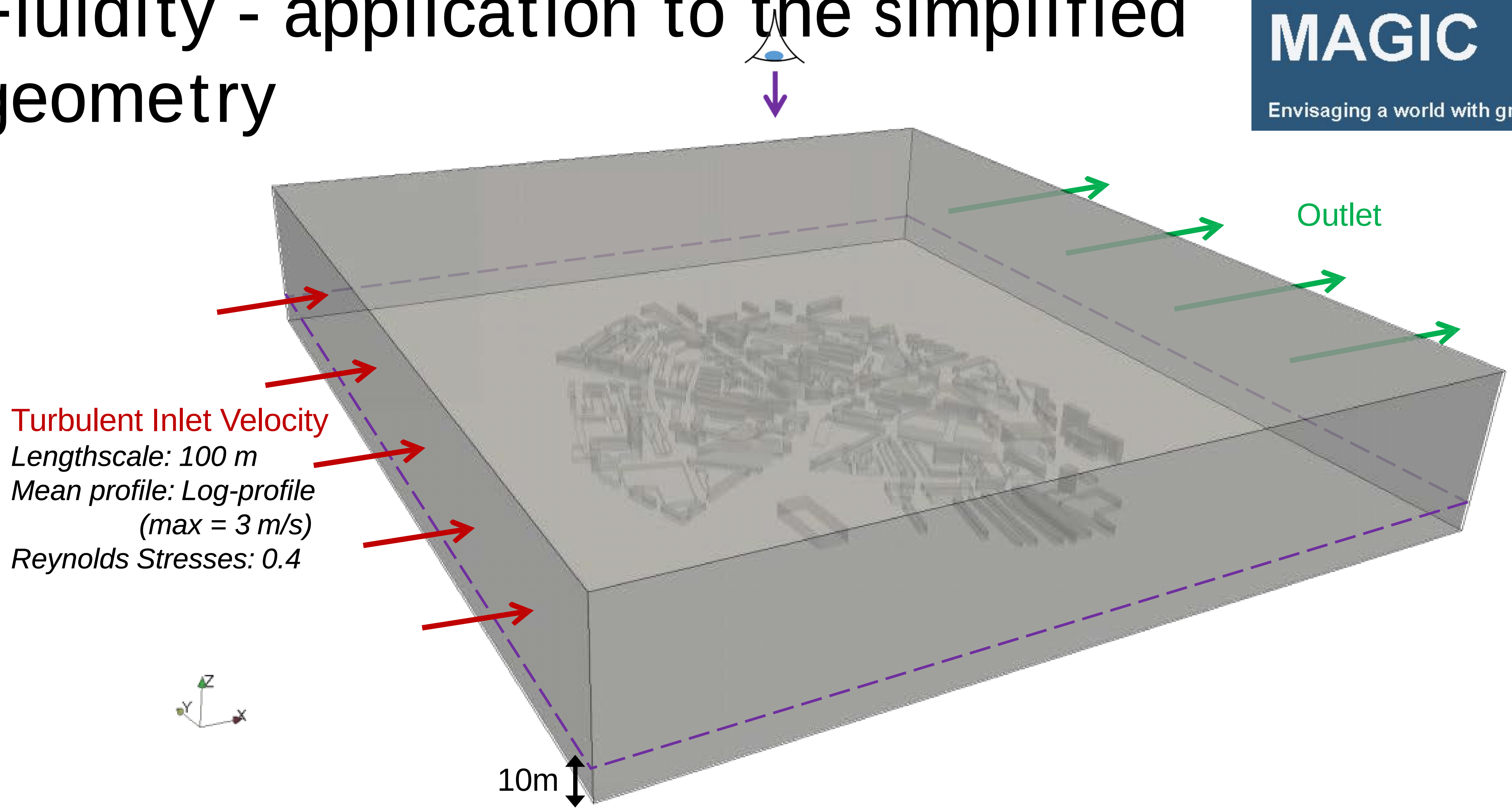

Fluidity - application to the simplified geometry

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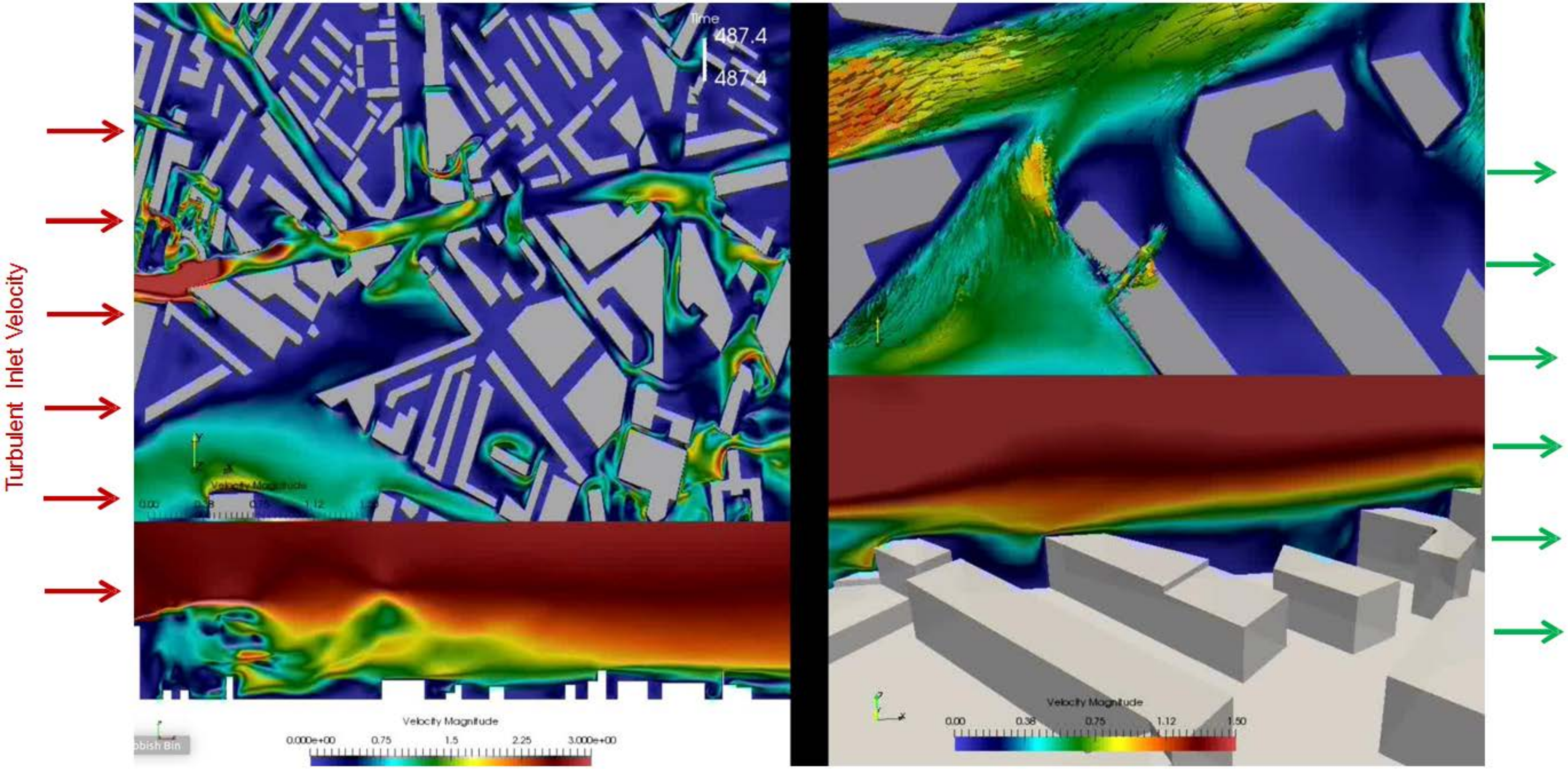

Next steps and objectives

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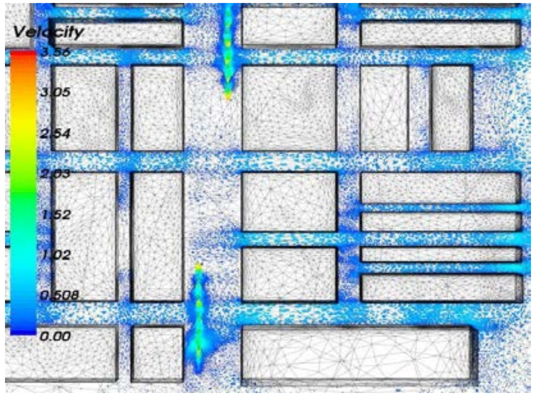
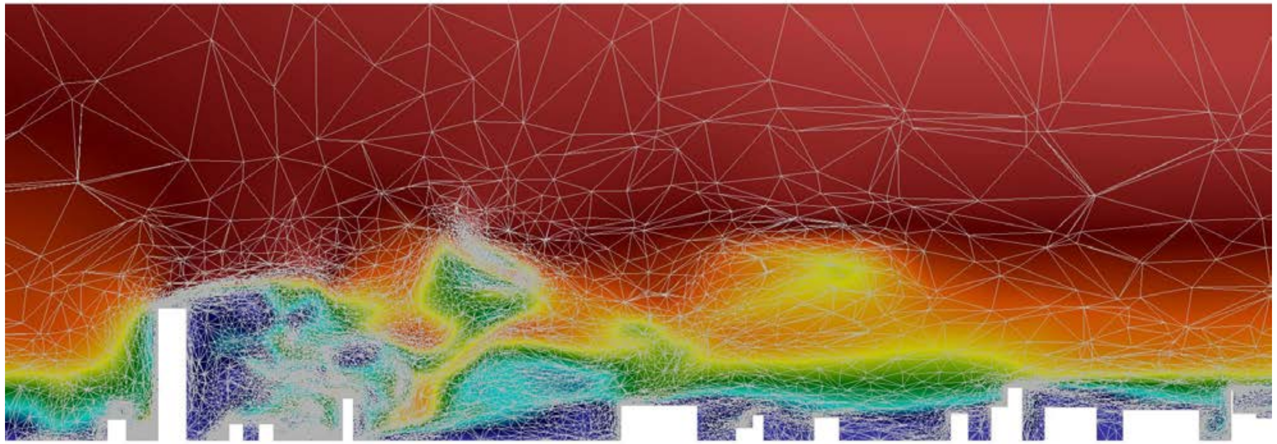
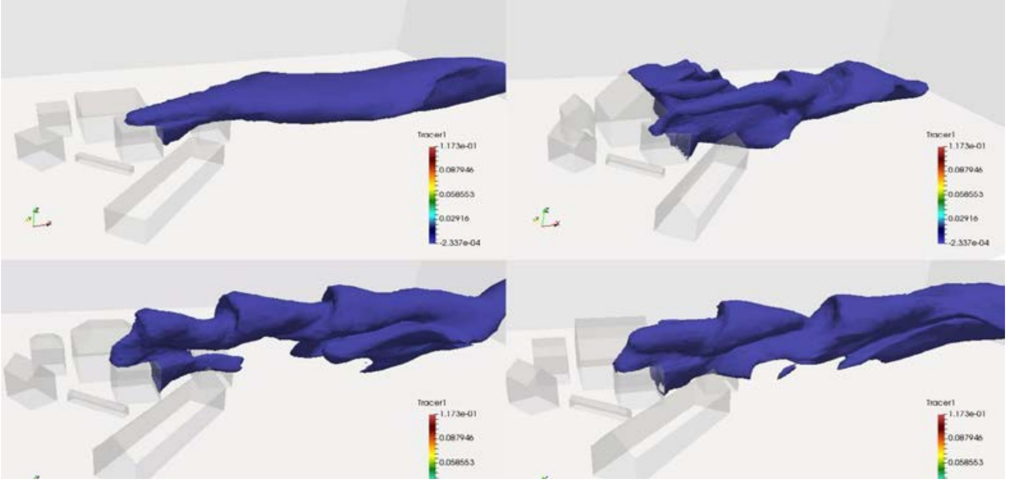
- Demonstrate the robustness of the geometry generation (and add roofs)
- Add traffic modelling
- Add thermal effects
- Develop indoor modelling
- Coupled indoor and outdoor models



Traffic modelling, Pavlidis, 2011


Adaptive mesh


Roof effect on a passive tracer dispersion

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My role and goal in MAGIC project

Jiyun Song

Supervised by Prof. Paul Linden

Department of Applied Mathematics and Theoretical Physics

Self-introduction

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- 2016 Dec: Ph.D. degree in Civil, Environmental and Sustainable Engineering from Arizona State University, U.S.
- Ph.D. dissertation title: Urban Microclimatic Response to Landscape Changes via Land-Atmosphere Interactions (Best Dissertation Award of Year 2016 by Chinese-American Oceanic and Atmospheric Association)
- Research interests: Urban microclimate, urban land-atmosphere interactions, building energy performance, natural ventilation, etc.
- 2017 Jan: Joined MAGIC project

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My research objective in MAGIC

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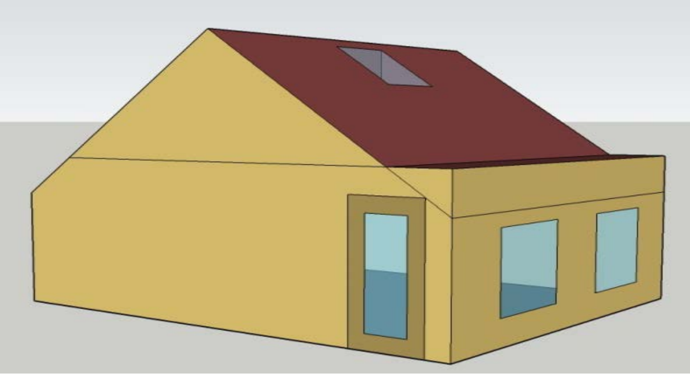
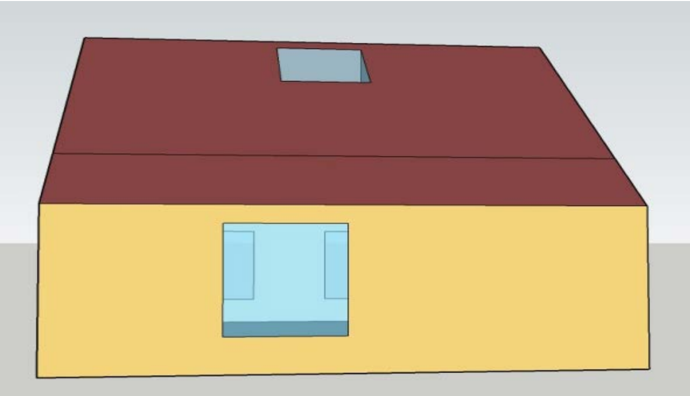
London Road side



Courtyard side



Study site:

Office room (DC302) in

London South Bank University

Modeling tool: EnergyPlus

Research goal:

A sustainable and comfortable

working environment

How to achieve the goal?

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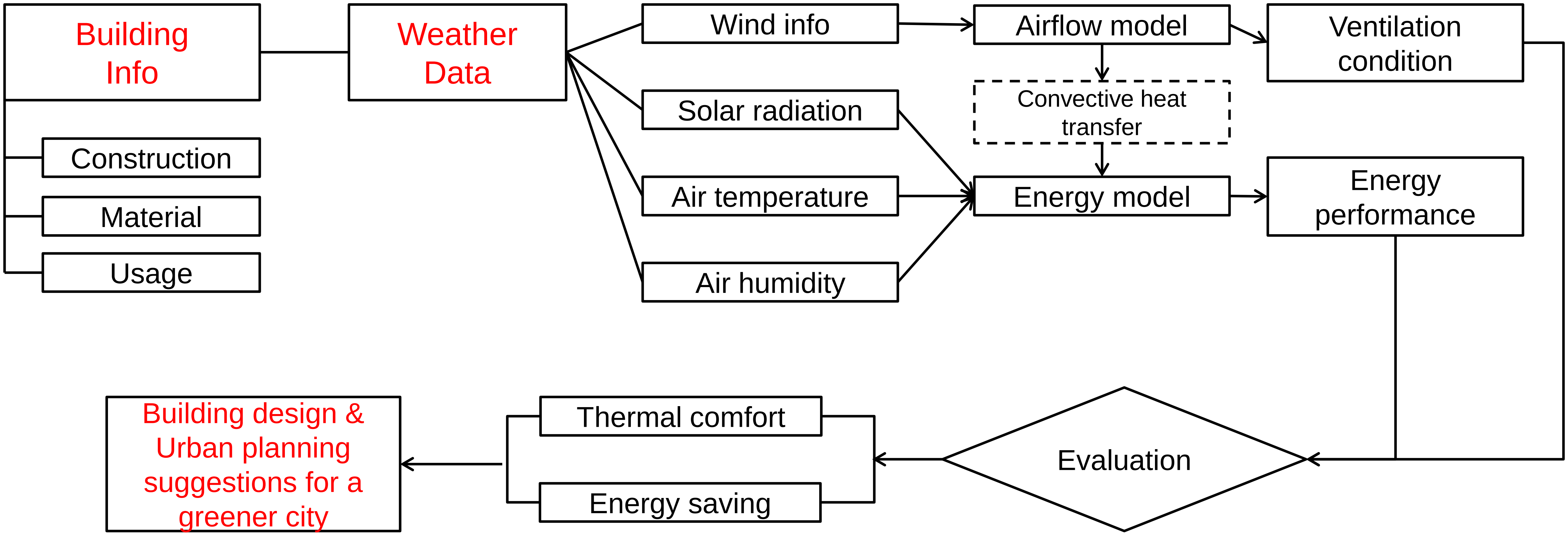

Experimental fluid dynamics

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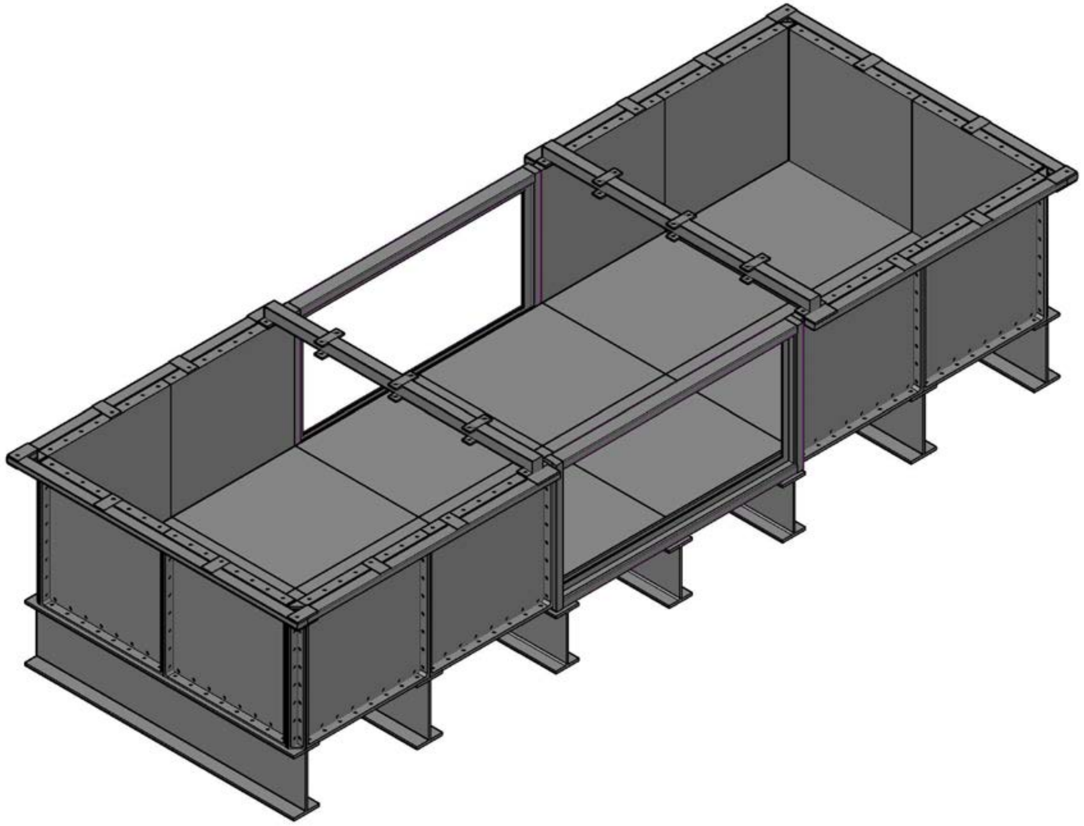
Megan S. Davies Wykes

Department of Applied Mathematics and Theoretical Physics

PhD: Mixing in buoyancy driven flows.

Postdoc: Flow-structure interaction at the microscale.



Build laboratory experiments that are dimensionally similar to the real room

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Reynolds number
Buoyancy forcing vs viscous dissipation

$$Re = \frac{g'^{\frac{1}{2}} H^{\frac{3}{2}}}{\mu}$$

Peclet number
Advection vs diffusion of heat

$$Pe = \frac{g'^{\frac{1}{2}} H^{\frac{3}{2}}}{\kappa}$$

Froude number
Buoyancy velocity vs wind velocity

$$Fr = \frac{U}{\sqrt{2g'H}}$$

Experiments will examine the effect of wind and buoyancy on ventilation rates

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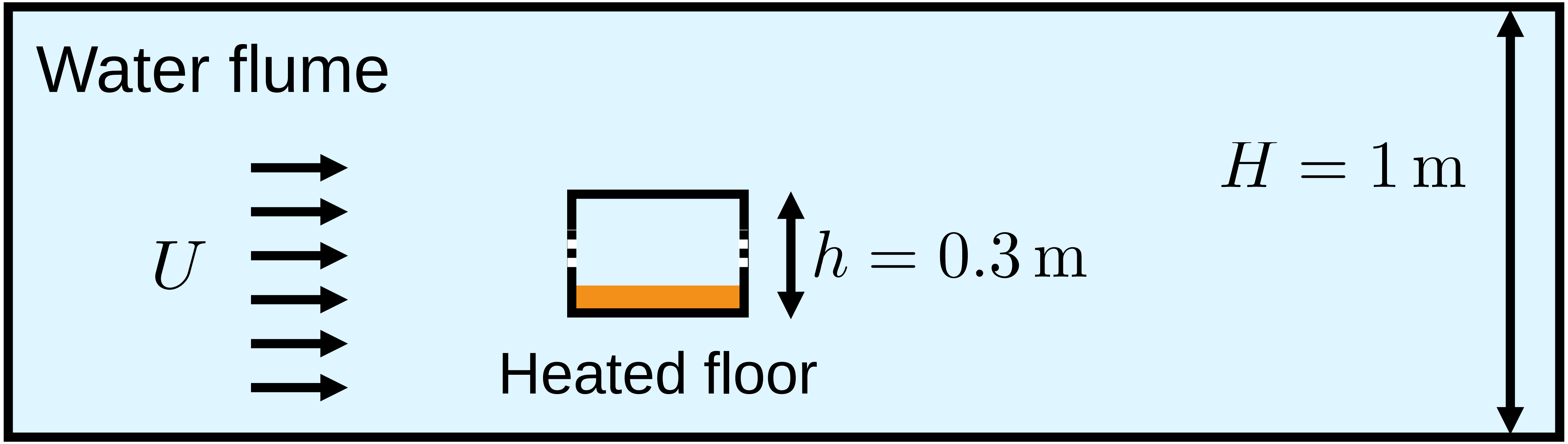

Measure: ventilation rate and temperature profiles

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Data assimilation
MAGIC partners meeting

24^{th} March 2017

David Fairbairn

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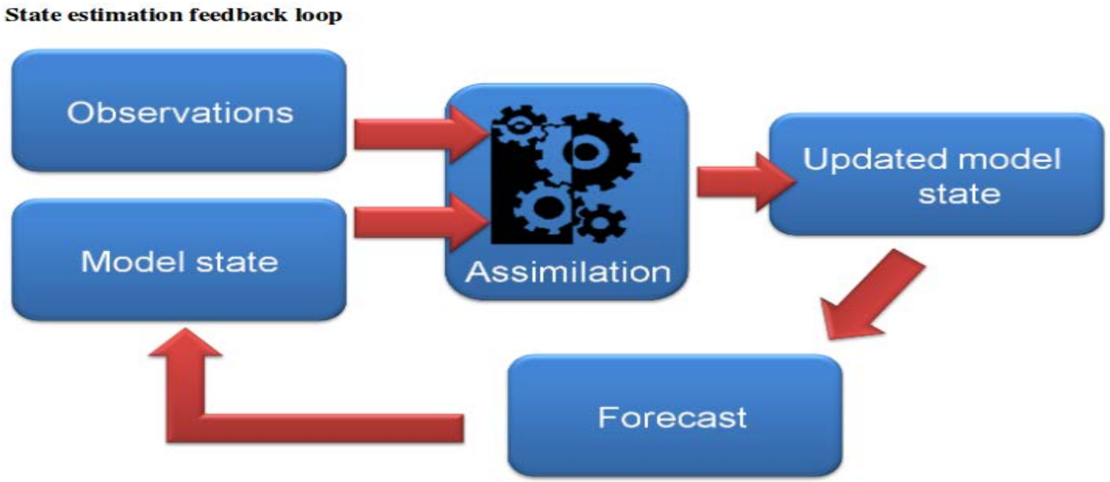
Introduction

Data assimilation combines a model with data to better estimate the state of a system:

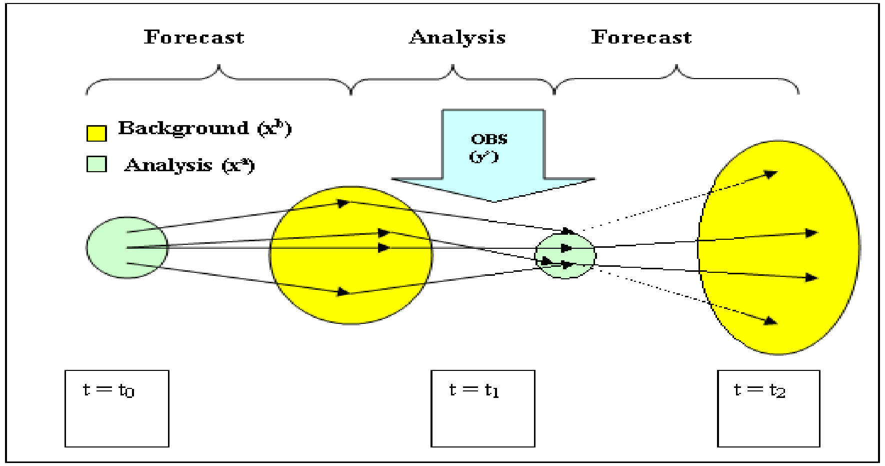


My background is in data assimilation for geophysical systems:

- Data assimilation for Numerical Weather Prediction at the Met Office (2009-2013)
- Land surface data assimilation at Meteo-France (2014-2016)
- MAGIC project: Assimilating sensor data in urban air pollution models (2016-)

My role in MAGIC

- *Lead research into advanced techniques for data assimilation and sensor optimization (including sensor placement) for adaptive mesh air pollution model (fluidity software);*
- *Use data assimilation to spread the observed information both spatially and temporally;*
- *Improve uncertainty estimates of the model and the data;*
- *Implement Ensemble Kalman filter methods, which provide dynamic uncertainty estimates of the model state prior to assimilation (see diagram)*



Strategy

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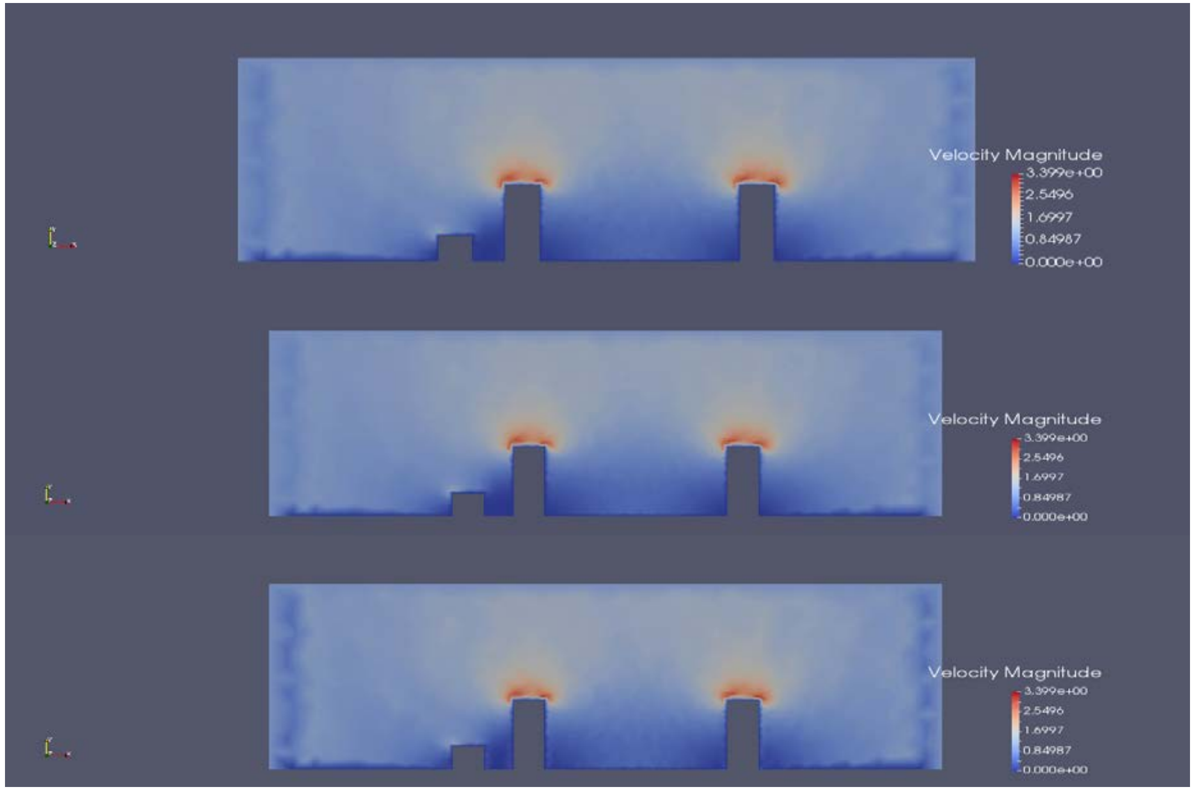
1) Test the EnKF for assimilating pseudo observations with a simple finite element fixed mesh model e.g. 2D street canyon (see video on RHS);

2) Assimilate wind tunnel data into urban air pollution model;

3) Optimize air pollution sensor placements over London site (about 1 km radius)

4) Assimilate air pollution data over London site in order to improve on the model

Video: EnKF assimilation of pseudo observations in street canyon: Model (top), truht (middle) and DA analysis (bottom)



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Sensors
MAGIC partners meeting

24th March 2017

Shiwei Fan

UNIVERSITY OF CAMBRIDGE

Imperial College London

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Shiwei Fan

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2016-present, Post-doc, University of Cambridge

- Indoor/Outdoor Sensor Networks for Model Validation and Improvement

2014-2016, Post-doc, Schlumberger Cambridge Research Centre, UK

- Fluids Group, Multiphase Flow Measurement and Characterisation

2011-2014, PhD, Cranfield University, UK

- Thesis: Characterisation and Measurement of Gas-Liquid Slug Flow in Pipes

2008-2011, MSc, Beihang University, China

- Instrumentation Science and Technology

2004-2008, BSc, Harbin Institute of Technology, China

- Measurement & Control Technology and Instrumentation

Sensor Unit Development

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14 cm

3 cm

9 cm

CO

NO$_2$

Pressure
Temperature
Relative Humility

CO$_2$

- Low-cost, lightweight, battery powered unit
- Trace gases, e.g. CO_2, CO, NO_2 and meteorological measurements

Sensor Network

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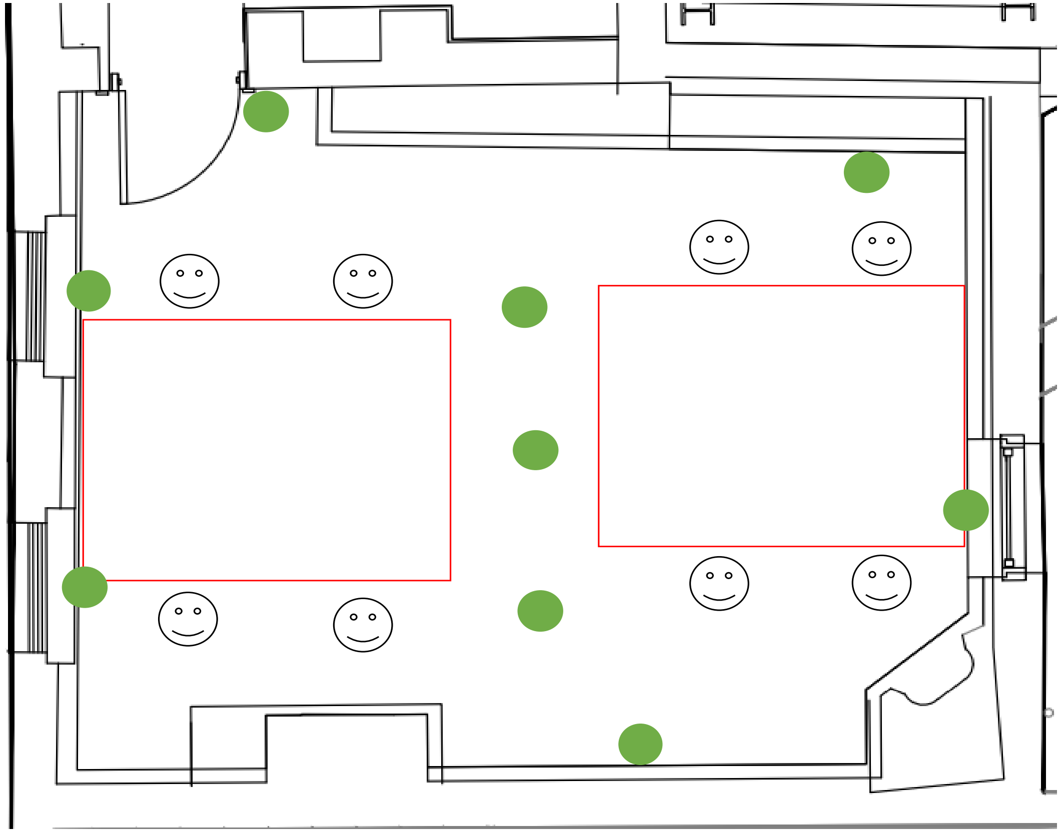
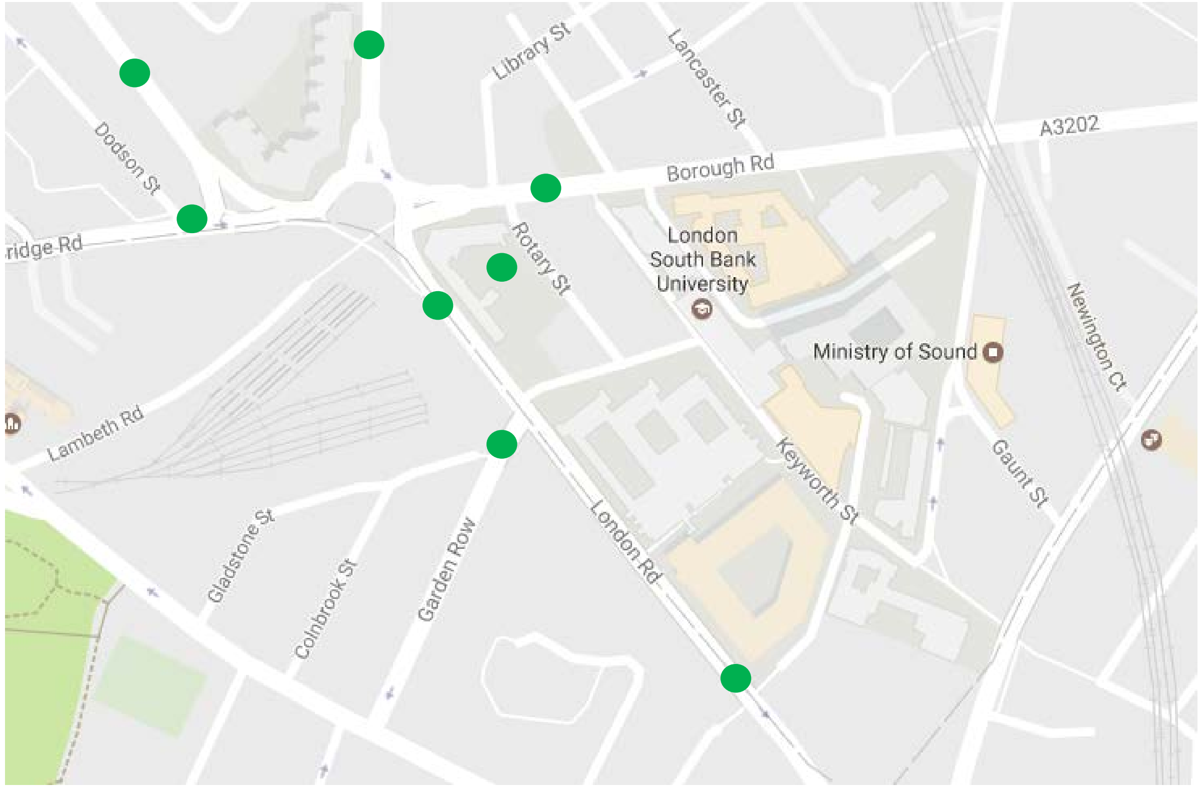


Indoor Sensor Network



Outdoor Sensor Network (Street, City)

- High temporal resolution and high spatial resolution

Data Processing

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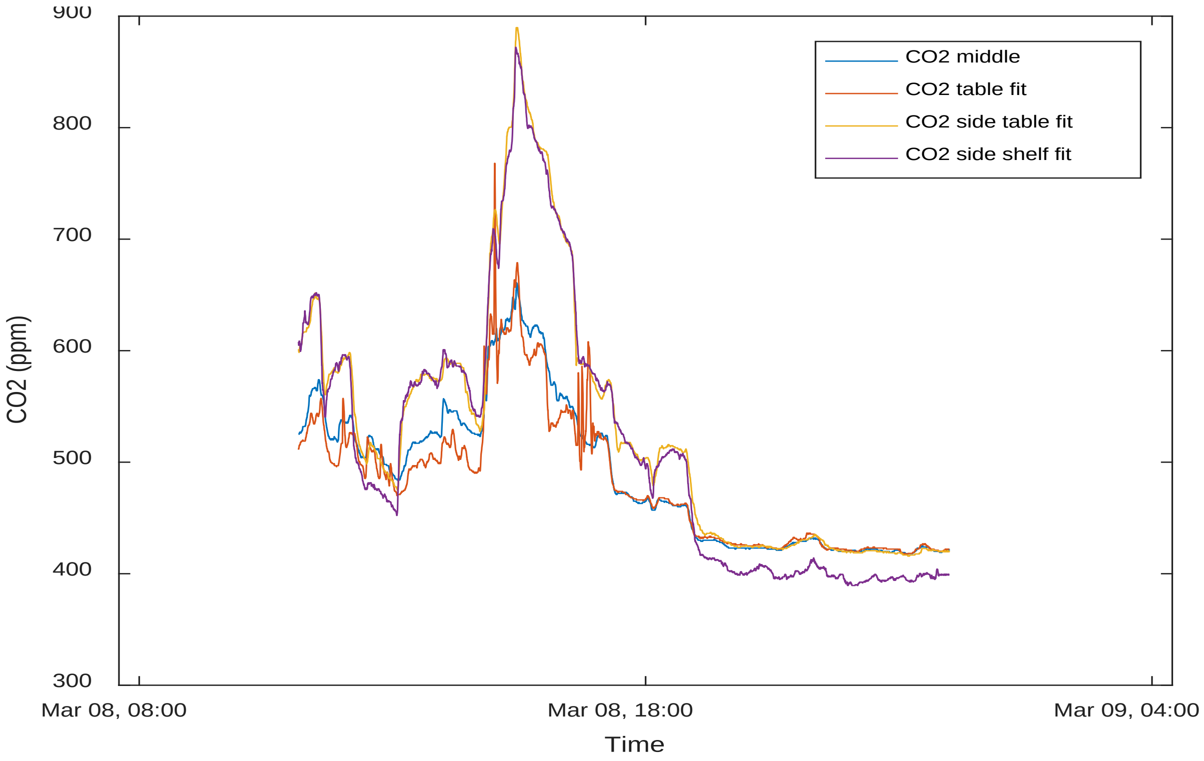
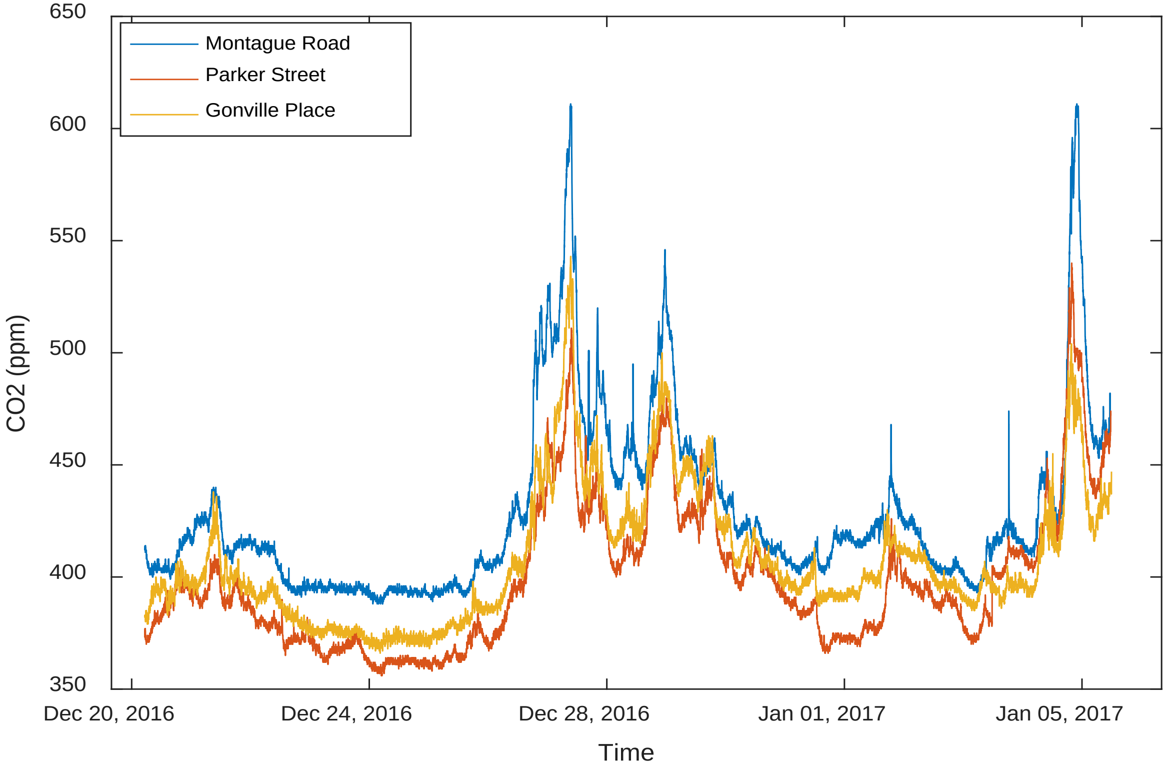


Indoor



Outdoor

- Extract parameters for model validation and improvement

Wind tunnel studies of pollutant dispersion at the Clarence Centre site in South London, UK

MAGIC Research Team at
www.magic-air.uk
Prof Alan G Robins, Dr David M Birch, Dr Matteo Carpentieri, Dr Paul Hayden, Dr Paul Nathan and Dr William E Lin

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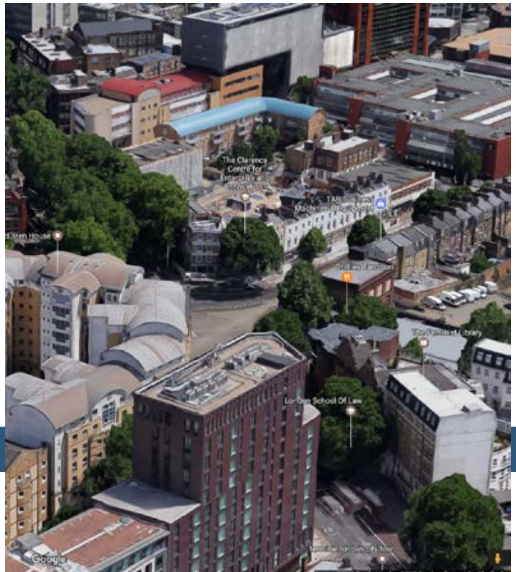
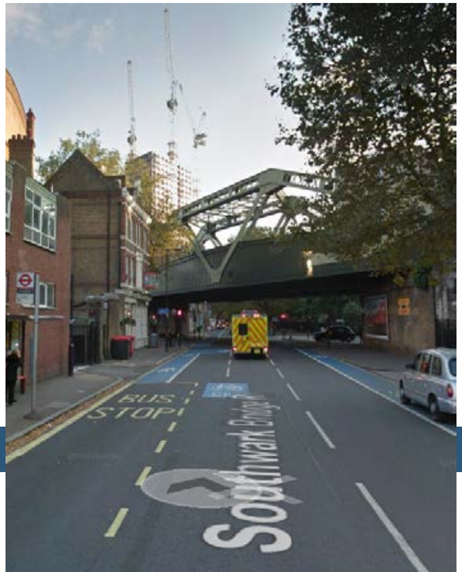
Extracting a simplified urban geometry

Site visit observations (15 Feb 2017)

Ordnance Survey GIS data
(BHA alpha release 17 Mar 2014)

Google Maps satellite and Streetview imagery (≈ Fall 2016)





Initial Model for Wind Tunnel

- Plan area within 300 m radius of St George's Circus obelisk
- Length scaling of 1:200
- Flat model buildings based on reported full-scale eave heights

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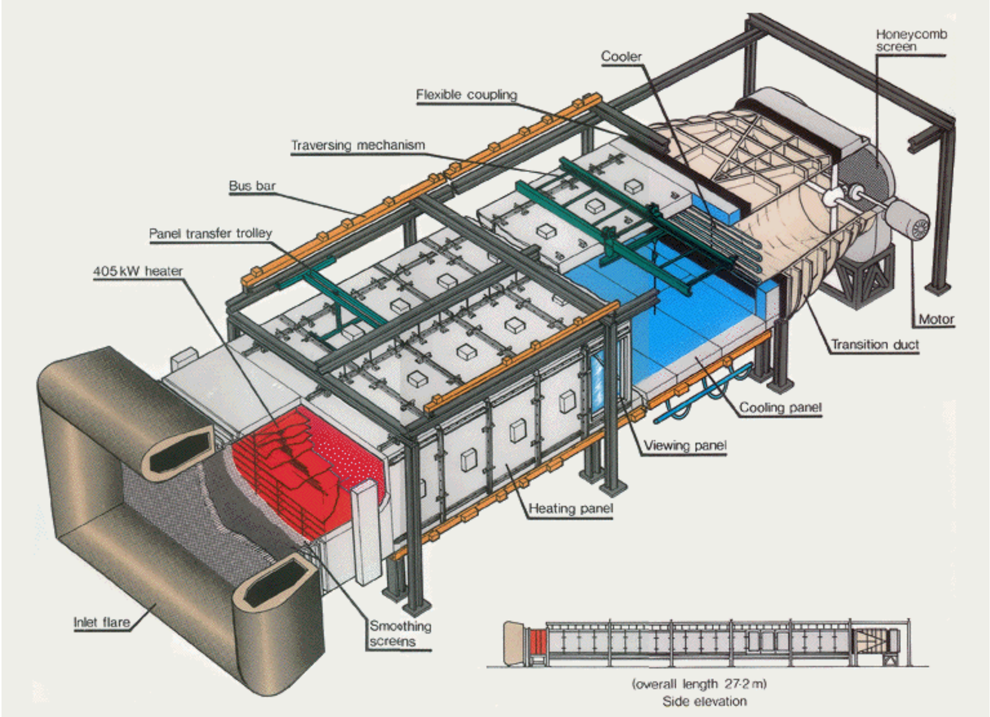
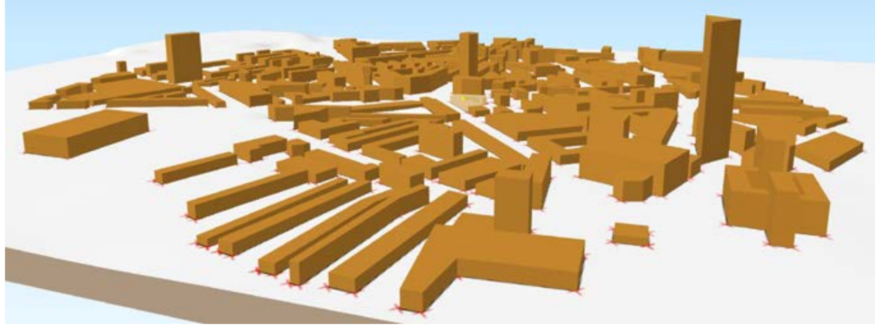
EnFlo wind tunnel & instrumentation

Neutral, stable or unstable boundary layer generation with flow and temperature control (Hancock *et al.* 2013; Marucci PhD 2018)

- Working section: 20 x 3.5 x 1.5 m (L x W x H)
- Air speed range: 0.5 to 2.5 m/s



- Carpentieri M, Robins A, Baldi S: *Bound-Lay Meteorol* 2009, 133:277–96.
- Carpentieri M, Hayden P, Robins AG: *Atmos Environ* 2012a, 46: 669–674
- Carpentieri M, Salizzoni P, Robins A, Soulhac L: *Environ Model Softw* 2012b, 37:110–124.
- Hancock PE, Zhang S, Hayden P: *Boundary-Layer Meteorol* 2013, 149:355–380
- Scaperdas A: PhD thesis, Imperial College, University of London 2000.



Carpentieri *et al.* 2012a

Building modelling

Flow visualization

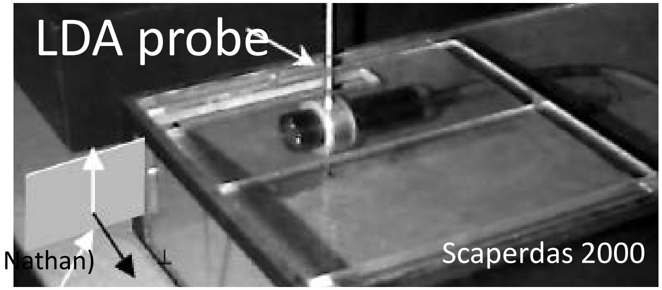
- Smoke-air tracer
- Laser light sheet

Carpentieri *et al.* 2009

Velocity measurement

- Laser Doppler Anemometry
- Particle Image Velocimetry
- Pressure-based velocity probes

(Surrey Fluid Sensor Development Initiative, goo.gl/iDh2lZ, Birch and Nathan)

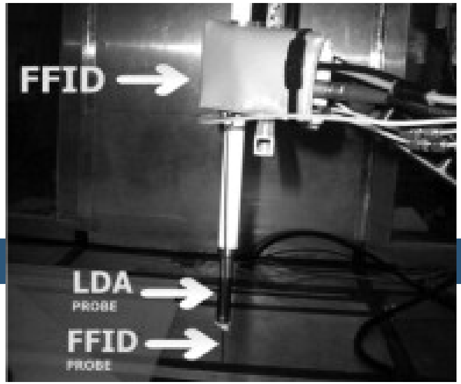


Scaperdas 2000

Pollutant emission and tracer concentration measurement

- Propane-in-air point source(s)
- Fast-response flame ionisation detection

(Carpentieri *et al.* 2012b)



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Non-intrusive Reduced Order Modelling methods For Rapid Air Flow and Pollution Modelling

Dunhui Xiao

MAGIC meeting,

University of Cambridge, 24, March

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Introduction of myself and my work

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- I am currently a research associate at Imperial College London.
- I did my PhD in AMCG supervised by Dr Fang and Prof Pain, Imperial College London on Non-intrusive reduced order modelling and their applications eg fluids, fluids-solids coupling, multiphase problems.

Motivation of ROM

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Full physics models can represent the fluid dynamics but have millions of degrees of freedom (up to $10^8 - 10^9$).

- Not feasible to run 100s or 1000s of runs for
  - production optimisation and history matching
  - data assimilation (hundreds or thousands of runs)
  - optimization of processes.
  - real-time operation and emergency response.

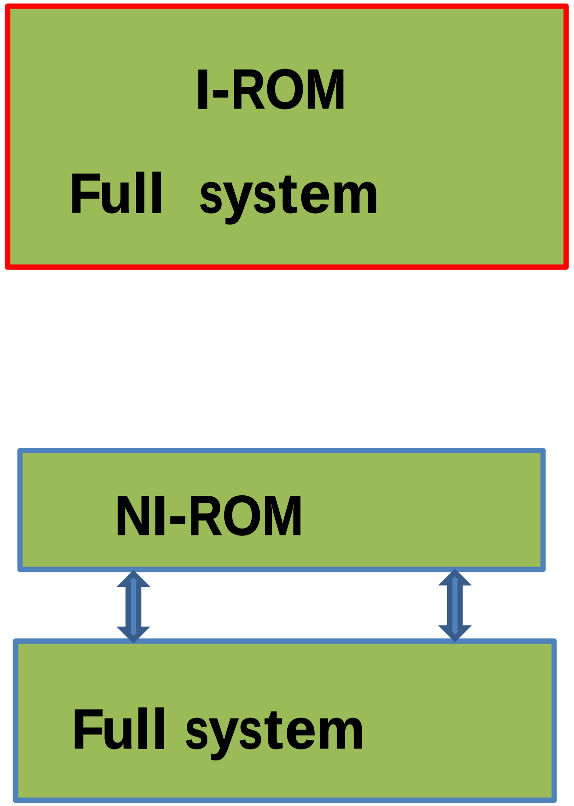
- Need an approximate model which
  - can represent the dominant flow dynamics accurately
  - are fast

Intrusive and Non-intrusive ROM

Intrusive ROM:

•*Integrated with full physics model and source code.*

- ➢Closer to the full physical system.
- ➢Difficult to implement, modify and extend.
- ➢Stability and non-linear inefficiency issues.



Non-intrusive ROM:

• *independent of the full physical system and the source code.*
easy to implement, modify and extend.

What I have done on MAGIC

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1. Developed a new domain decomposition non-intrusive reduced order model DDNIROM.

2. Applied DDNIROM to a number of benchmark problems e.g. street canyon case.

3. Make DDNIROM and NIROM work for simulations with parallel cores.

4. Applied to LSBU test area.

Developed a new domain decomposition non-intrusive reduced order model

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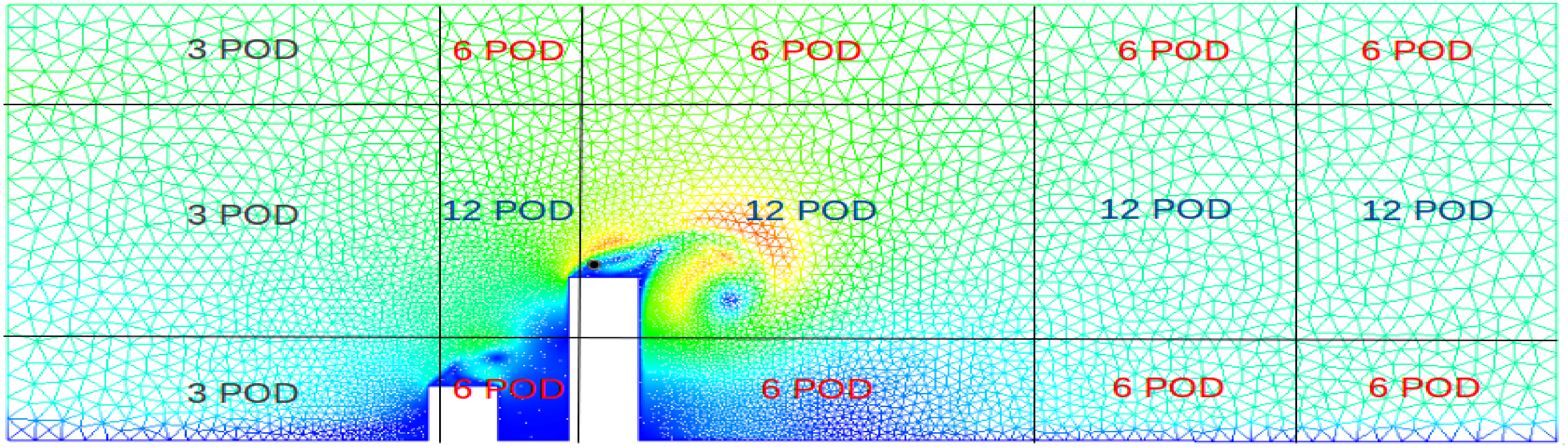

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Left: NIROM with 48 POD, right: full model