#### Managing Air in Green Inner Cities (MAGIC)



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#### Overview

- Introduction to MAGIC
- EnFlo facilities
- London modelled at two scales
- MAGIC-DAPPLE comparisons
- Study of model detail and extent
  - Effect of traffic-induced flow
  - **Conclusions Future plans**



#### MAGIC Southwark site London

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# MAGIC

Envisaging a world with greener cities

### Project background and objectives

- EPSRC Grand Challenge Project, 2016 2020
- To promote natural ventilation in urban areas

 Develop 'practical' high fidelity prediction methods for outdoor and indoor conditions





Imperial College London





### The MAGIC Circle of activities



Outdoor condition --- Indoor condition

ADMS: Urban flow model DA: Data Assimilation ROM: Reduced order model Energy+: EnergyPlus

- (1) Outdoor boundary conditions
- (2) Comparison of indoor temperature and pollutant concentration
- (3) Comparison of outdoor tracer gas concentration
- (4) Comparison of profiles of indoor temperature
- (5) Incorporate sensor data into models for increased accuracy of predictions
- (6) Improved accuracy of ROM predictions
- (7) Comparison of outdoor velocity field and tracer gas concentration distribution
- (8) Comparison of indoor tracer gas concentration distribution
- (9) Comparison of outdoor pollution



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#### Wind tunnel work objectives

- Provide boundary conditions for EnergyPlus and Fluidity
- Provide detailed data in controlled conditions for model development and evaluation
- Develop underlying knowledge
  - physics
  - sensitivities



## The EnFlo Meteorological wind tunnel



Working section:  $3.5 \text{ m} \times 1.5 \text{ m} \times 20$ m  $(W \times H \times L)$ 

Wind speed range: 1.0 to 3.0 ms<sup>-1</sup>

Heating and cooling for stable/unstable BL flow simulation



### Velocity measurement u-v / u-w





#### Laser Doppler Anemometry (LDA): Pointwise time-resolved sampling of two air velocity components



#### Concentration measurement



Fast Flame Ionization Detection (FFID): Pointwise time-resolved sampling of hydrocarbon tracer concentration ~200Hz





### Surface pressure measurement



#### Velocity, concentration and pressure fields



Time-averaged P-P<sub>ref</sub> (WT300s mean; Pa) at met240°; biharmonic spline interpolation



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#### London model at two scales

1:500 Scale Lower blockage Ease of Modification

1:200 Scale Better access for probes



- Derived from Ordnance Survey maps, aerial images and site visits
- Base model of 160 buildings with flat roofs at eaves height

#### Concentrations at two scales





## Dispersion of Air Pollution & its Penetration into the Local Environment (2002-2010) DAPPLE





# Comparison with DAPPLE (2002-2010)



Dimensionless concentrations 15  $C^* = CU(h)h^2/Q$ 



#### Effect of model extent on street canyon

#### 4 cases with varying neighbour extent 1 case with height-based criterion



4 measurement

planes in street

#### Model detail – Roofs





#### Upwind dispersion - effect of moving vehicles



Vehicle passes through pollutant cloud at t = 0. Then by analogy with building wake theory:

$$\frac{dC}{dt} \sim \frac{C}{T} \quad \vartriangleright \quad C = C_o e^{-\frac{t}{T}}$$
  
and

$$T \sim \frac{h}{U+V}$$
  $\triangleright$   $L = TV \sim \frac{V}{U+V}h$  O National Centre for  
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#### Extent of traffic-induced upwind spread



Canyon cross-section 100mm high x200mm wide Block 160x72(h)x40 mm

#### Conclusions

- EnFlo wind tunnel fully automated system including simultaneous velocity, pressure, concentration measurement
- Practical to use models at range of scales to further different aspects of experimental programme
- Comparisons with previous DAPPLE work show a degree of similarity in dispersion behaviour
- Vehicle motion can generate significant upwind dispersion.





#### c-u-p correlations, isolated building

More sensitivity studies

Upwind dispersion



#### Future Plans

#### Non-Neutral Stability

Marucci, D., Carpentieri, M., & Hayden, P. (2018) International Journal of Heat and Fluid Flow, 72, 37.



#### Thank you for your attention



# Effect of model extent on street canyon flow

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# Effect of model extent



Summarise effects of model extent - % changes from Williams table ...

Added eight buildings and railway viaduct at southeast periphery

Explored channeling effect of railway underpasses

Summarise conclusions from 1:500 scale work No significant change in scatter as seen in previous slide



#### Future plans



## Conclusions

- EnFlo wind tunnel fully automated system including simultaneous velocity, pressure, concentration measurement
- Comparisons with previous DAPPLE work show a degree of similarity in dispersion behaviour
- Sensitivity studies need further experiments and comparisons with DAPPLE results
- Practical to use models at range of scales to further different aspects of experimental programme
- Pressure-concentration-velocity correlations need to be investigated for isolated building
- Vehicle motion can generate significant upwind dispersion.



#### Velocity, concentration and pressure fields

What is the correlation between fluctuating concentrations and pressure on a building surface and local wind speeds?

Results from Clarence Centre and full model are complex and inconclusive.

Need to study building in isolation



# Wind tunnel experiments in a street canyon

