The DAPPLE Dispersion Project: Comparison of full scale and wind tunnel experiments with CFD

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Acknowledgements to:
DAPPLE Consortium members
John Lally, Westminster City Council, BT
Urban pollution dispersion depends on complex flow patterns around streets and intersections.
London-based research projects

DAPPLE (2002-2009) – street level dispersion
REPARTEE (2006-2007) – vertical pollutant distribution
ACTUAL (2009-2014) – building design interactions with urban climate at a range of scales
ClearfLo (2010-2013) – air quality at city scale
DAPPLE I (2002-06) Main Activities

- Traffic movement
- Emissions
- Pollutant monitoring (CO, NOx, CO2...)
- Wind and meteorology
- Urban tracer studies (3xPFCs, SF6)
- Wind tunnel modelling
- Computer modelling (LES -> empirical)
- Personal exposure rate measurement (location, CO, fine particles)
- Analysis -> Practical outputs -> knowledge transfer

Consortium leader: Prof Alan Robins, Uni of Surrey
Reading, Leeds, Imperial, Bristol, Cambridge

www.dapple.org.uk
Thanks to Steve Evans, UCL

Regents Park

Roof-top site

BT Tower

Marylebone Road

1.6 km
2004 campaign
BT Tower NE wind direction

Roof-top reference $U_H$
DAPPLE 2004 tracer release

Release: 2m, 15 min. 2 from X1.

Samples: 1.5m, 30 min
- 15: inside WCC
- 13: rooftop, 14: street (1.5m)
DAPPLE wind tunnel work (Prof Alan Robins, EnFlo)

- Scale 1:200
- Reference wind speed: $U_r = 2.5\text{m/s}$
- Extensive tracer releases, flow measurements
Three DAPPLE CFD studies

Panagiotou I, Neophytou MKA, Hamlyn D, Britter RE (2013) City breathability as quantified by the exchange velocity and its spatial variation in real inhomogeneous urban geometries, STOTEN, 442, 466-477


Panagiotou et al. 2013 – set-up

- RANS (FLUENT), with Reynolds Stress Turbulence model (permits anisotropic turb typical in obstacle wakes)
- 1:200 model; average building height $H= 0.11\text{m}$,
- Packing densities $\lambda_f = 0.25$, $\lambda_p = 0.5$
Panagiotou et al. 2013 – streamwise windspeed

- $z = H/2$
- $z = H$
- $z = 2H$
Panagiotou et al. 2013 – particle visualisation

- Exchange of air between street and flow above
- Building scale vortices combined with along street channelling
Xie and Castro 2009 – set-up

- Polyhedral mesh (nearwall H/15, c. 1m)
- Inlet:
  Digital filter inlet condition, realistic lengthscales (Xie and Castro 2008);
  Wind and stress profile matching windtunnel;
  Periodic bo. co.’s did not give accurate results!
Separation not captured using $k-\varepsilon$ (not shown)
• Excellent agreement with windtunnel
• RANS overestimates street level concentrations
Xie 2011 “Modelling street-scale flow and dispersion in realistic winds – towards coupling with mesoscale meteorological models”

- Deriving realistic, large-scale varying inlet conditions using observed winds on BT Tower
Inlet varies according to varying wind direction
Xie 2011 – BT Tower wind data

- 15 min tracer release at fullscale from 16:30
- 30 min sample from 16:30 to 17:00
- 10 Hz data in 30 second averages from BT Tower

Fig. 6  30-s averaged wind magnitude $U$ and direction $\theta$ (bearing clockwise to the Marylebone-Rd direction, i.e. $x_1$ in Fig. 1) at the BT Tower top with a mark indicating 15-min release duration
Xie 2011 – tracer concentrations
Xie 2011 tracer distribution

- Contours of 30min averaged concentration
- c) 30min averaged data
- d) 30 sec averaged data
London-based research projects

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Mesoscale modelling

• Regional and city scale flow causes low frequency perturbations

• Numerical Weather Prediction (NWP) models

• Grid typically 12, 4, 1.5km

• 25th July 2012, 19:00 – sea breezes cross London
Vertical velocity at 293m

Unified Model, 100m grid resolution

LES mode

Urban surface heat flux parameterization

Enhanced roughness

Thanks to Humphrey Lean, UK Met Office
ACTUAL: observing flow at range of scales

BT Tower at 190 m

Doppler lidar 90 m < z < 2000 m

BARLOW et al. 2011 ACP
BARLOW et al. 2014 EFM
WOOD et al. 2010 BLM
LANE et al. 2013 JWEIA
DREW et al. 2013 JWEIA

NEW urban sodar <200m

KCL: Scintillometers (various heights)

PAUSCHER et al. 2012 ICUC8 poster (KCL)
BARTLOW et al. 2009 BLM

Roof top at ~20m

WOOD et al. 2012 STOTEN
Potential temperature

Wind-speed

- Met Office Operational UKV model
Potential temperature

Wind-speed

21:00
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Thanks to
Hannah Gough
PhD student @ Reading
Refresh CFD simulations... work in progress

Thanks to Marco-Felipe King, PDRA @ Leeds
Conclusions

• LES reproduces unsteady urban turbulence well – pay attention to inlet conditions!
• Current mesoscale model capability reasonably good at capturing city flow features above building height
• Combination of windtunnel and fullscale observations powerful
• Next step: analyse impact of all flow scales on ventilation

Please visit www.actual.ac.uk to see more London data!

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