VALIDATION OF GAUSSIAN MODELS USING WIND TUNNEL EXPERIMENTS AND NUMERICAL SIMULATION

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Introduction

Atmospheric dispersion of odorous compounds

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Odour Dispersion Modelling

Important aspects:

- Low average concentration levels (below detection threshold)
- Impact due to short concentration peaks (few seconds)
- Averaging time
- Peak-to-Mean ratio (P/M)
- Intermittency

Pollutant dispersion studies usually employ long averaging times (1 hour and up)

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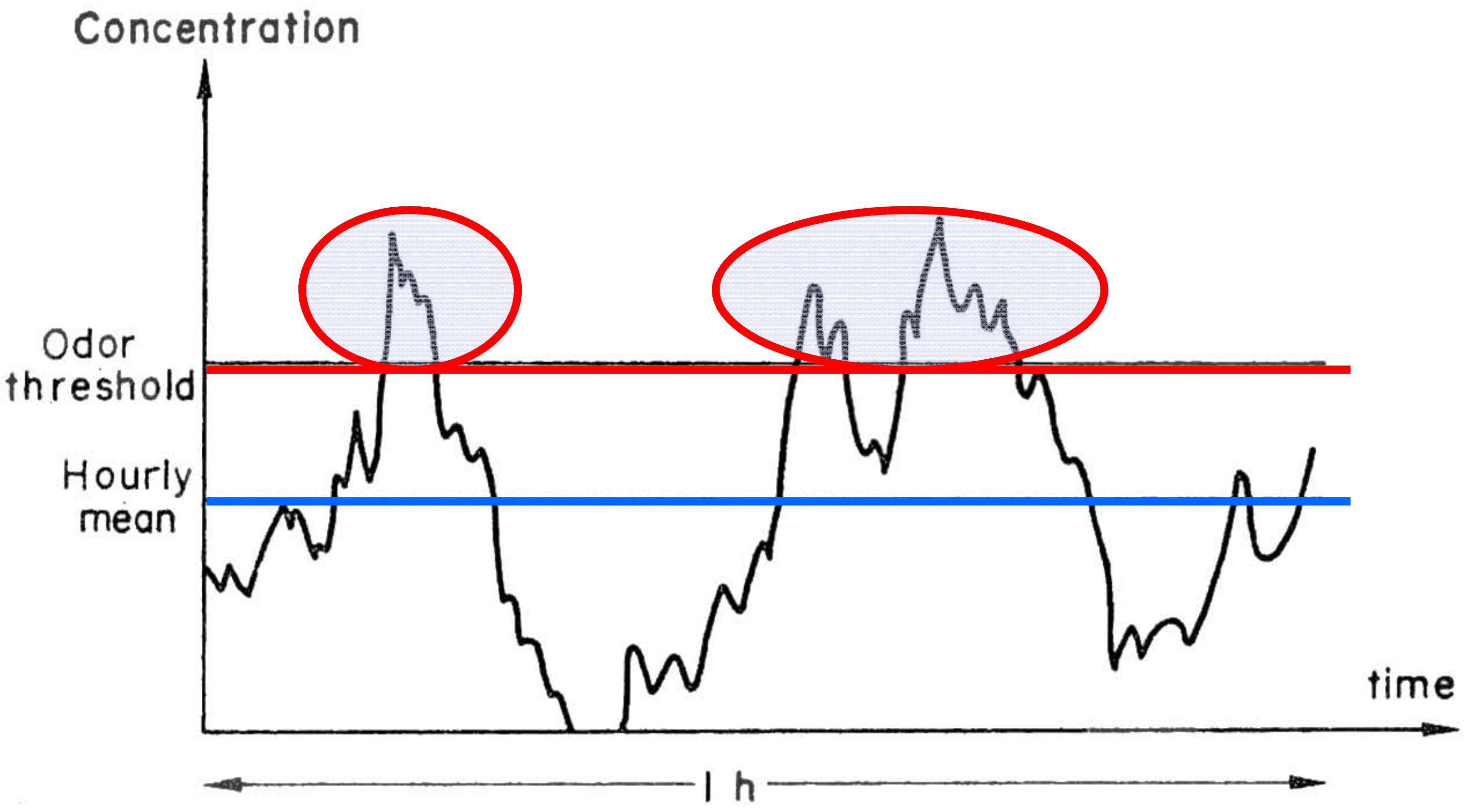
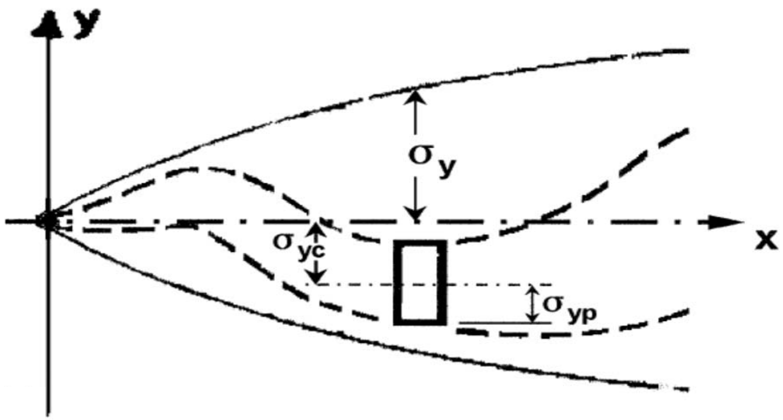
Odour Dispersion Modelling



Högström, 1972

The Fluctuating Gaussian Plume Model

- Plume spreading is the result of meandering and dispersion and both processes are described through Gaussian distributions (Gifford, 1959)



(Mussio *et. al*, 2001)

$$\sigma_y^{\ 2} = \sigma_{yp}^{\ 2} + \sigma_{yc}^{\ 2}$$

$$\sigma_z^{\ 2} = \sigma_{zp}^{\ 2} + \sigma_{zc}^{\ 2}$$

The Fluctuating Gaussian Plume Model

$$\sigma_y^{\;2} = \sigma_{yp}^{\;2} + \sigma_{yc}^{\;2}$$

$$\sigma_z^{\;2} = \sigma_{zp}^{\;2} + \sigma_{zc}^{\;2}$$

- σ_y and σ_z are the usual gaussian dispersion parameters, called **long term parameters**;
- σ_{yp} and σ_{zp} are the plume segment dispersion parameters, calculated by Högstrom (1972) expressions;
- σ_{yc} and σ_{zc} are the standard deviation of each plume element centroid position and are obtained from the above equations;
- σ_{yp}, σ_{zp}, σ_{yc}, σ_{zc} are called the **short-term parameters**.

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The Fluctuating Gaussian Plume Model

The FPM model can be an useful tool for odour dispersion modelling:

- Estimation of the Peak-to-mean concentration ratio;
- Intermittency factor;
- Frequency of occurrence of odour events;

$$P/M = \frac{C_p}{C_M}$$

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The Fluctuating Gaussian Plume Model

The FPM model Can be an useful tool for odour dispersion modelling:

- Estimation of the Peak-to-mean concentration ratio;
- Intermittency factor;
- Frequency of occurrence of odour events;

Percentage of time during which the concentration stays above a defined threshold (Aubrun & Leitl, 2004)

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The Fluctuating Gaussian Plume Model

The FPM model Can be an useful tool for odour dispersion modelling:

- Estimation of the Peak-to-mean concentration ratio;
- Intermittency factor;
- Frequency of occurrence of odour events;

Probability of exceeding a defined odour intensity (Yu et al., 2011) or histogram of the distribution of odour events of different intensities at a recptor (Murray et al., 1978; De Melo Lisboa et al., 2006)

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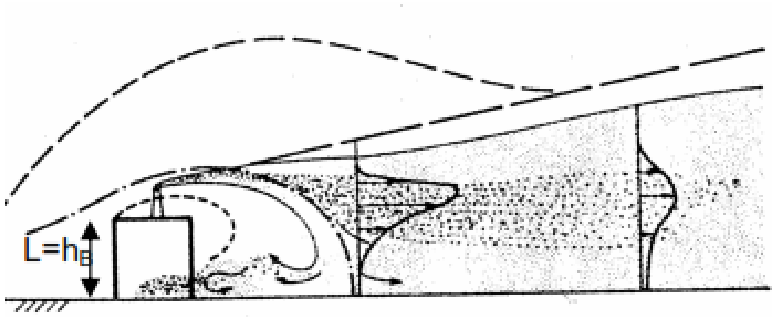
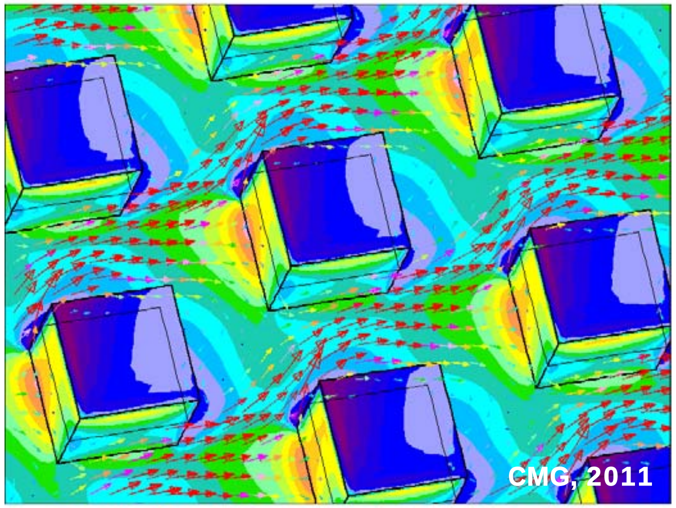
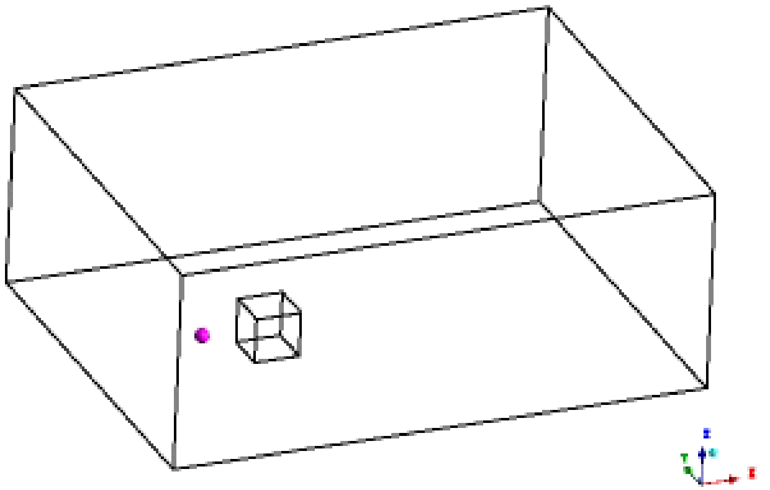
Urban area dispersion



Meroney, 1982





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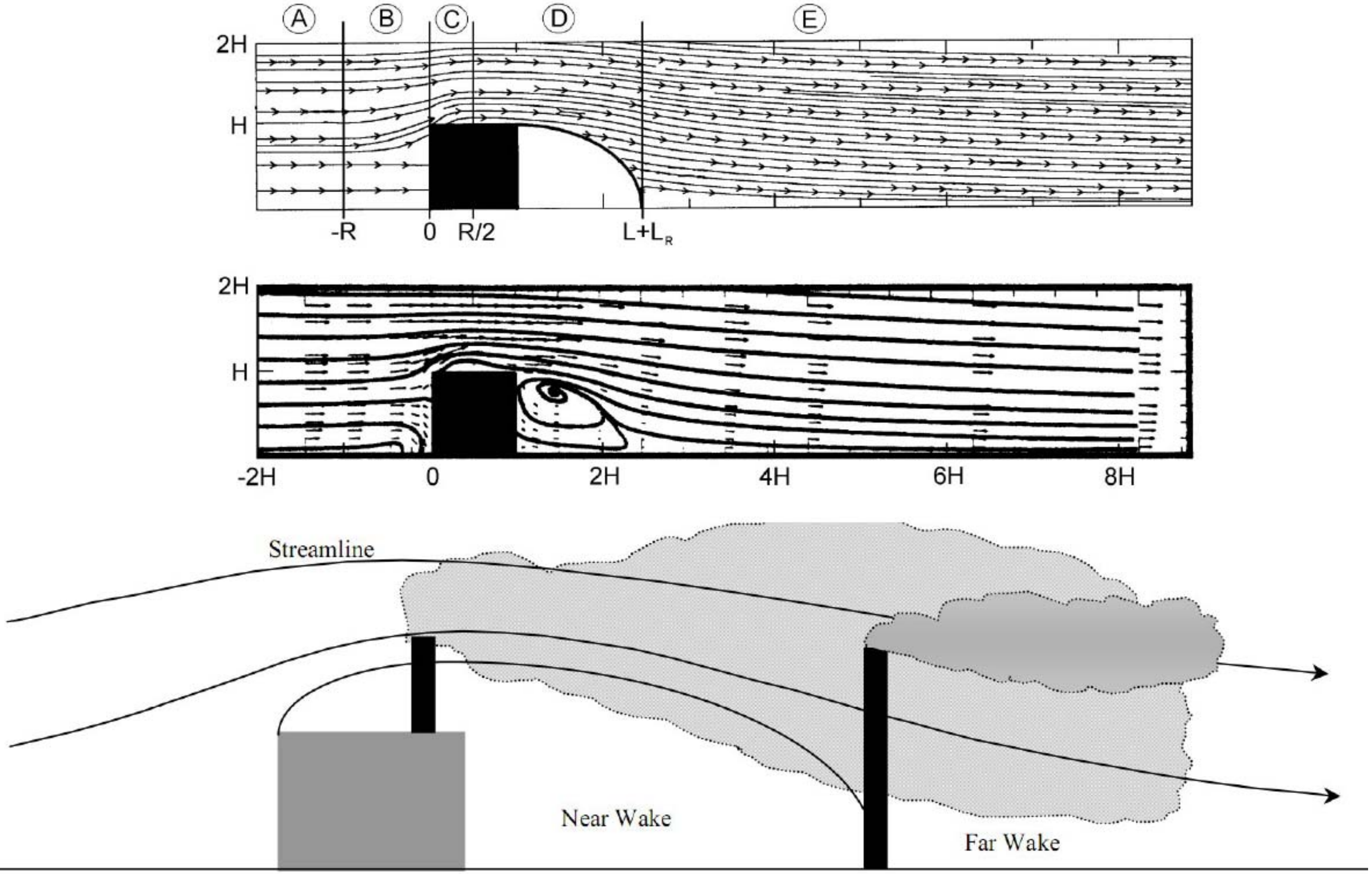
The PRIME Model

- The PRIME model (Plume Rise Model Enhancements), incorporates the effect of plume elevation and downwash due to buoyancy and the presence of obstacles (Schulman et al., 2000);
- Developed based on experimental observations of field and wind tunnel experiments;
- Currently used both in AERMOD and CALPUFF regulatory models (Cimorelli et al., 2004; Scire et al., 2000).

The PRIME Model



The FPM-PRIME Model

- Incorporates the concept of the fluctuating plume and the effect of streamlines deflection due to the presence of an obstacle in the plume trajectory;
- The growth rate of the long-term dispersion parameters is determined using the PRIME method and the short term parameters (σ_c and σ_p) are calculated based on Gifford (1959) proposition and on Högstrom (1972) methods;

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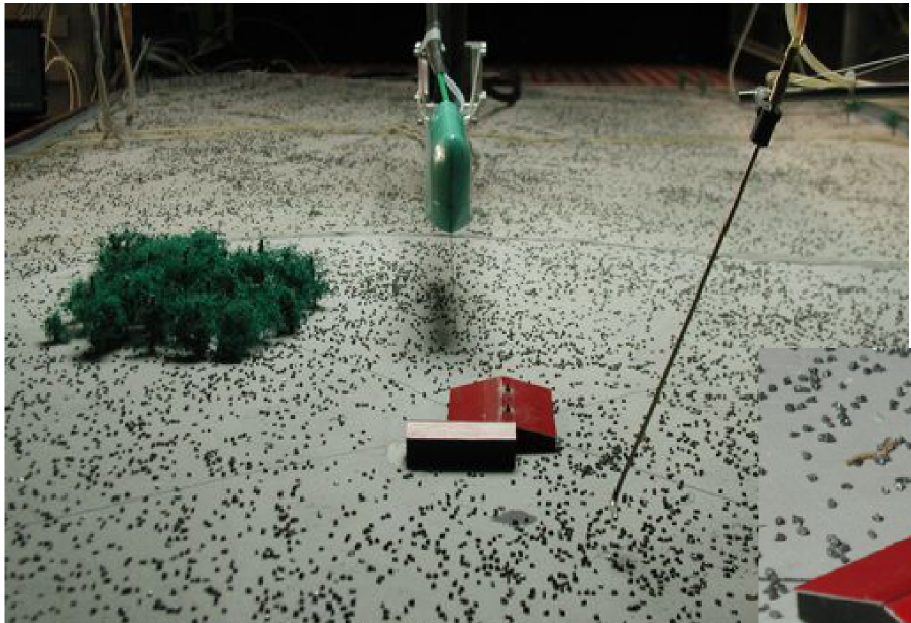
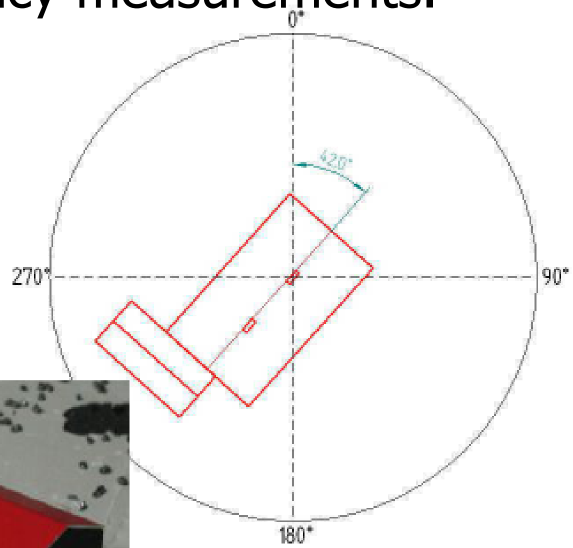
Wind tunnel experiment

(Aubrun and Leitl, 2004)

- Wind tunnel experiments, 1:400 scale;
- Tracer gas emitted from a stack at the top of a pig barn model;
- Average concentration and intermittency measurements.

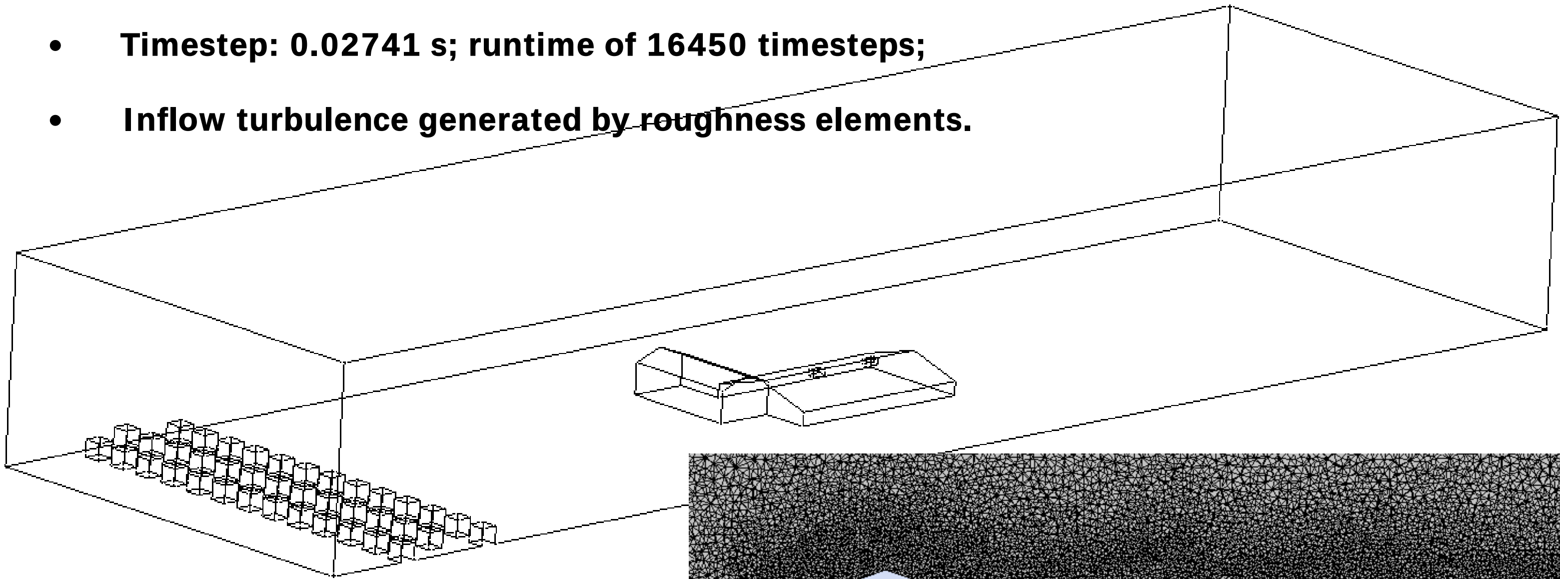


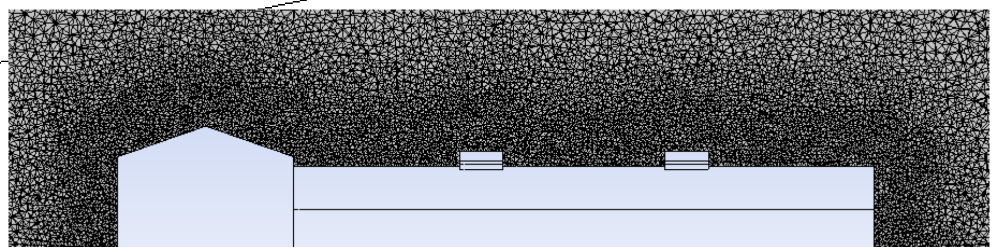


(CEDVAL, 2006)

LES simulation

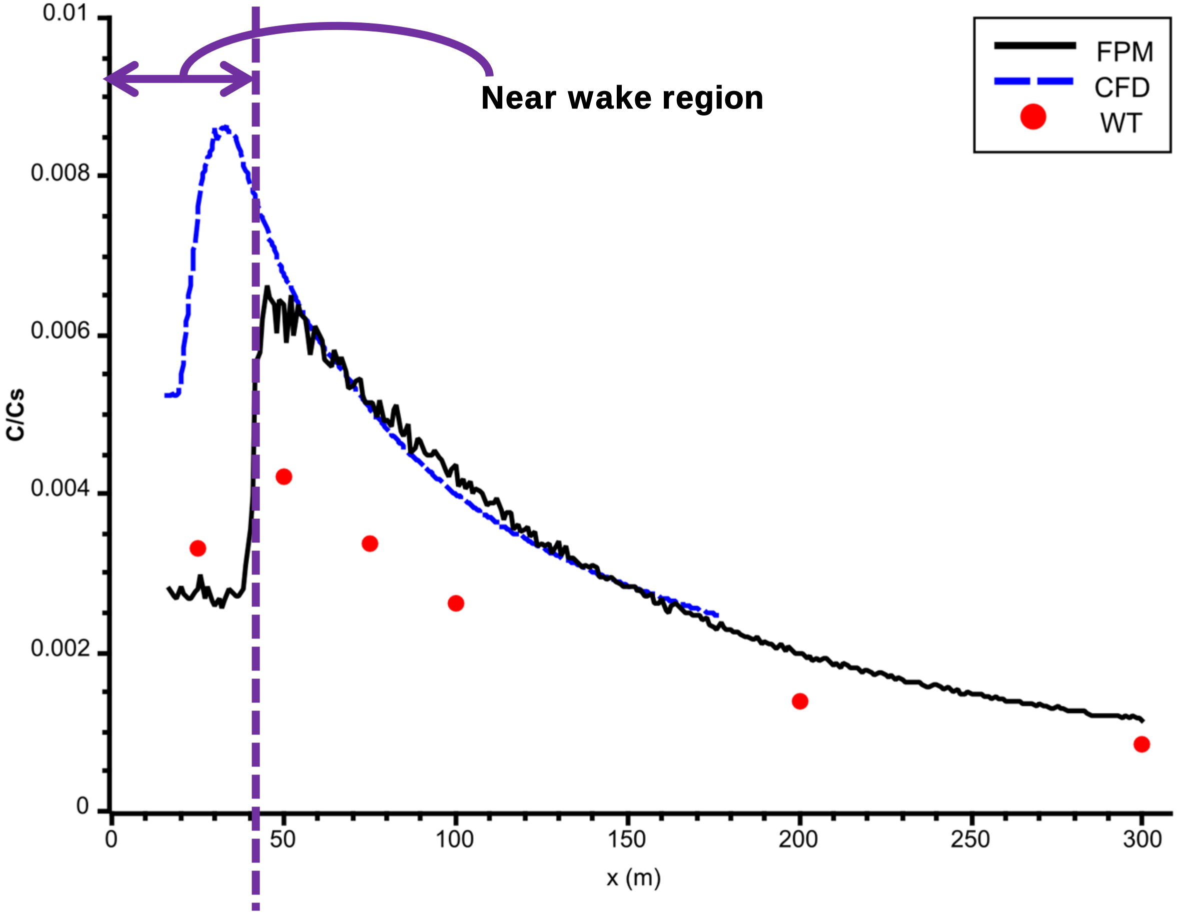
- Model: complex obstacle, H = 8.8 m (height);
- Domain: 45H, 13H and 6H;
- Source located upwind 25H of domain entrance;
- Non-structured tetrahedrycal mesh, finer resolution about H/32;
- >5.23 million nodes;
- WALE sub grid model;
- Timestep: 0.02741 s; runtime of 16450 timesteps;
- Inflow turbulence generated by roughness elements.





Results

- Downwind average concentration for a receptor located 1.6 m above ground (y=0).



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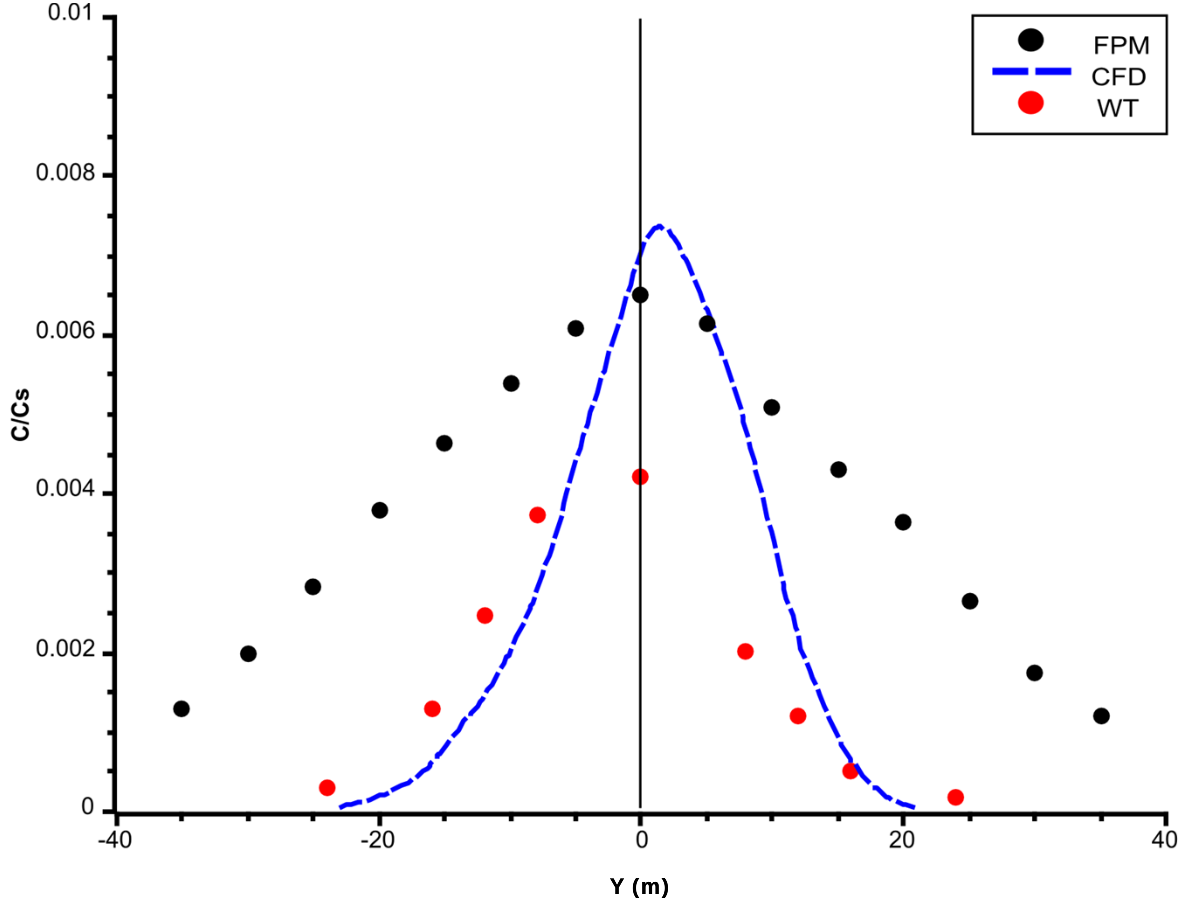
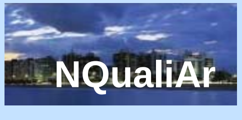
Results

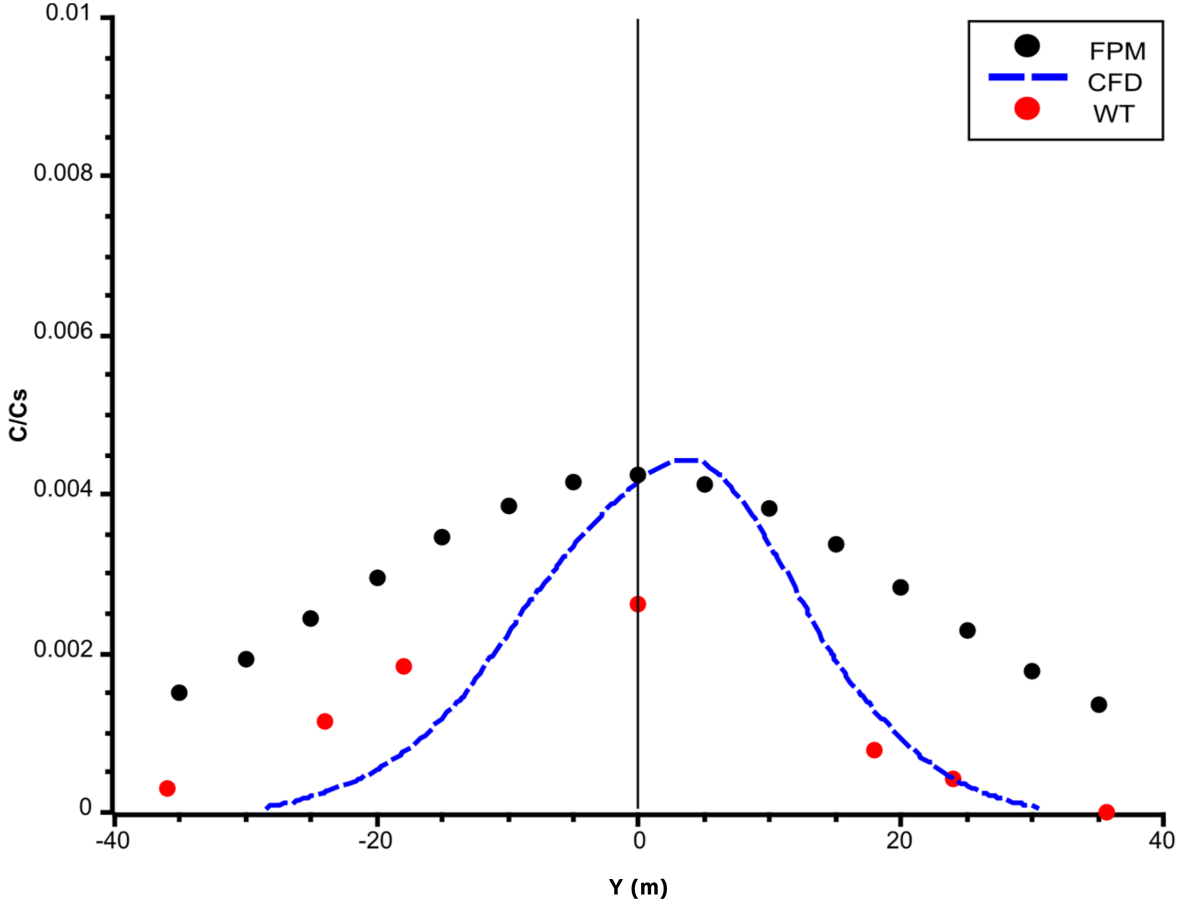
- Lateral average concentration for a receptor located 1.6 m above ground at x=50 m form the source.





Results

- Lateral average concentration for a receptor located 1.6 m above ground at x=100 m form the source.



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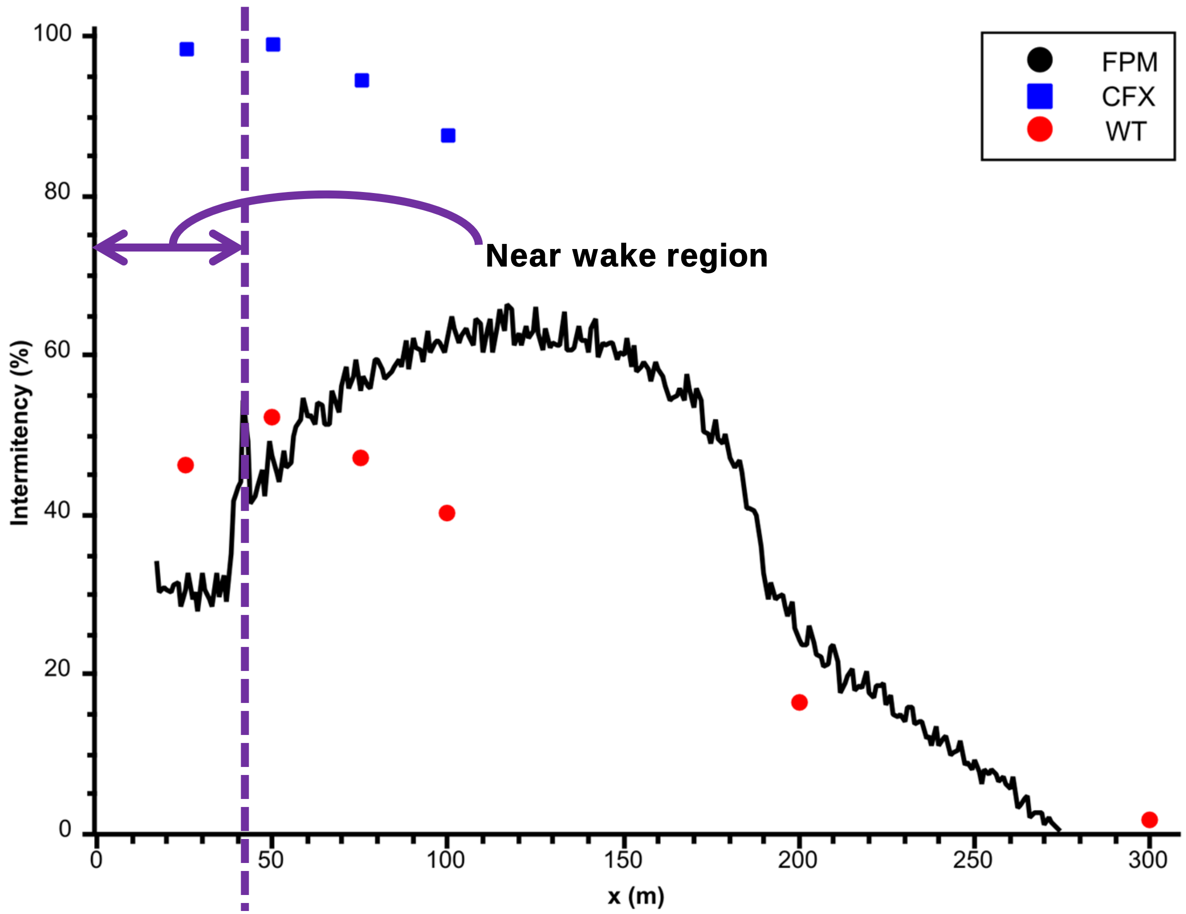
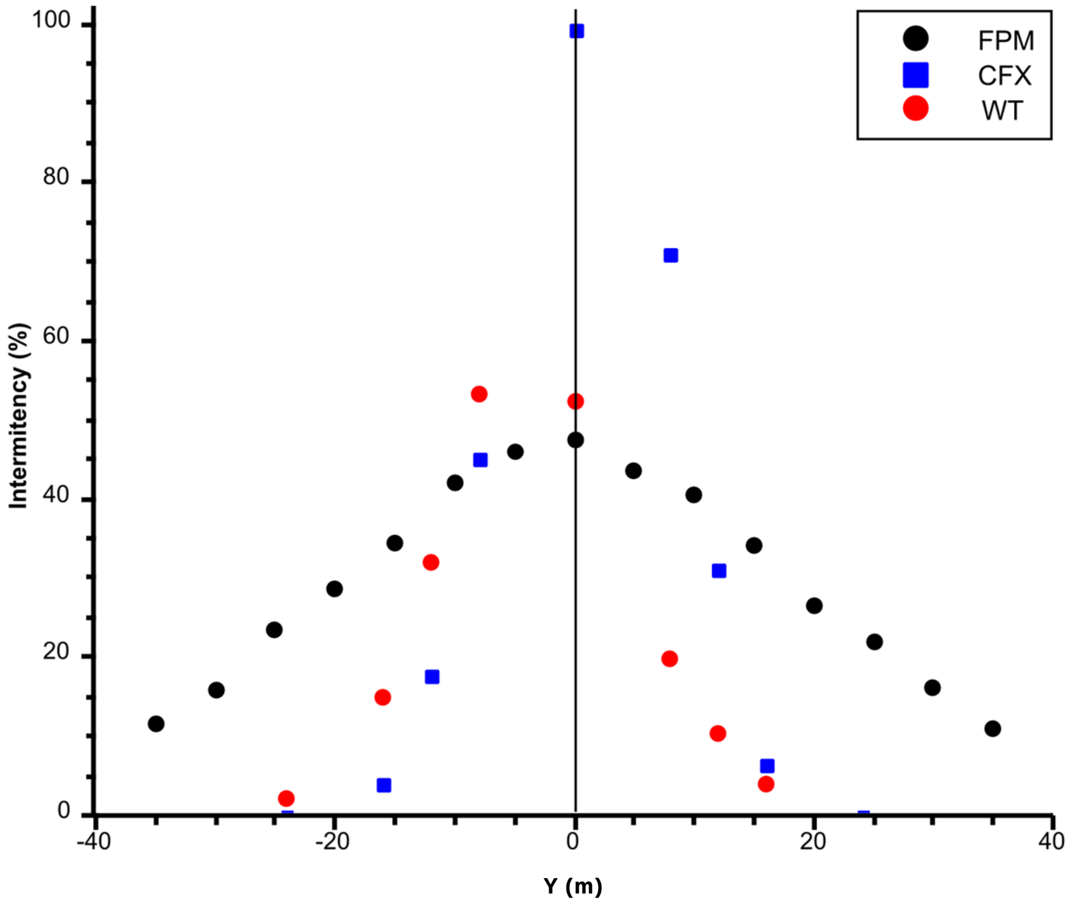
Results

- Downwind intermittency for a receptor located 1.6 m above ground (C_{thresh} = 0.25% C_s).



Results

- Lateral intermittency for a receptor located 1.6 m above ground at x=50 m form the source (C_{thresh} = 0.25% C_s).



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Conclusion

- Good agreement between FPM, LES and FPM for the downwind average concentration – results within an order of magnitude;
- FPM overpredicted lateral average concentration distribution; LES and WT with good agreement;
- Results suggest FPM is a viable tool for odour dispersion modelling in the presence of obstacles;

Thank you for your attention

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