VALIDATION OF GAUSSIAN MODELS USING WIND TUNNEL EXPERIMENTS AND NUMERICAL SIMULATION

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Introduction

Atmospheric dispersion of odorous compounds
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)
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)

\[
\sigma_y^2 = \sigma_{yp}^2 + \sigma_{yc}^2
\]

\[
\sigma_z^2 = \sigma_{zp}^2 + \sigma_{zc}^2
\]

(Mussio et al, 2001)
The Fluctuating Gaussian Plume Model

\[ \sigma_y^2 = \sigma_{yp}^2 + \sigma_{yc}^2 \]
\[ \sigma_z^2 = \sigma_{zp}^2 + \sigma_{zc}^2 \]

- \( \sigma_y \) and \( \sigma_z \) are the usual gaussian dispersion parameters, called long term parameters;
- \( \sigma_{yp} \) and \( \sigma_{zp} \) are the plume segment dispersion parameters, calculated by Högstrom (1972) expressions;
- \( \sigma_{yc} \) and \( \sigma_{zc} \) are the standard deviation of each plume element centroid position and are obtained from the above equations;
- \( \sigma_{yp}, \sigma_{zp}, \sigma_y, \sigma_z \) are called the short-term parameters.
The FPM model can be a useful tool for odour dispersion modelling:

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

\[
P/M = \frac{C_P}{C_M}
\]
The FPM model can be a 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)
The FPM model can be a 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 receptor (Murray et al., 1978; De Melo Lisboa et al., 2006)
Urban area dispersion

Meroney, 1982
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 PRI ME Model
The FPM-PRI ME 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 ($\sigma_c$ and $\sigma_p$) are calculated based on Gifford (1959) proposition and on Högstrom (1972) methods;
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.
LES simulation

- Model: complex obstacle, $H = 8.8$ m (height);
- Domain: 45H, 13H and 6H;
- Source located upwind 25H of domain entrance;
- Non-structured tetrahedral 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).
Results

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

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

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

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