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vision on technology

Dispersion parameters in a wind tunnel and in the field: analysing Thompson's 1991 wind tunnel data for isolated stacks with IFDM and its application to building downwash modelling

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INTRODUCTION

We want formulae for the ground-level concentrations at short distances from buildings for plumes subject to building downwash.

These concentrations should be accurate enough to allow for reverse modelling.

Steps towards goal

1) Literature: state of art:

Gaussian models: PRIME / OML …
problem: poor performance at near building distance

CFD models: Miscam, Envi-met, …
☺: better looking concentration profiles
problem: too much computer resources
question: scaling with the field

2) Do it yourself:
Steps:

A) identify reference data-sets:
Thompson (1991) wind-tunnel

B) reproduce concentrations for isolated stacks in wind-tunnel

C) compare wind-tunnel dispersion with dispersion in the field (of interest)

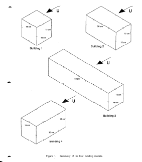
D) investigate whether a combination of ground-level concentration profiles from isolated stacks can reproduce these of a building down-wash plume.

A: Thompson's (1991) US-EPA Wind-Tunnel Data

- Measurements of ground-level centreline concentration profiles for 350 combinations of building shape, stack height and stack location relative to the building
- Non-buoyant plume
- Neutral atmospheric stability conditions

350 combinations, with approx. 45000 ground-level concentrations measured

Building types:
(Side cube = 150 mm)

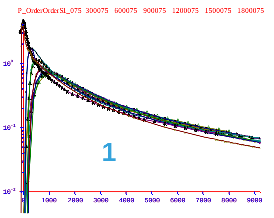


Stack heights (mm): 38
150 188 225
300 375 450

Stack location: from 2100 mm upwind of building to 1800 mm downwind

Receptors (distance from stack):
closest: from -300 mm till 4000 mm
spacing: from 10 mm till 300 mm
greatest distance: till 9800 mm

Isolated stacks (without building): 9 profiles



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D: Building downwash

Personal observation in the field. The material of the plume in the wake of the building is distributed chaotically between two heights.

Mathematical approach. The long-term averaged ground-level concentration is the sum of the impact of a number of plumes whose heights and pollutant content are log-normally-type distributed

Basic Formula. *(For details: see paper.)*

$$C(x_{receptor-S},0,0,H_S,H_{building},X_{S-building}) =$$

$$\int_{-\infty}^{+\infty} \frac{Q_{zp}}{\pi u(h_{zp})\sigma_y(x^*)\sigma_z(x^*)} \exp\left(-\frac{1}{2}\left\{\frac{h_{zp}}{\sigma_z(x^*)}\right\}^2\right) dz_p$$

Some results *(Status at May, 24th)* ☺

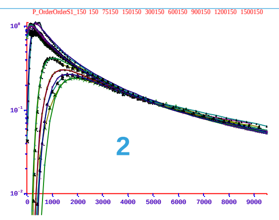
Some ground-level concentrations (measured: markers, modelled: broken lines) for the cubical building:

1) *Stack = 75 mm, at different locations downwind the building*

2) *Stack height = building height, at 3 positions on the roof (wind side, middle, downwind side) and at 5 different locations downwind the building*

3) *Stack = 188 mm, three positions above roof of building*

4) *Stack height = building height, at 6 different upwind positions of the building*



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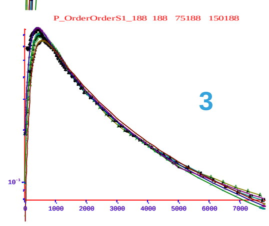

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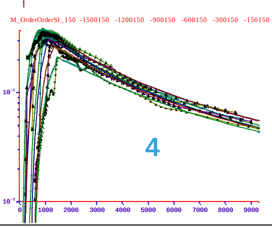

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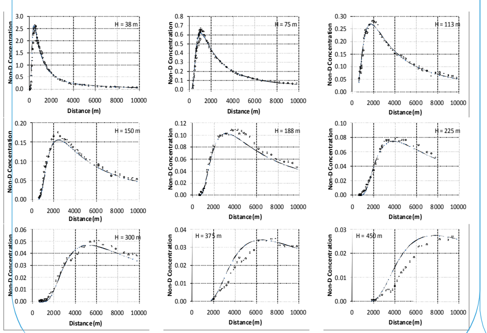
B: Reproduction of isolated stack concentration profiles ☺



C: Dispersion parameters for the field (IFDM, Bultynck-Malet) and the wind-tunnel ☺

$$\sigma_y(x) = a\,x^{\alpha}$$
$$\sigma_z(x) = b\,x^{\beta}$$

Dispersion parameters		$\sigma_y(x)$		$\sigma_z(x)$	
Coefficient & exponent		a	α	b	β
wind-tunnel	generic	*Eq.1*	0.796	*Eq.2*	0.711
	h=37	0.441	0.796	0.350	0.711
	h=450	0.256	0.796	0.532	0.711
field	slightly stable	0.297	0.796	0.382	0.711
	neutral	0.418	0.796	0.52	0.711

$a(hs) = a(E_3) - 0.0001(4.5hs+500)$ (1)

$b(hs) = b(E_2) + 0.0001(4.5hs-0.0005(hs-150)^2)$ (2)

$$C(x,H_S) = \frac{Q}{\pi\, u(H_S)\sigma_y(x)\sigma_z(x)} \exp\left(-\frac{1}{2}\left\{\frac{H_S}{\sigma_z(x)}\right\}^2\right)$$

Implicit scale assumption: 1 mm wind-tunnel = 1 m in the field.

CONCLUSIONS: This 'Do it yourself' approach has given, up to now, pretty promising results ☺.

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