Accounting for Concentration Fluctuations in SIRANERISK, an Operational Dispersion Model dedicated to Urban Areas

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Problem position

In the field of atmospheric risk assessment and modelling, futures advances depend on our capabilities to solve the following questions:

1. Strongly non-stationary situations have to be handled because of the short duration of some accidental release
2. Complex boundary conditions should also be represented to model urban areas (i.e. the places where the impact is likely to be the most serious)
3. Predictions of extreme values are necessary to determine specific toxicity thresholds and other physical and statistical indicators

Items 1. and 3. influenced both the simulations and predictions of concentration fluctuations. Although the considerable efforts developed in this latter field, the solutions retained in operational models do not meet general agreement and the furnished results remain therefore somehow questionable.

$$C=\frac{M}{[2\pi]^{3/2}\sigma_x\sigma_y\sigma_z}exp\left[-\frac{1}{2}\left(\frac{(x-x_0)^2}{\sigma_x^2}+\frac{(y-y_0)^2}{\sigma_y^2}+\frac{(z-z_0)^2}{\sigma_z^2}\right)\right]$$

$$\begin{cases}C=M.f(x-x_b,\sigma_x,L)\,f(y-y_b,\sigma_y,W)\,f(z-z_b,\sigma_z,H)\\ f(x_i,\sigma_{x,i},L_i)=\frac{1}{2L_i}\left[erf\left(\frac{x_i+L_i/2}{\sqrt{2}\sigma_{x,i}}\right)-erf\left(\frac{x_i-L_i/2}{\sqrt{2}\sigma_{x,i}}\right)\right]\end{cases}$$

Equation 1 and 2: Mean concentration distribution for point and volume sources

The SIRANERISK puff model for urban areas

The SIRANERISK dispersion model is dedicated to crisis management and has therefore been designed to:

1. Deal with unsteady releases thanks to a Gaussian-puff model above roof level
2. Evaluate the diffusion in a network of street-canyons to account for the complexity of urban areas
3. Give an estimation of concentration fluctuations at puff centre thanks to an empiric parametrical law.

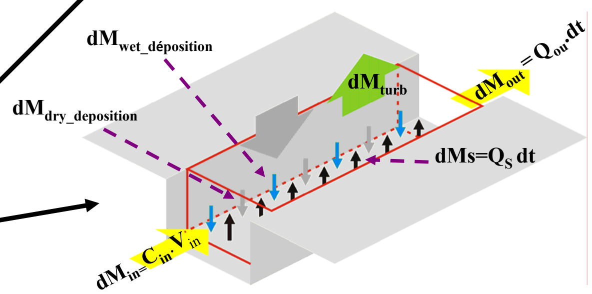

Figure 1: Pollutant mass budget in street-canyon

$$i_{c0}=x^{-a}+b$$
$$\sigma_{C0}=i_{c0}C_0=\left(x^{-a}+b\right)C_0$$

Equation 3 and 4: parametric law giving the i_c evolution and expression of σ_C

Experimental study of concentration fluctuations

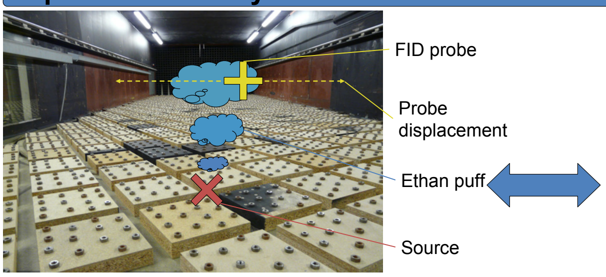

Figure 2: Experimental setting

"Instantaneous" puffs and continuous plumes were successively released in a boundary layer flow. The measurements and the related statistical analysis included :

1. Dispersion on open terrain (over different rough surfaces named R20, R50)
2. Dispersion in an idealized urban area (30° and 45° wind directions were tested; the resulting configurations were named B30 and B45; see Figure 2-6)
3. Complete characterisation of wind profile
4. Statistical analysis of the two first order moments of the concentration distribution

Results and discussion

These extensive measurements showed that:

1. Variability in the concentration distribution due to short releases was extremely important (Figure 3).
2. Experimental distribution of the variance of the concentration could be fitted with the two theoretical models from Gifford (1959) and Yee et al. (1994). Nevertheless the regression using Gifford's puff model led to an inadequate value for M_y (Figure 4).
3. Spread of the averaged concentration distribution was comparable for short and continuous releases (Figure 5).
4. The concentration fluctuation intensity i_{c0} is independent on the dynamic characteristics of the flow and can be easily parameterized (Figure 6).

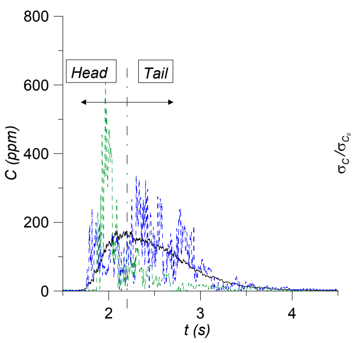

Figure 3: Temporal evolution of concentration

Puff 1
Puff 2
Ensemble average

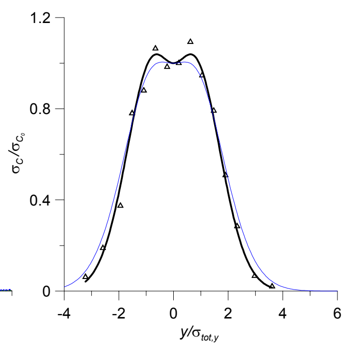

Figure 4: Qualification of a theoretical model

Experimental Data: M=0.36
Best fit using Yee et al. model: M=0.37. k=2.78)
Best fit using Gifford's model: M=4.0 , k=0)
Where M and k are defined through: $\frac{\overline{c^2}}{c_{r,0}^2}=\frac{1}{(1+2M)}\left[\frac{1}{k^2}\frac{\Gamma(2+k)}{\Gamma(k)}\right]e^{-\frac{1}{2}\left[\frac{y^2}{(1+2M)\sigma_{y}^2/2}\right]}$

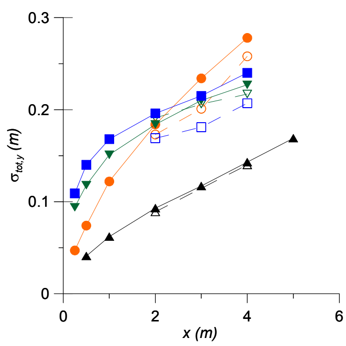

Figure 5: Comparison of continuous and short releases spread

Plume	Puff
R20	R20
R50	R50
B30	B30
B45	B45

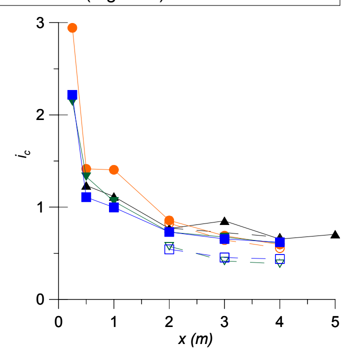

Figure 6: Longitudinal evolution of i_c

Plume	Puff
R20	R20
R50	R50
B30	B30
B45	B45

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