Development of a new Plume-in-Grid model for roadways combining an Eulerian Model with a Gaussian line-source model.

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Introduction

- Gaussian plume model for line source
- Modeling platform Polyphemus (`http://cerea.enpc.fr/polyphemus/`)
- Comparisons to measurements
- Plume-In-Grid model using line sources

Hypotheses

- Emission rate (Q in $\mathrm{g\,s^{-1}}$) and meteorological parameters are constant.
- The plume is at steady state
- The wind (u in $\mathrm{m\,s^{-1}}$) is strong enough so that the turbulent diffusion in the wind direction is not significant (slender plume approximation)

Point source Gaussian formula

$$c(x, y, z, t) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2{\sigma_y}^2} - \frac{z^2}{2{\sigma_z}^2}\right)$$

- σ_y, σ_z : standard deviation coefficients along y and z axes computed with Briggs parameterization.

Integration of the point source equation

$\Rightarrow$ Horst-Venkatram approximation (HV approximation)

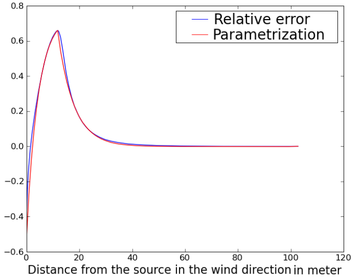
[1] Venkatram, A. and Horst, T.W. (2006). Approximating dispersion from a finite line source. *Atmospheric Environment.*, 40:2401-2408.

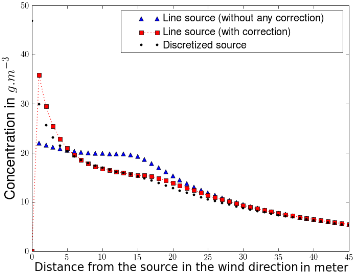
Line source Gaussian formula

$$\mathrm{C}(x, y, z) = \frac{Q}{2\sqrt{2\pi} u \cos\theta \sigma_z} \exp\left(\frac{-z^2}{2\sigma_z^2}\right) \times \left[\mathrm{erf}\left(\frac{(y - y_1)\cos\theta - x\sin\theta}{\sqrt{2}\sigma_{y_1}}\right) - \mathrm{erf}\left(\frac{(y - y_2)\cos\theta - x\sin\theta}{\sqrt{2}\sigma_{y_2}}\right)\right]$$

- $\cos\theta$ makes the solution diverges when the wind is parallel to the road

⇒ Parameterization of the error induce by the HV approximation detailed in:

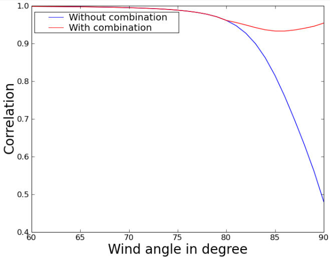




- If $\theta \in [0, 80[$, $concentration = c_{line}$
- If $\theta \in [80, 90]$, $concentration = \alpha c_{line} + (1 - \alpha) c_{discretized}$

⇒ α varies between 0 and 1

Line source / discretized source combination



[1] Briant, R., Korsakissok, I. & Seigneur, C., (2011). An improved line source model for air pollutant dispersion from roadway traffic. *Atmospheric Environment*, 45:4099-4107.

Additional features

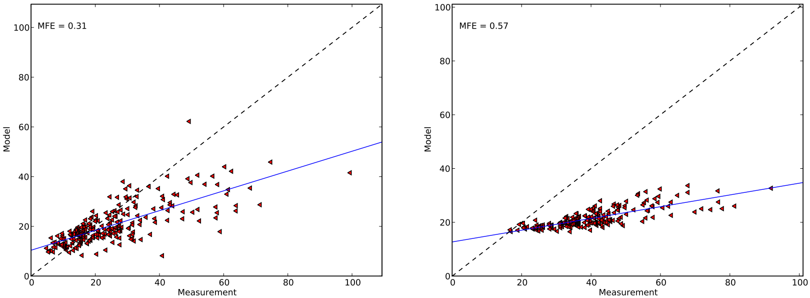
- Romberg integration to model the line source width
- Simple NO_2 chemistry

Simulation set up

Paris region

- 1371 road sections divided in 5425 segments (831 km).
- NO_x emissions from the European model COPERT3.
- NO_2 concentrations measurement at 242 locations with passive diffusion tubes .
- NO_2, NO and O_3 background concentrations from on air quality model (Polair3D).
- Meteorological data simulated with the Weather Research and Forecasting model (WRF).

Data provided by the Centre d'Étude technique de l'Équipement (CETE) Nord Picardie, France



Scatter plot of measure versus both Polyphemus using the rural option in $\mu g\, m^{-3}$ (summer campaign on the left and winter campaign on the right).

Polyphemus performance indicators (Root Mean Square Error and averaged concentrations in $\mu g\, m^{-3}$)

Summer	Measurement	Polyphemus
Correlation	1.	0.74
Root Mean Square Error	0.	11.93
Averaged concentrations	26.0	20.7
Mean Normalized Error	0.	0.31
Mean Normalized Bias	0.	−0.2

Winter campaign	Measurement	Polyphemus
Correlation	1.	0.79
RMSE	0.	21.59
Averaged concentrations	40.5	21.6
Mean Normalized Error	0.	0.47
Mean Normalized Bias	0.	−0.47

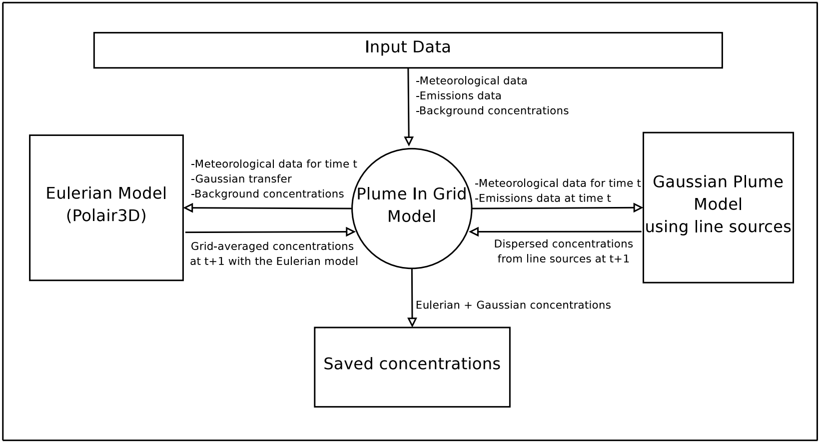
Performance indicators of Polyphemus and ADMS for the winter campaign only (62 passive tubes only)

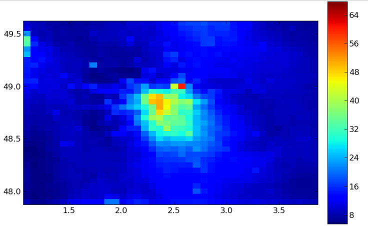
	Measurement	Polyphemus	ADMS
Correlation	1.	0.81	0.79
RMSE	0.	18.47	19.12
Averaged concentrations	35.15	19.87	19.4
Mean Normalized Error	0.	0.38	0.4
Mean Normalized Bias	0.	−0.38	0.39

- Underestimation of emission by the traffic model in winter.
- Uncertainty of measurement

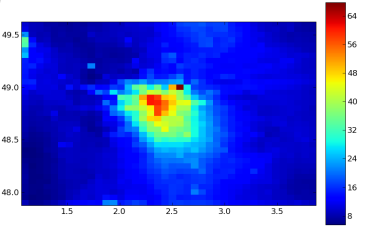
Plume-In-Grid model

- Better representation of sources in an Eulerian model
- Coupling between:
  - Gaussian model using line sources ⇒ constant with time
  - Eulerian model (Polair 3d) ⇒ time dependent model
- No discretization of the plume with puffs

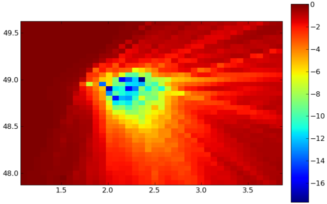

Input Data
-Meteorological data
-Emissions data
-Background concentrations
Eulerian Model
(Polair3D)
-Meteorological data for time t
-Gaussian transfer
-Background concentrations
Plume In Grid
Model
Grid-averaged concentrations
at t+1 with the Eulerian model
-Meteorological data for time t
-Emissions data at time t
Gaussian Plume
Model
using line sources
Dispersed concentrations
from line sources at t+1
Eulerian + Gaussian concentrations
Saved concentrations



(a) Polair3D results in $\mu g\, m^{-3}$



(b) PinG results in $\mu g\, m^{-3}$



(c) (Polair3D - Plume-In-Grid) in $\mu g\, m^{-3}$

Conclusion

- Improved line source model, already implemented and available online (`http://cerea.enpc.fr/polyphemus/`).
- New Plume-In-Grid model fully implemented and tested on simple cases

Ongoing work

- Use this new model for a longer period
- Compare results with Polair 3d model results

Questions?

Thank you for your attention.