Dipartimento di
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dell'Ambiente, del
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Pollutant dispersion over industrial sites: numerical modelling and experiments

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Why focusing on industrial sites ?

Seveso catastrophe 1976 [1]

Accidental pollutant emissions at industrial sites:

- leaks (tanks, pipes)
- fires/explosions

Pollutants (chemical compounds, ashes…)
→ risks (human health, environment)

Obstacles (buildings, tanks, complex structures …)

- Perturb the wind field over the site
- Impact plume shape
    - Flow channelling
    - Increased mixing


Image credits [2]

Main questions:
→ which obstacles effects can be captured by operational modelling approaches?
→ how the simplifications of operational models on the flow description affects the simulated plume?

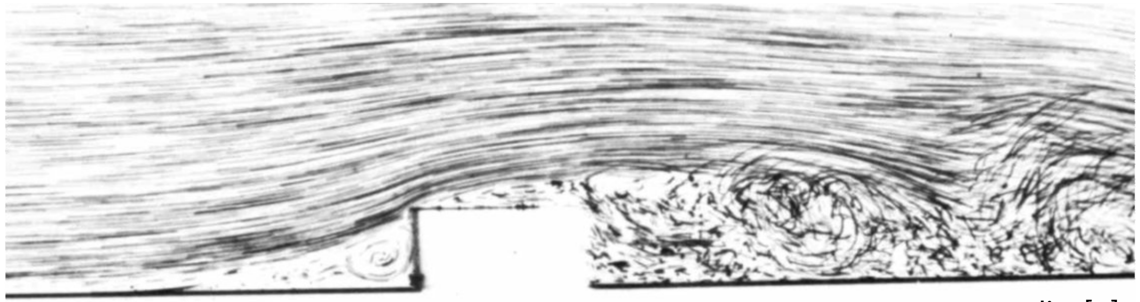
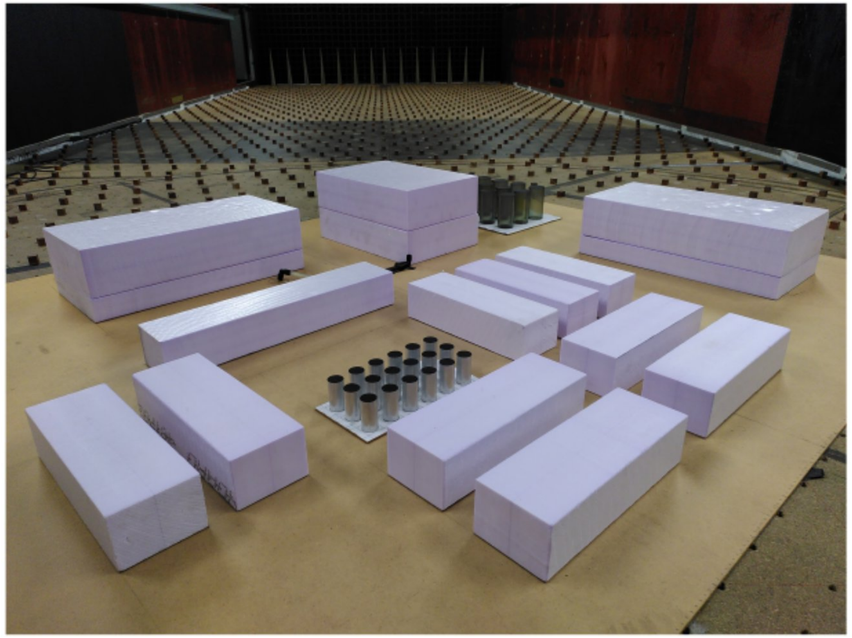


Image credits [4]

Idealised industrial site



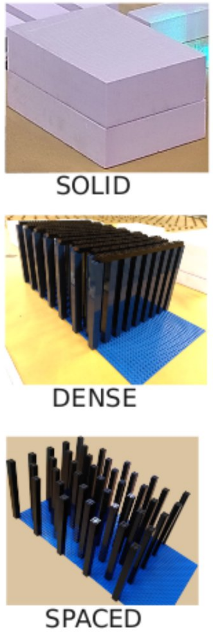
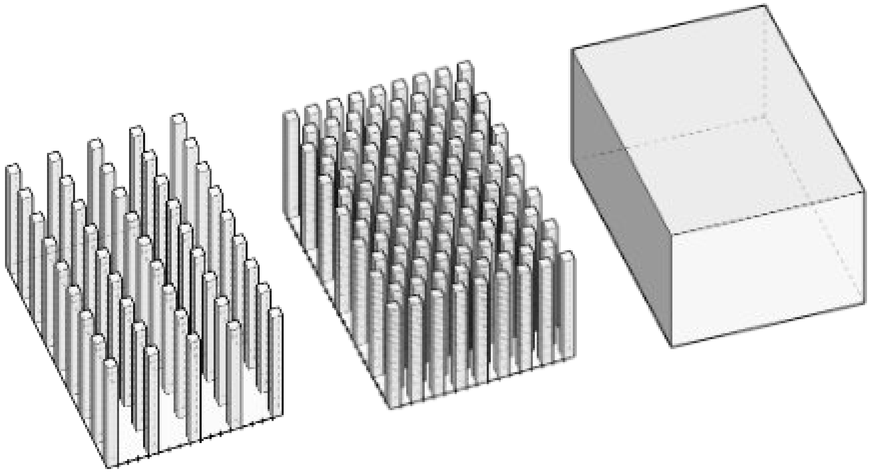


Image credits [6]

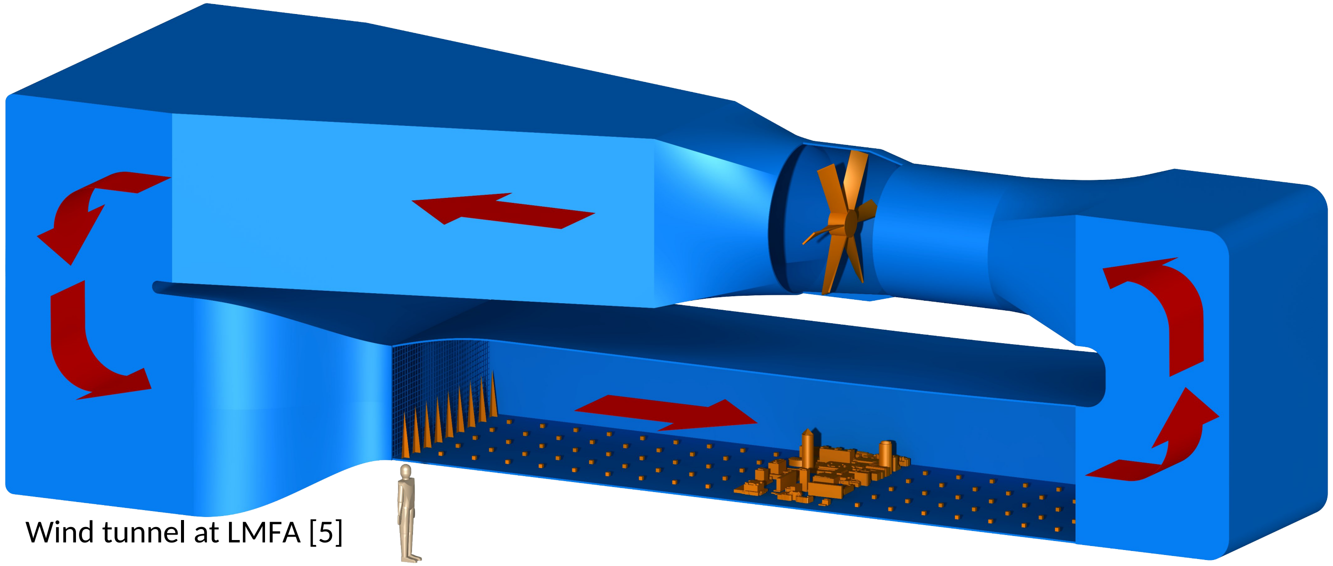
Main elements:
- buildings of various sizes
- storage tanks
- porous structure

Density :
- Solid (100%)
- Dense (25%)
- Spaced (10%)



Variation of:
- wind direction
- source position
- site geometry

Database of wind tunnel measurements



Wind tunnel at LMFA [5]

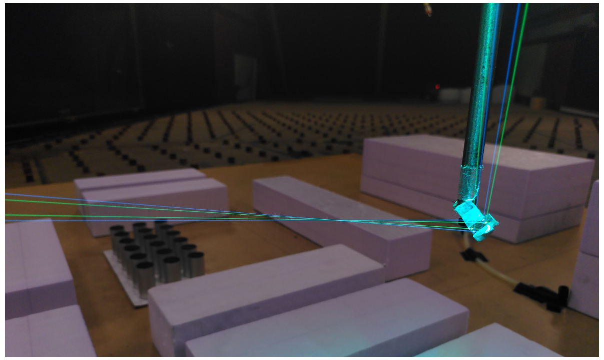
Boundary layer studied by Nironi *et al.*, 2015:

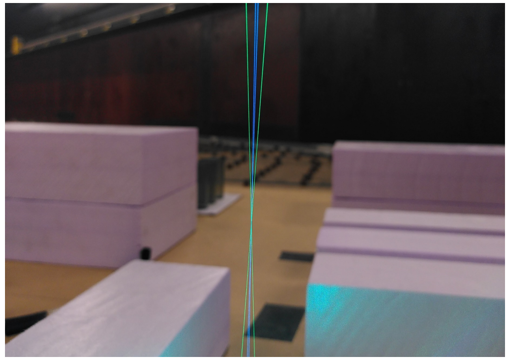
- 80cm height
- top velocity 5m/s
- neutral stratification

Passive tracer: ethane

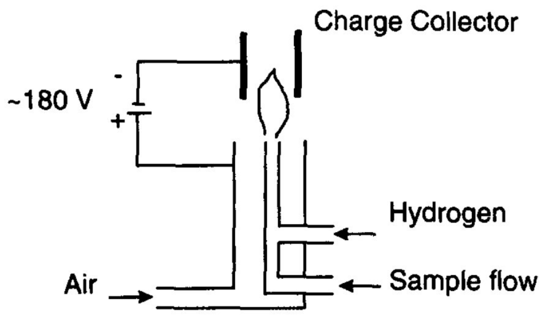
Point sources close to the ground

Laser Doppler Anemometer (LDA):
- point measurement
- UV / UW
- duration: 200000 detections (approx. 2 min)

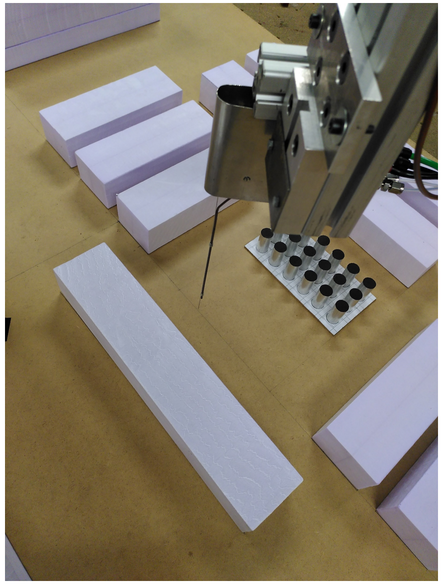




Flame Ionisation Detector (FID):
- 0-5000 ppm
- 300s continuous measurement
→ statistical moments up to order 4



Principle of FID [7]



Numerical methodologies

PMSS
(Parallelised Micro Swift Spray, Oldrini et al., 2017)

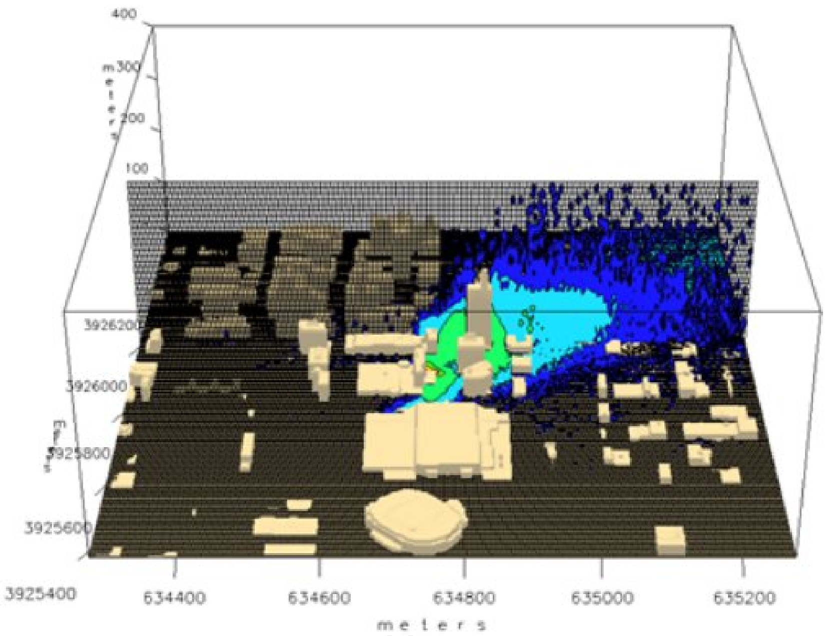
- Velocity field: SWIFT
  meteorological pre-processor.
  semi-empirical parametrisation of recirculation zones

- concentration: Lagrangian dispersion model (SPRAY)

SLAM
(Safety Lagrangian Atmospheric Model, Vendel et al., 2011)

- Relies on CFD database (RANS)
  varied wind directions and atmospheric stability
  interpolation

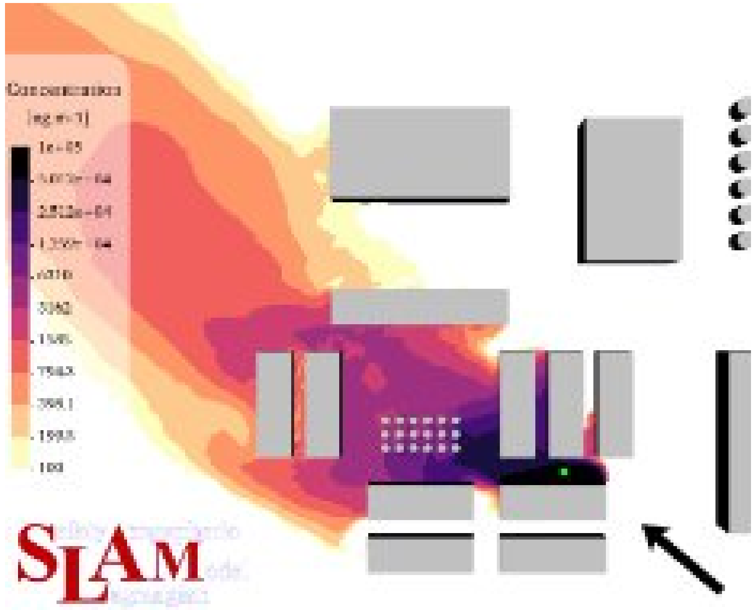
- concentration: Lagrangian dispersion model (SLAM)



Example of PMSS simulation [3]

Common points:
- operational & parallelised
- consider effects of obstacles
- Lagrangian dispersion

Differences:
- flow field computation
  (simplifications)

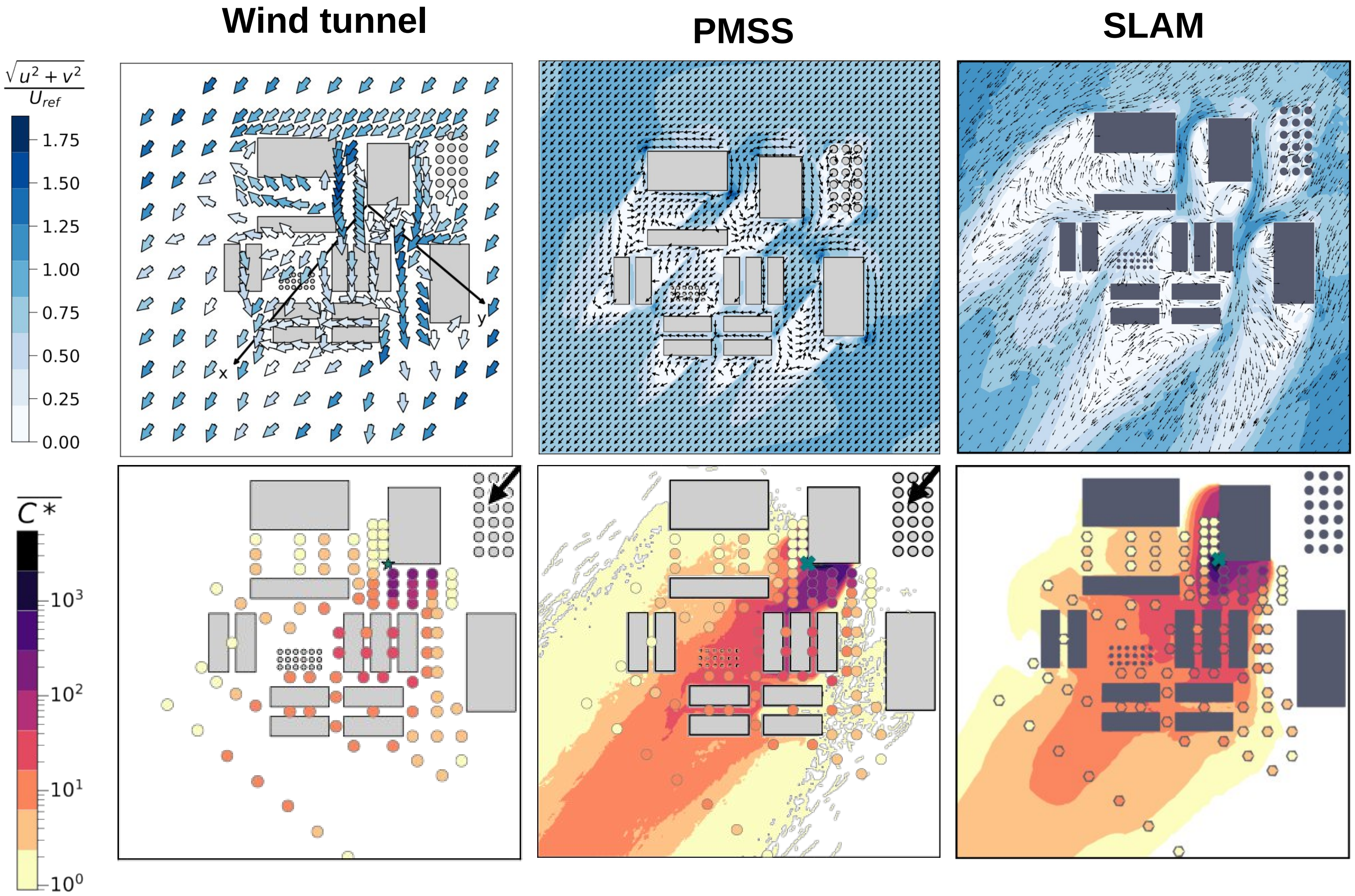


Numerical modelling of the wind and concentration fields

`Solid' configuration, 40° incoming wind direction

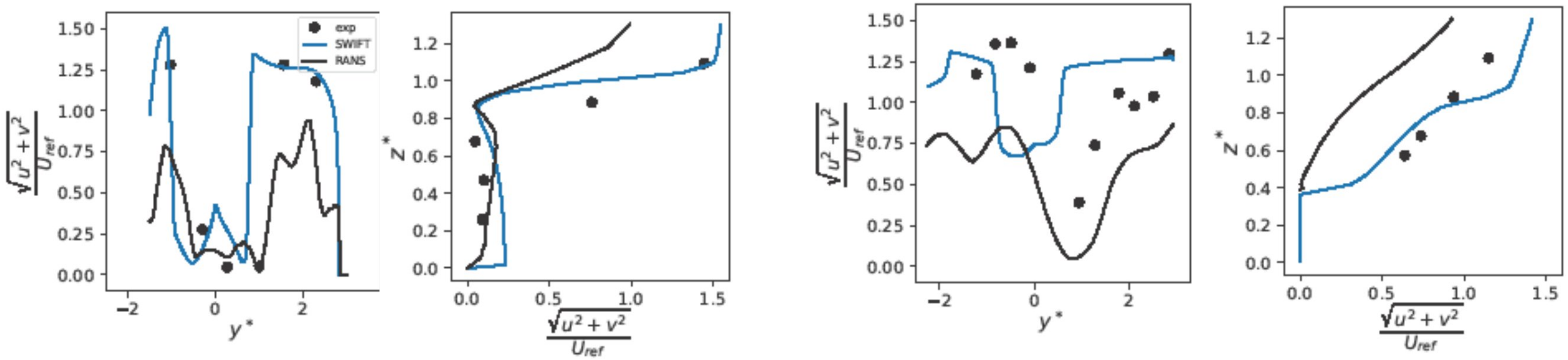
Mean velocity field at z*=0.26

Mean concentration field at ground level

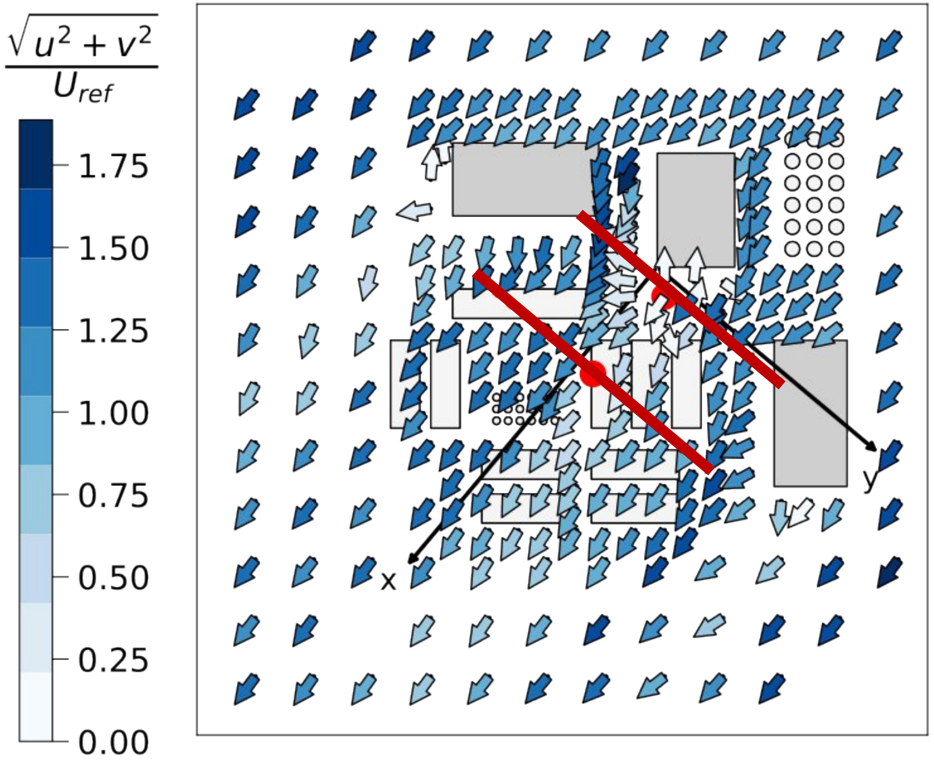


Simulated wind field in the `solid’ configuration

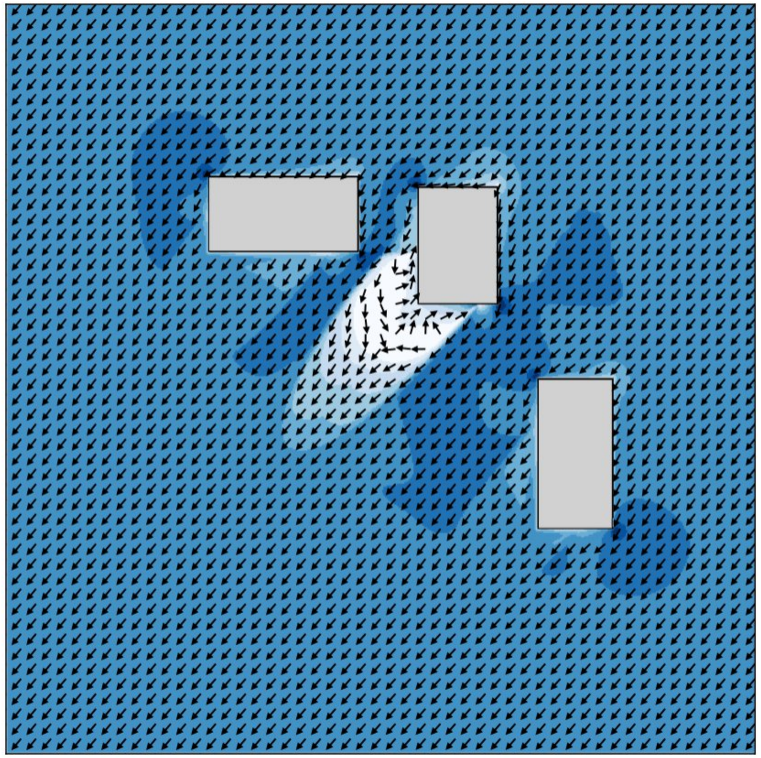
Mean velocity field at z*=0.78



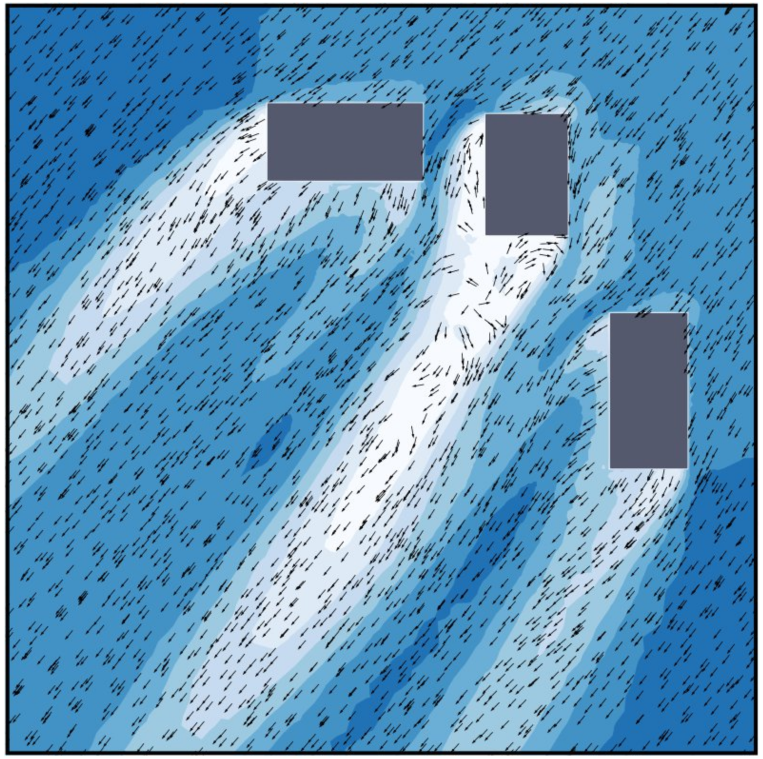
Wind tunnel



PMSS

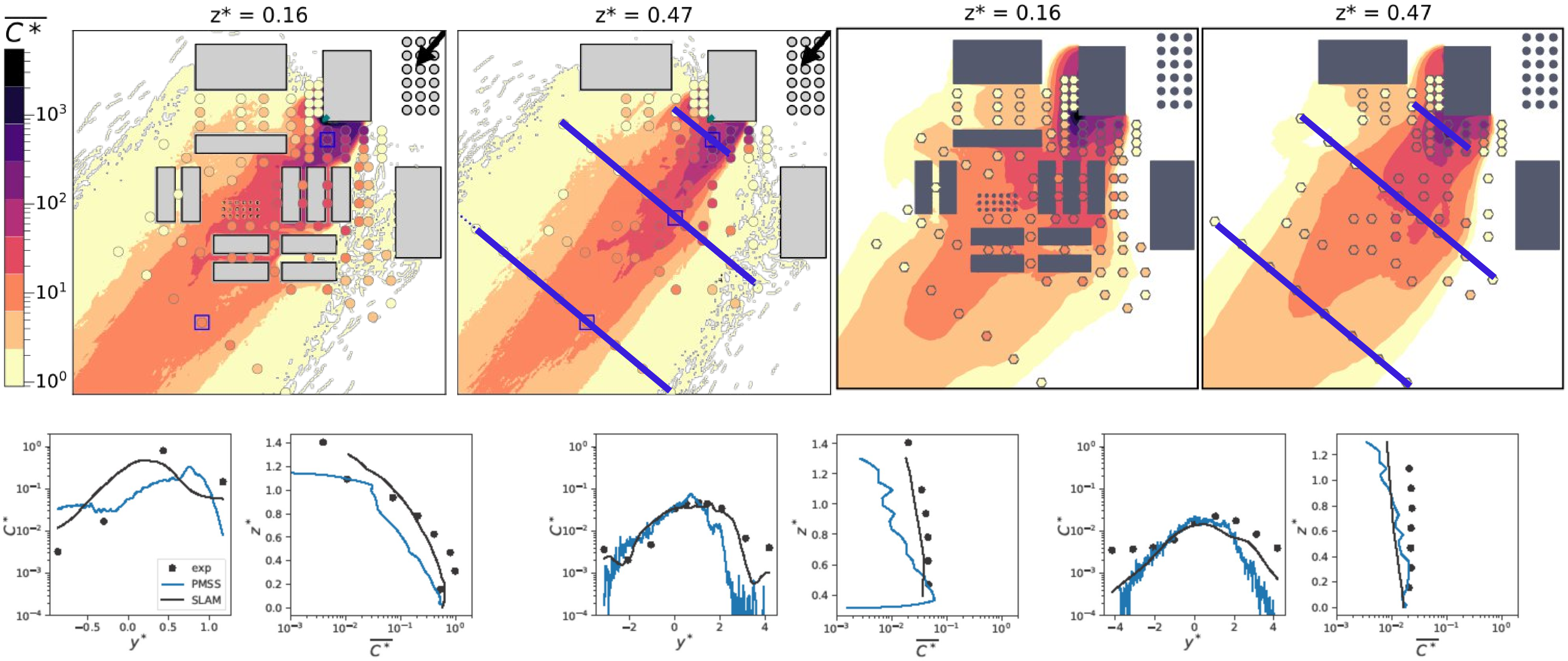


SLAM



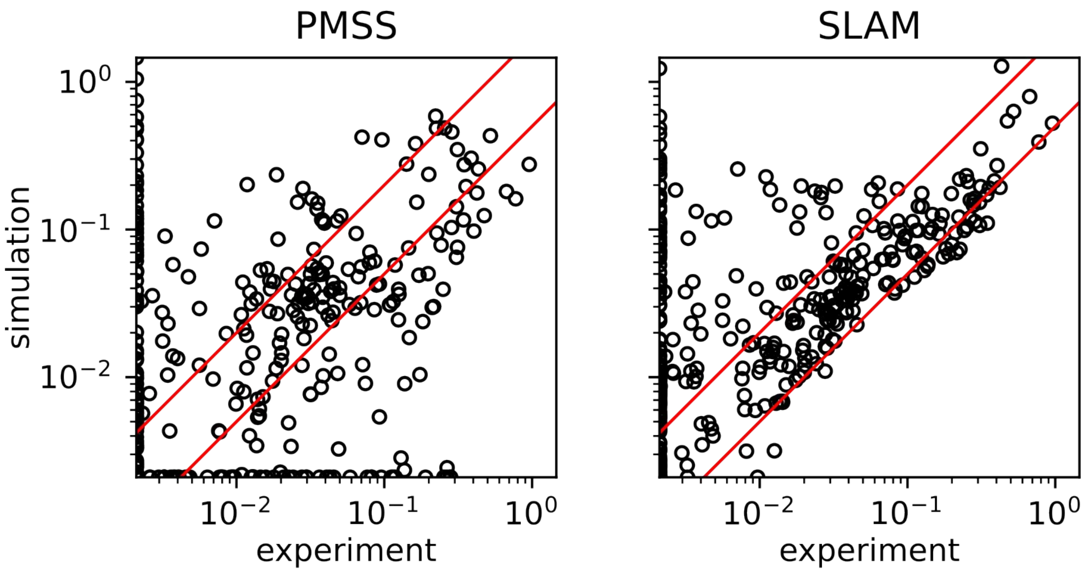
Simulated concentration field in the `solid' configuration

PMSS vs wind tunnel **SLAM vs wind tunnel**



Performance metrics

	PMSS	SLAM	Target	Satisfactory value
FAC2	0.49	0.58	1	FAC2 > 0.3
MG	0.78	0.38	1	0.7 < MG < 1.3
VG	28.4	20.5	1	VG < 4
NMSE	8.1	5.6	0	NMSE < 6
AFB	1.13	0.85	0	AFB < 0.3
R	0.29	0.55	1	R > 0.6

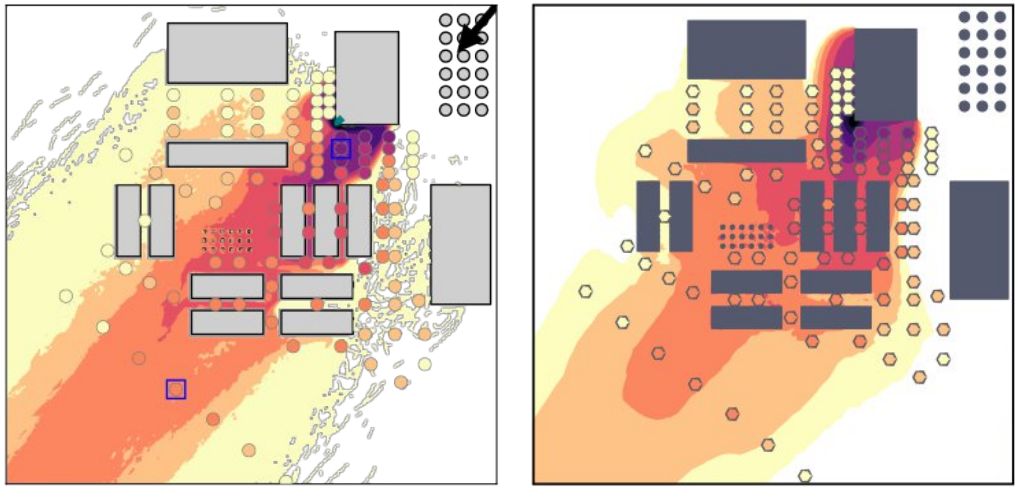


Metrics value show a low agreement

- Local discrepancies
- Far field: plume centreline shifted but shape reproduced
- Discrepancies at plume borders

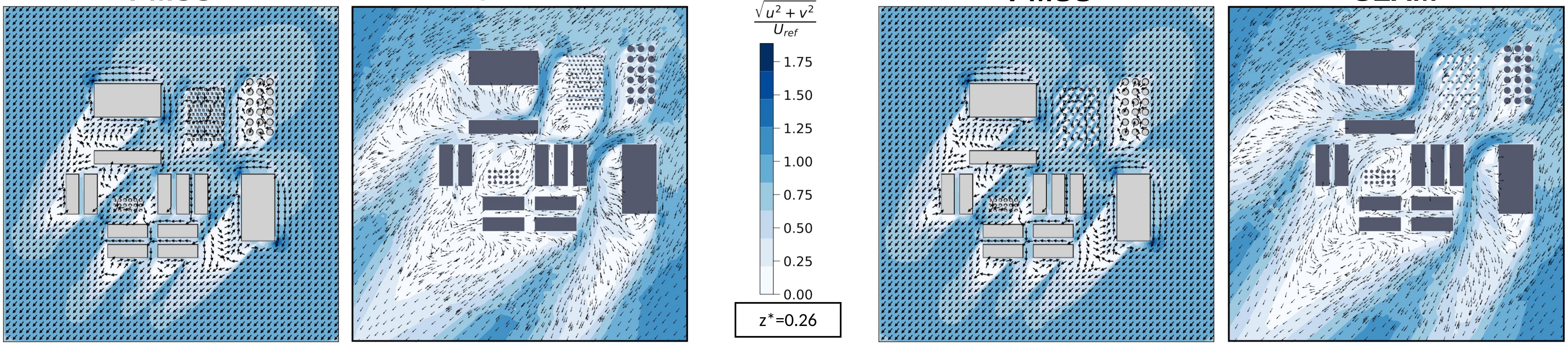
Metrics are not sufficient to assess model-data agreement

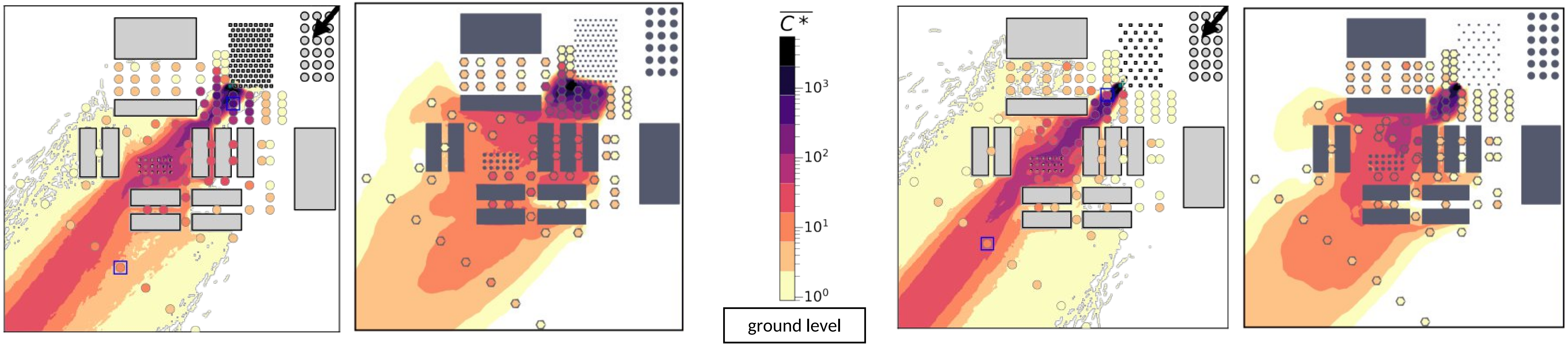
PMSS **SLAM**



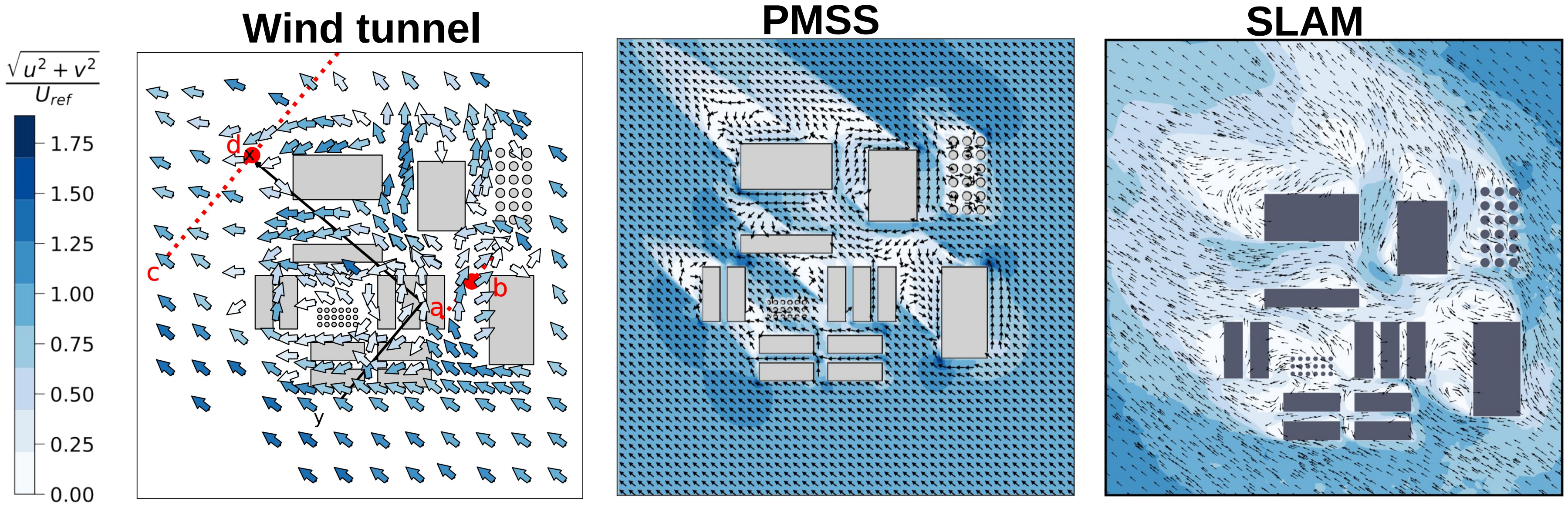
Effect of obstacle porosity: `dense’ and `spaced’ cases

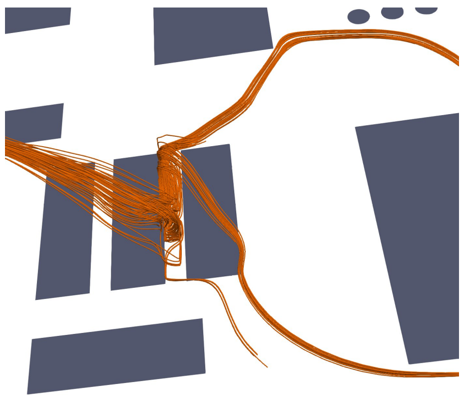
PMSS **SLAM** **PMSS** **SLAM**

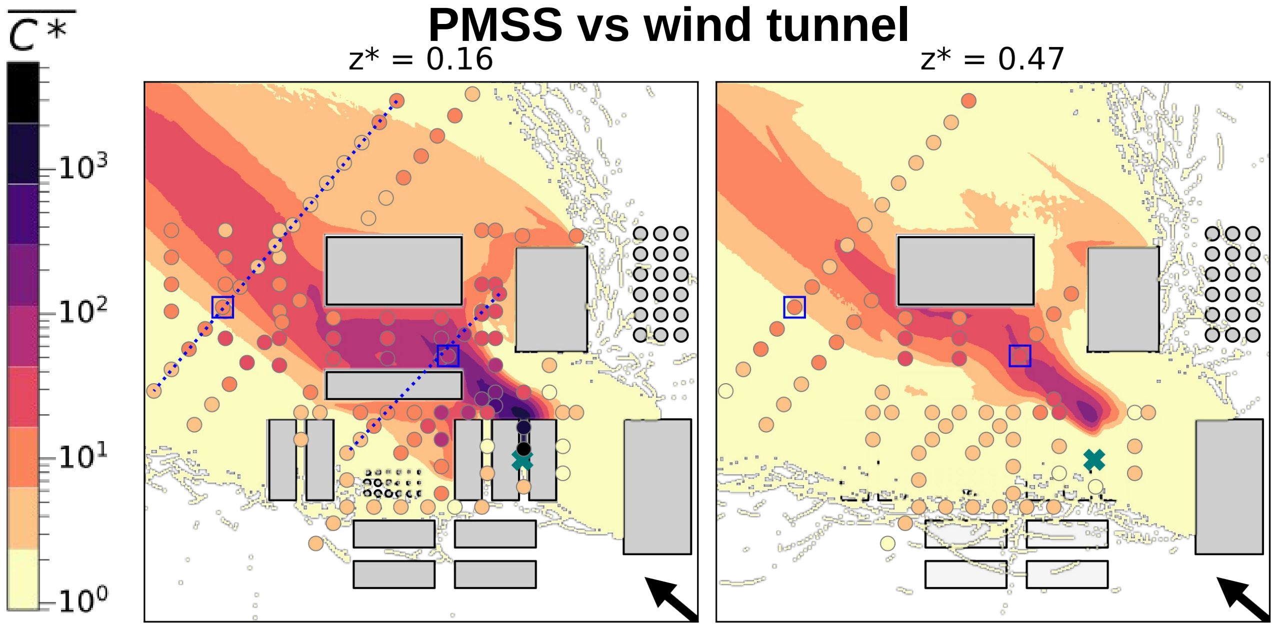


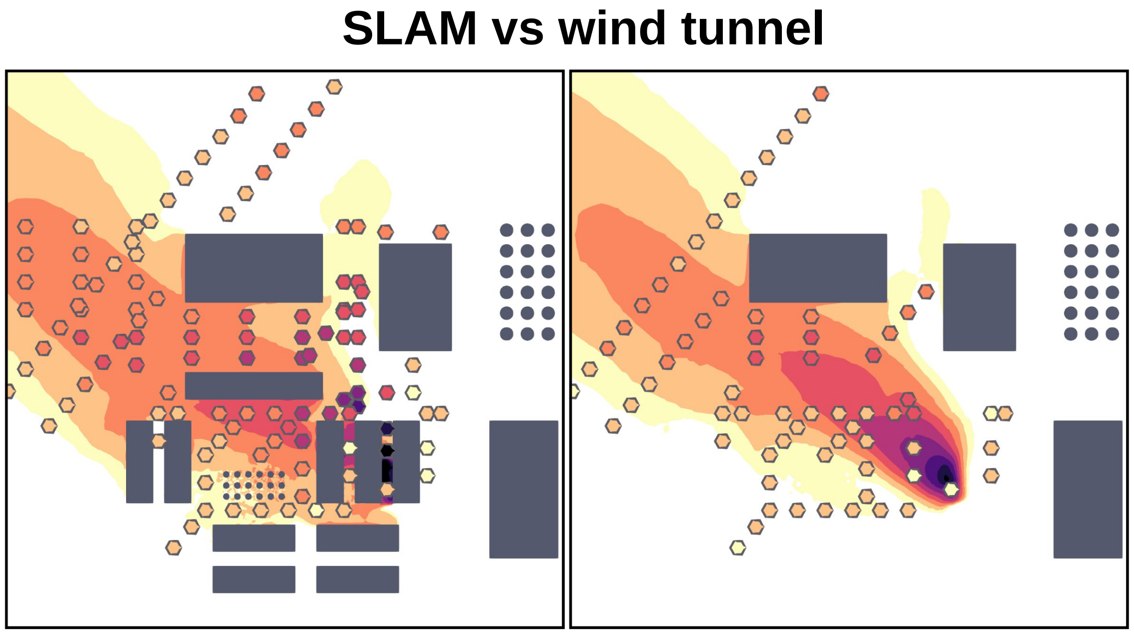


S4 configuration: source in a corridor

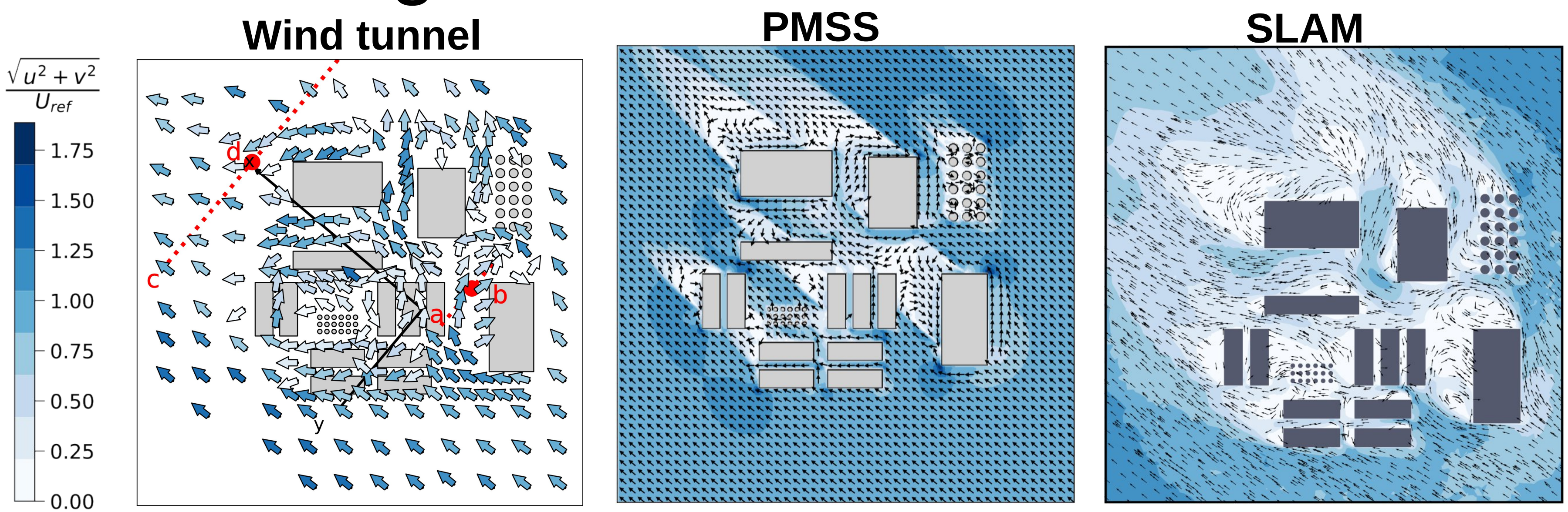


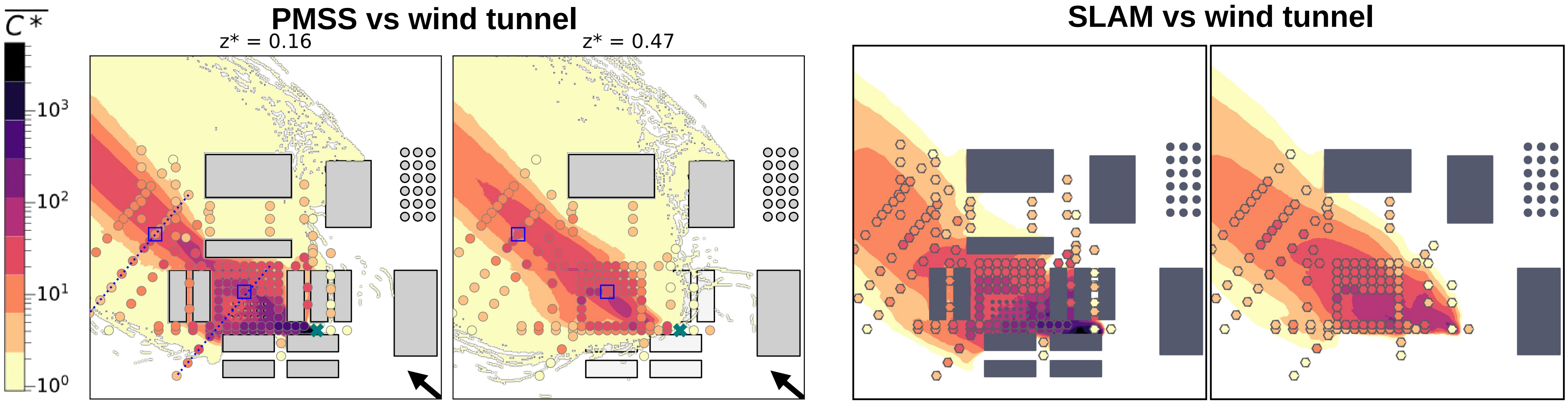




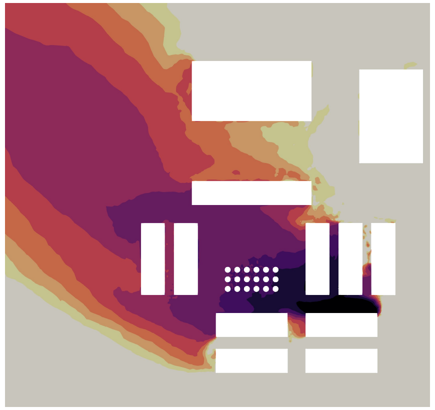


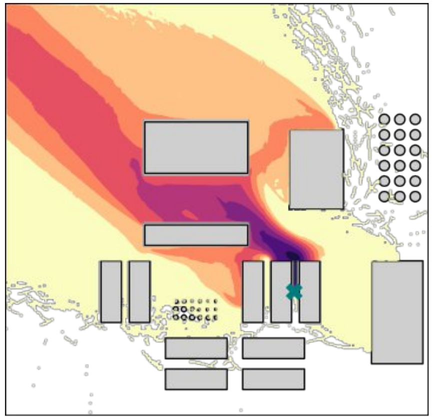
S5 configuration: source in another corridor





Conclusion and perspectives





Which obstacles effects on the wind flow are captured by operational models?
How does the flow acuracy impact the simulated pollutant plume ?

PMSS: no consideration of complex interacting wakes
-> strongly alters the results when upwind obstacles perturb the flow
-> accurate description where geometry is less perturbative

SLAM: RANS simulations reproduce channelling effects and complex recirculation zones
-> accurate description of configurations with a porous obstacle
-> strong effect of wall roughness produces discrepancies

General conclusions

- near-source discrepancies propagate up to the far field
- wake dynamics strongly influenced by obstacle porosity
- flow complexity due to few big (highly perturbative) obstacles better captured by RANS
- dispersion within an array of obstacles acurately captured by PMSS (less sensitive to uncertainty of input parameters than RANS)

Perspectives

- dataset of wind tunnel measurements suitable for model validation
- with concentration fluctuations (concentration peaks, short term exposure...)

Thank you for your attention!

Main references:

- Nironi, C., Salizzoni, P., Marro, M., Mejean, P., Grosjean, N., and Soulhac, L. (2015). “Dispersion of a Passive Scalar Fluctuating Plume in a Turbulent Boundary Layer. Part I: Velocity and Concentration Measurements”. In: Boundary-Layer Meteorology 156.3, pp. 415–446. issn: 1573-1472. doi: 10.1007/s10546-015-0040-x.
- Oldrini, O., Armand, P., Duchenne, C., Olry, C., Moussafir, J., and Tinarelli, G. (2017). “Description and Preliminary Validation of the PMSS Fast Response Parallel Atmospheric Flow and Dispersion Solver in Complex Built-up Areas”. In: Environmental Fluid Mechanics 17.5, pp. 997–1014. issn: 1573-1510. doi: 10.1007/s10652-017-9532-1.
- Tinarelli, G., Brusasca, G., Oldrini, O., Anfossi, D., Castelli, S. T., and Moussafir, J. (2007). “Micro-Swift-Spray (MSS): A New Modelling System for the Simulation of Dispersion at Microscale. General Description and Validation”. In: Air Pollution Modeling and Its Application XVII. Ed. by C. Borrego and A.-L. Norman. Boston, MA: Springer US, pp. 449–458. isbn: 978-0-387-68854-1. doi: 10.1007/978-0-387-68854-1_49.
- Vendel, F., Soulhac, L., Méjean, P., Donnat, L., and Duclaux, O. (2011). “Validation of the Safety Lagrangian Atmospheric Model (SLAM) against a Wind Tunnel Experiment over an Industrial Complex Area”. In: 14th Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes. Kos, Greece, p. 5.

Images

[1] https://ehne.fr/fr/encyclopedie/th%C3%A9matiques/%C3%A9cologies-et-environnements/les-risques-environnementaux/la-catastrophe-de-seveso
[2] https://www.google.fr/intl/fr/earth/index.html
[3] PMSS manual
[4] Van Dyke, M. (1982). An Album of Fluid Motion. The Parabolic Press. Stanford, California: The Parabolic Press.
[5] Image courtesy of Horacio Correia