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Validation of Lagrangian dispersion models with wind tunnel experiments for an idealised industrial site

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Context and objectives

Risks linked to industrial activities

Industrial sites can be subject to accidental airborne pollutant spread due to leaks, fires, explosions or radiological emissions, that generate risks for human health and the environment. There is thus a need for fast modelling tools that are able to simulate pollutant dispersion inside the complex building geometries of industrial sites. One of the key aspects is to find an equilibrium between the accuracy of the results and the time and memory consumption of the simulations.

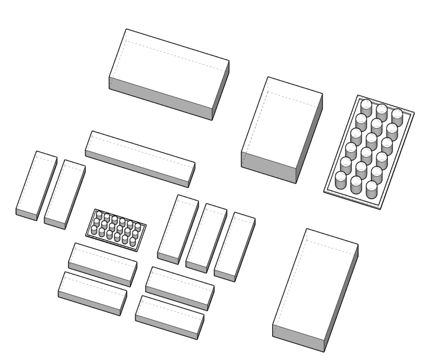

Figure 1: *Idealised industrial site.*

Objectives

- comparison of 2 operational modelling methods based on different approaches of computation of the wind field, however both methodologies include the Lagrangian formulation of pollutant dispersion.
- creation of a database of velocity and concentration measurements for model-data comparison.

Site definition

We designed an idealised industrial site that reproduces typical features of real production plants. The geometry is kept simple enough to avoid site specificity.

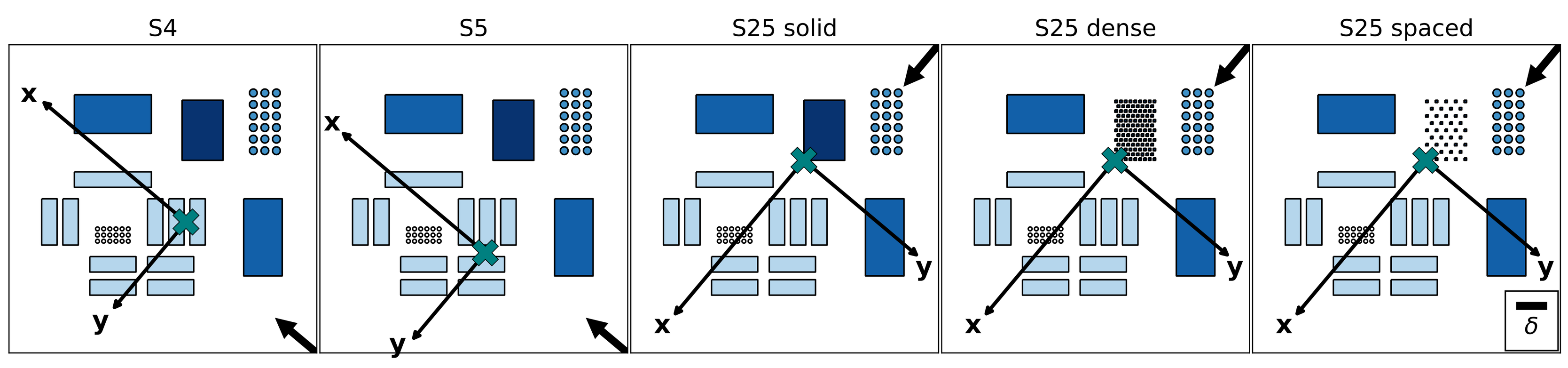

Figure 2: *Studied configurations: change in the source position, wind direction, and site geometry. Darker colours indicate higher buildings.*

Physical and numerical modelling

To focus on the effects of the site geometry on the wind and concentration fields, the considered configuration consists of:

- a neutral atmospheric boundary layer
- with a point source of ethane (which has same density as air)
- at ambient temperature

Wind tunnel measurements

Velocity and concentration measurements were performed in wind tunnel [1] using the following tools:

- velocity: LDA (Laser Doppler Anemometer), point measurements, 2 components of velocity simultaneously: longitudinal (U) + transversal (V) ; or U + vertical (W).
- concentration: FID (Flame Ionisation Detector), point measurements, mean and fluctuations of concentration are retrieved.

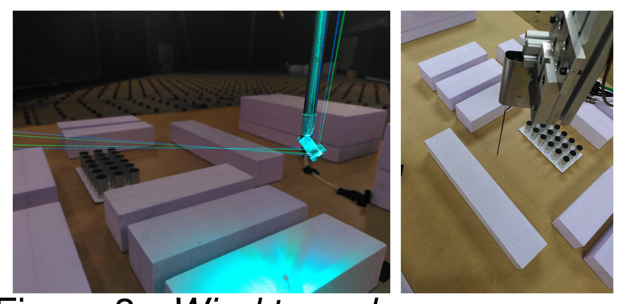

Figure 3: *Wind tunnel measurements were performed with a Laser Doppler Anemometer (LDA) and a Flame Ionisation Detector (FID).*

We compare the experimental velocity and concentration fields to numerical simulations:

PMSS (Parallelised Micro Swift Spray)

- wind field: SWIFT, semi-empirical approach based on geometrical parameters to reproduce the effects of recirculation zones.
- concentration field: Micro-SPRAY[3], a Lagrangian dispersion model able to consider the impact of obstacles.

Both SWIFT and SPRAY are parallelised to optimise the computation time [2].

SLAM (Safety Lagrangian Atmospheric Model)

- wind field: database of pre-computed wind and turbulence fields obtained from RANS (Reynolds Averaged Navier Stokes) simulations, which are interpolated.
- concentration field: SLAM [4], a parallelised Lagrangian dispersion model.

Analysis of the velocity field for the 'S25 dense' configuration

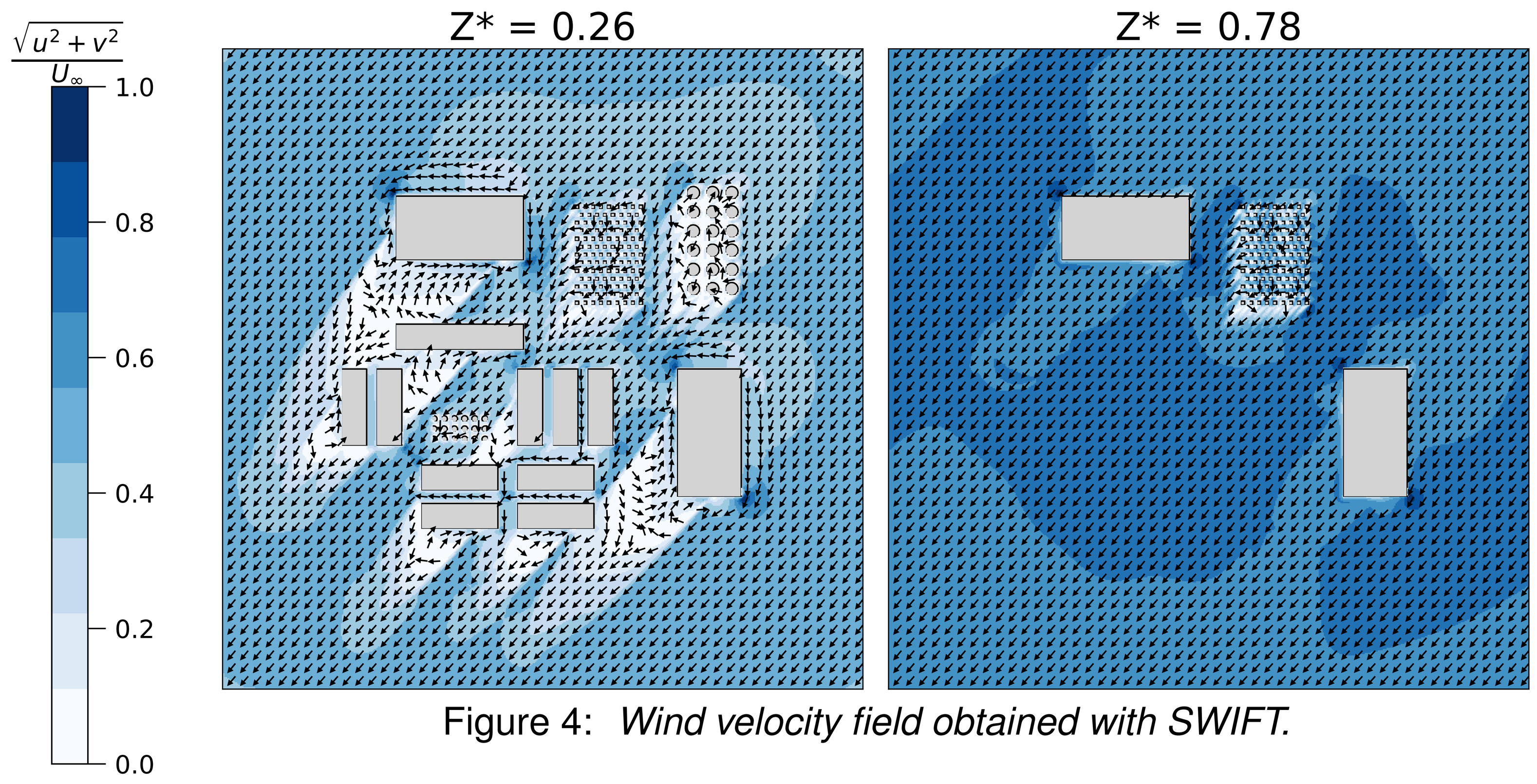

Figure 4: *Wind velocity field obtained with SWIFT.*

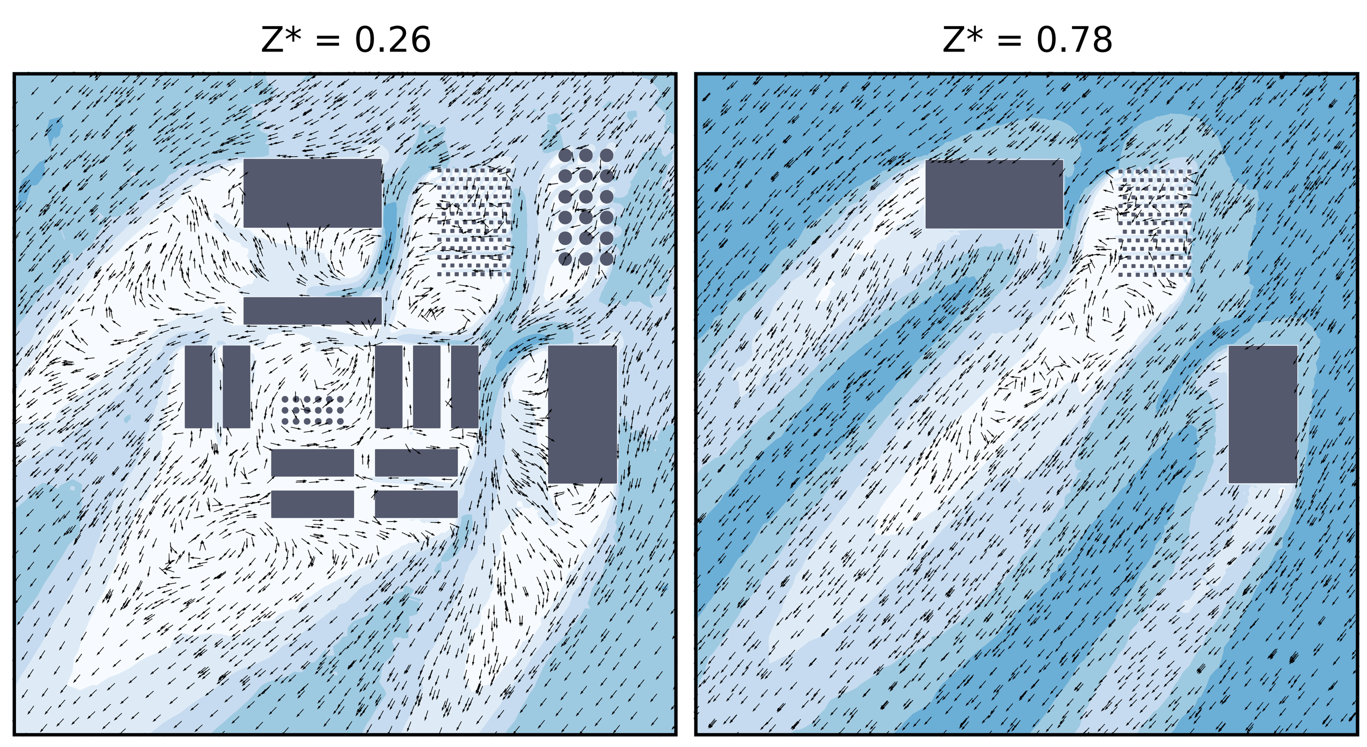

Figure 5: *Wind velocity field obtained from interpolation of RANS simulations.*

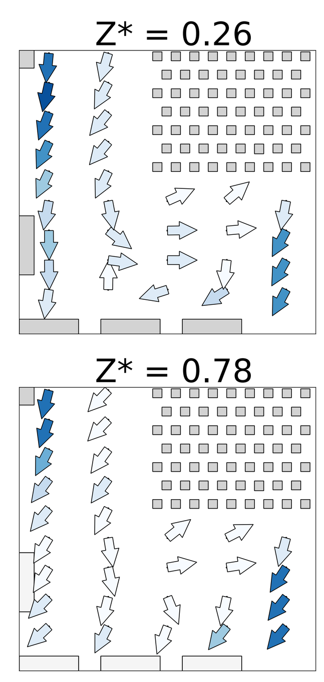

Figure 6: *LDA velocity in the wake of the porous obstacle.*

Figure 5 shows larger recirculation zones in the RANS simulations, associated to a local underestimation of the norm of velocity. The recirculation zone generated by the porous obstacle is smaller in the SWIFT simulation (Fig. 4), which leads to an overestimation of the norm of velocity in this region. The presence of grouped obstacles strongly impacts the wind field and renders more complex the computation of wind velocity.

Analysis of concentration field for the 'S25 dense' configuration

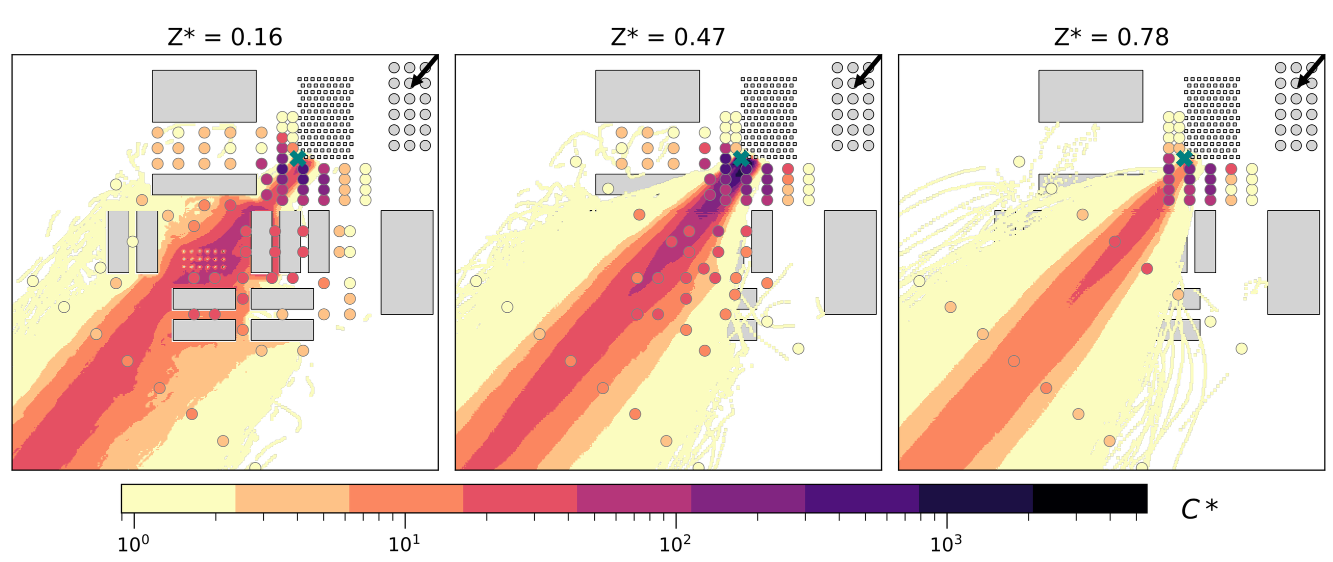

Figure 7: *Maps of dimensionless concentration obtained with PMSS.*

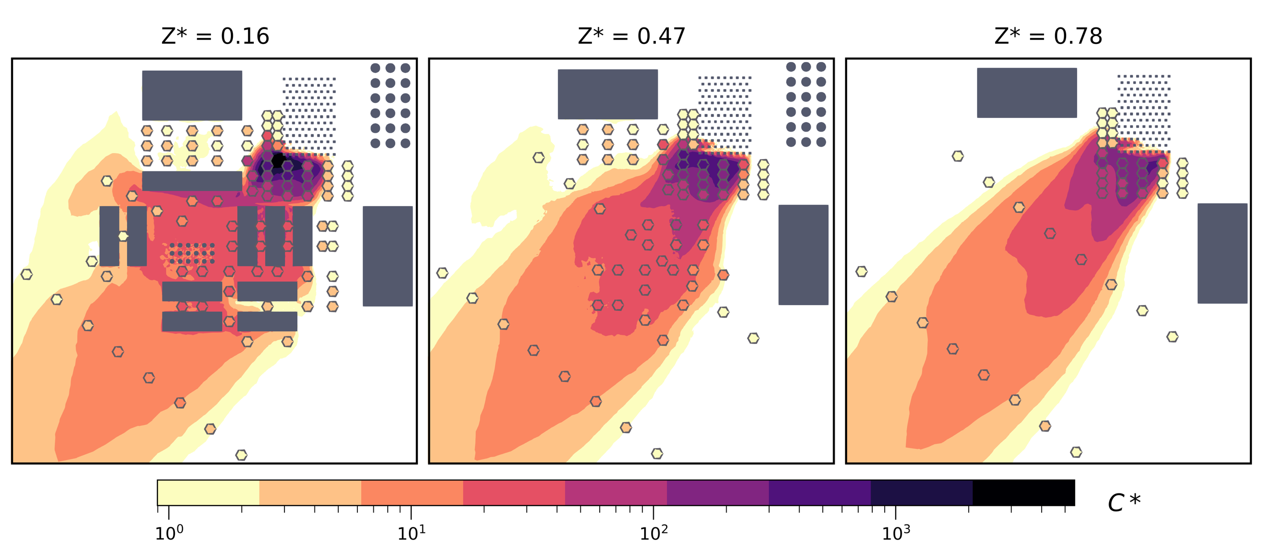

Figure 8: *Maps of dimensionless concentration obtained with SLAM.*

Wind computation methods strongly impact the plume shape, particularly in the near field, due to the recirculation zone generated by the porous building. As a consequence, plume extent in the mid- and the far-field is much wider in SLAM and the experiment compared to PMSS, associated to higher concentration values in the PMSS simulation. Discrepancies between experimental and SLAM concentration fields appear mainly at ground level on the plume borders, due to the local effects of grouped buildings.

Conclusion

This work highlights the importance of the wind field computation accuracy to obtain reliable pollutant dispersion simulations in sites with a complex geometry. Notably, recirculation zones generated by complex obstacles, such as the upwind building in the presented configuration, strongly impact the wind and concentration fields. The analysis of all 5 configurations will lead to publication.

References

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