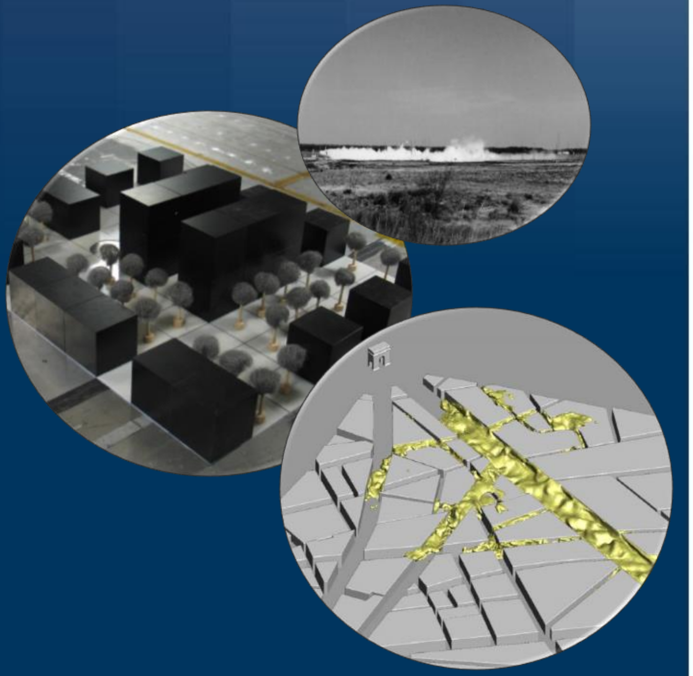
MODITIC

Modelling the dispersion of toxic industrial chemicals in urban environments

MODITIC WIND TUNNEL EXPERIMENTS NEUTRAL AND HEAVY GAS SIMULATION USING RANS



Harmo’17

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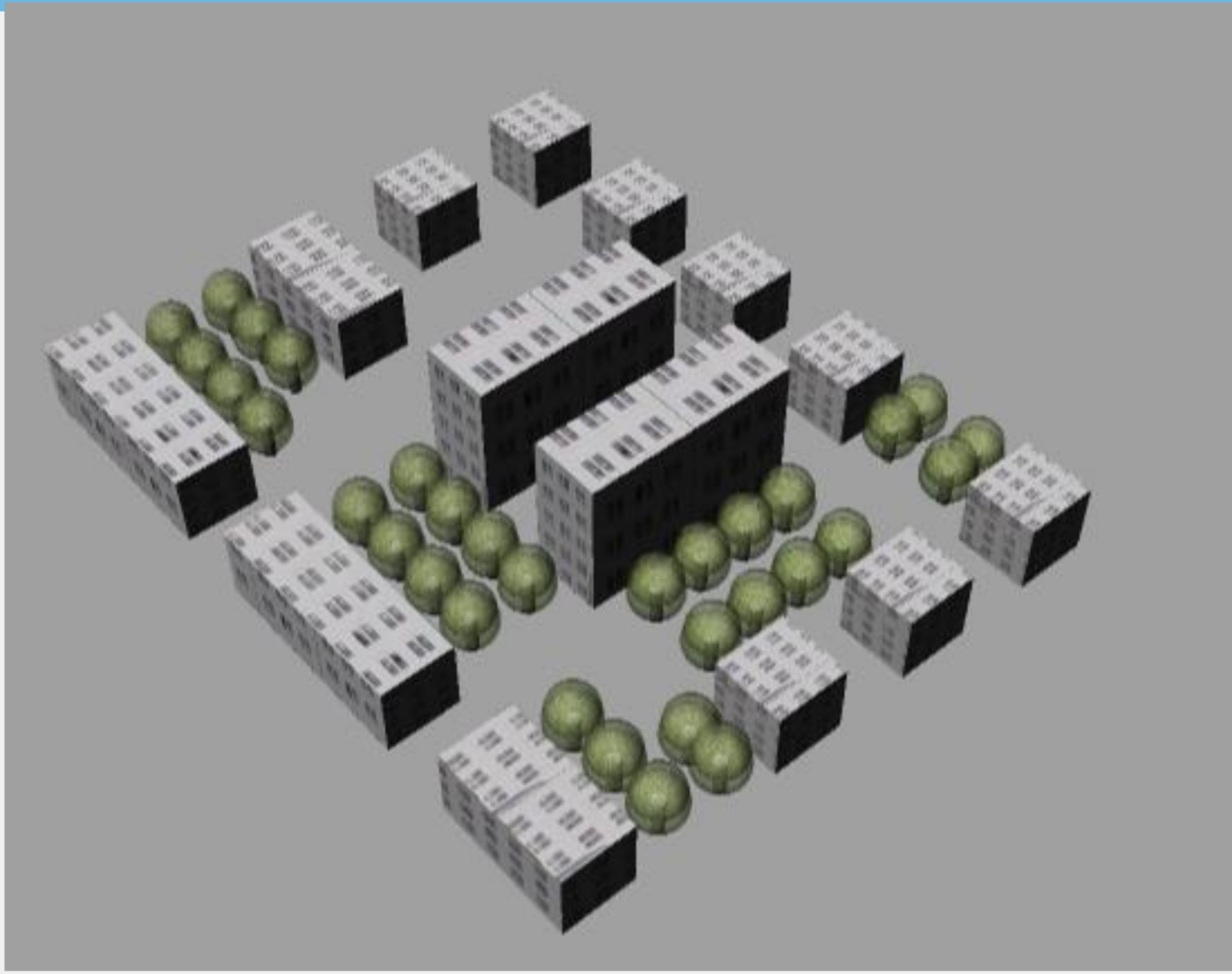
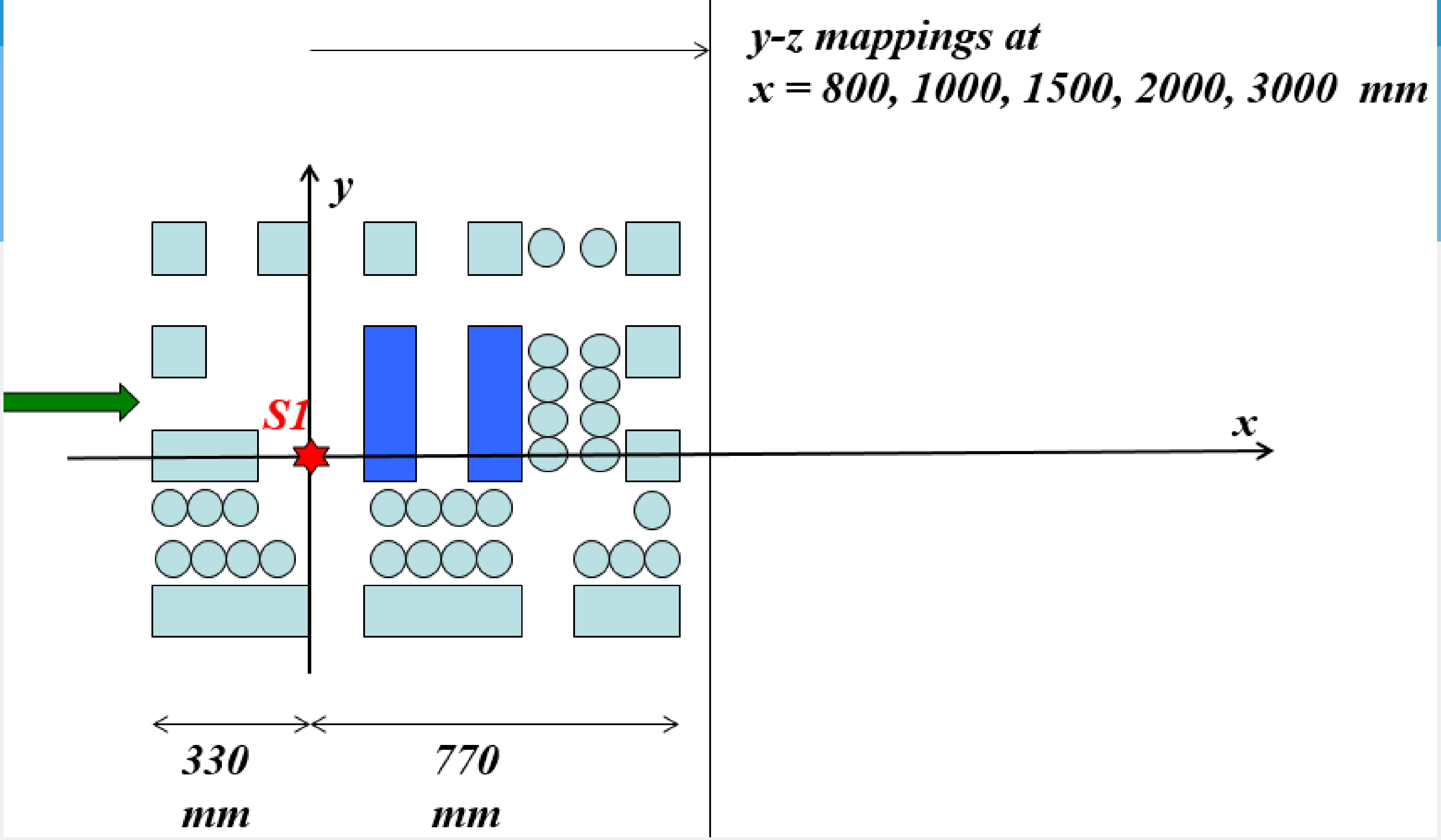
Modelled scenarios in the wind tunnel

- Flat terrain
- Ramp
- 2D Backstep
- Simple array
- **Complex array**
- Paris

- Suggested scenario





The Complex array seen from above. The source location is positioned at S1. The filled circles represent tree objects which can be used in separate cases. The concentration is mapped at distances 800 mm etc. from the source. (Vertical plotted line is at 800 mm)

Note! The trees are not included in the simulations for this presentation.

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RANS MODELS

Assuming that instantaneous values can be replaced with a mean and fluctuating part($\phi = \bar{\phi} + \phi'$) in Navier-Stokes equations and then applying Reynolds averaging, returns the same equation with mean values instead, plus a stress term. RANS modelling is how to model the stress term.

RANS modell 1: The code Saturne v4.0 developed by EDF. It uses a high Reynolds k-ε turbulent model with linear production that corrects the known flaw of the standard k-ε model which overestimates the turbulence level in case of strong velocity gradients. And an atmospheric module developed at EDF. (code-saturne.org)

This module can a priori handle neutral, slightly stable and unstable atmospheres dry or wet (adiabatic profile modified).

Turbulent production gravity term is included in the k-ε equations.

A “scalable wall law” instead of a log law is used in well meshed cases (y+ < 10).

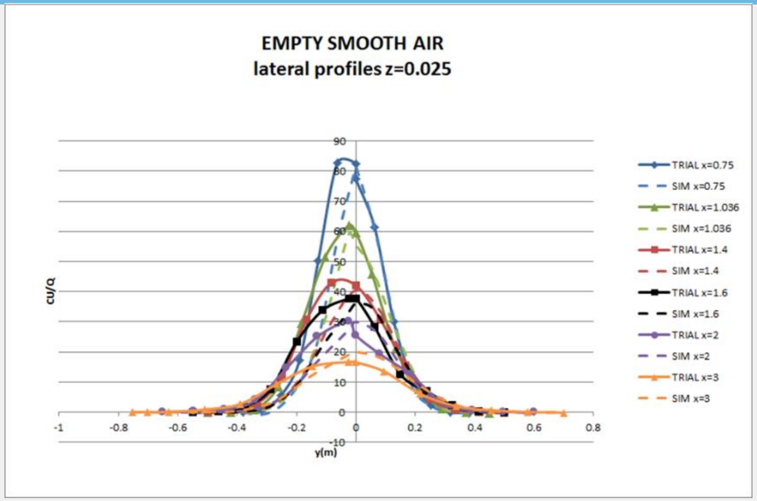
RANS MODELS

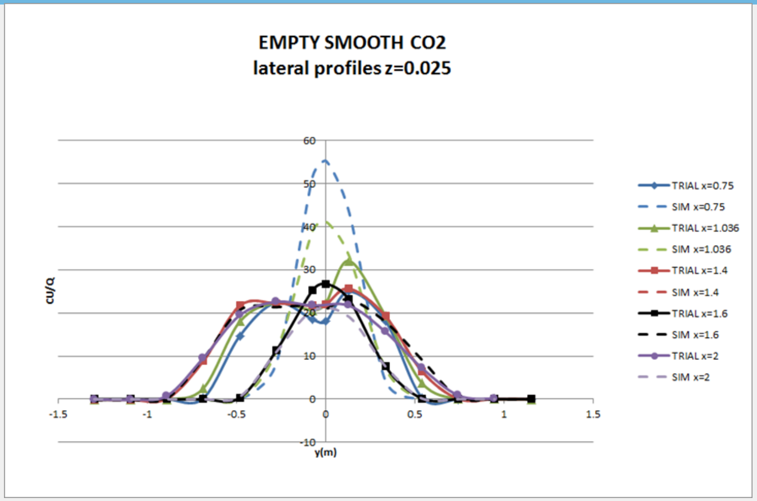
RANS modell 2: The code PHOENICS developed by CHAM

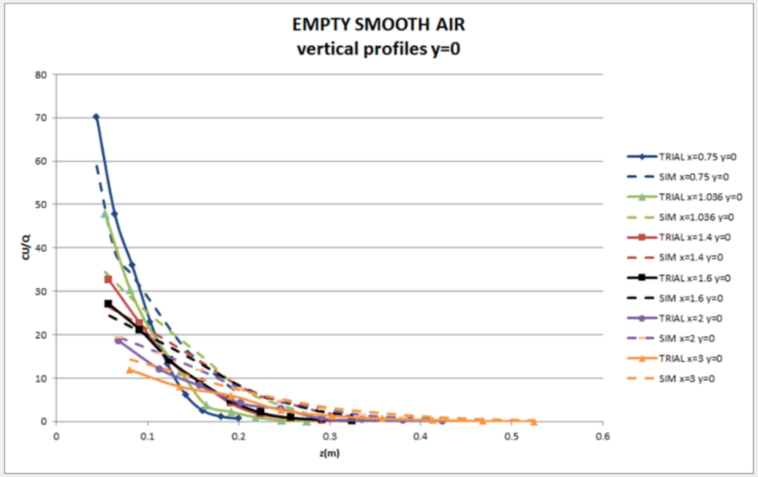
PHOENICS is a general purpose CFD-code that allows for easy implementation of boundary conditions and grid generation for this case. Boundary conditions are set according to the measured values from the wind tunnel for wind speed and turbulence for the approaching flow. The MMK model differs from the standard high Reynolds k-ε turbulent model in that the eddy viscosity coefficient is limited in strong shear by multiplication with the ratio of the vorticity and strain parameters [3]. The same turbulent production gravity term as in Saturne is here included.

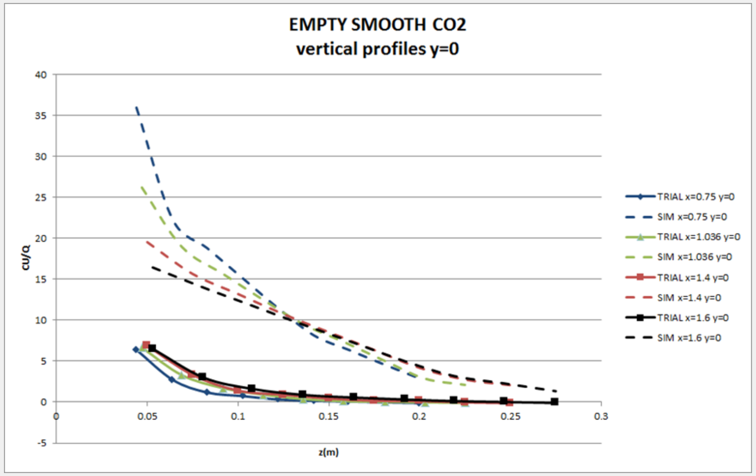
* M. Tsuchiya, Murakami,S.,Mochida, A., Kondo,K.,Ishida, Y., Development of a new k-e model for flow and pressure fields around bluff body, J.Wind Engineeering & Industrial Aerodynamics, 67,68 (1997) 169-182.

Normalized concentration for AIR (left) and CO2 (right) on Flat Surface with Code Saturne



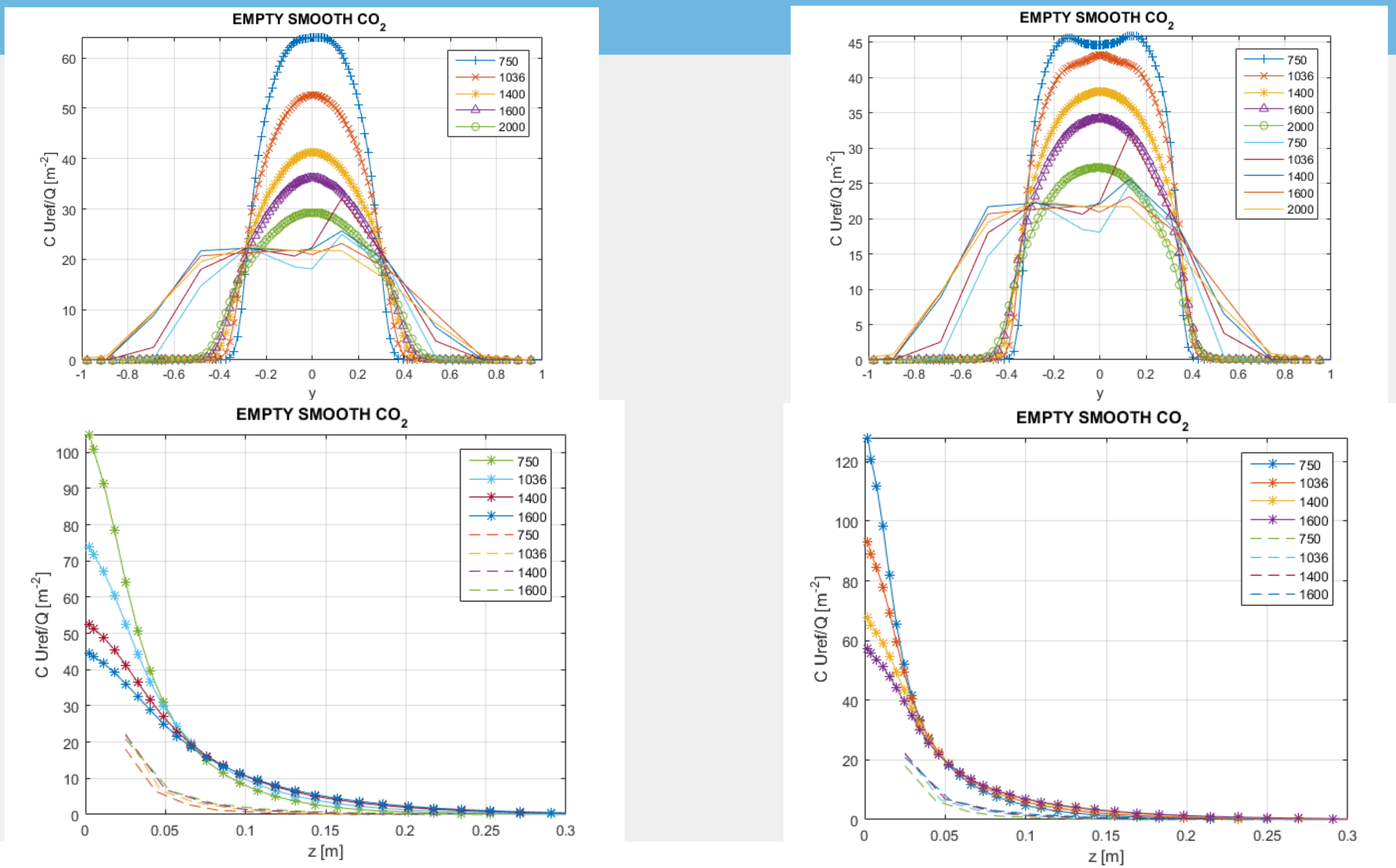






Lateral and vertical plots of concentration at different distances from the source

Normalized concentration for AIR (left) and CO2 (right) on Flat Surface with Code PHOENICS



Lateral and vertical plots of concentration at different distances from the source, Left pane is standard formulation, right is revised

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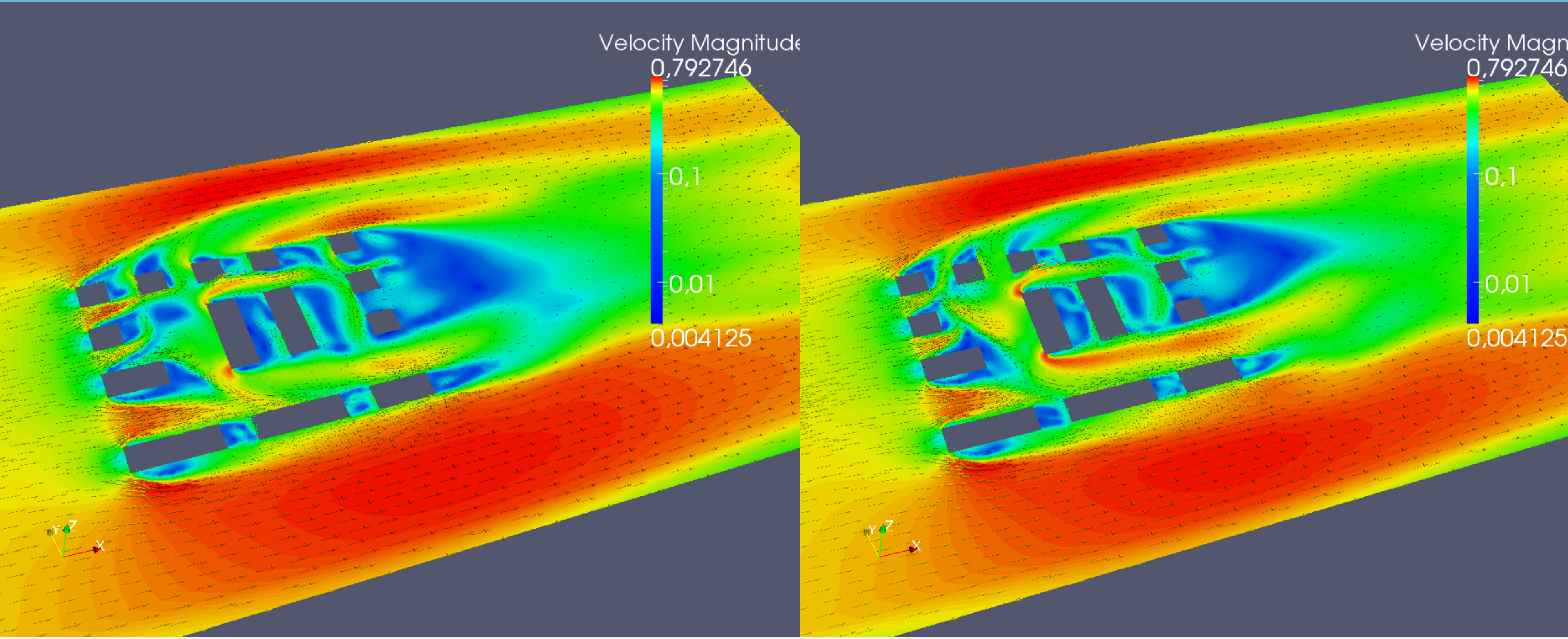
Comparison neutral – heavy gas release in the Complex Array scenario: SATURNE



Velocity contours for AIR (left) and CO2 (right) for complex array case

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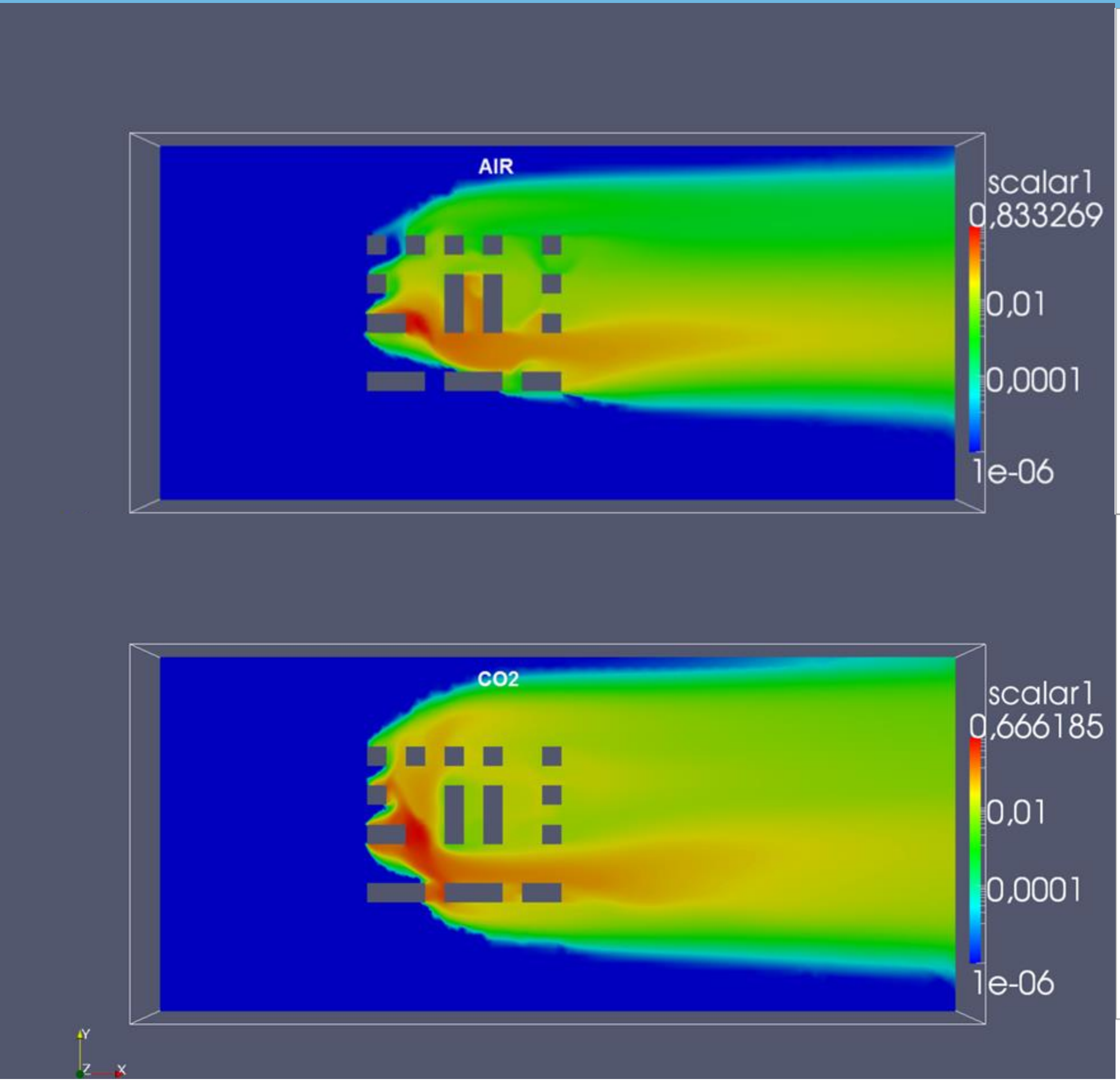
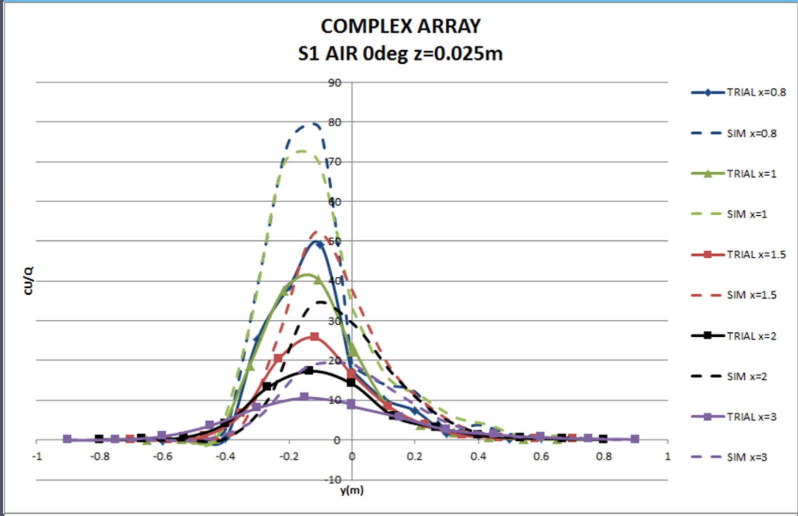
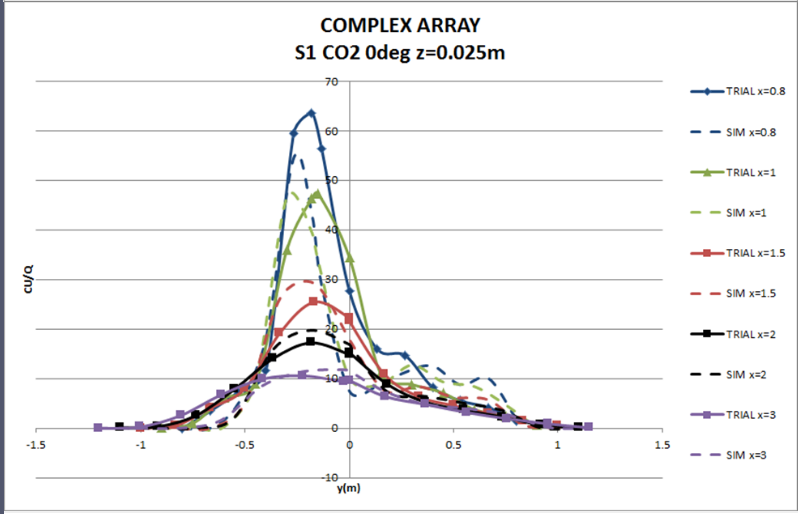
Comparison neutral – heavy gas release in the Complex Array scenario: SATURNE







Mass Fraction contours for AIR (top) and CO_2 (bottom) and cross wind profiles close to the ground

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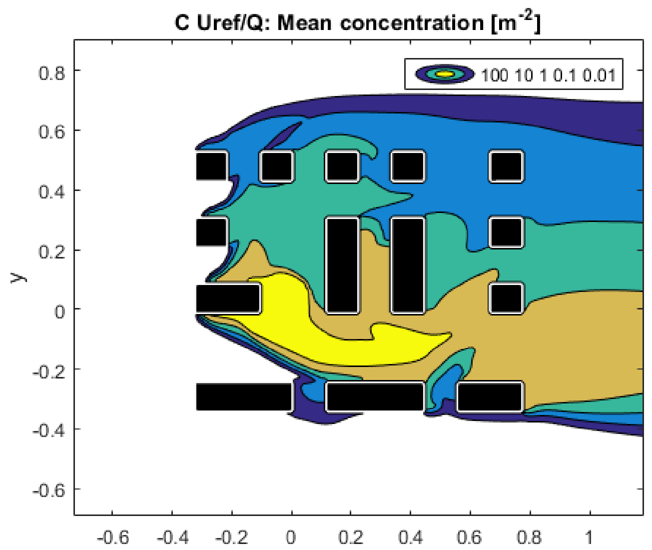
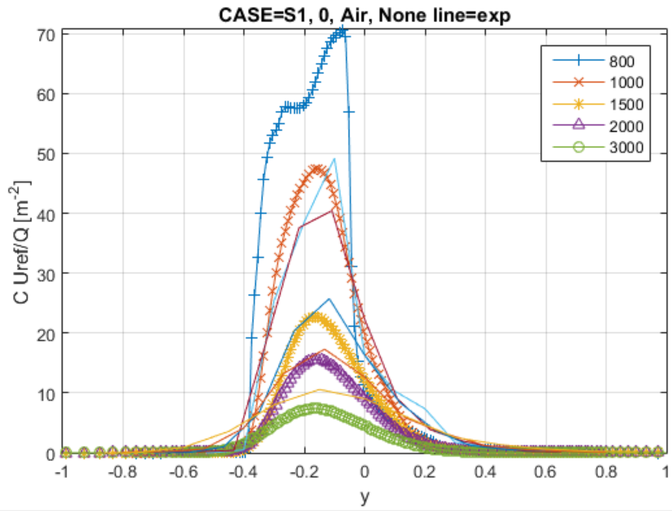
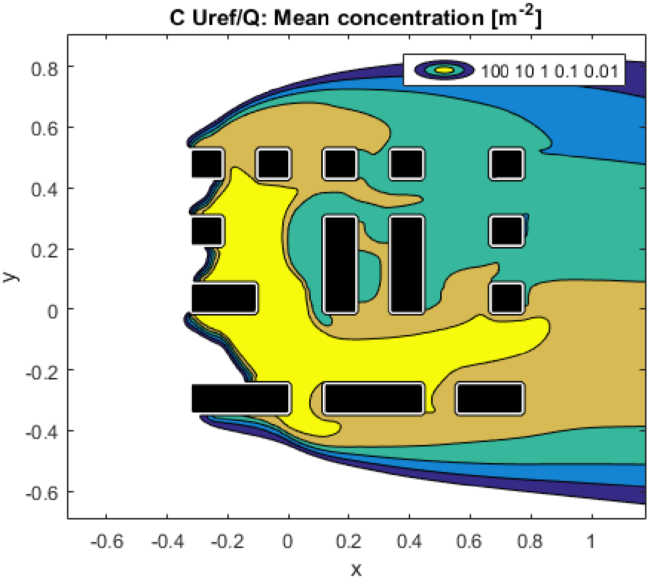
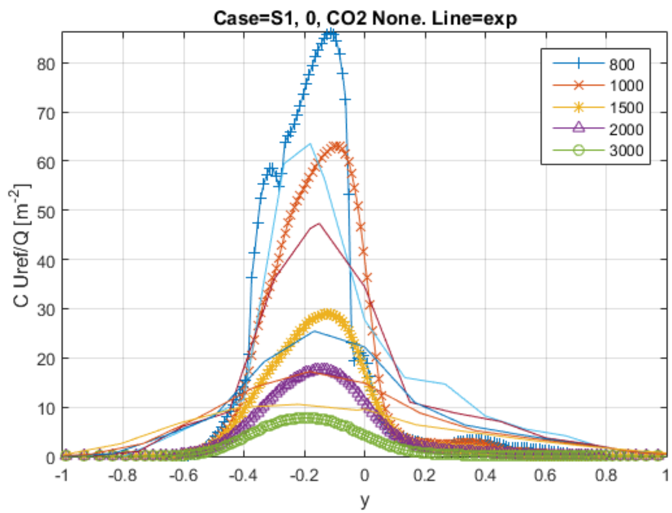
Comparison neutral – heavy gas release in the Complex Array scenario: PHOENICS









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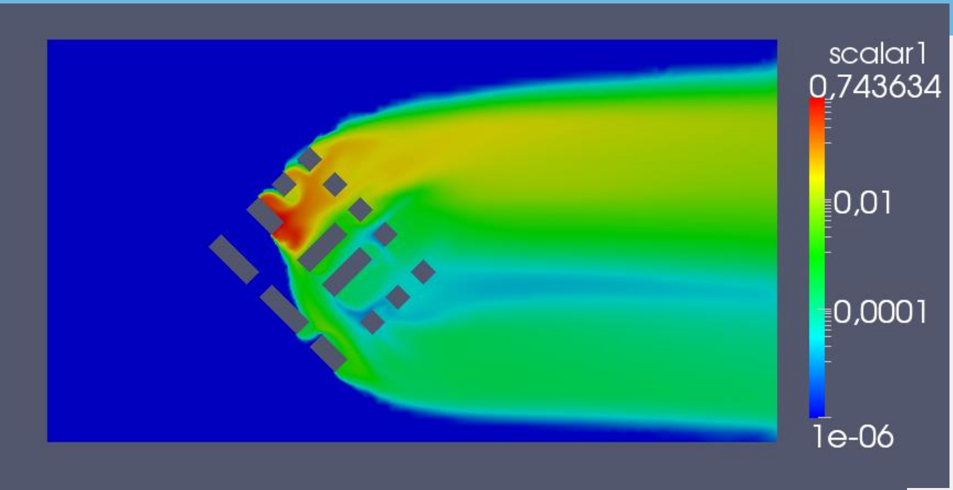
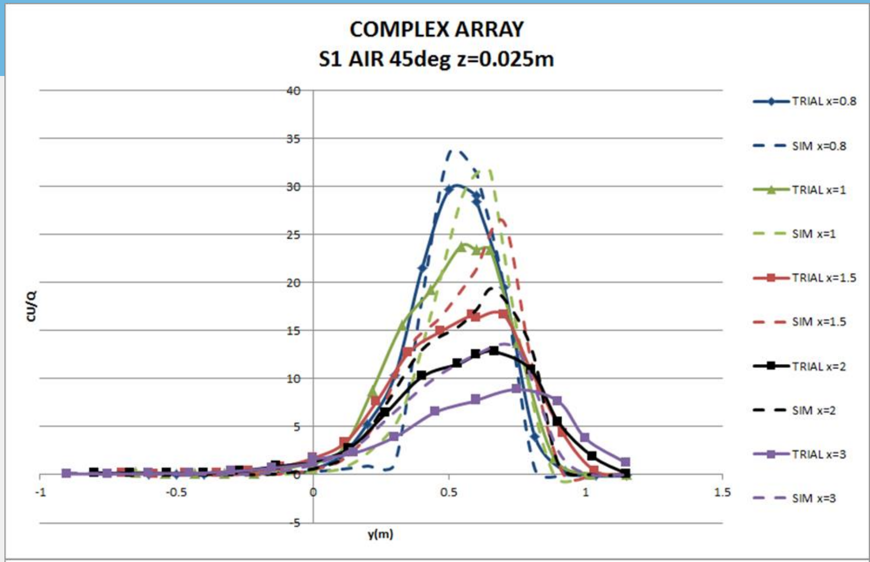
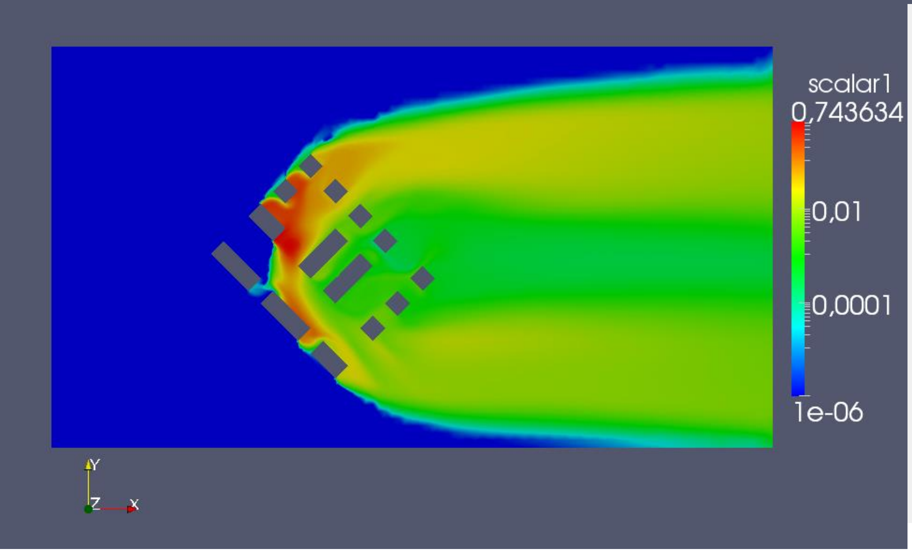
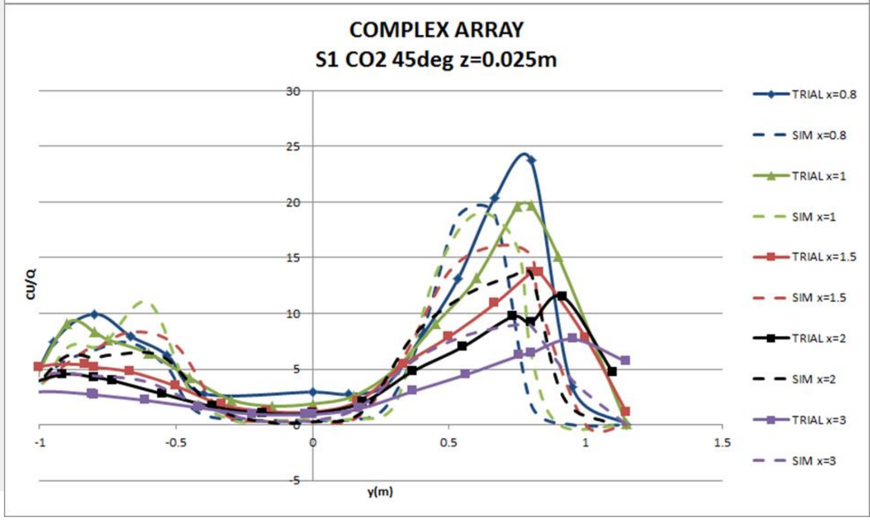
Comparison neutral – heavy gas release in the Complex Array scenario: SATURNE





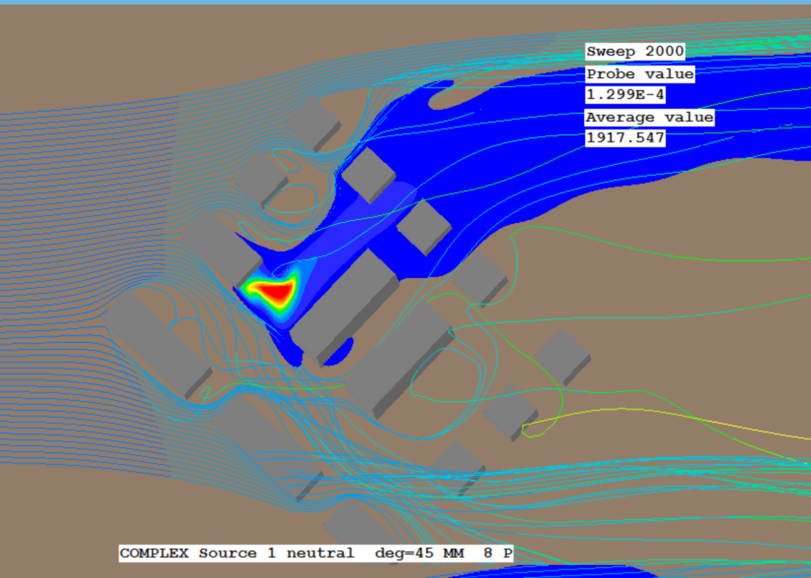


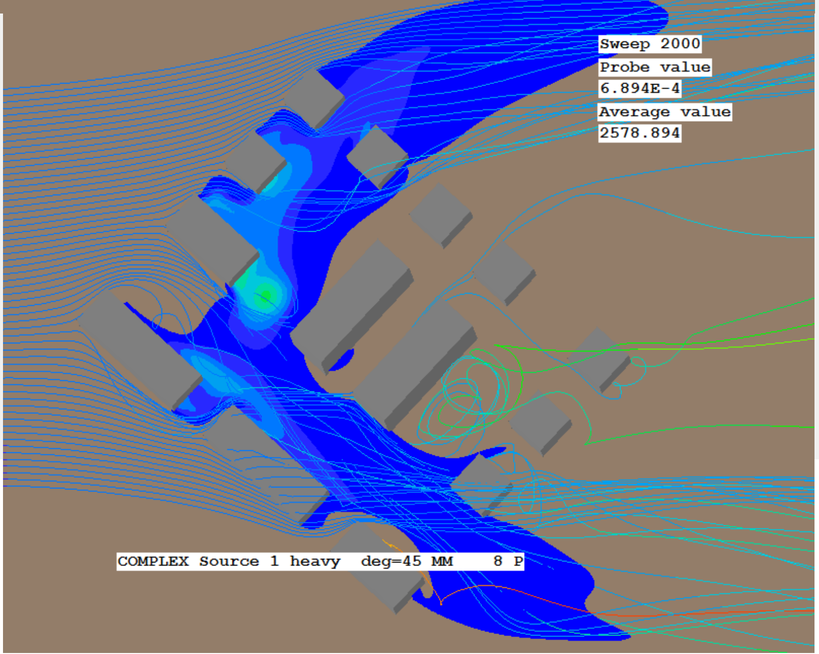


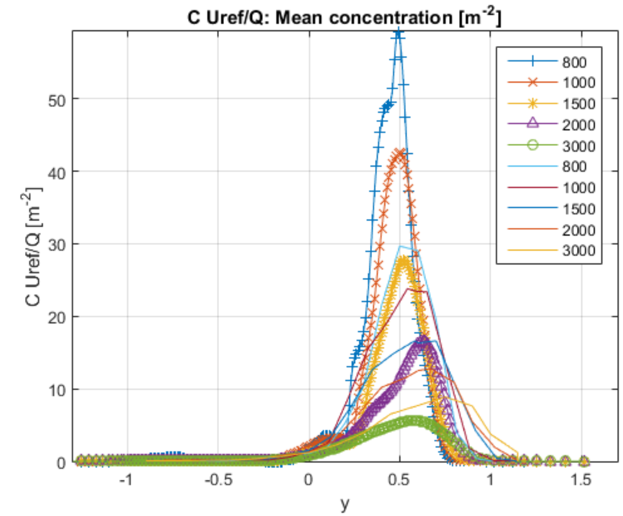
Mass Fraction contours for AIR (top) and CO2 (bottom) and cross wind profiles close to the ground for the 45° orientated array

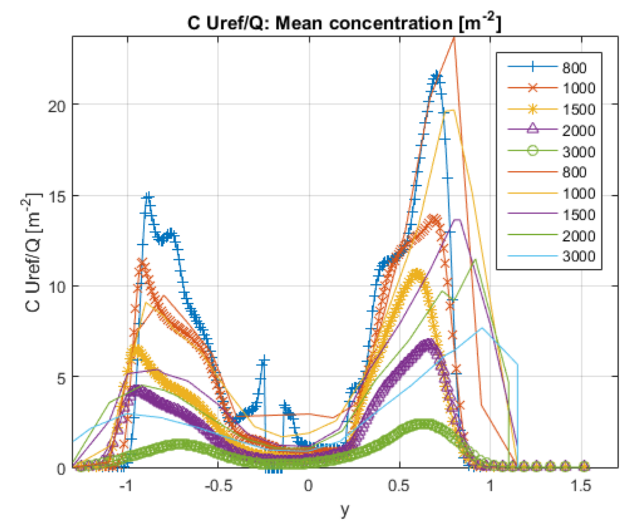
This results in a better correlation for Air concentrations and CO2 as well, where the two plumes are captured

Comparison neutral – heavy gas release in the Complex Array scenario: PHOENICS









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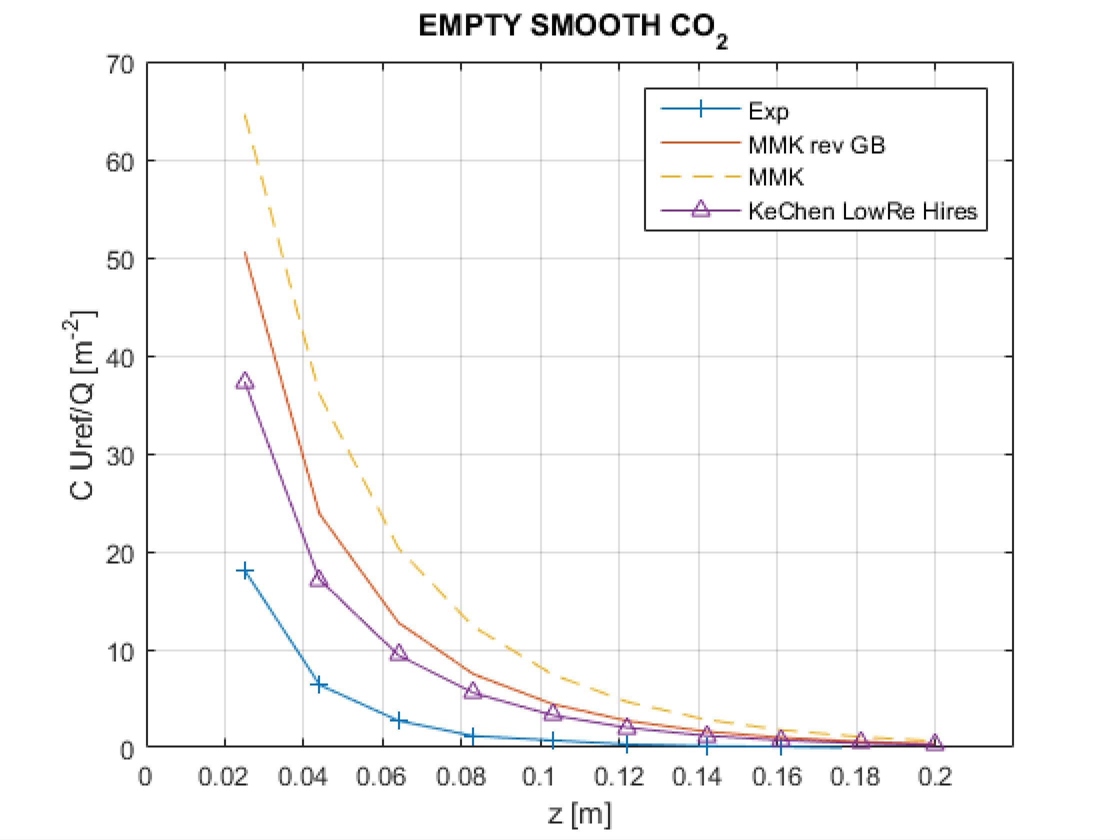
CONCLUSIONS

- As long as the source is surrounded by buildings, AIR as well as CO_2 (dense) gas release is well reproduced by RANS models tested here in terms of concentration.
- Still it seems as that the non-stationary mixing turbulent process is under-rated. A suggestion is to run RANS not in stationary mode but as URANS.
- Problematic is the CO_2 flat case that highlights the flaws of RANS models in this context: high Re turbulence models overestimate the turbulent viscosity, the gravity terms in *k*-*e* equations is probably not sufficiently resolved at the plume edge (where high density gradients happen).
- Finally the dependence of turbulent viscosity with plume Ri number to further reduce it would be worth to study.

The End



EMPTY SMOOTH CO_2
C Uref/Q [m^{-2}]
z [m]
Exp
MMK rev GB
MMK
KeChen LowRe Hires
0
10
20
30
40
50
60
70
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

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