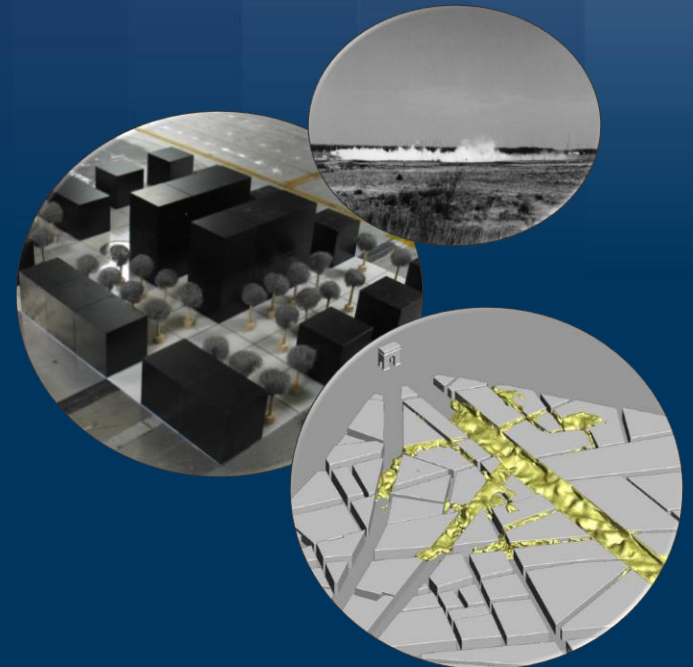# MODITIC

Modelling the dispersion of toxic industrial chemicals in urban environments

Large Eddy Simulation of dispersion of neutral and non-neutral scalar fields in complex urban-like geometries
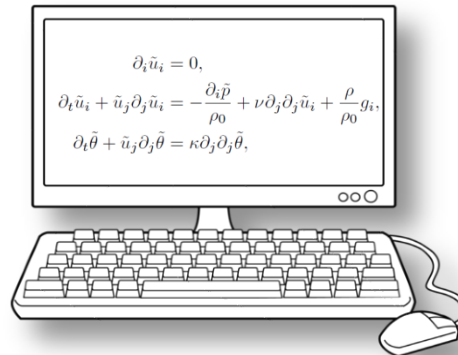
Harmo'17

12.05.2016

E. M. M. Wingstedt, D. Eriksson, O. Parmhed, G. Leroy, A. N. Osnes, B. A. Pettersson Reif and J. Burman
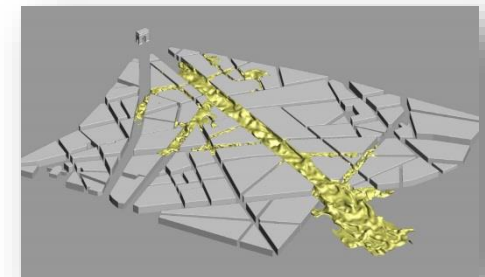
FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

FOI

DGA

INERIS

UNIVERSITY OF SURREY

Overview of the presentation

Motivation

Simulations

$$\partial_i \tilde{u}_i = 0,$$
$$\partial_t \tilde{u}_i + \tilde{u}_j \partial_j \tilde{u}_i = -\frac{\partial_i \tilde{p}}{\rho_0} + \nu \partial_j \partial_j \tilde{u}_i + \frac{\rho}{\rho_0} g_i,$$
$$\partial_t \tilde{\theta} + \tilde{u}_j \partial_j \tilde{\theta} = \kappa \partial_j \partial_j \tilde{\theta},$$

Results

Why do we want to do simulations and why the use of LES?

Why do we want to do simulations and why the use of LES?

# Why do we want to do simulations and why the use of LES?

- Experiments → limitations in number of measurement positions
- Simulations → collect data "everywhere"

- Need to have a correct description of the flow field
  – Dense gas changes the flow field

- Urban flow field
  – Kinematic blocking
  – Non-local pressure effects

> LES resolves the inherent unsteadiness of large scale turbulence irrespectively of the averaged flow field

Dispersion of neutral and dense gas in two different urban-like geometries
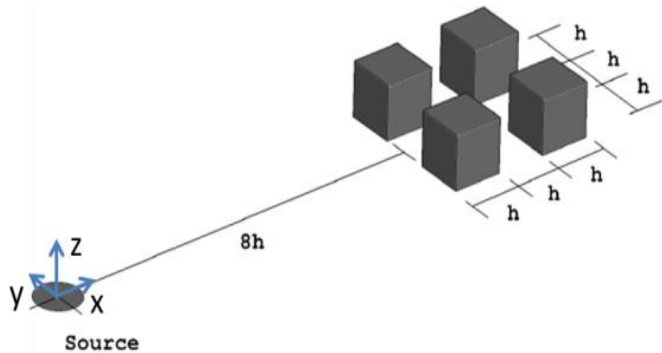
Array of four cubes
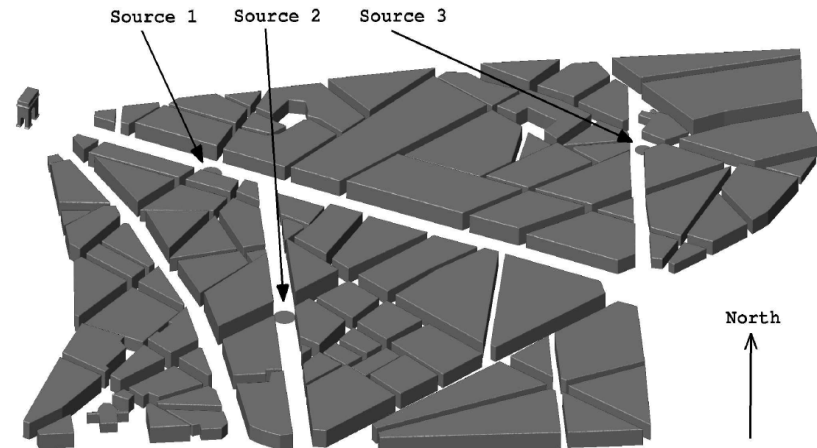
Paris

Emission rate	Source diameter	Reference velocity	Boundary layer height	Friction velocity
50 dm³/min	0.1 m	1 m/s	1 m	0.055 m/s

Large Eddy Simulations using different dense gas formulations

Variable density

- Take effects of density variation on the flow field into account

Boussinesq approach

- Limited to small density variations
- Effect of density difference only affects vertical velocity

Visualization of neutral and dense gas release over an array of four cubes
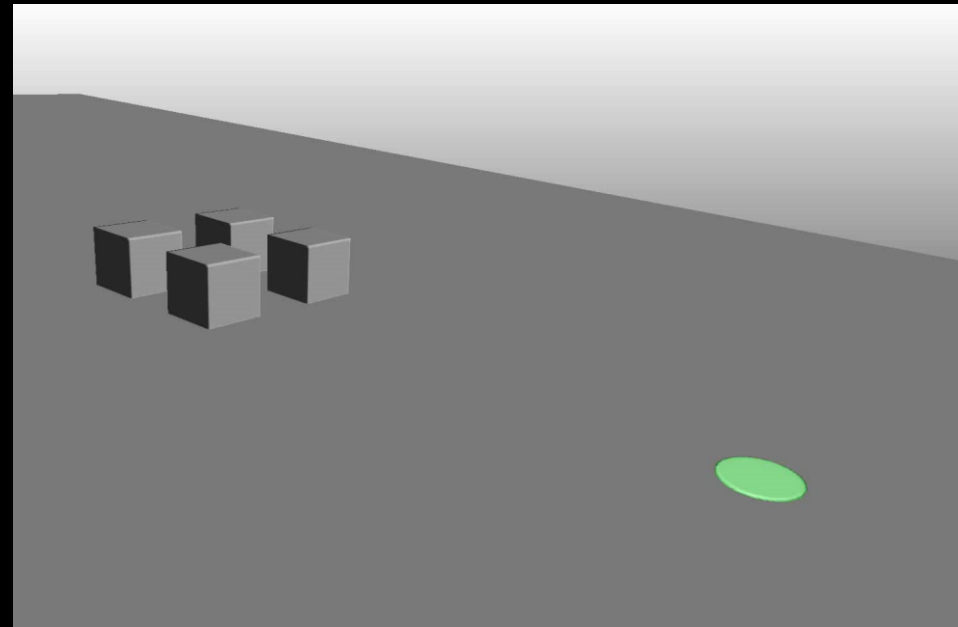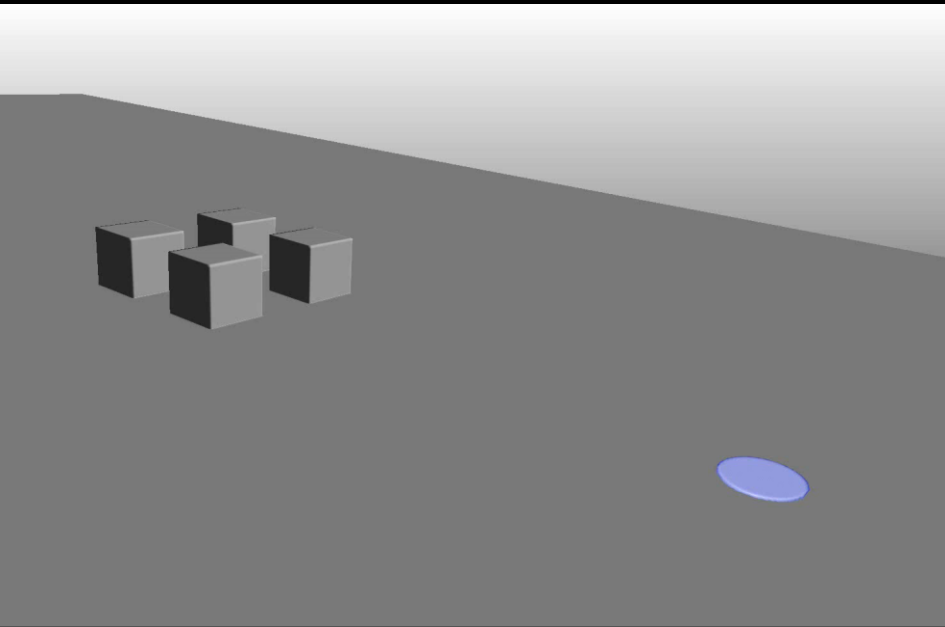
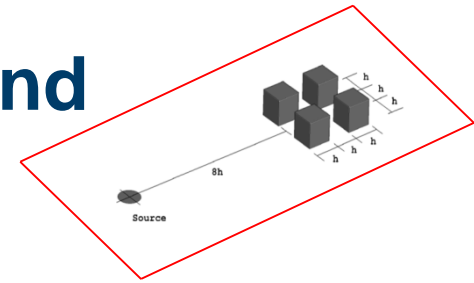# Mean concentration close to the source – upstream spread
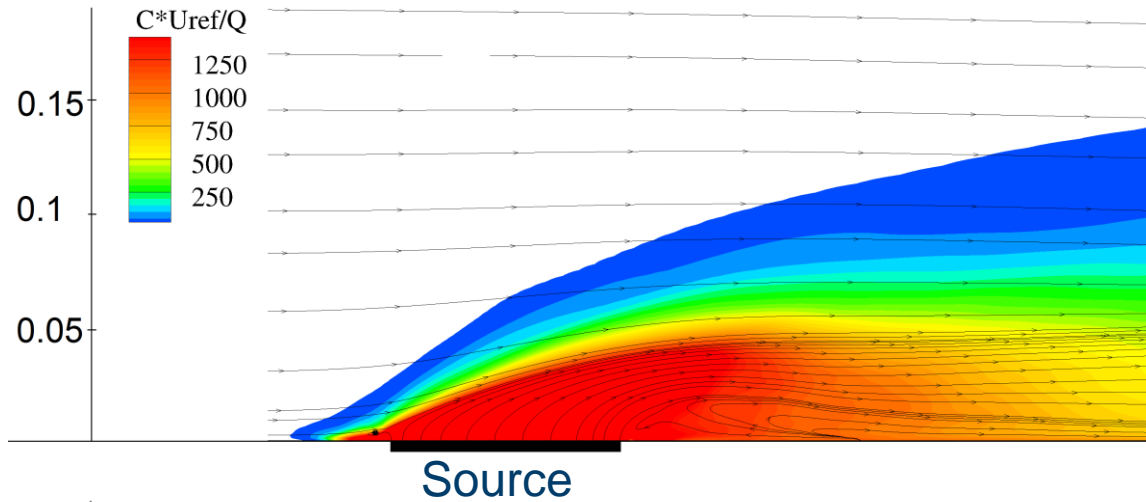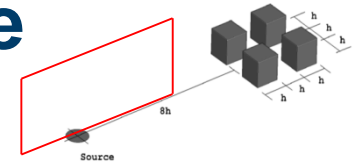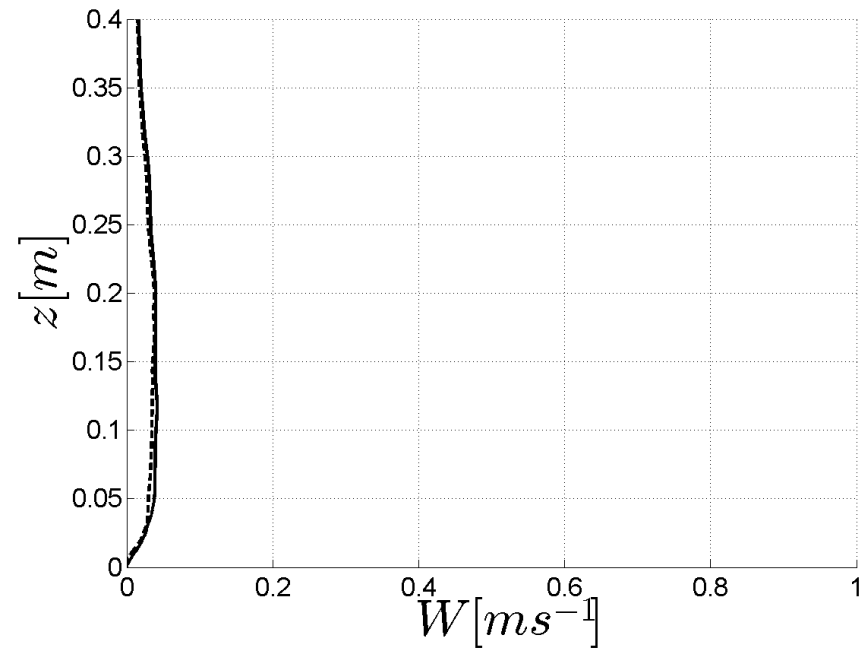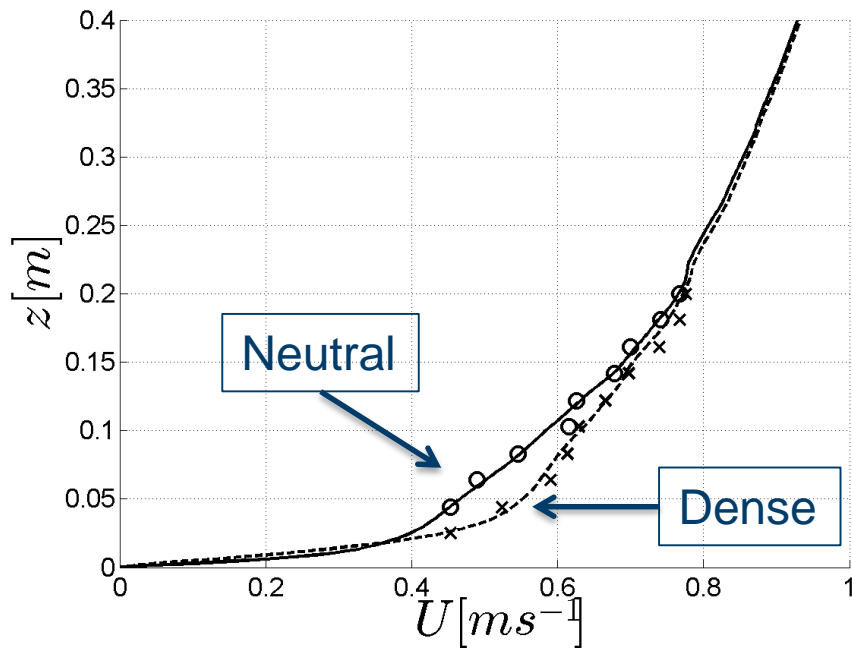

Neutral gas
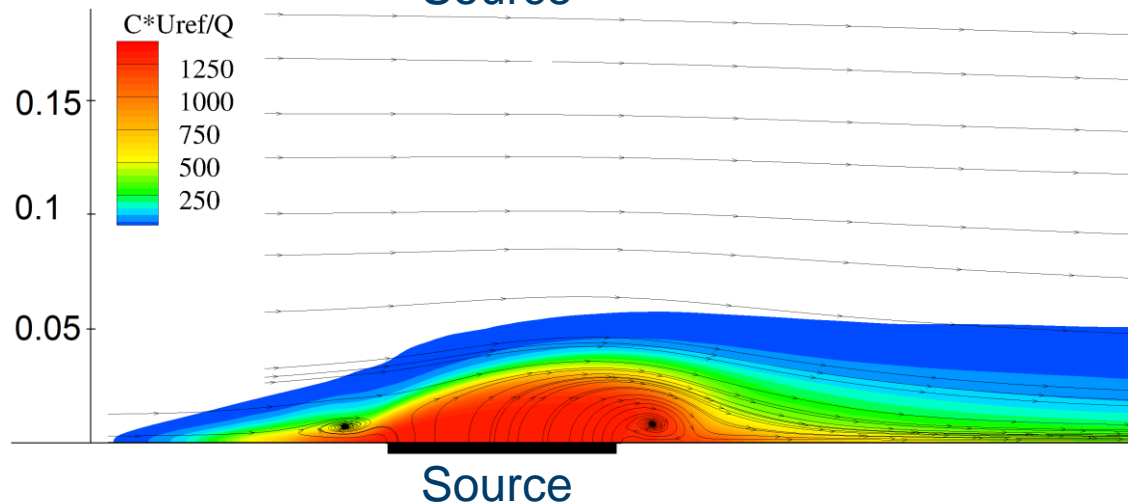
Dense gas

Mean concentration close to the ground – difference in lateral spread

Neutral gas

Dense gas

$C*U_{ref}/Q$
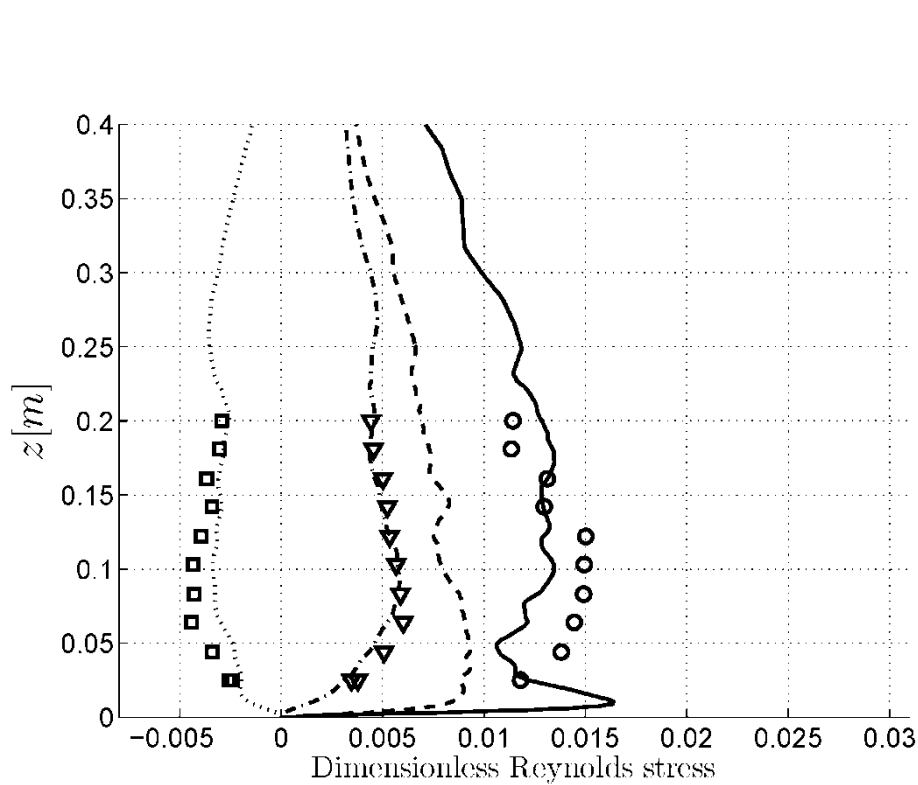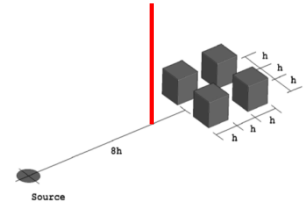
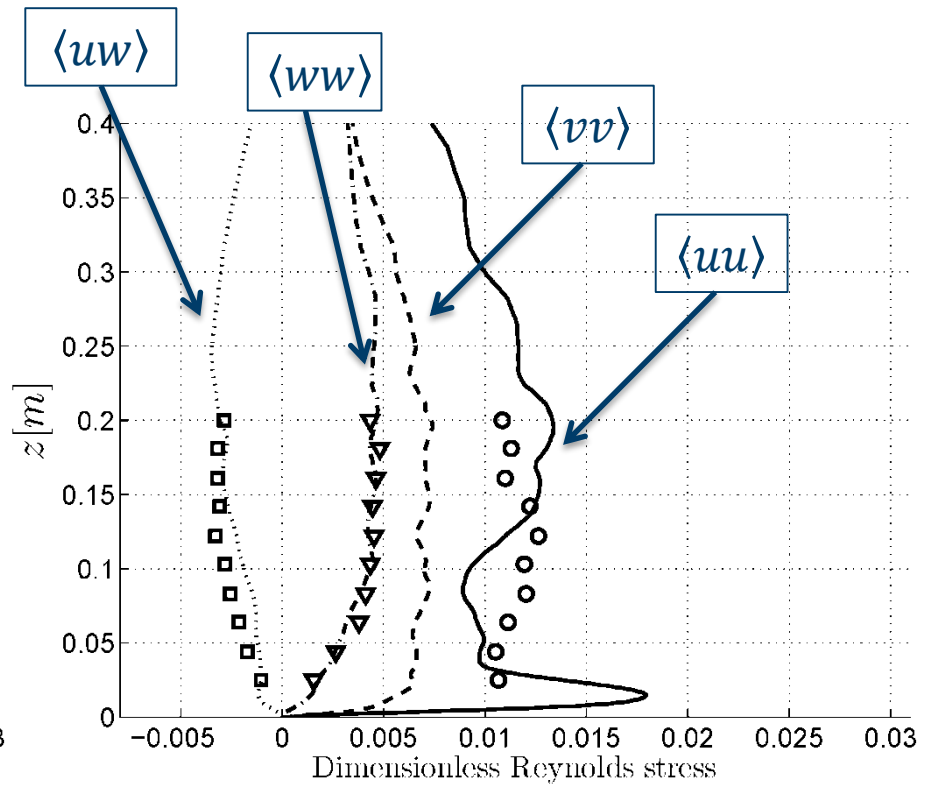|	
	1250
	1000
	750
	500
	250
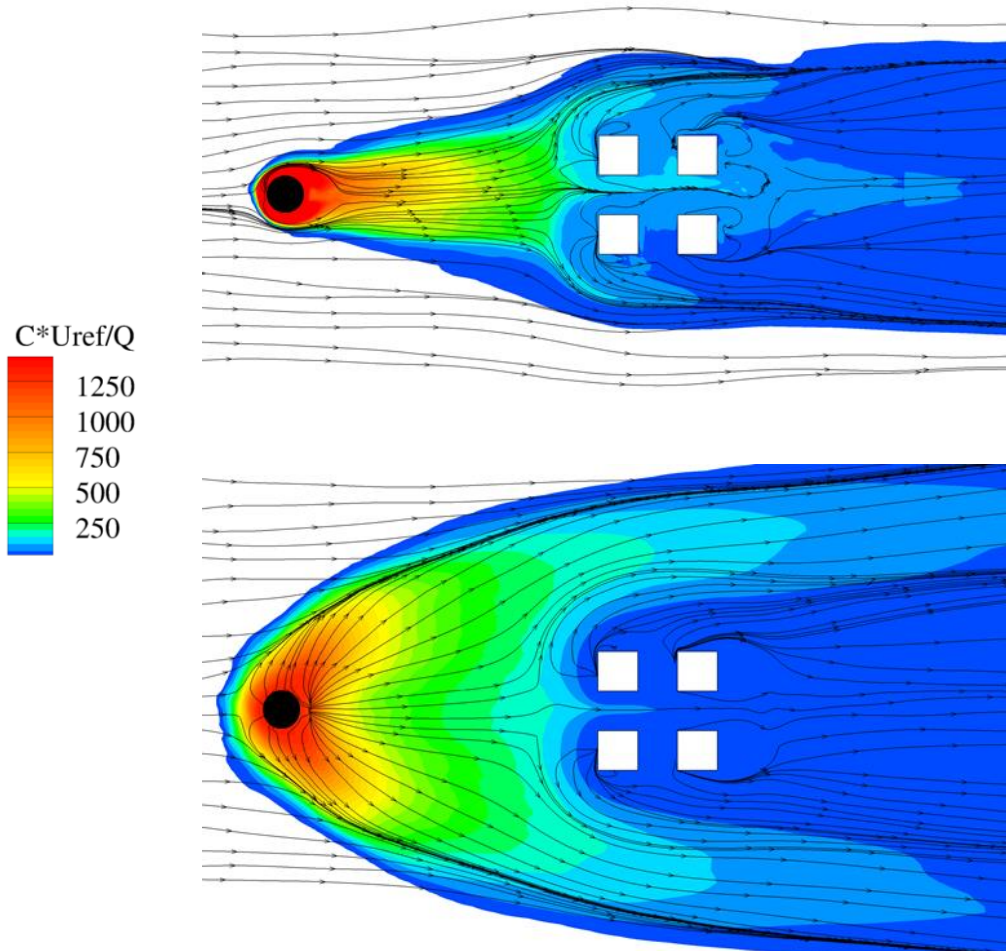
Vertical profiles of mean velocity components for neutral and dense gas in front of the cubes

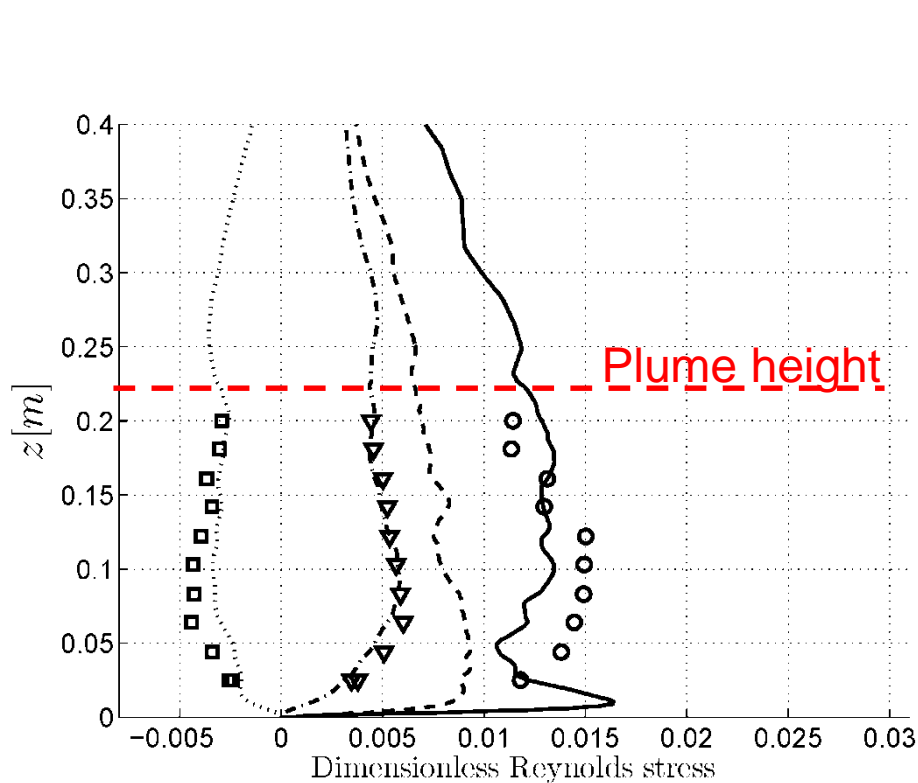# Vertical variation of Reynolds stresses for neutral and dense gas in front of the cubes
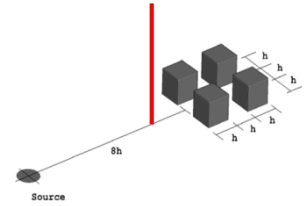
$\langle uw \rangle$

$\langle ww \rangle$

$\langle vv \rangle$

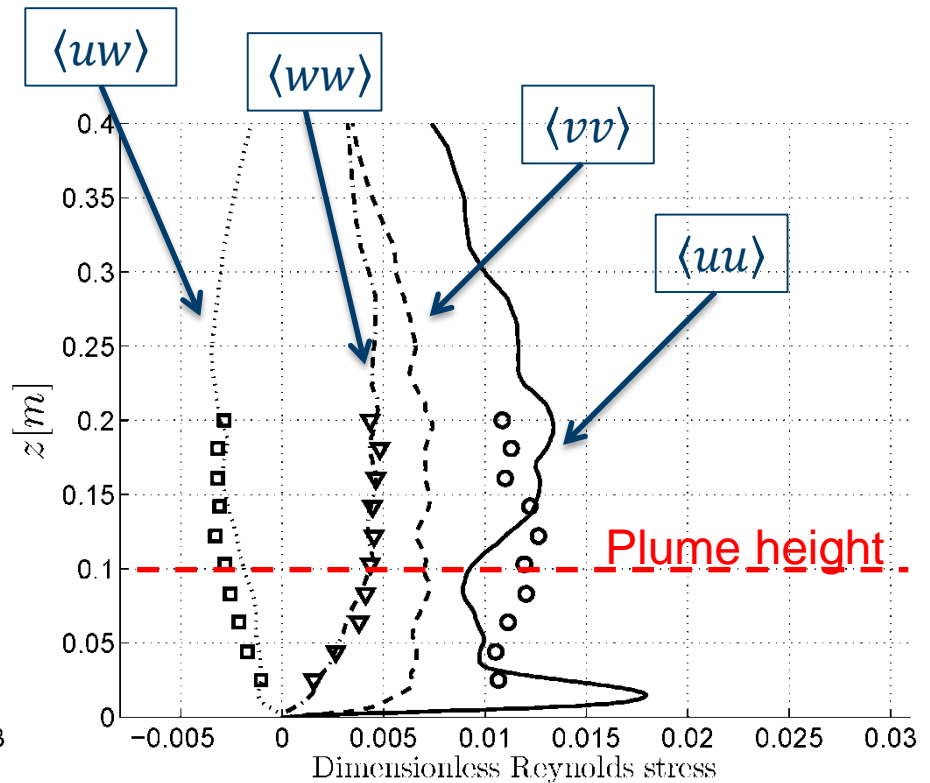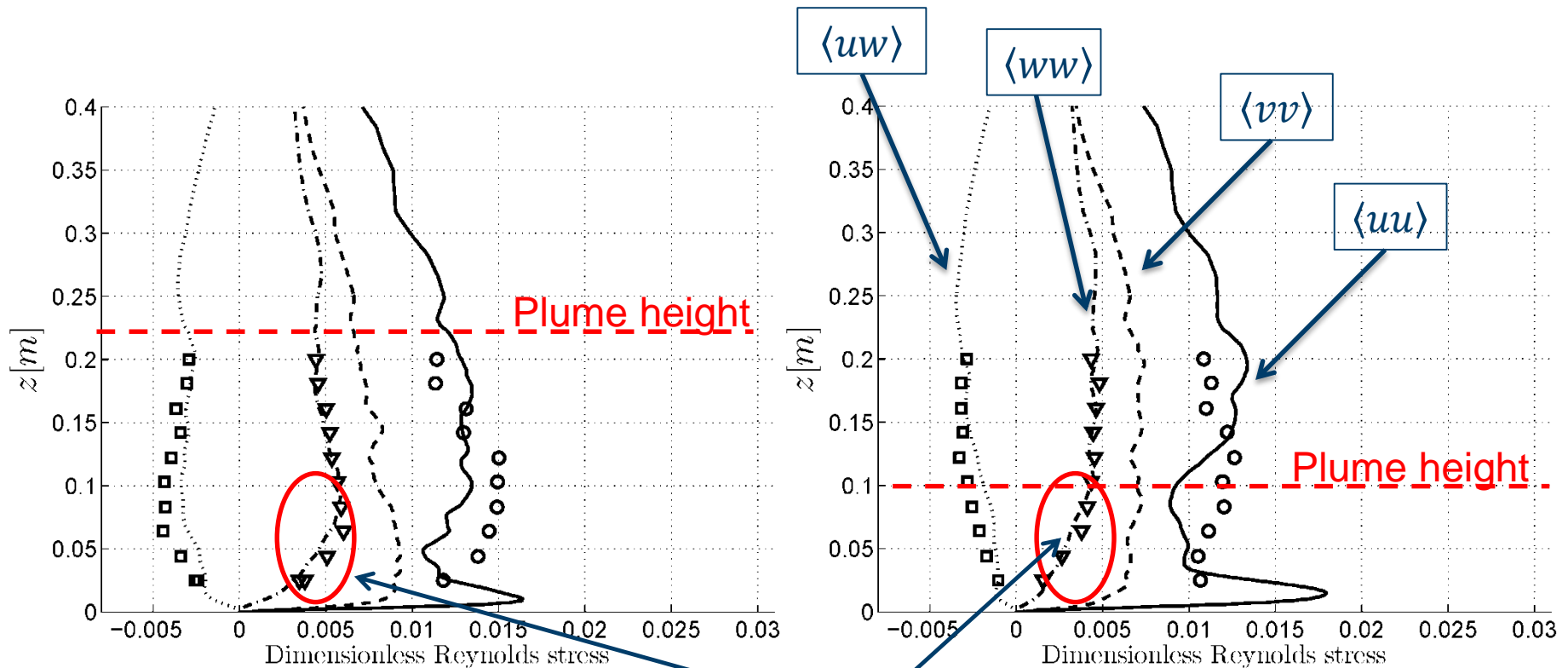$\langle uu \rangle$

Neutral gas
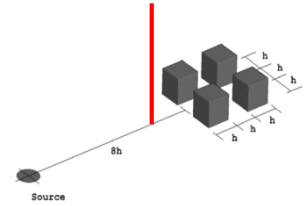
Dense gas

Vertical variation of Reynolds stresses for neutral and dense gas in front of the cubes
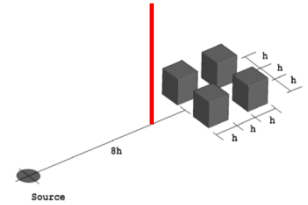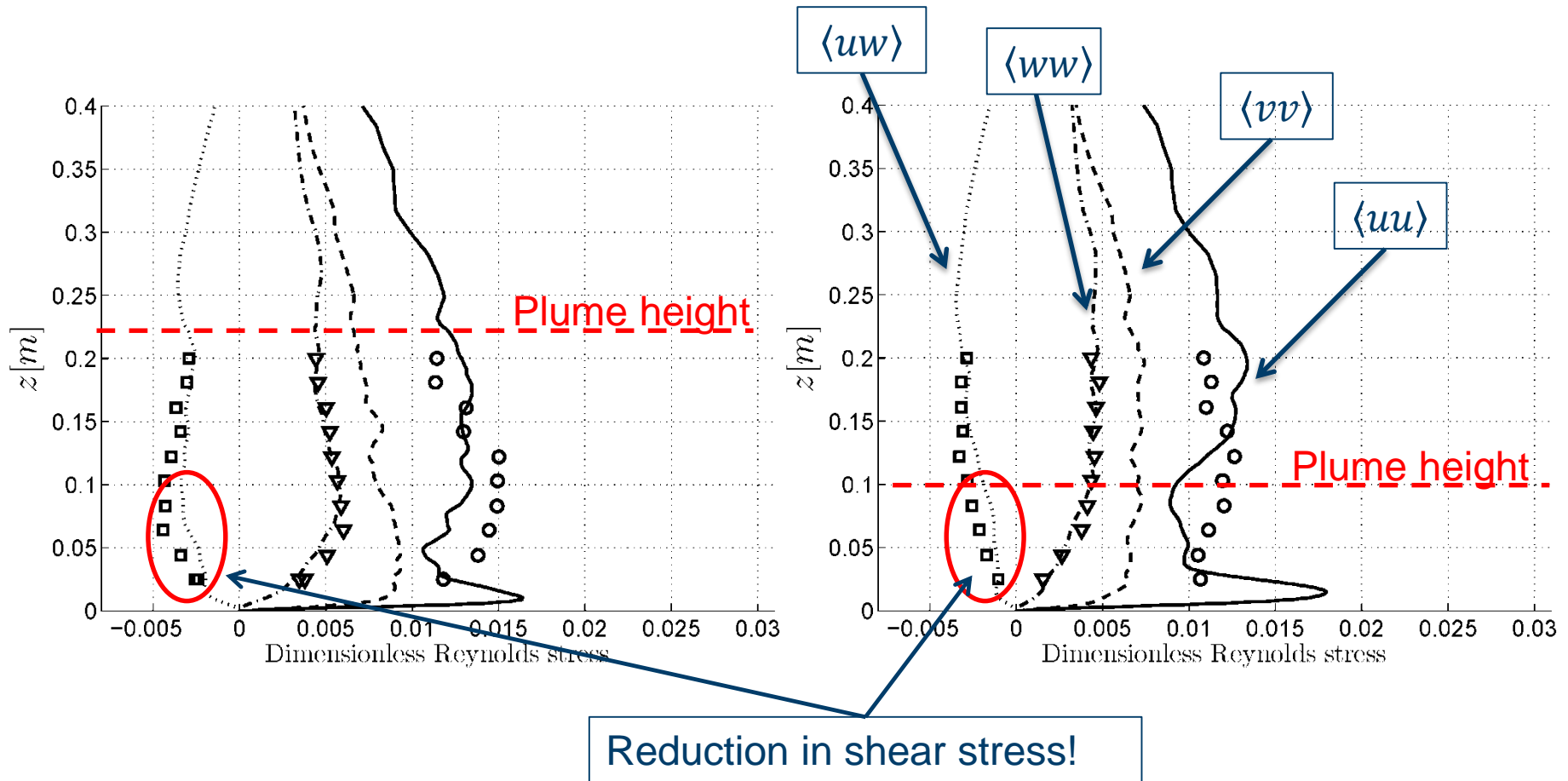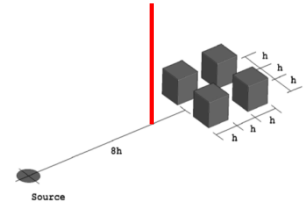

Neutral gas

Dense gas

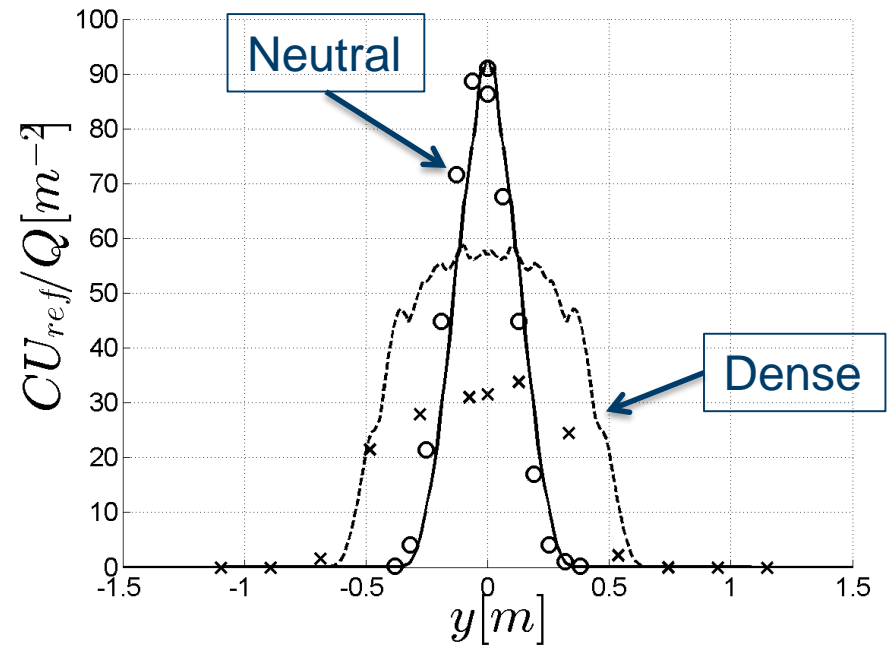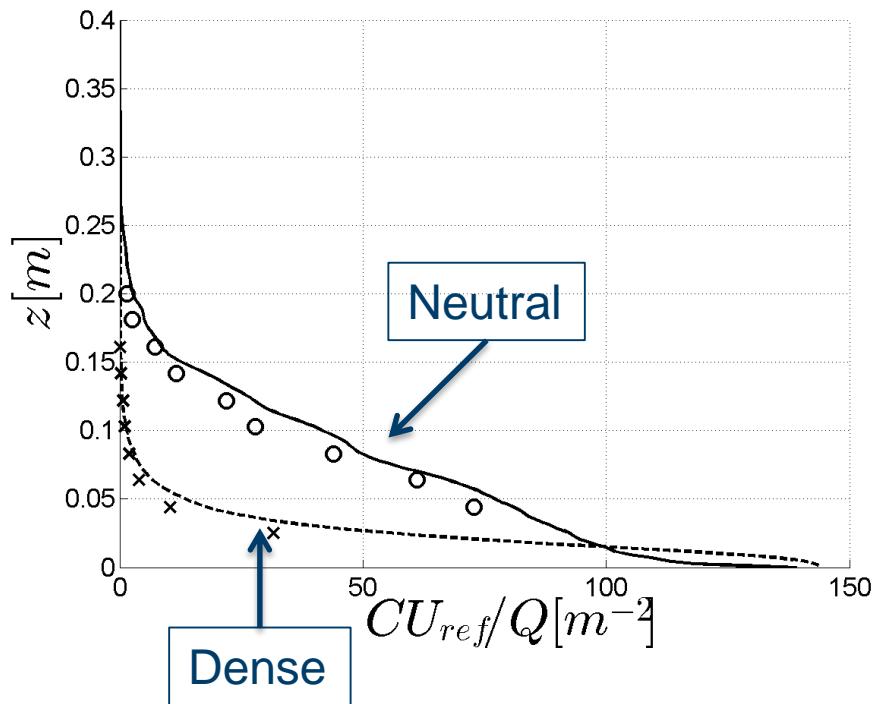# Vertical variation of Reynolds stresses for dense and neutral gas in front of the cubes
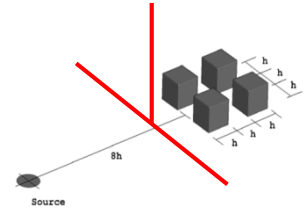

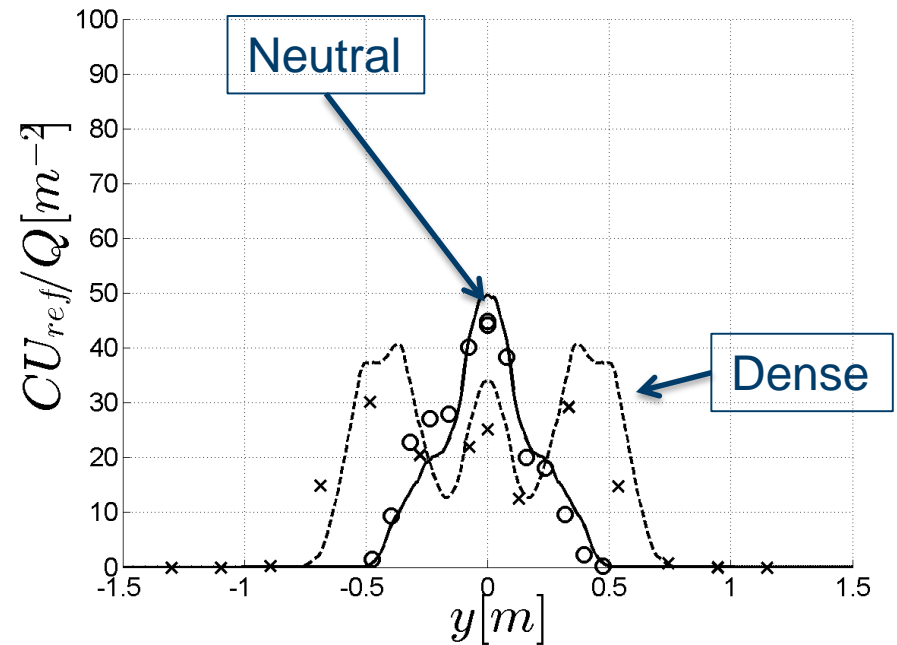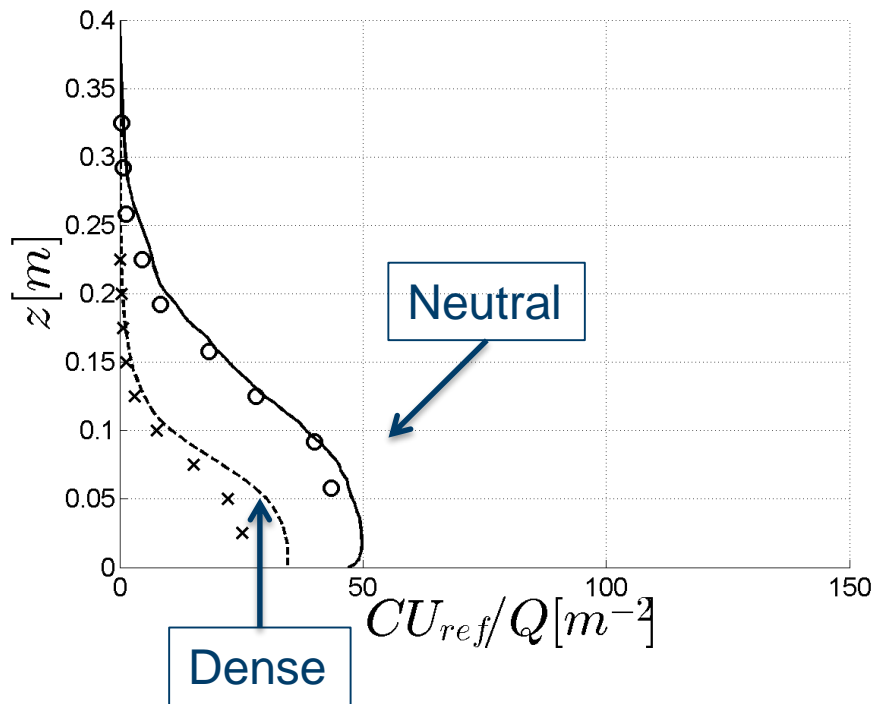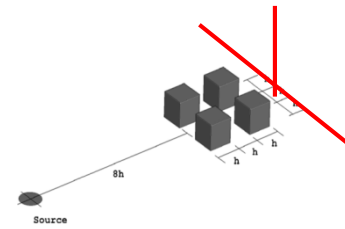Reduction in wall normal Reynolds stress component!

Vertical variation of Reynolds stresses for neutral and dense gas in front of the cubes
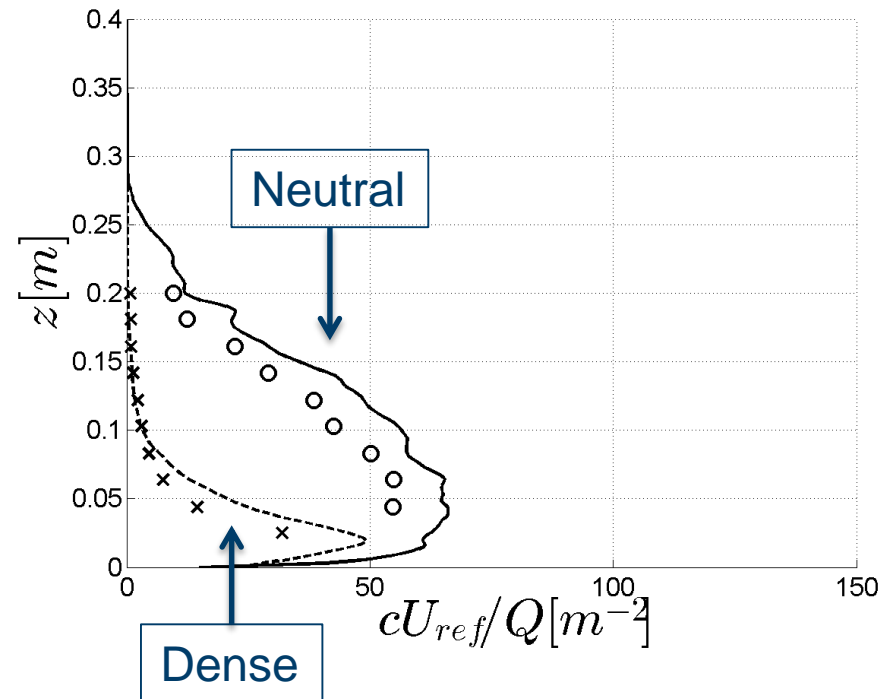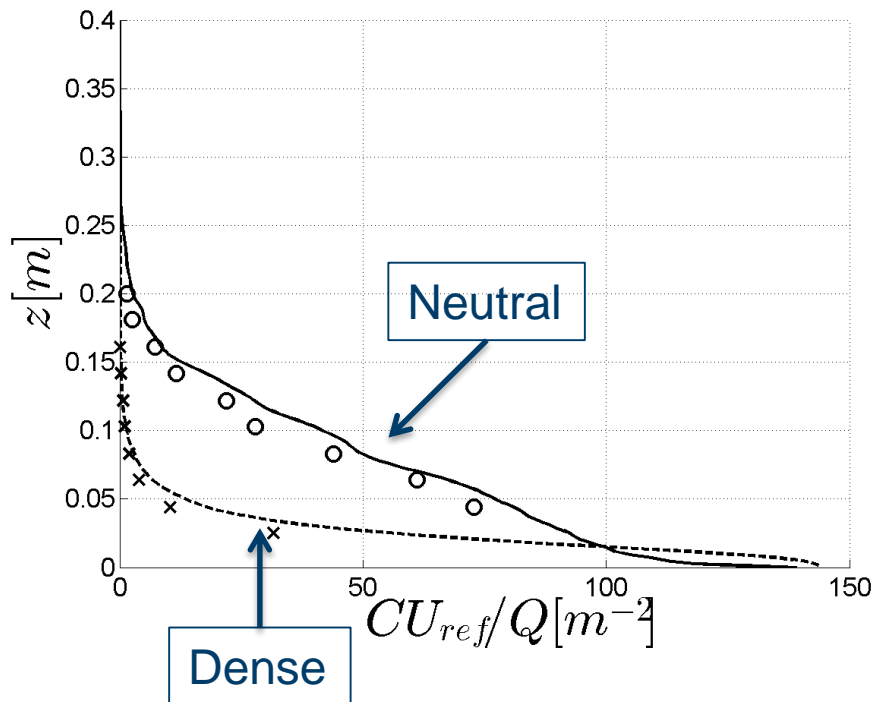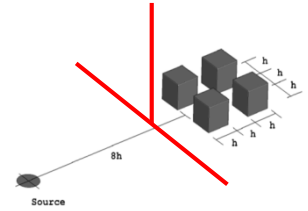
# Vertical and lateral variation of concentration for neutral and dense gas in front of the cubes

Vertical and lateral variation of concentration for neutral and dense gas behind the cubes
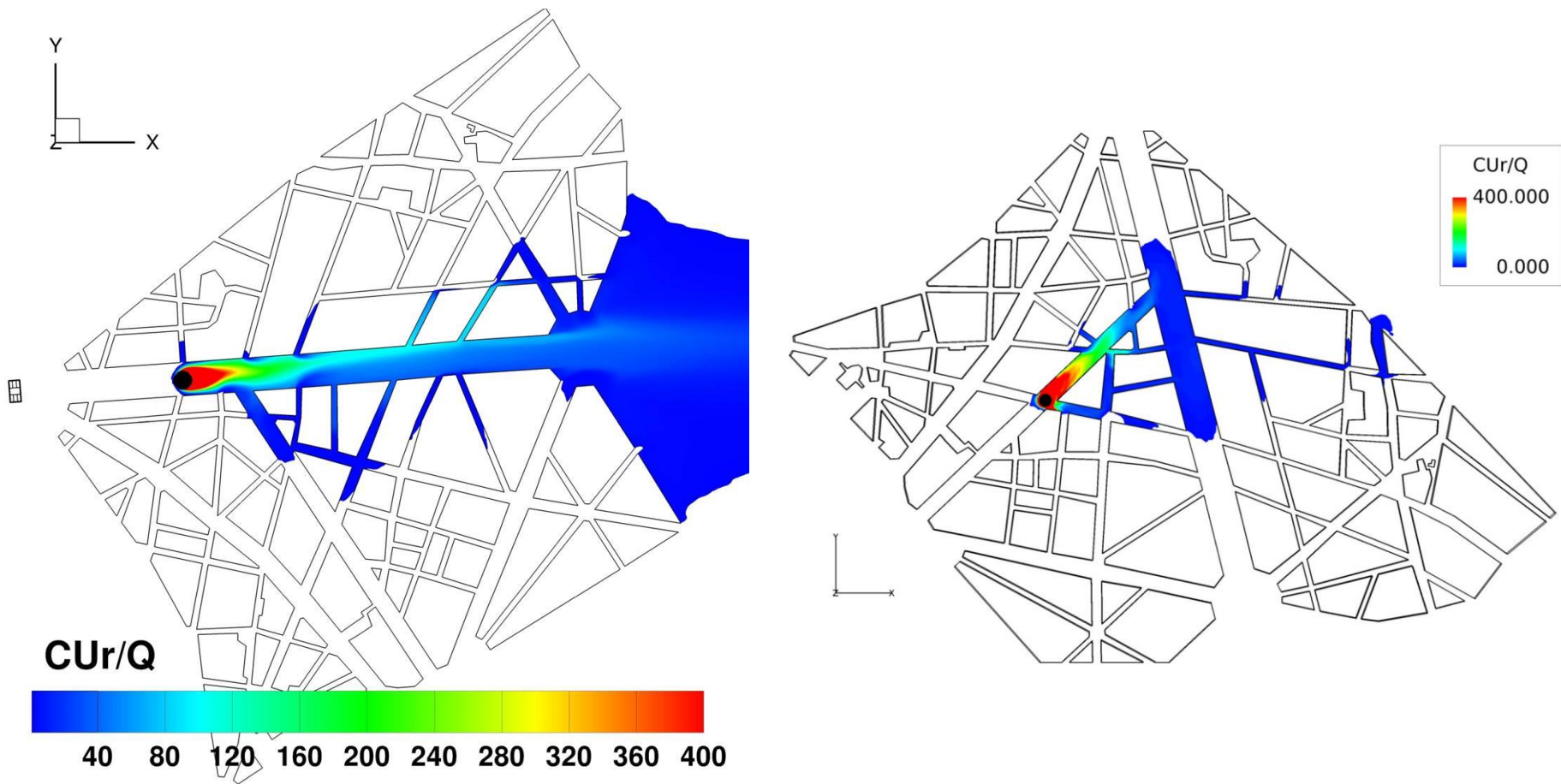
Vertical variation of mean- and fluctuating concentration for neutral and dense gas in front of the cubes
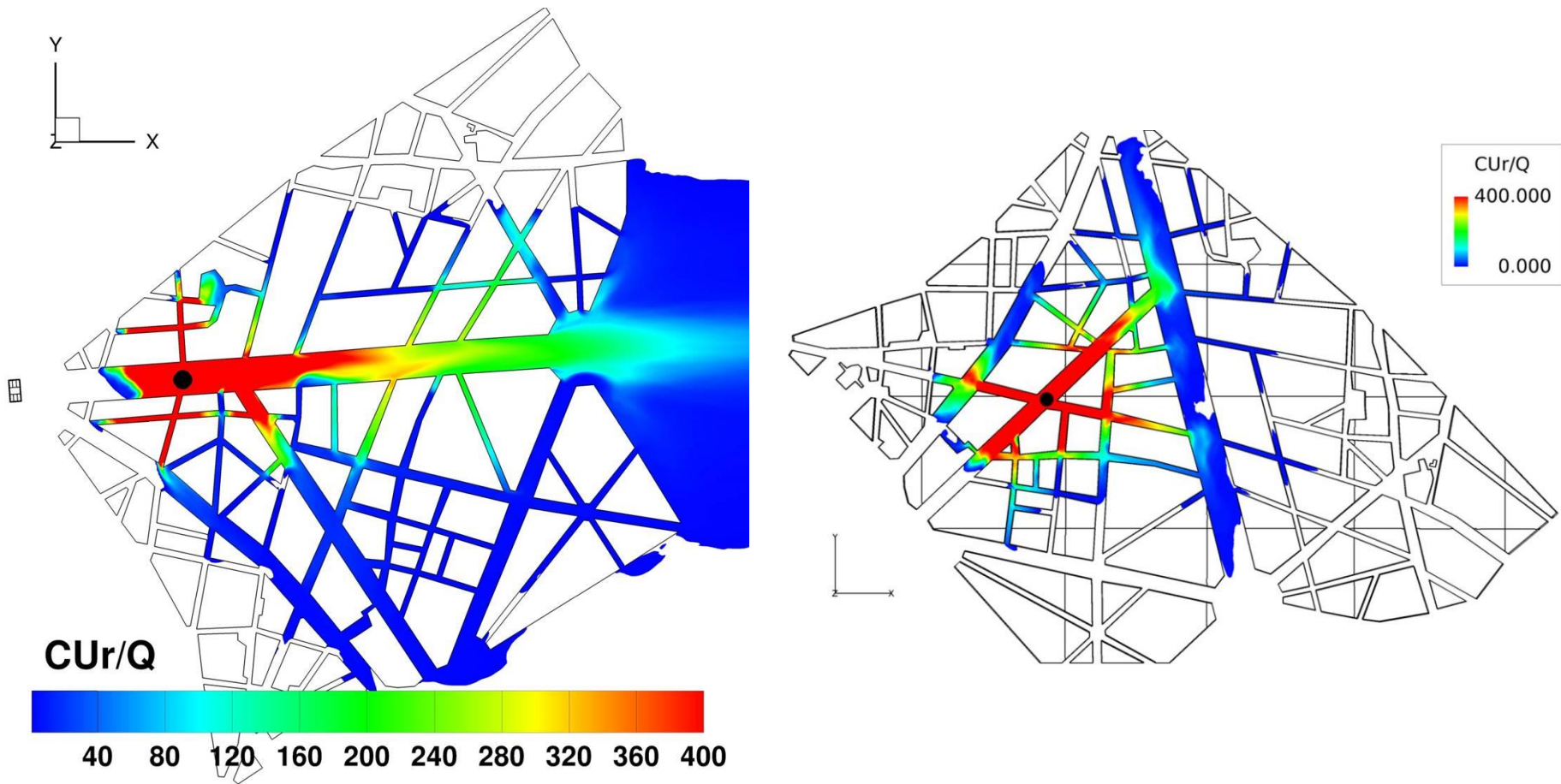
Visualization of neutral and dense gas release along Champs-Élysées in Paris
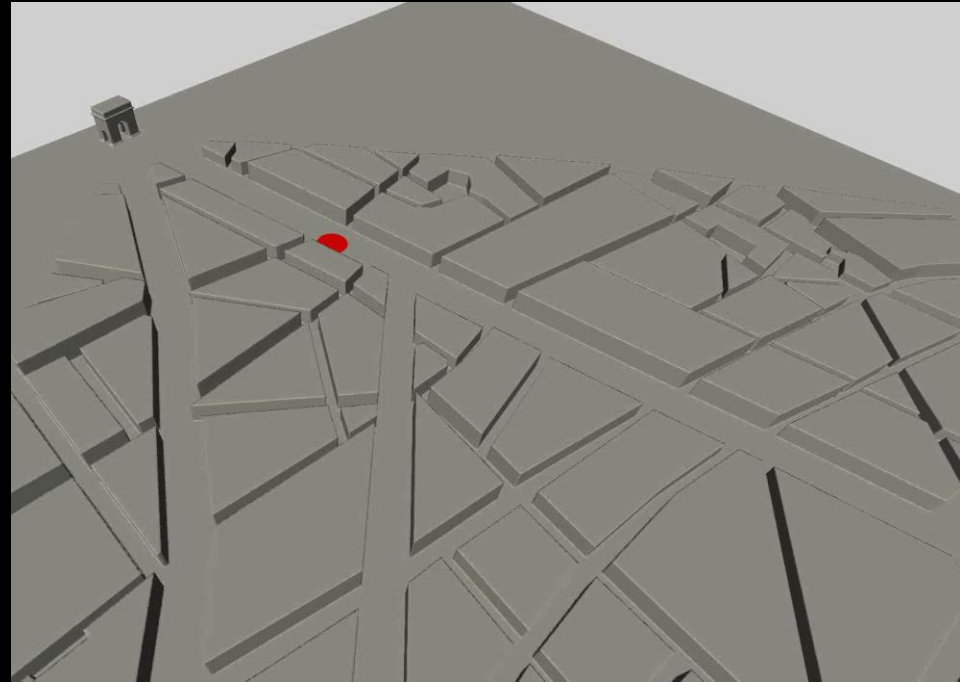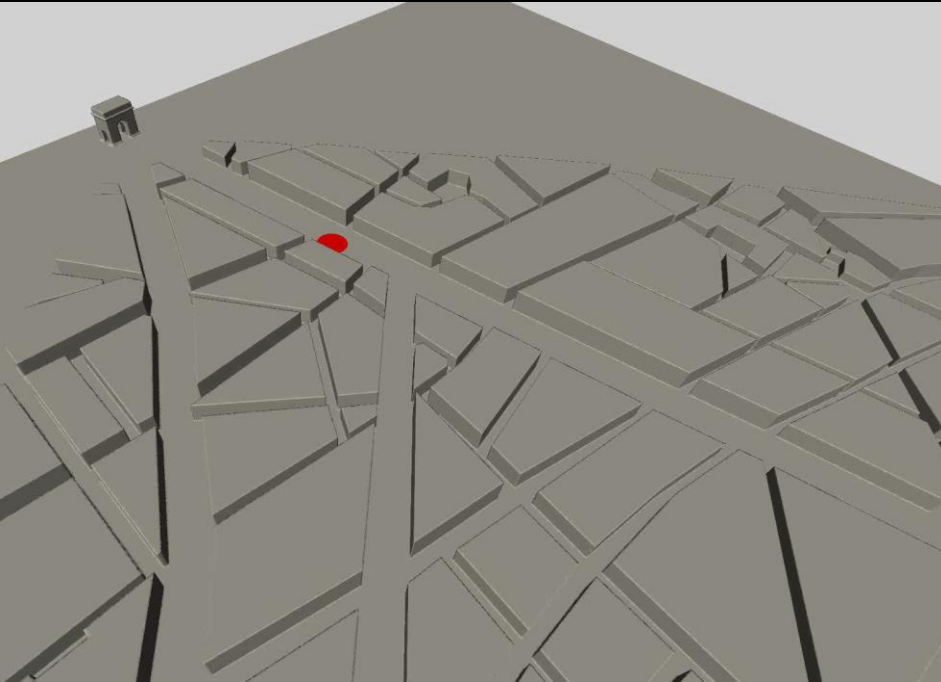
Concentration of neutral gas close to the ground from two different sources in Paris

CUr/Q

40 80 120 160 200 240 280 320 360 400

Concentration of dense gas close to the ground from two different sources in Paris

Conclusions and future work

- Very good agreement between simulations and experiments!
- Dense gas changes the wind field
  - Resemblance of solid walls
  - Reduction of turbulence kinetic energy
- No significant difference between variable density and Boussinesq approach for a real urban area
- Care need to be taken to the inflow conditions!!!

- In the future:
  - Detailed flow and concentration field analysis
  - Look at denser gas release