ANALYSIS OF THE DYNAMICAL INTERACTIONS BETWEEN ATMOSPHERE AND URBAN CANOPIES OF DIFFERENT DENSITIES USING A DRAG FORCE APPROACH

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Object

- Investigation of the influence of **<u>urban morpholgy</u>** on transfers between air **<u>flow within the canopy and above</u>**

- Distinction of flow characteristics in function of the morphology of districts

Example of 2 districts with different morphology

Outline

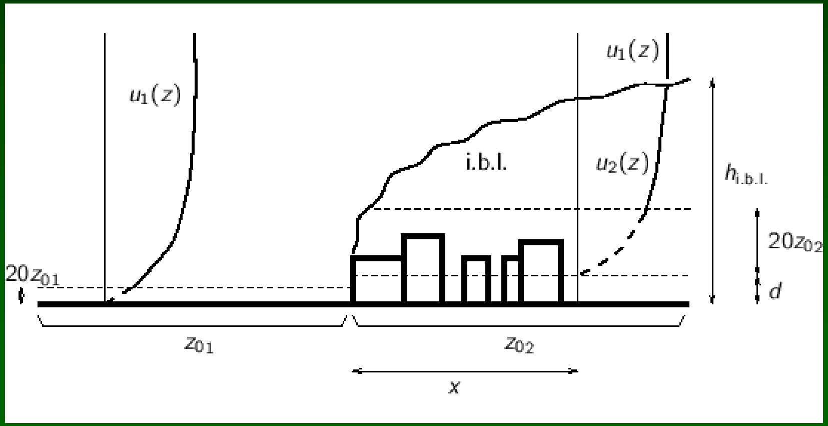
- Introduction
- Method
- Results
- Conclusion and Prospects

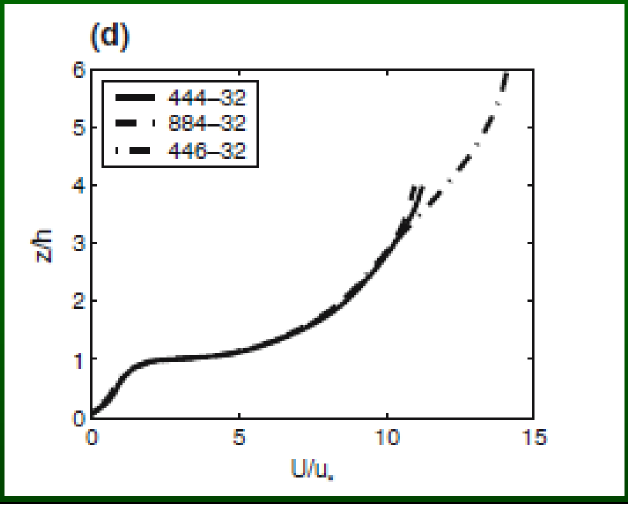
Introduction

Existing methods:

- Above the canopy:
  - Logarithmic law – roughness approach → not enough information inside of the canopy

- Inside of the canopy:
  - Obstacles resolving methods are too expensive at city scale





Coceal et al 06: DNS: 3 diff. Resolutions, density: 25%

Method

LES with **drag force approach** will be used

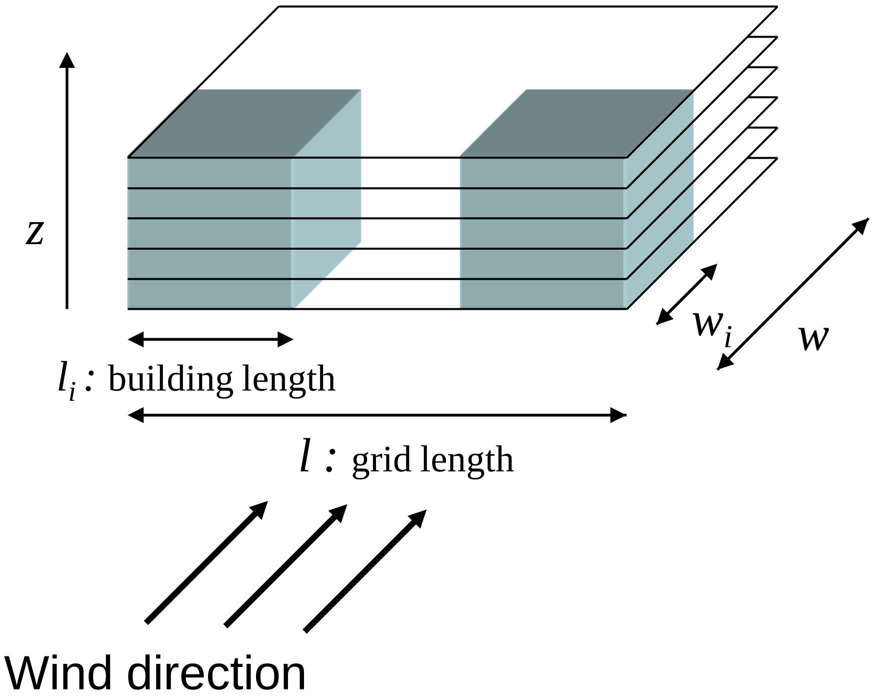
- Atmospheric code used: ARPS

$$a_f = \frac{\sum z l_i}{lwz - \sum l_i w_i z}$$

$$F_{D(z)} = \frac{\rho c_d(z) U (U^2 + V^2)^{0,5}}{2} a_f(z)$$

ρ…fluid density
U…wind velocity in x-direction
V…wind velocity in y-direction
c_d…sectional drag coefficient
a_f…frontal area density

Additional term in the tke-equation



Method

The drag approach was introduced in the code ARPS by Dupont and Brunet 2008 for an application on vegetation canopies.

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Parameters describing the canopy:

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a_f…frontal density (per unit volume)

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Adaptation of the code ARPS to urban canopies

- a_f given by the geometry of the buildings (density)
- c_d higher value than in vegetation canopies, important variations inside of the canopy

Distribution of cd values (in function of height) found by adjusting results to experimental data of Macdonald et al. 2000.

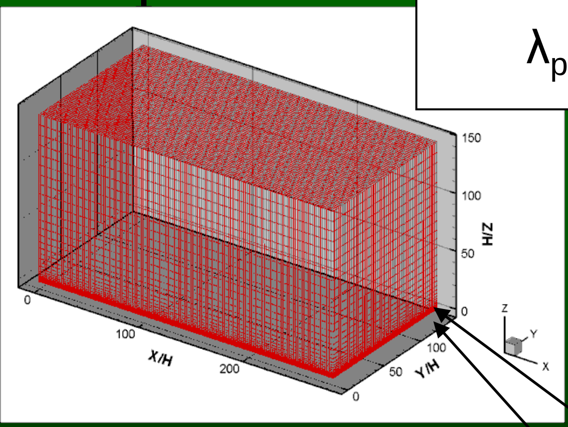
Method

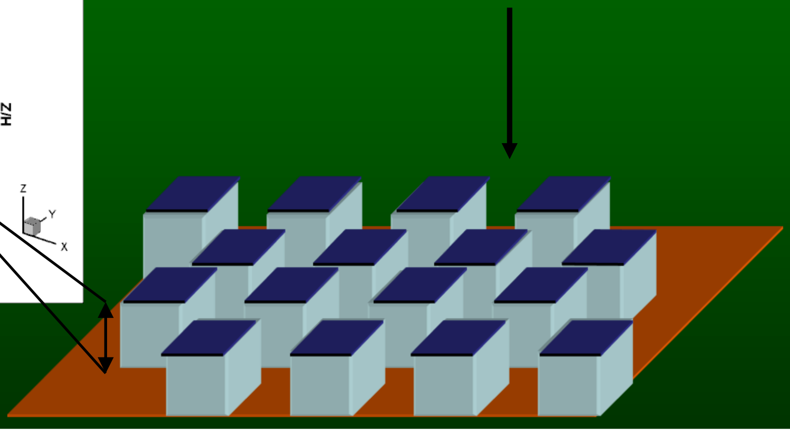
- Domaine size:
- 3000m*1500m*1500m
  (=143*73*59 grids)
- grid size: 20m*20m*25m (average dz)

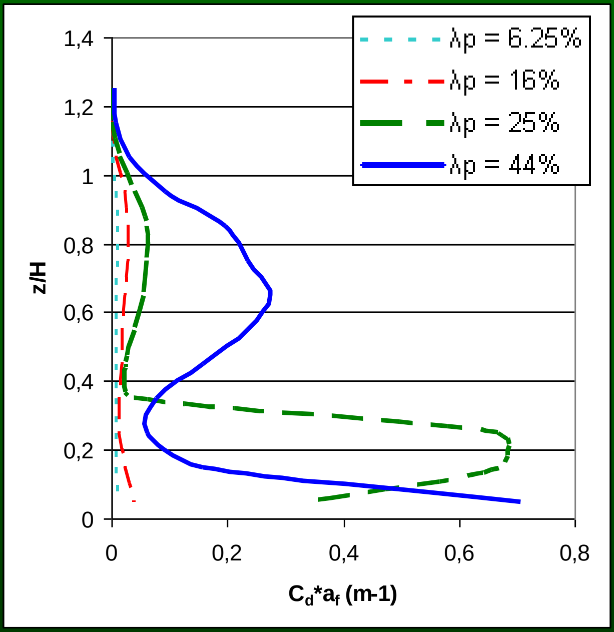
- Homogeneous canopy
- Periodic boundary conditions
- Δt = 0.03 s
- Variations within z<H at different λ_p

CANOPY
- height H = 10m
- Vertical grid size: 1m
- 4 simulations: λ_p = 6.25%;16%;25%;44%

$$\lambda_p = \frac{\text{occupied ground area}}{\text{total ground area}}$$



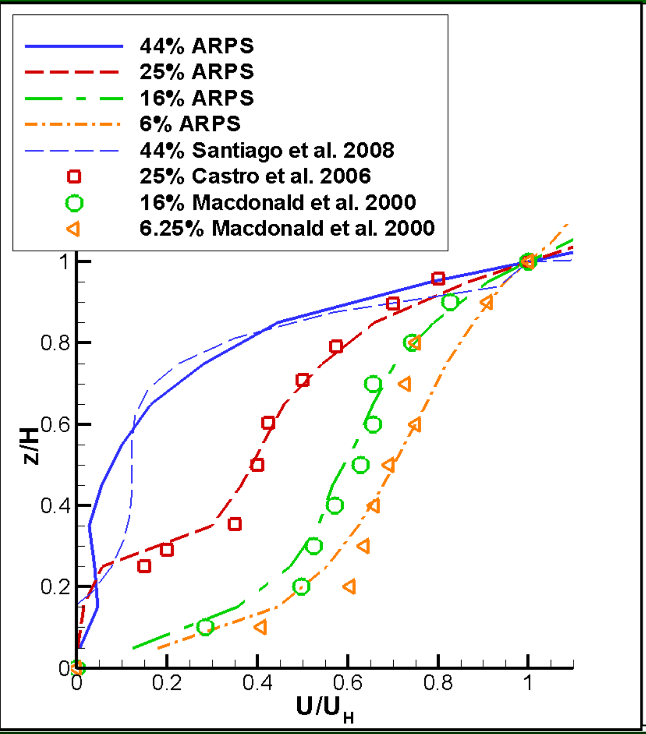


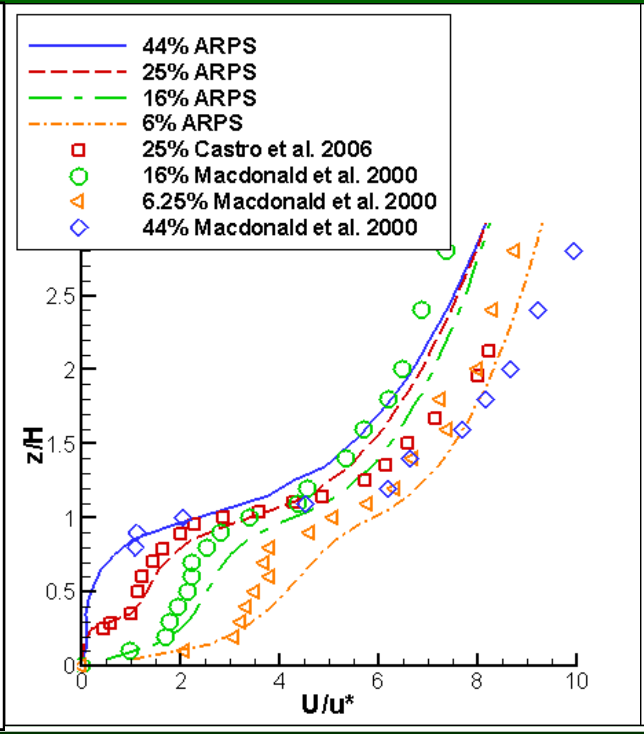


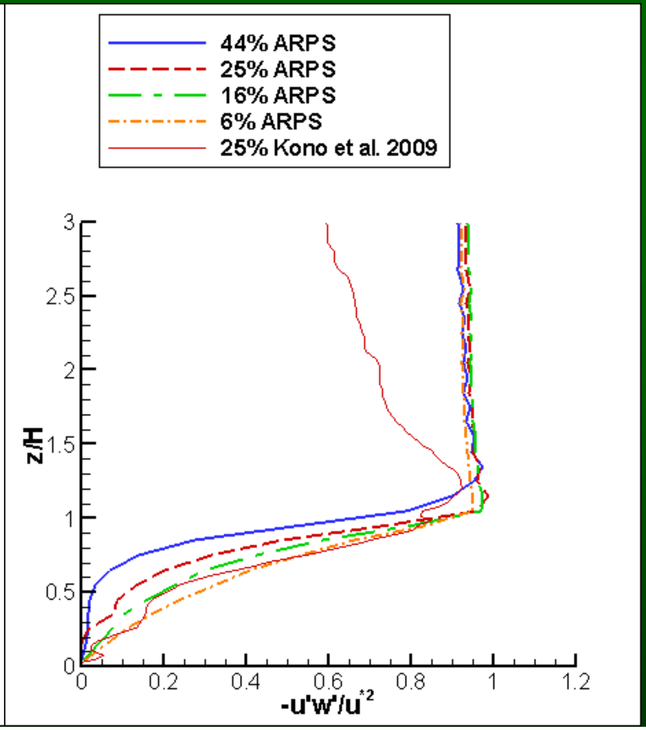
Results

Statistical analyses:
Comparison of 4 densities with literature

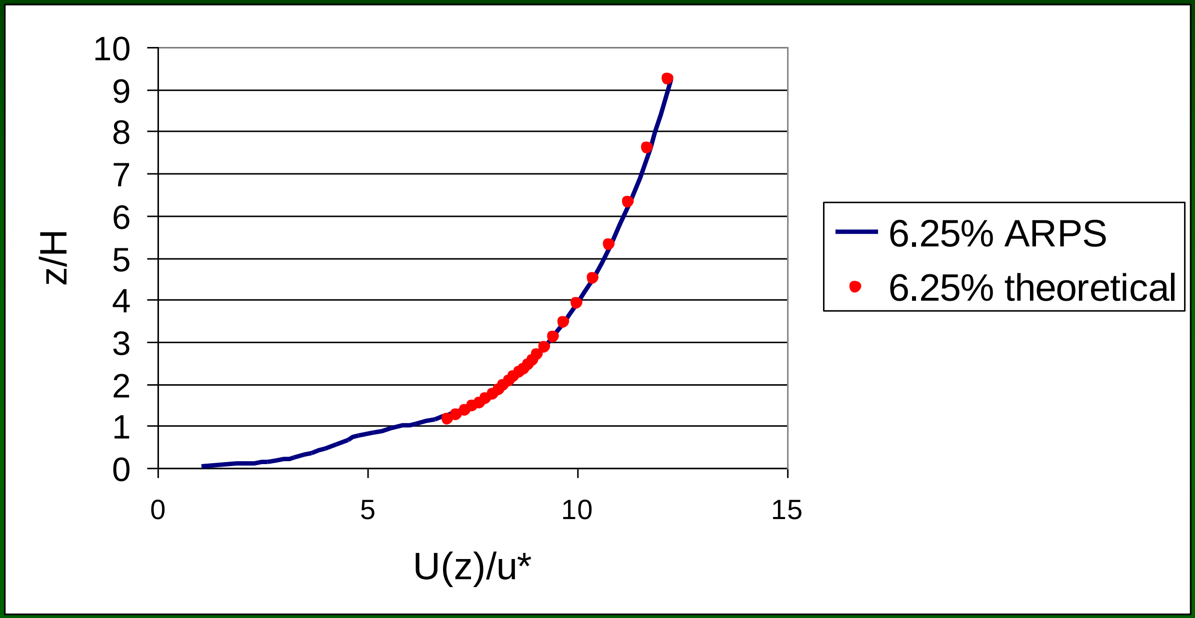
Statistical averaging
- temporally (12600 à 16200 s)
- spatially in homogeneous directions







Results



Comparison of the mean velocity profile above the canopy with the logarithmic law

Based on these results:

Determination of the parameters z_0 and d

- - - ARPS Simulation

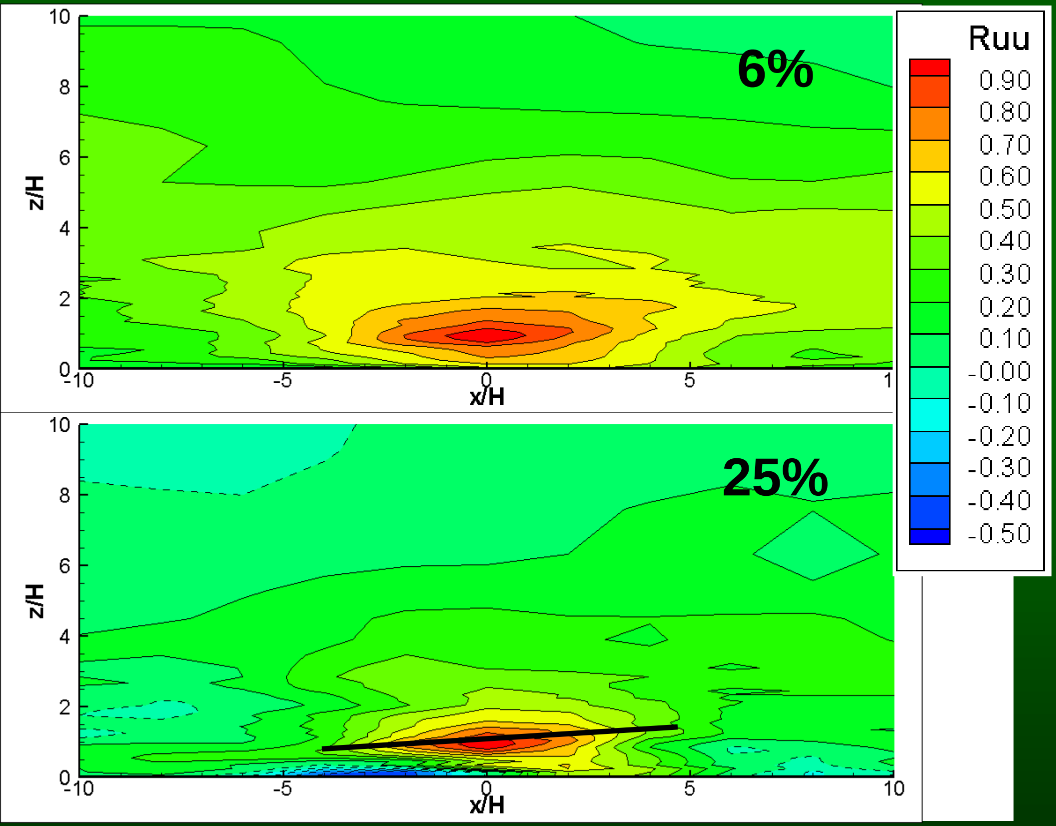
—— Logarithmic Profile

$$\frac{U}{u^*} = \frac{1}{\kappa} \ln\left(\frac{z-d}{z_0}\right)$$

	0,0625	0,16	0,25	0,44
z_0/H - Macdonald et al. 1998	0,06	0,13	0,13	0,06
z_0/H - LES	0,07	0,13	0,09	0,09
d/H - Macdonald et al. 1998	0,18	0,32	0,5	0,7
d/H - LES	0,12	0,17	0,53	0,75

Results

$$R_{ii}(x,y,z) = \frac{\langle u_i(x,y,z)u_i(0,0,h)\rangle}{\sigma_{u_i}(x,y,z)\sigma_{u_i}(0,0,h)}$$



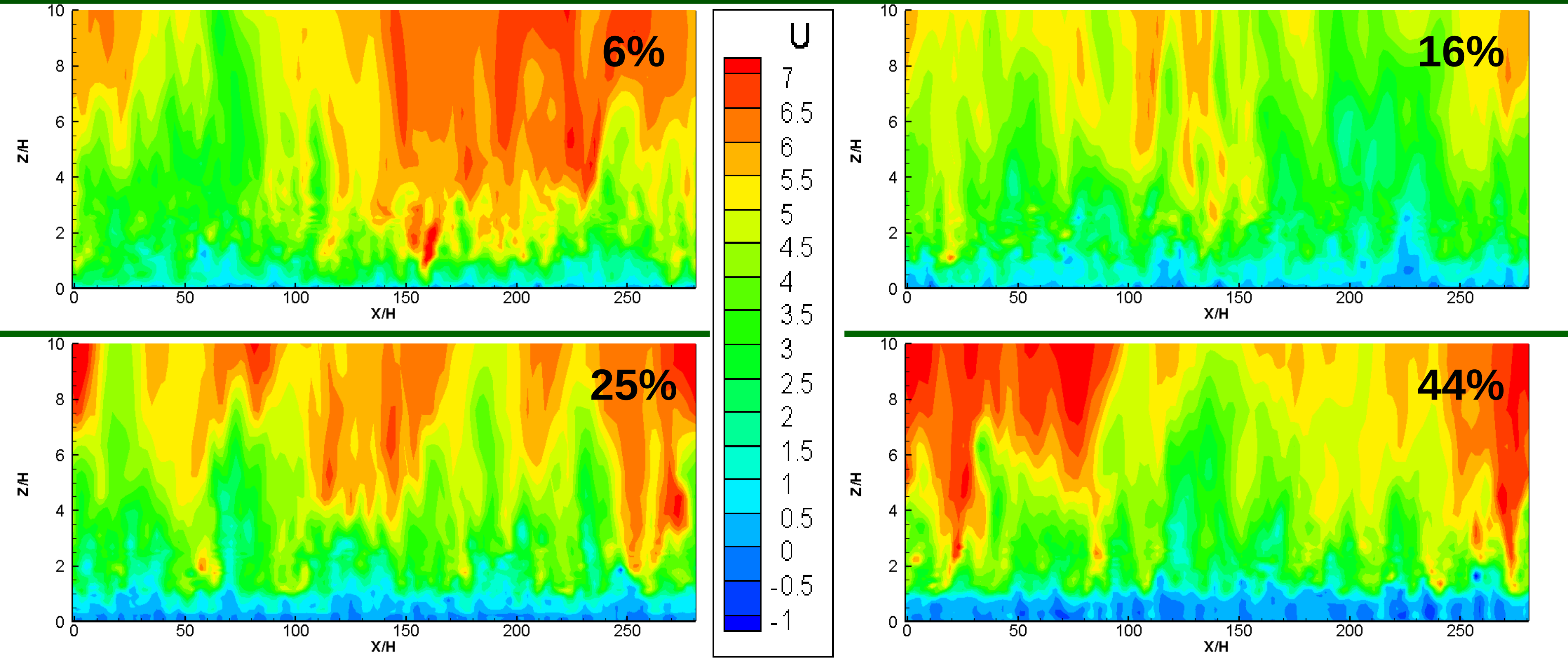
Correlation coefficient

Reference point at (0|0|0.95H)

- Size of zone decreases with density
- Negative correlation zone appears at high density

Results

Instanteneous velocity at 16200 s

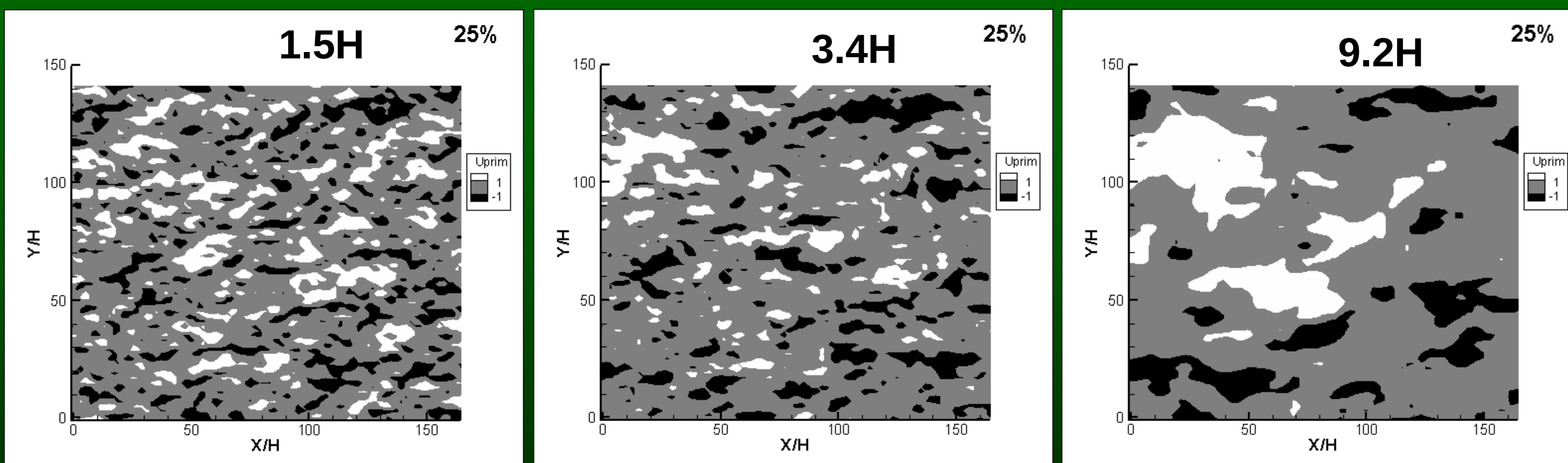


Interactions between air within the canopy and above depend on the density

Results

<u>Snapshots of variations of u</u>

- Negative variations (as positive variations) grouped into distinct regions (Coceal et al. 2007)
- Structures grow with height
- Size cannot be reproduced because of the grid size



Conclusion & Perspectives

- **Within the canopy**: U-profile can be reproduced with accuracy by a LES with drag approach.
- **Above the canopy**: U-profile is in agreement with the logarithmic law.
- **Interactions** between the canopy and the air above depend on canopy density.
- First comparison of instantaneous fields with detailed simulations are encouraging
- An efficient method to simulate pollutant dispersion at **city scale**?
- Heterogeneous canopies, heat and humidity transfers will be simulated

Thank you for your attention!

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