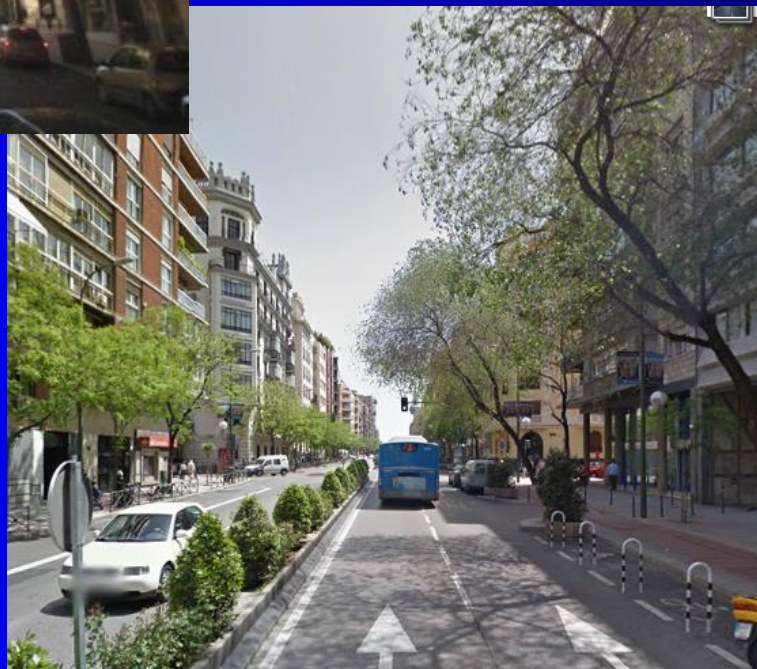# *Estimating the impact of street vegetation on air quality: a simple case with different types and positions of vegetation*

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GOBIERNO DE ESPAÑA  MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

**Ciemat**
Centro de Investigaciones
Energéticas, Medioambientales
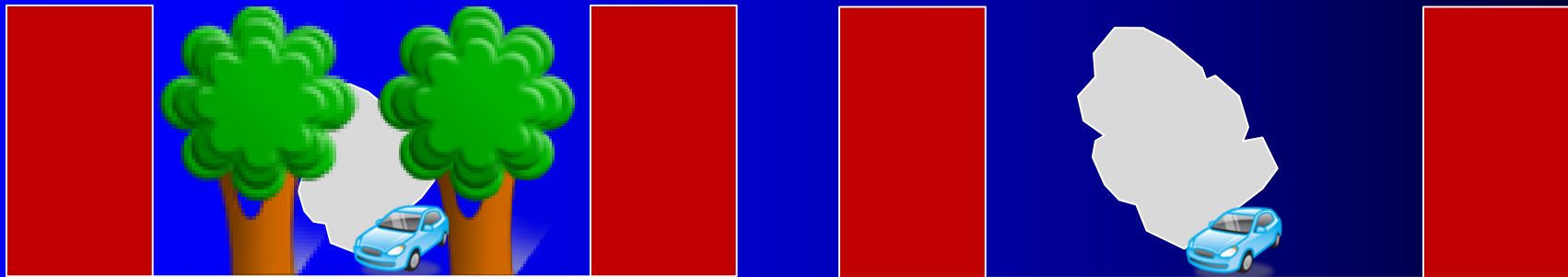y Tecnológicas

# *Introduction*

# *Introduction*

❑    Vegetation plays an important role in urban climate and air quality.

❑    Effects of urban vegetation on air quality:

  o    Aerodynamics effects

  o    Pollutant deposition

# *Introduction*

## Effects of urban vegetation on air quality:
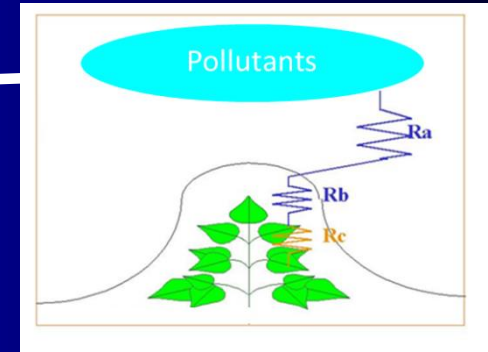## Aerodynamics effects



- ❑    Traffic emissions (located at ground)

- ❑    Vegetation within street (in general):

  - ○   **Reduces ventilation → Increases concentration**

In general, this effect, due to traffic emissions, can deteriorate local air quality

# *Introduction*

## Effects of urban vegetation on air quality:
## Deposition



- ❑ Traffic emissions (located at ground)

- ❑ Vegetation within street: **Removes part of the pollutant from the atmosphere**

- ❑ Depends on: type of pollutant, type and location of vegetation, meteorological conditions,…

## This effect improves local air quality

# *Objective*

❑ Evaluate the impact of urban vegetation on air quality taking into account both effects, the aerodynamics and the pollutant deposition.

❑ For this purpose, CFD simulations over a simple configuration (array of cubes) with and without vegetation are carried out. Vegetation within the street located at different height and with different leaf area densities (LAD) and deposition velocities are simulated.

# *Model Description*

- ❑ CFD model: RANS with k-ε turbulence model

- ❑ Vegetation Modelling:

**Aerodynamics effects**

Momentum

$$Su_i = -\rho LADc_d |U| u_i$$

TKE

$$S_k = \rho LADc_d \left( \beta_p |U|^3 - \beta_d |U| k \right)$$

ε

$$S_\varepsilon = \rho LADc_d \left( C_{\varepsilon 4} \beta_p \frac{\varepsilon}{k} |U|^3 - C_{\varepsilon 5} \beta_d |U| \varepsilon \right)$$

**Deposition**

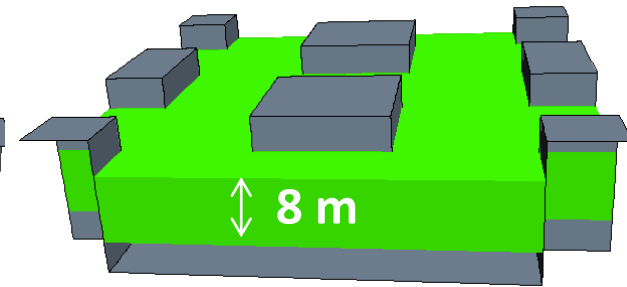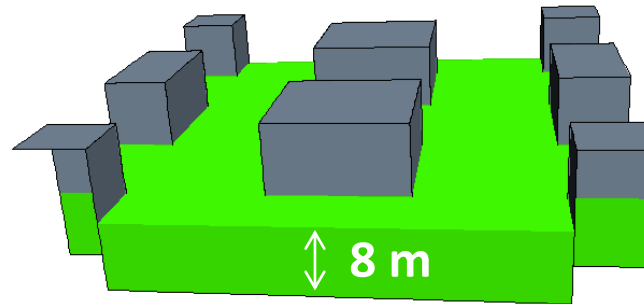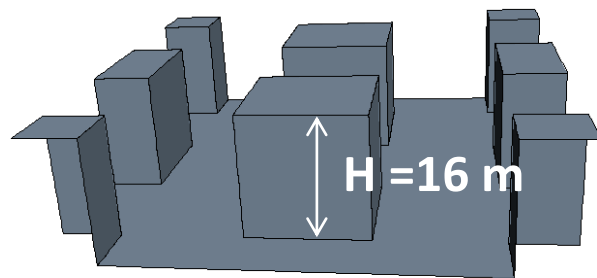Pollutant Concentration

$$S_{tr} = -LAD \cdot V_d \cdot C(x, y, z)$$

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# *Configuration set-ups*

❑ Cases studied (geometry, vegetation position):

**NO VEG**

H =16 m
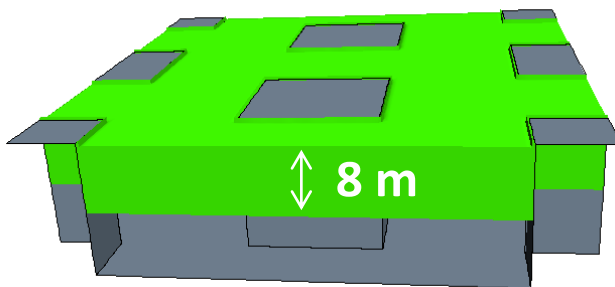
**Tree 1**

8 m

**Tree 2**

8 m

**Tree 3**
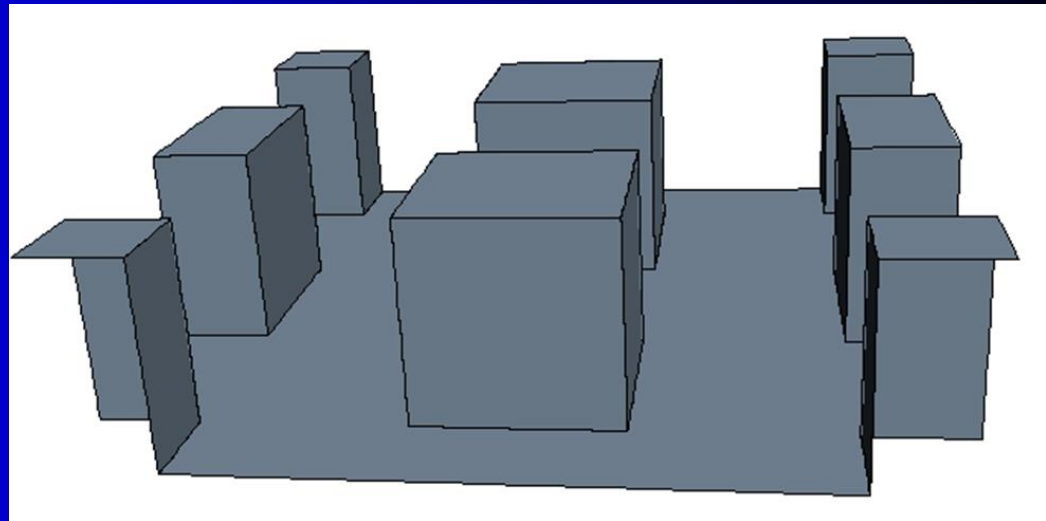
8 m

**Tree 4**

8 m

**Tree 5**

8 m
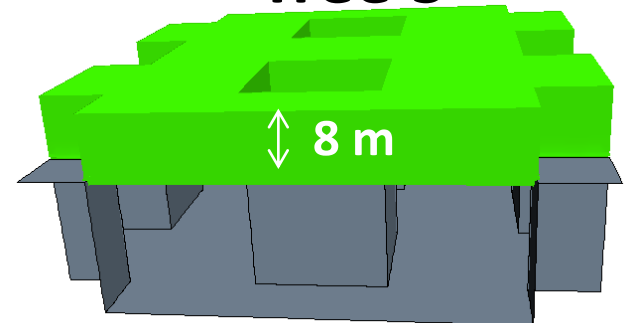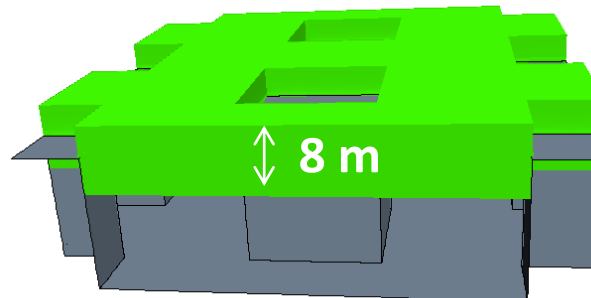
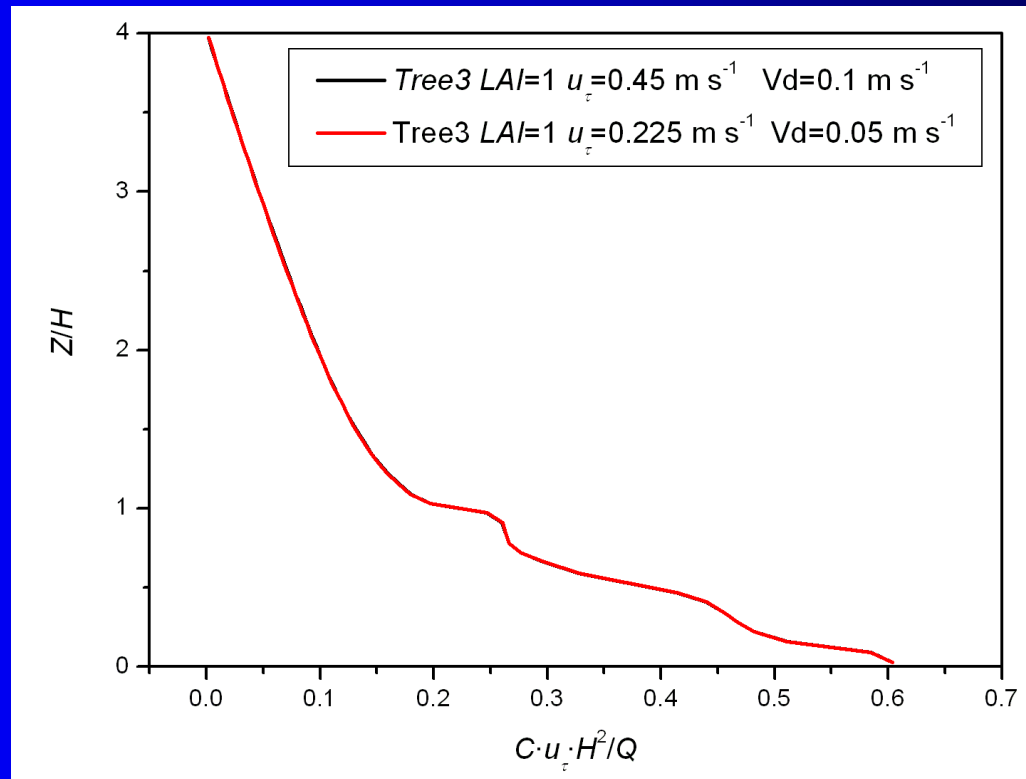$\lambda p = 0.25$

# *Configuration set-ups*

❑ For every vegetation position, 10 cases are simulated:

    o    LAD = 0.125, 0.5 $m^2\,m^{-3}$ (LAI = 1, 4)

    o    Deposition Velocity (Vd = 0.1, 0.05, 0.01, 0.005, 0 $m\,s^{-1}$)

❑ Height of domain = 4 H

❑ Periodic simulations

❑ The flow is maintained by pressure gradient (τ). $u_\tau = \sqrt{4\tau H / \rho}$



❑ Mesh resolution: 1 m

# *Results*

❑ Normalized concentration $C^* = C\, u_\tau\, H^2/Q$

○ Horizontal spatial average at each height

○ Equivalent cases with the same *LAD* and Vegetation position and $V_d / u_\tau$



*Tree3 LAI*=1 $u_\tau$=0.45 m s$^{-1}$   Vd=0.1 m s$^{-1}$
Tree3 *LAI*=1 $u_\tau$=0.225 m s$^{-1}$  Vd=0.05 m s$^{-1}$

(x-axis) $C \cdot u_\tau \cdot H^2/Q$

(y-axis) $Z/H$

# *Results*

❑ Effects of vegetation on air quality: comparison concentration for case without vegetation ($C_{NOVEG}$) vs concentration for each vegetation case (C).

❑ Comparison of:

  o Ratio between total pollutant deposited on vegetation ($Q_{DEPO}$) and total pollutant emitted ($Q_{EMI}$)

  o Average concentration at 2.5 m

  o Average concentration within the canopy

  o Maximum of concentration at 2.5 m

# Ratio between total pollutant deposited on vegetation ($Q_{DEPO}$) and total pollutant emitted ($Q_{EMI}$)
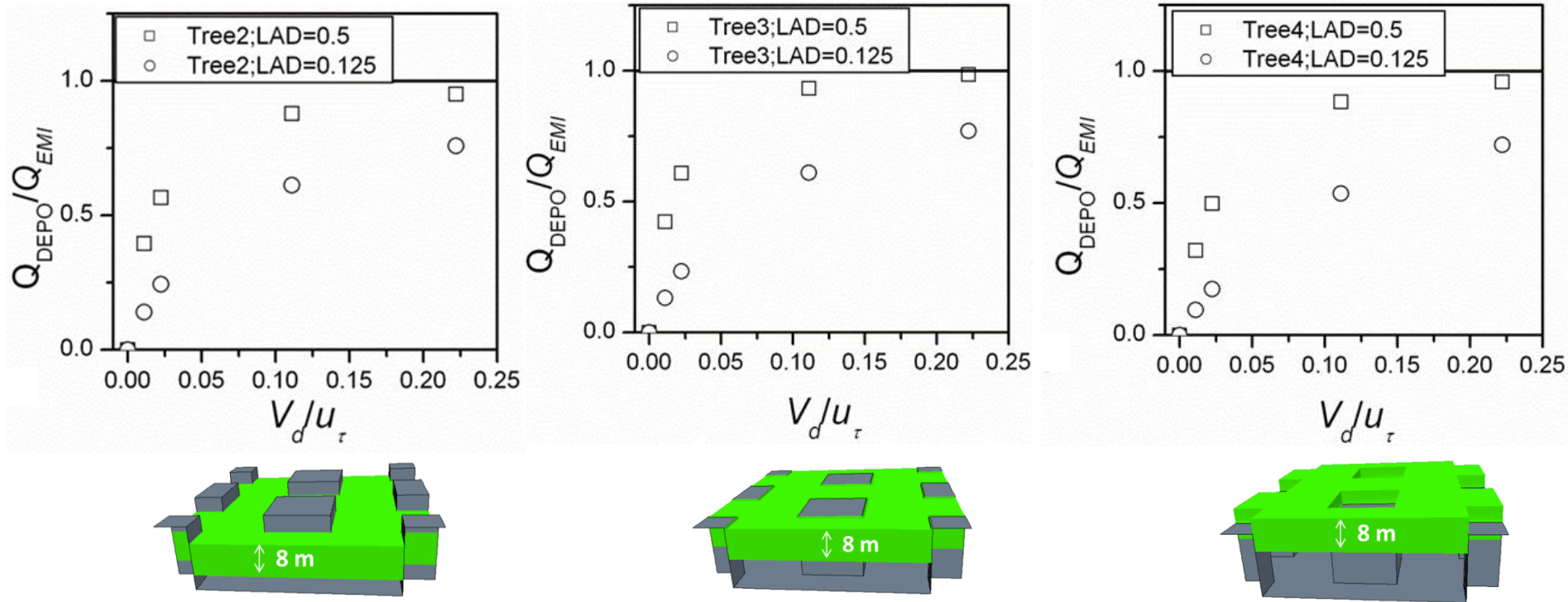


- ❑ Depends on type of vegetation and pollutant through the *LAD* and the deposition velocity.

- ❑ The location of vegetation has less influence on pollutant deposited than other features (*LAD* and deposition velocity)

# *Average concentration at 2.5 m*
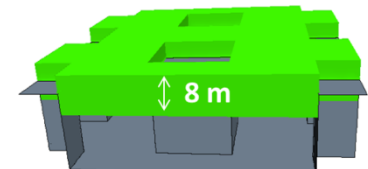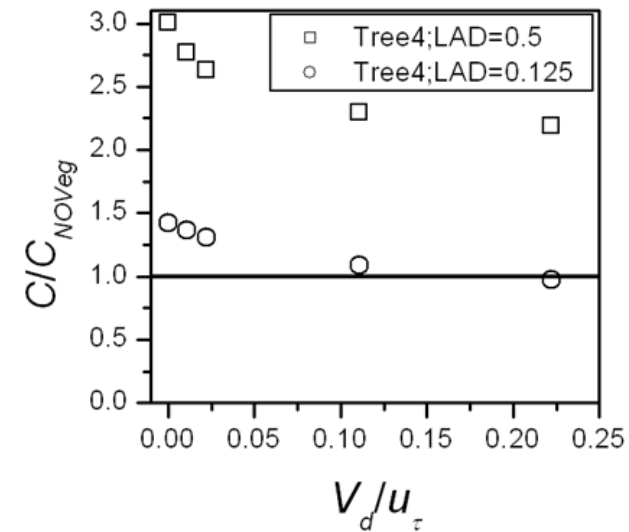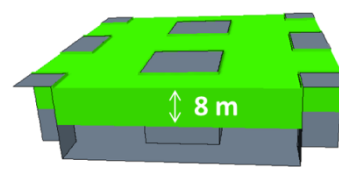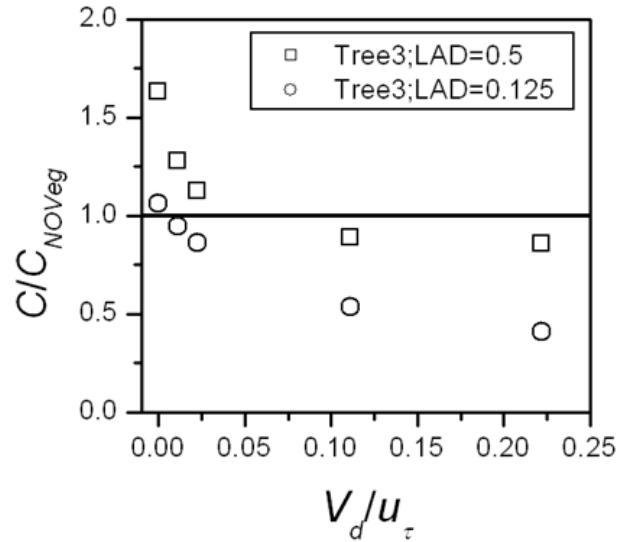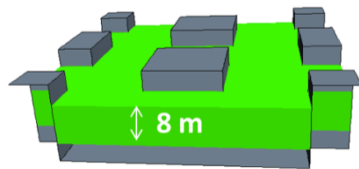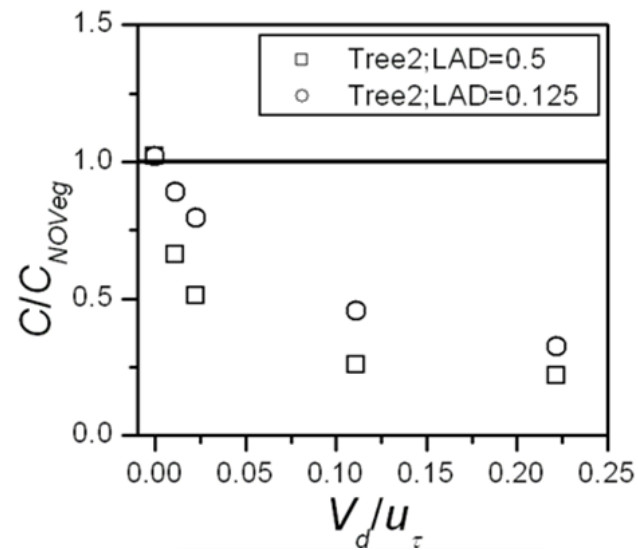


- ❑ Higher deposition velocity, lower concentration average.
- ❑ Influence of vegetation (type, location,…) on concentration is higher.
- ❑ Vegetation at top and above canopy reduces ventilation and increase concentration
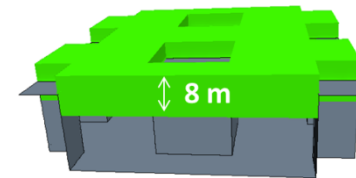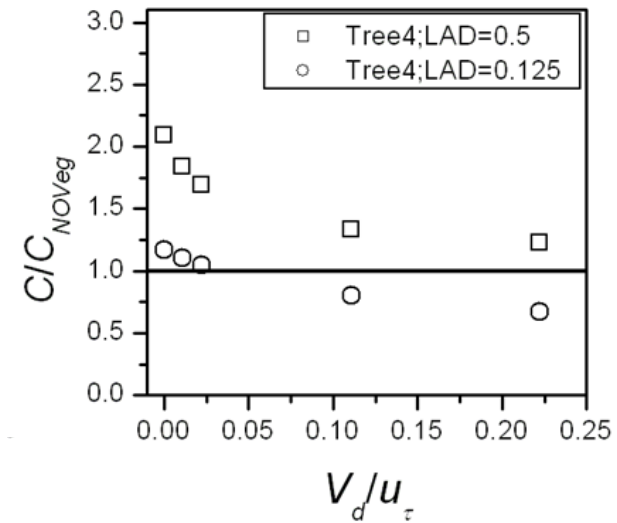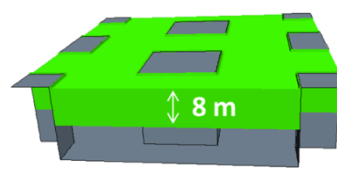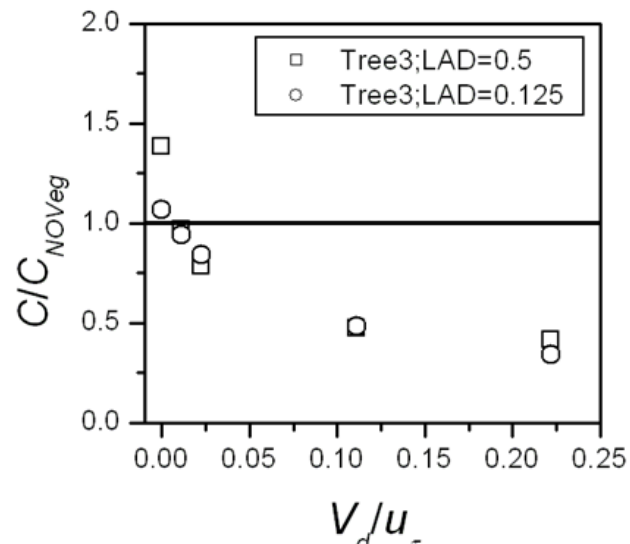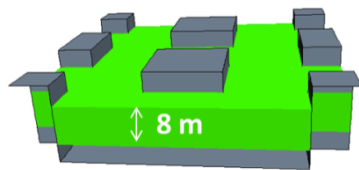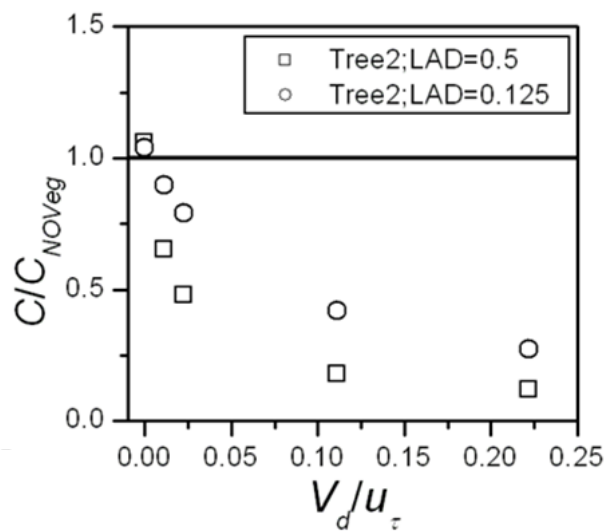
# *Average concentration at 2.5 m*
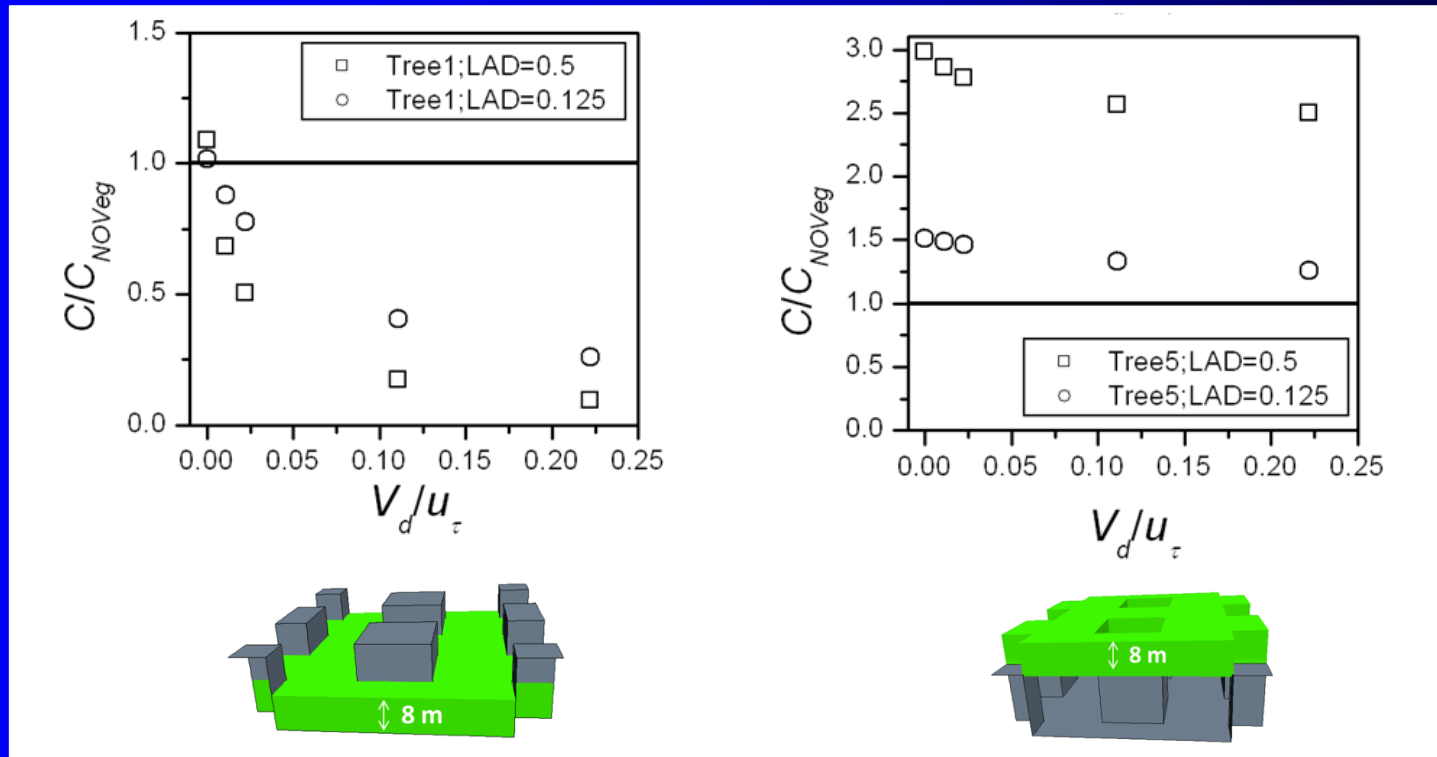


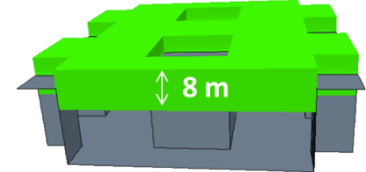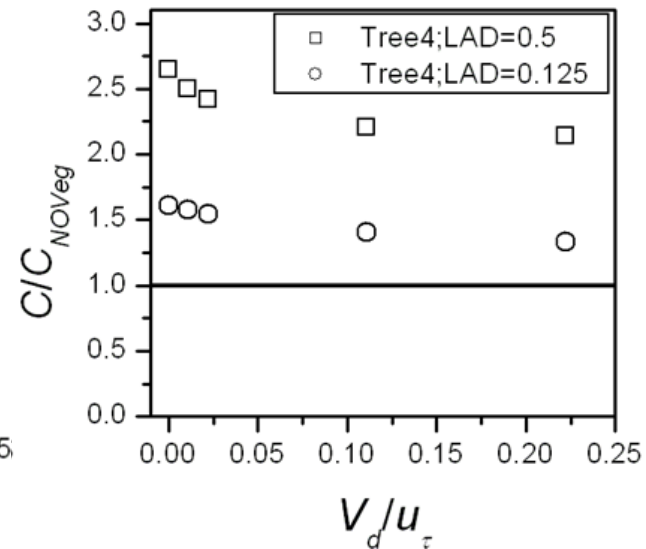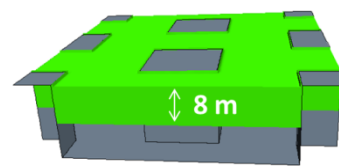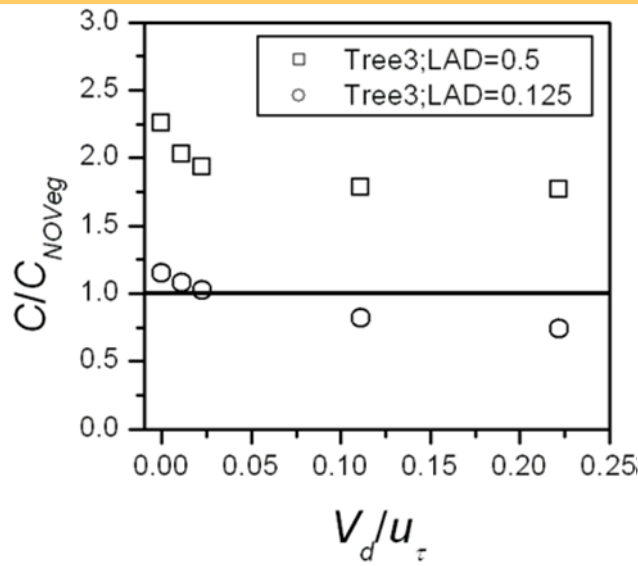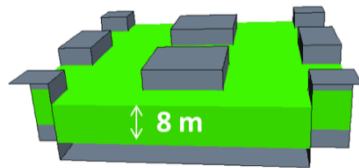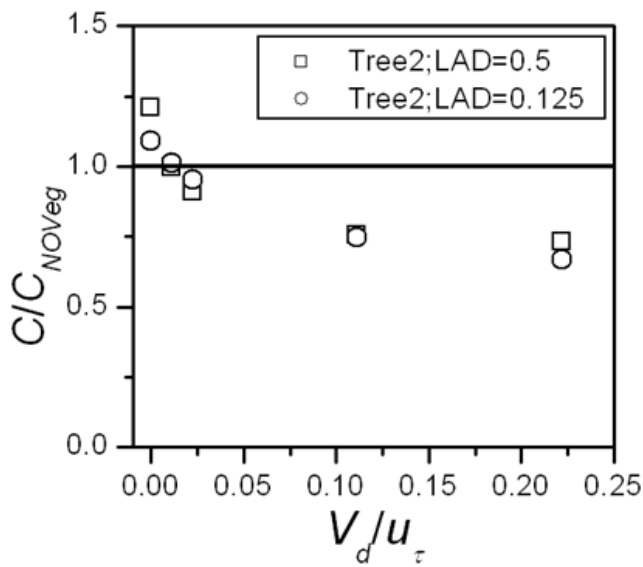☐  Tree 1 is similar to Tree2 (vegetation below canopy) and Tree 5 is similar to Tree 4 (vegetation above canopy)

# *Average concentration within canopy*



□ Similar behaviour to average at 2.5 m

- ❑ The re-distribution of pollutant concentration inducing by the presence of vegetation produces, in general, an increase of the maximum concentration for each case respect to the no-vegetation case.

- ❑ For trees located above the canopy (tree 4 and 5), the maxima located at 2.5m are higher than for the no-vegetation case and for tree 3 only for high deposition the vegetation induces lower maximum at this height.

# *Concentration (C\* = C u$_\tau$ H$^2$/Q) distribution in a vertical plane in the middle of the canyon*
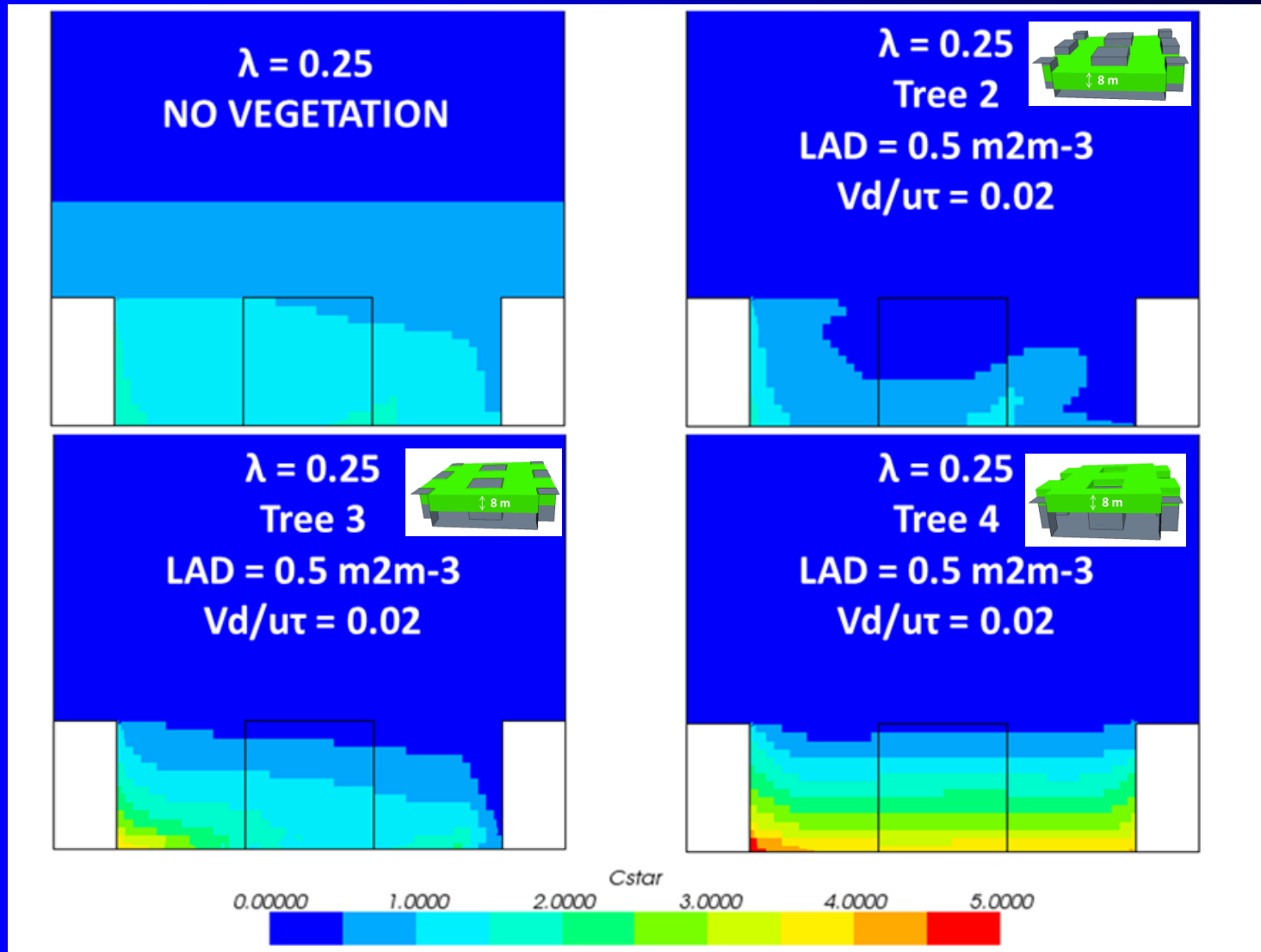
# *Summary and Conclusions*

❑ Three features of the vegetation (leaf area density, deposition velocity and position) are important factors to be taken into account to determine whether the street trees induce a reduction or an increase of the concentration of pollutant emitted from traffic respect to the case without vegetation.

❑ Trees higher than buildings induce a high increase of pollution inside streets respect to NO vegetation cases

❑ These results have been obtained for a fixed configuration of buildings and type of vegetation, and need to be extended to other configurations. However, the methodology adopted and the main conclusions on the relative importance of the vegetation on air quality are expected to be general.

# *Thank you for your attention*

Acknowledgements: