Influence of vegetation on urban canyon ventilation. Part I : experimental and numerical investigation of averged concentration and bulk exchange velocity.

M. Barulli[1] , S. Fellini[2] , A. Del Ponte[3] , L. Ridolfi[3] , L. Shoulhac[2] , M. Marro[4] , A. Emmanuelli[4] , P. Salizzoni[4]

[1] Department of Mathematical Sciences "Giuseppe Luigi Lagrange", Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129, Turin, Italy
[2]Univ Lyon, INSA Lyon, CNRS, Ecole Centrale de Lyon, Univ Claude Bernard Lyon 1, LMFA, UMR5509, 69621, Villeurbanne France
[3] Department of Environmental, Land, and Infrastructure Engineering, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129, Turin, Italy
[4]Laboratoire de Mécanique des Fluides et D'Acoustique, UMR CNRS 5509, Université de Lyon, Ecole Centrale de Lyon, INSA Lyon, Université Claude Bernard Lyon I, 36, Avenue Guy de Collongue, 69134, Ecully, France

Abstract

The urban environment represents an area with particular microclimatic characteristics, due to human activities and to the geometry of the buildings. Urbanization processes can alter the processes of heat, mass and exchange momentum between the ground and the atmosphere. The most important phenomenon is the formation of the so-called heat island (Cancelli et al., 2006), a limited region above the city with higher temperature with respect to that of the surrounding atmosphere. Among the main reason for the formation of the heat island, there are the absorption of the solar radiation, which is higher for the materials used in the city (concrete, asphalt etc.) with respect to the rural environment, and the reduction of phenomena of evaporation and transpiration that, for a surface protected from vegetation, counteract the increase of temperature. The positive effects of vegetation on temperature and humidity, known as "urban cool island", are clearly visible during the afternoon and the evening, when the evaporative cooling has a greater impact. Despite its positive effect on urban microclimate, vegetation can negatively affect the pollutant concentration in urban areas. In fact, vegetation can play a dual role. On one side, foliage helps the deposition and the absorption of pollutants and on the other side, vegetation can cause an obstruction, inhibiting the ventilation in the canyon. Therefore, in the context of urban pollution and prevention of the risks on human health, the main goal of the present work is to advance the understanding of the effect of the presence of trees on the dispersion of pollutants in an urban geometry. To this purpose, the results obtained from an experimental campaign conducted in a wind tunnel are compared to the results obtained from RANS two-dimensional numerical simulations. The urban geometry considered consists in a street canyon placed perpendicular to the wind direction. Three configurations are analysed, namely: no trees, two rows of scattered trees and two dense rows of trees. A source emitting a mixture of ethane and air is used to simulate the pollutant and concentration measurements are performed by means of a Flame Ionization Detector (FID).

The obtained results show how the presence of trees modifies the pollutant concentration field (*Figure 1*). In particular, the configuration without trees results in a nearly two-dimensional concentration field, while the two configurations with trees present a three-dimensional field.

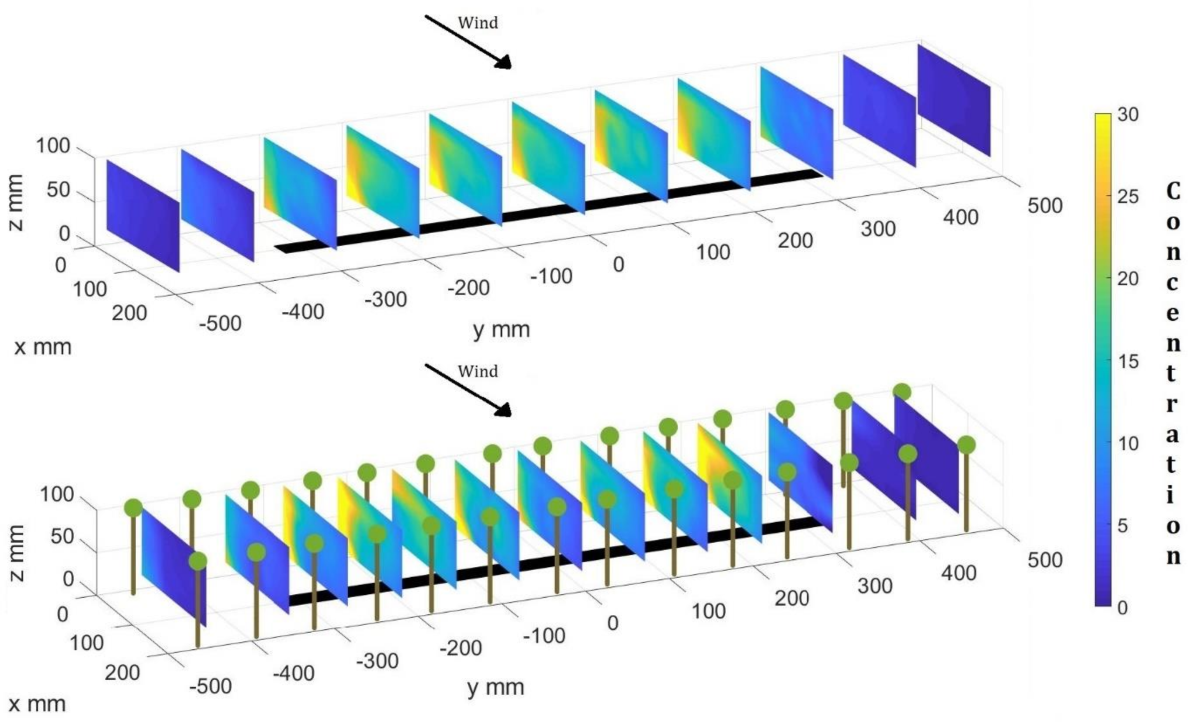

Figure 1 – *Concentration field at different sections along y direction. Configuration without trees (top) and with trees (bottom). The black bar on the ground represents the ethane source, the green dots represent the crowns of the trees, and the brown lines represent the trunks.*

Furthermore, the results from the computation of the vertical mass transfer velocity (*Figure 2*), as defined in (Salizzoni et al., 2009) and (Fellini et al., 2020), did not show any significant difference among the configurations analysed, therefore suggesting that the presence of trees does not affect the ventilation in the canyon. In the light of these experimental evidences, the outputs of simulations are analysed and their reliability in reproducing the processes responsible for the ventilation of the canyon is critically discussed. The obtained numerical results (*Figure 3*) are in a good agreement with the experimental campaign conducted in the wind tunnel. However, due to the inherent constraints of the RANS approach, they have provided only a qualitative behaviour of the concentration field.

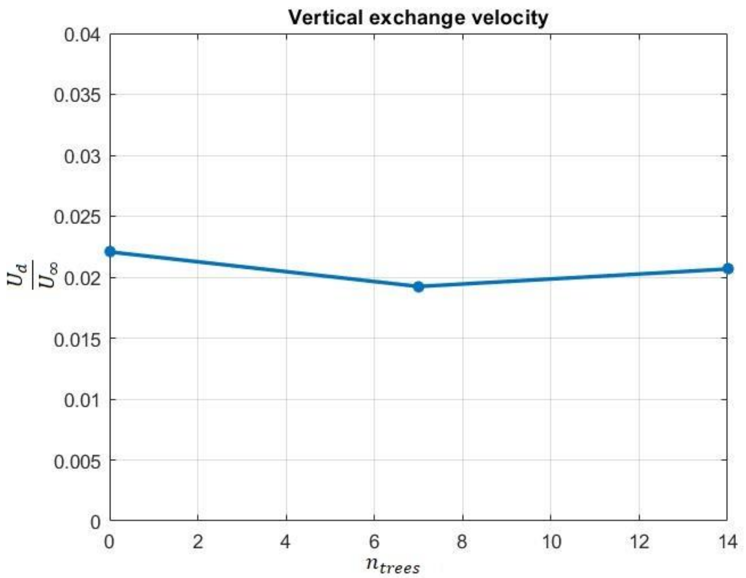

***Figure 2 –** Vertical exchange velocity computed for the three different configurations analysed. The velocity is normalized with respect to the horizontal velocity at the top of the boundary layer, i.e., U_∞. The number of trees 0, 7 and 14 stay for the configurations with no trees, with two rows of scattered trees and with two dense rows of trees respectively.*

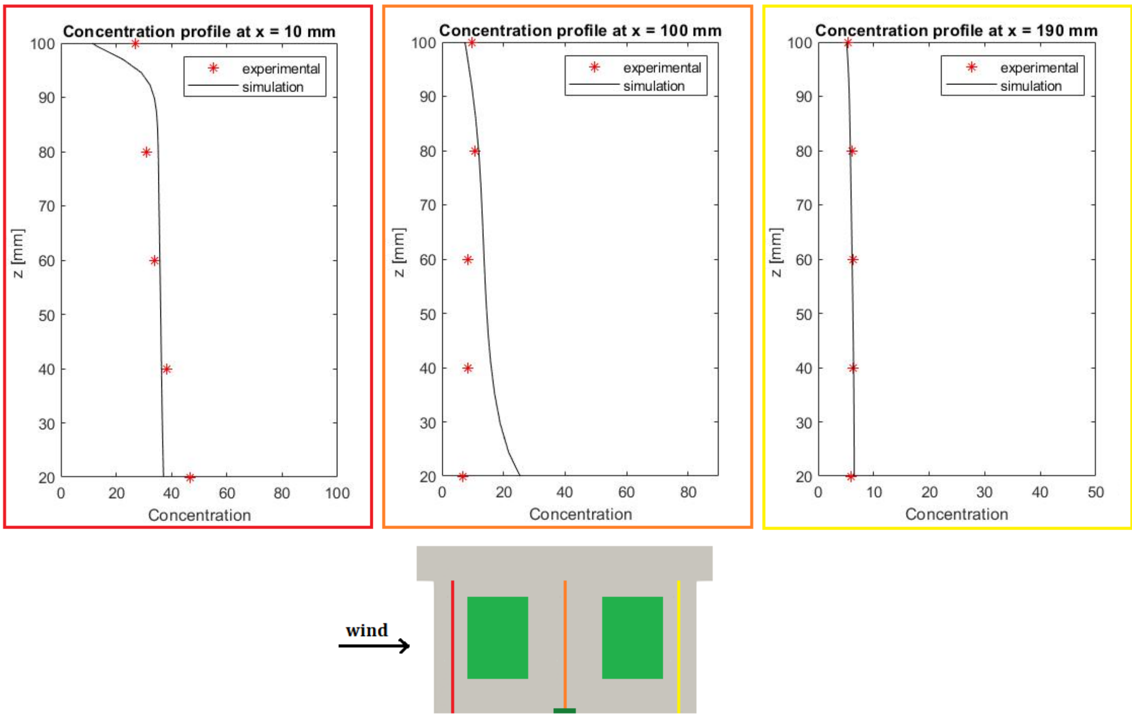

***Figure 3 –** Profiles of concentration field obtained from numerical simulations compared to experiments. Red, orange, and yellow lines represent the different positions along x direction in the cavity where the profiles are compared. At the bottom part of the figure, sketch of the section of the cavity along the wind direction. The green boxes represent the trees.*

References

Cancelli, C., Boffadossi, M., and Salizzoni, P. (2006). *Fluidodinamica ambientale: Turbolenza e dispersione*. Otto Editore.

Fellini, S., Ridolfi, L., and Salizzoni, P. (2020). *Street canyon ventilation: Combined effect of cross-section geometry and wall heating*. Quarterly Journal of the Royal Meteorological Society, 146(730):2347–2367.

Salizzoni, P., Soulhac, L., and Mejean, P. (2009). *Street canyon ventilation and atmospheric turbulence*. Atmospheric Environment, 43(32):5056–5067.