Modeling of Urban Greening Effects on Air Quality in an Undeveloped Residential Area

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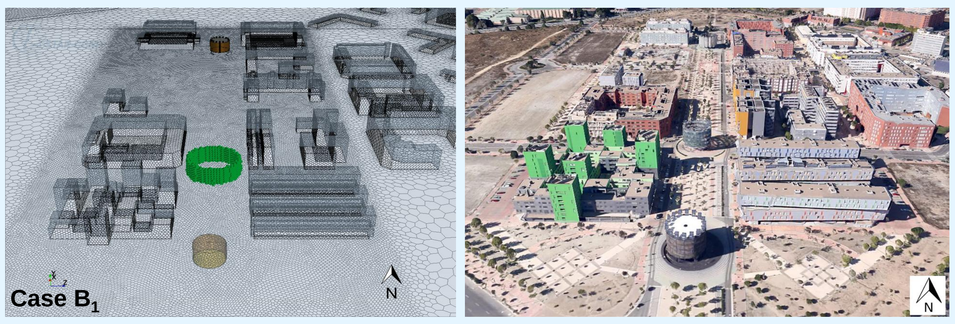
1. Introduction

Urban green development has influence on pedestrian comfort and pollutant dispersion. For this reason, the development of public open spaces is adapted to the new lifestyle in compact cities by upgrading the public environments used by pedestrians. Not only visual aspects like compacity, technical or social criteria, but also environmental, urban climate, air quality and thermal comfort must be highly considered. A framework for urban greening in a new undeveloped area in Madrid was developed in the 'ECO-Valle Mediterranean Verandahways' project within LIFE Program.

- **Objective**: Analyze the effect of different types of vegetation in the main boulevard on pedestrian wind comfort and air quality in this undeveloped urban zone in Madrid

2. Numerical Simulation Description: Cases of Study



- The undeveloped area located in the southeast of Madrid with 15-20 m high buildings.
- Evaluation the effect of different urban green design on air quality in the main boulevard of this residential area by a Computational Fluid Dynamics (CFD) model:
  - Numerical domain: area of 1km x 0.8 km and 200m high
  - Three million computational grid with polyhedral cells and a resolution down to 0.5m near the buildings
  - Steady state conditions applying 3D RANS equations with realizable k-ε turbulence model and transport equation for passive scalars
  - The prevailing wind orientation is Northeast and the corresponding average wind velocity is 2.6m/s at 18 m height

Three main scenarios have been simulated considering different phases of urban greening development:

Case A: Base case without vegetation

Case B: Green spaces at three specific locations

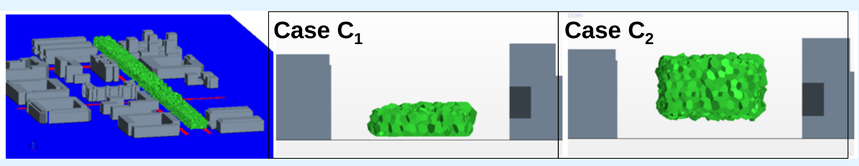
Case B_1: Current development conditions , with three artificial trees

Case B_2: Replacing artificial trees with natural vegetation (Leaf Area Density (LAD) = 0.5).

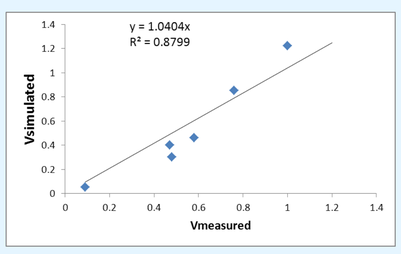
Case C: Different green spaces along the main boulevard (LAD =0.5)

Case C_1: vegetation 2- 5m high

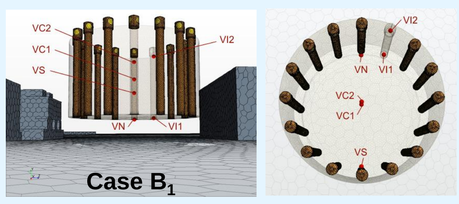
Case C_2: vegetation 4-18m high



- Evaluation of simulation carried out in the case B_1 by means of experimental wind velocity measurements
- Wind velocity has been monitored in six points located inside the northern artificial tree during winter period.



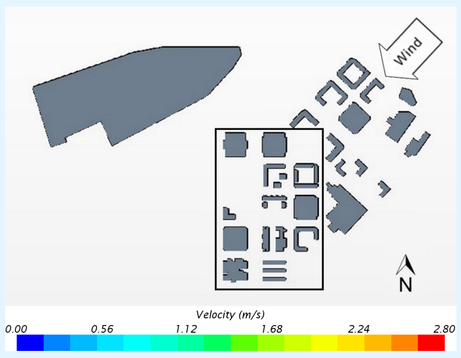
- The scatter plot shows a good correlation between simulated and measured wind speed monitored in six points located inside the northern artificial tree
- Given the available evaluation data, the CFD model used in this study is deemed acceptable for the simulation of flow in this scenario.

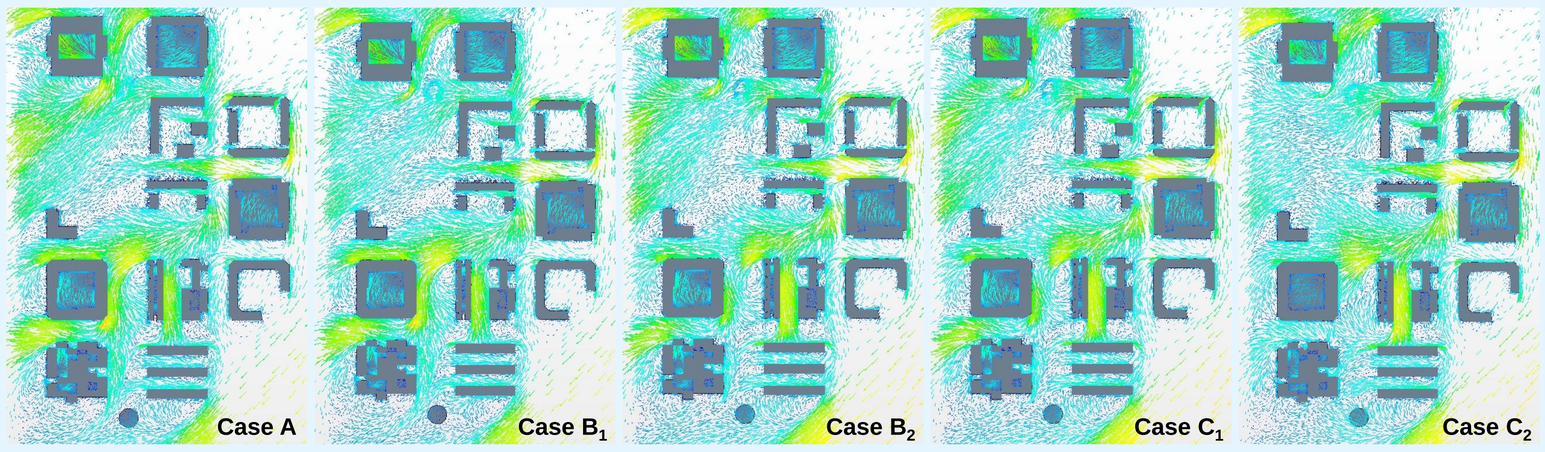


3. Results

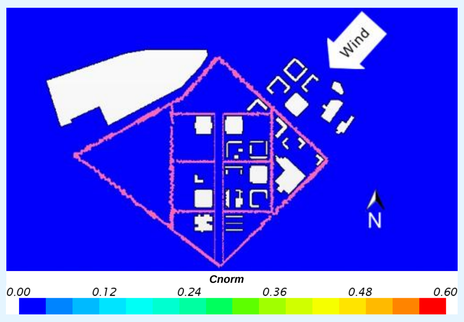
- Values are calculated at pedestrian level (1.5 m) for prevailing Northeast wind direction
- Emissions are imposed assuming the number of vehicles is the same in all streets.
- Cnorm is the normalized concentration. Cnorm = C/Cmax(at z=1.5m for case A)

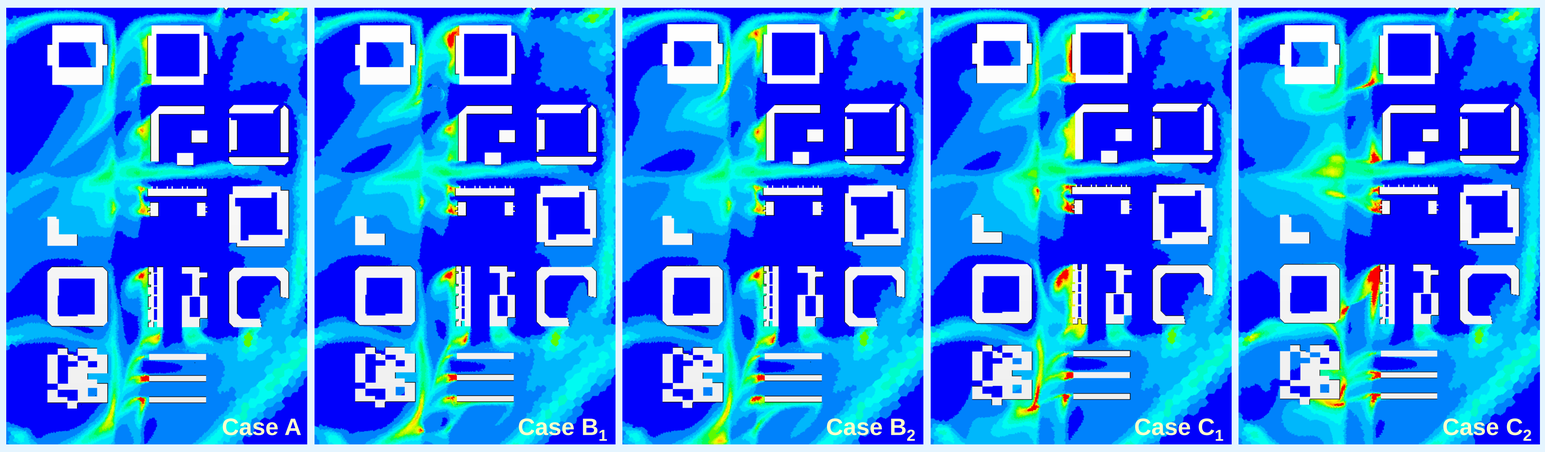
3.1. Wind Field





3.2. Pollutant Dispersion





- The influence of urban green design on wind velocity is relevant in cases of green spaces at the main boulevard (C_1 and C_2).
- The natural vegetation decreases the ventilation within the main boulevard especially in case C_2.
- Changes in flow fields induce variation in the concentration within the main boulevard.
- The presence of vegetation reduces the ventilation and increases the concentration.
- The influence of urban green design on concentration is more relevant in cases of green spaces at the main boulevard (C_1 and C_2).
- Respect to base case, the maximum increase 72% in case C_1 and 45% in case C_2 and the area with Cnorm>0.5 is 3.55 higher in the case C_1 and 4.98 in case C_2.

	$\frac{Cmax\ (case)}{Cmax\ (case\ A)}$	$\frac{Area\ (Cnorm\ (case) > 0.5)}{Area\ (Cnorm\ (case\ A) > 0.5)}$
Case A	1	1
Case B_1	1.02	2.13
Case B_2	1.19	1.40
Case C_1	1.72	3.55
Case C_2	1.45	4.98

4. Conclusions

- A CFD model has been used to evaluate de effect of green vegetation development in new residential areas.
- Simulation results of wind velocity for the current conditions in the main boulevard were evaluated with available experimental measurements.
- Wind field and pollutant concentration have been analyzed in different scenarios representing several green vegetation development (possible future scenarios).
- The presence of vegetation modifies velocity fields in all cases, specially in cases C (natural vegetation along the boulevard), reducing the ventilation.
- The modifications of airflow induce an increase of concentration in the boulevard, especially in cases C. E.g. for case C_1, the maximum of concentration increases 72% respect to base case (A) and for case C_2 (taller vegetation) the zone with normalized concentration higher than 0.5 increases a factor 5 respect to base case.
- Future work: Analysis of other wind directions and other processes such as deposition of pollutant on vegetation or thermal comfort.

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