

Coupling Particle Tracing with Brinkman-Forchheimer Flow for the Interaction Between Vegetation and PM Dispersion

Tess Ysebaert¹, Siegfried Denys¹

1. Sustainable Energy, Air and Water Technology, Department of Bioscience Engineering, University of Antwerp, Belgium

INTRODUCTION: Vegetation is proposed as possible tool for urban particulate matter (PM) mitigation.



Figure 1. Green wall at Tokyo Station (Japan)

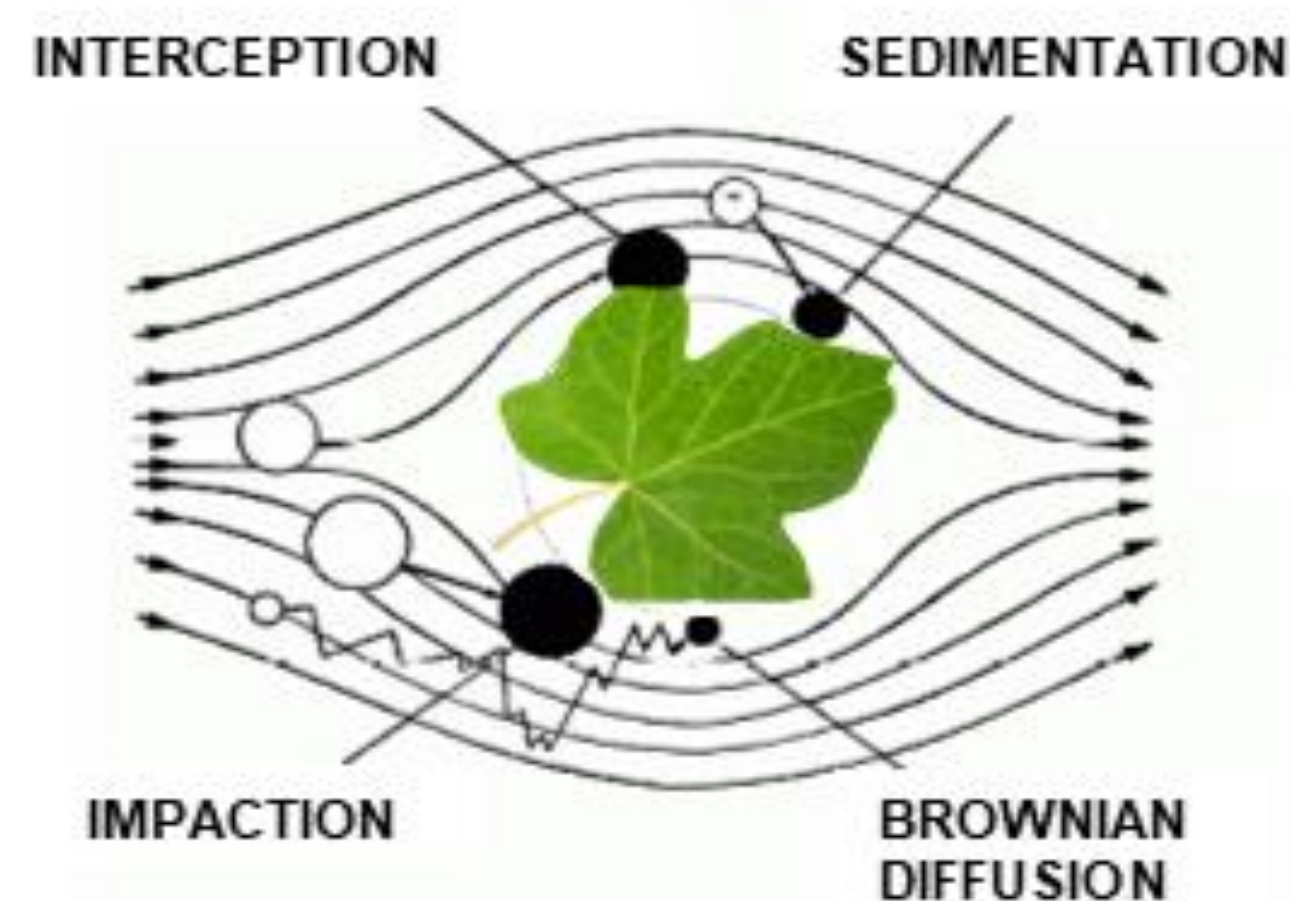


Figure 2. Different mechanisms of deposition on a plant leaf

We will study this with wind tunnel experiments in combination with COMSOL Multiphysics[®] modelling.

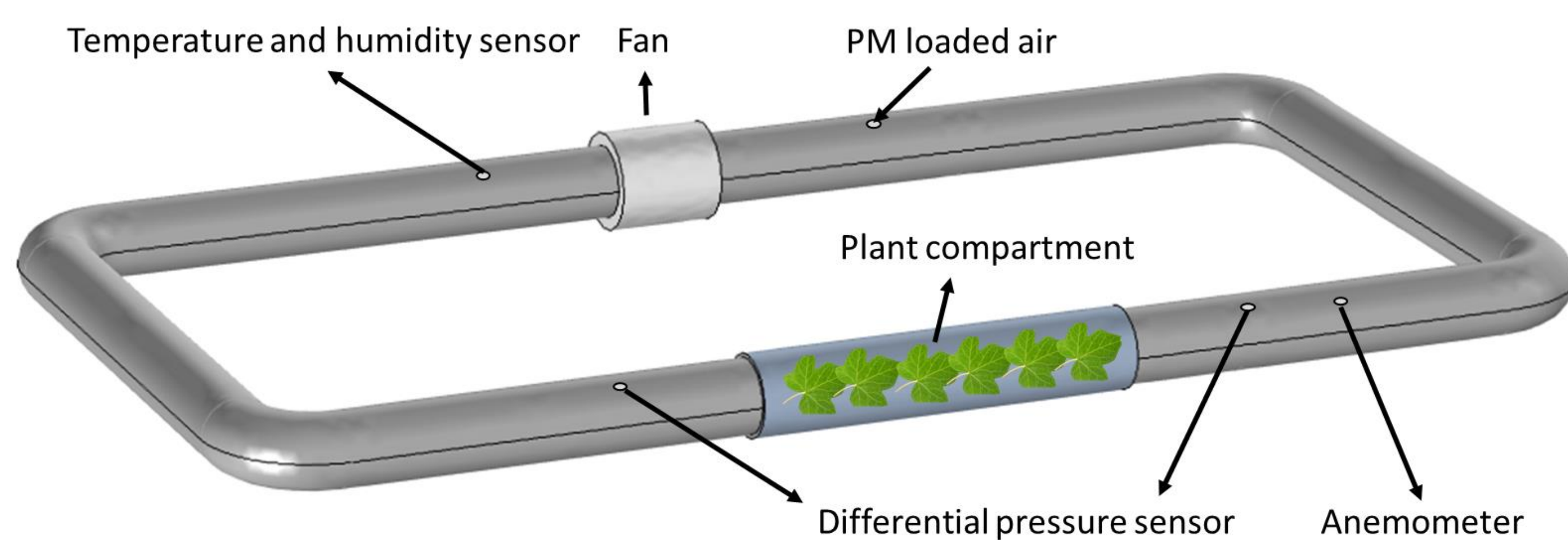


Figure 3. Wind tunnel with the plant compartment, measurement sensors and the inlet of the PM loaded air indicated

COMPUTATIONAL METHODS:

- Spatial averaging of vegetation: vegetation is simplified as a porous medium:
 - Turbulence air flow model $k-\omega$ for the bulk volume
 - Brinkman equations for the domain with vegetation → including Forchheimer drag to account for inertial effects
- Lagrangian particle tracing: as a first approximation only drag force (F_d) is considered for PM_{2.5} (Table 1)

$$\frac{d}{dt}(m_p u_i) = F_d$$

Variable	Value	Unit
Aerodynamic diameter	2.5	μm
Density	820	kg m ⁻³
Number	10,000	

Table 1. PM characteristics

RESULTS: Proof of concept

Test on ivy (*Hedera helix*) with different volumetric porosities (φ):

- the particle velocity magnitude is inversely proportional with the porosity
- higher probability of deposition

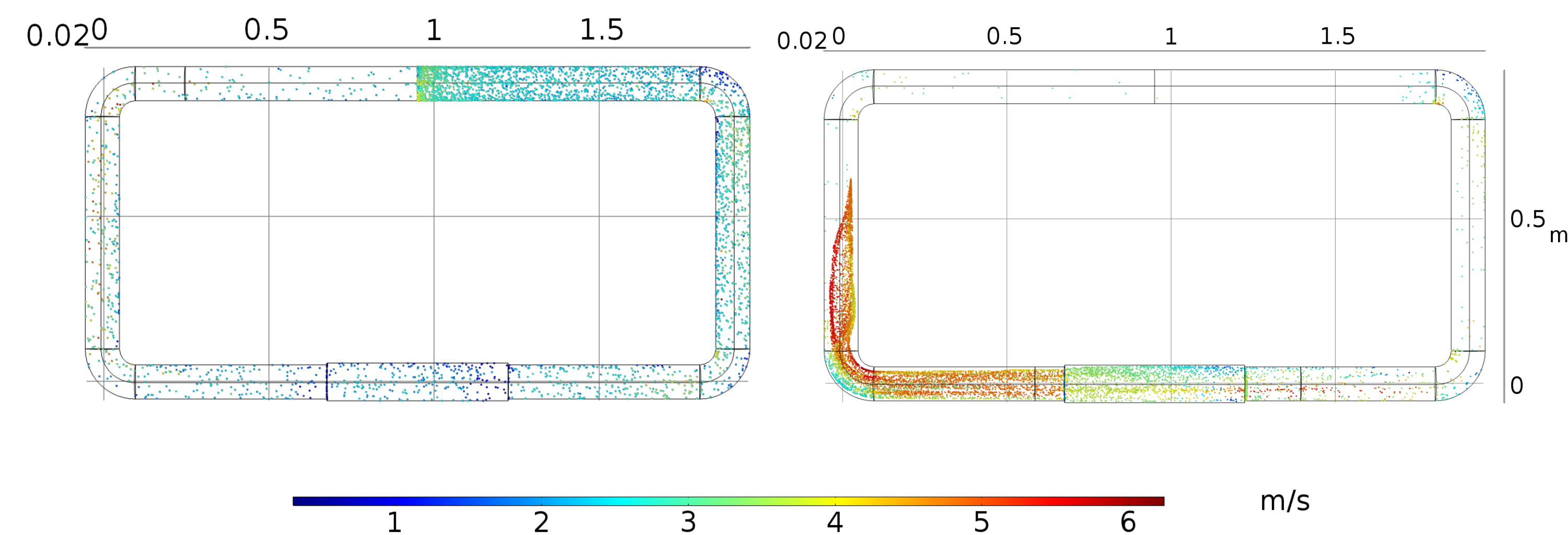


Figure 4. Particle trajectories in the wind tunnel without (left) and with plant leaves with $\varphi = 0.9955$ (right)

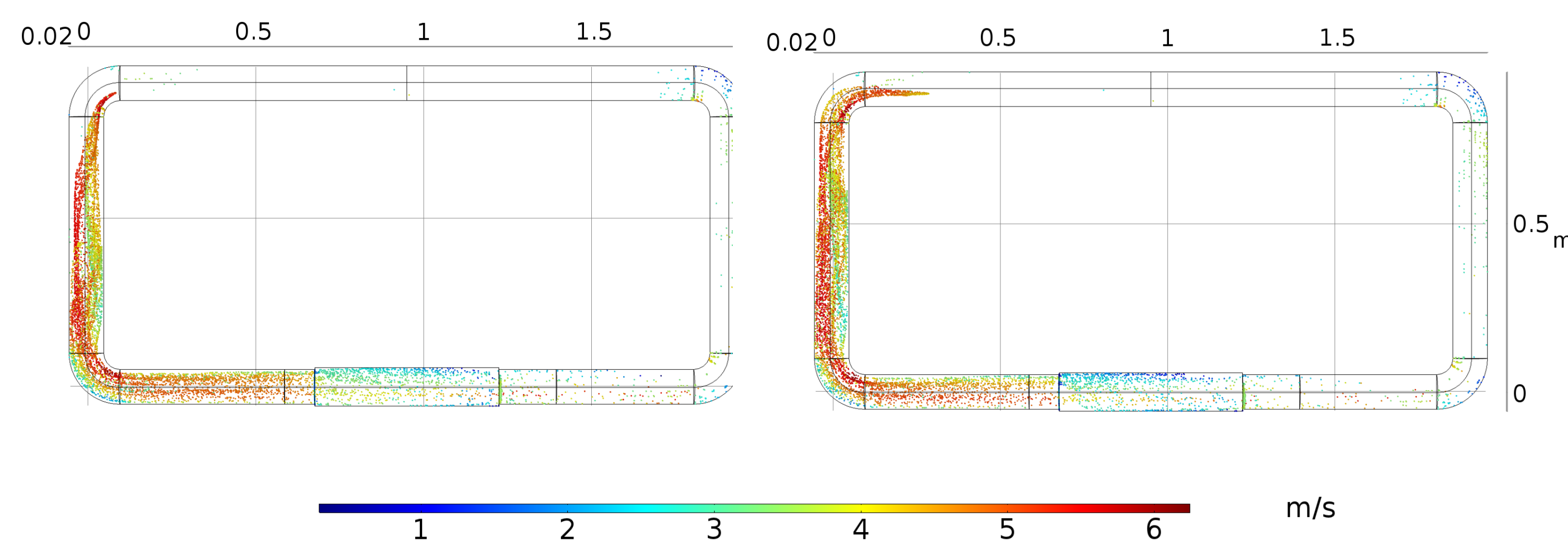


Figure 5. Particle trajectories in the wind tunnel filled with plant leaves with $\varphi = 0.9964$ (left) and plant leaves with $\varphi = 0.9973$ (right)

CONCLUSIONS: Vegetation slows down the air flow and, thereby, probably aids in the deposition of PM.

Future:

- Inclusion of particle removal by vegetation by adding a sink term to the Lagrangian framework
- Spatial averaging method was validated by Koch *et al.* (2018)¹ → further validation with real PM emissions generated with an experimental setup

REFERENCES:

1. Koch, K., Samson, R., Denys, S. (2018) Biosystems engineering. *Under review.*