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POROUS MEDIUM MODELING FOR AIR FLOW THROUGH FOREST-COMPARISON WITH WIND TUNNEL DATA

Zeinab Ahmadi Zeleti*,[1], Sandrine Aubrun[2] and Jari Hämäläinen[1]

[1] Lappeenranta University of Technology (LUT), P.O. Box 20, FI-53851 Lappeenranta, Finland, zeinab.ahmadi.zeleti@lut.fi, Jari.Hamalainen@lut.fi and http://www.lut.fi/

[2] University of Orleans, Château de la Source Avenue du Parc Floral BP 6749 45067 Orléans Cédex 2, France, sandrine.aubrun@univ-orleans.fr and http://www.univ-orleans.fr/

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INTRODUCTION

Forest is often characterized by a large variability in both vertical and horizontal direction due to vegetation distributions. This inconsistency affects the air flow to behave differently through and above a forest. Therefore, modeling the forested landscapes more efficiently has become a topic of interest for many researchers. This has largely been motivated due to its vast number of environmental applications, especially in predicting wind flow for wind energy application.

In order to take into account the existence of forest vegetation, earlier numerical air flow models have considered only the frontal leaf area density of tree or roughness length of forest. However, this study aims to model the forest canopy with porous medium approach. The CFD simulated results of wind profiles through the canopy are compared with finite forest wind tunnel data provided from University of Orleans, France.

APPROACH

The momentum balance equation written for incompressible air flow through forested landscape is $\varepsilon\rho\frac{DU}{Dt} = -\varepsilon\nabla p + \varepsilon\nabla.\tau + S$ where the source term representing the momentum absorbed within forest, $S = -\left(\frac{\mu}{\mathbf{K}}U + C\frac{1}{2}\rho|U|U\right)$, is composed of two parts, viscous (Darcy) and inertial drag forces, respectively. Here, the porosity of the medium is denoted as ε, the ability of the medium to permit flow is denoted as $\mathbf{K}$, and the canopy inertial resistance coefficient as C. The present work follows that the viscous forces are not significant for forest porous medium modelling. This has earlier been validated for flat terrain with obstacles representing tree canopies. Thus, by neglecting this term and with the help of drag-force approach [1], the inertial resistance coefficient can be calculated as $C = 2\ \mathrm{LAD}\ C_d$ where C_d is the canopy drag coefficient. Nevertheless, the detailed information of wind tunnel forest, such as LAD and porosity useful for CFD calculation has been provided by University of Orleans, France where a specific configuration of rings with fixed diameter made from metallic mesh was used to simulate the air flow through forest model.

A computational domain with wind tunnel scale porous forest, shown in Figure 1, has been discretised and the coefficients (C and ε) of single metallic tree are assigned over each cell centres. Here, the inertial resistance in the vertical direction is neglected. Furthermore, the standard k-epsilon turbulence model with standard wall functions for near wall treatment is used for numerical simulation.

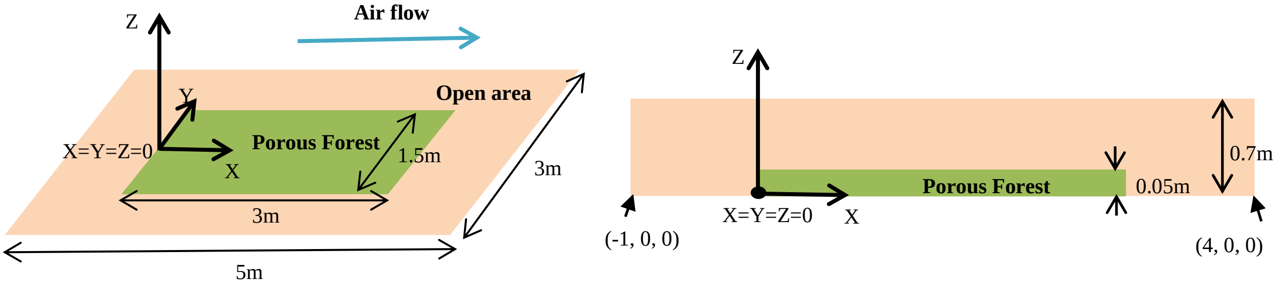

Figure 1: Computational domain.

RESULTS

Figure 2 depicts the comparison of the vertical wind profile of streamwise velocity between the simulated results and the wind tunnel measured data.at different locations. It is observed that the forest resistance causes the wind flow to slow down within the forest, while the difference in pressure causes the wind speed to increase with height above the forest. Nevertheless, the present results have overall good agreement with the wind tunnel data.

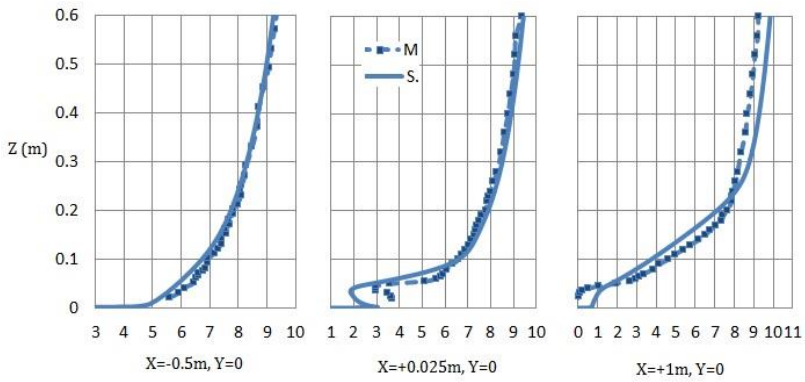

Figure 2: Vertical profiles of horizontal mean velocity of simulation result (solid line) and measured wind tunnel (dotted line) at three different locations ($X = -0.5\ m,\ X = 0.025\ m, and\ X = 1\ m$)

CONCLUSIONS

The agreement of vertical wind profile through forest between simulation result and experimental data justified the usage of porous medium approach for forest model. Also, the present method can represent a much more realistic situation, specifically for a real field, than previous studies that have considered only the frontal LAD or roughness length of forest canopy. This is mainly due to applicability of utilizing more detailed information on the vegetation derived from LiDAR measurements of forest, such as porosity and LAD at any x, y, z location, into the CFD calculation of flow model. More results, e.g. velocity profiles for other locations or turbulence intensity profiles, will be presented in the conference.

REFERENCES

[1] A.N. Ross and T.P. Baker, Flow Over Partially Forested Ridges. *Boundary-Layer Meteorology* Vol. **146**, pp. 375-92, 2013.