# SIMULATIONS OF SUB-CANOPY WINDS

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**Introduction:**

Operational fire models rely on wind reduction factors to relate the standard meteorological measured or forecast wind speed to the flame-height wind speeds within a tree canopy. We investigate the wind flow over idealised rectangular tree canopies using Large Eddy Simulation (LES) with an eye towards developing a model of the wind reduction factor.

## RESEARCH QUESTION: WHAT ARE THE MAIN FEATURES OF FLOW OVER A TREE CANOPY?

**Numerical methods:**

Large Eddy Simulation (LES) is quickly becoming the preferred tool to investigate complicated atmospheric flows. Simulations of sub-canopy winds have, for example, been successfully validated by Mueller et al. [1]. This study uses Fire Dynamics Simulator [2] to simulate flow over a canopy. The tree canopy is modelled as an aerodynamic drag term which relates the Leaf Area Density (LAD) to the drag force. The results (Figure 1) are visualised using time-averaged (1s sampling over a 1 hour period) streamlines, which show the path a massless fluid element will travel.

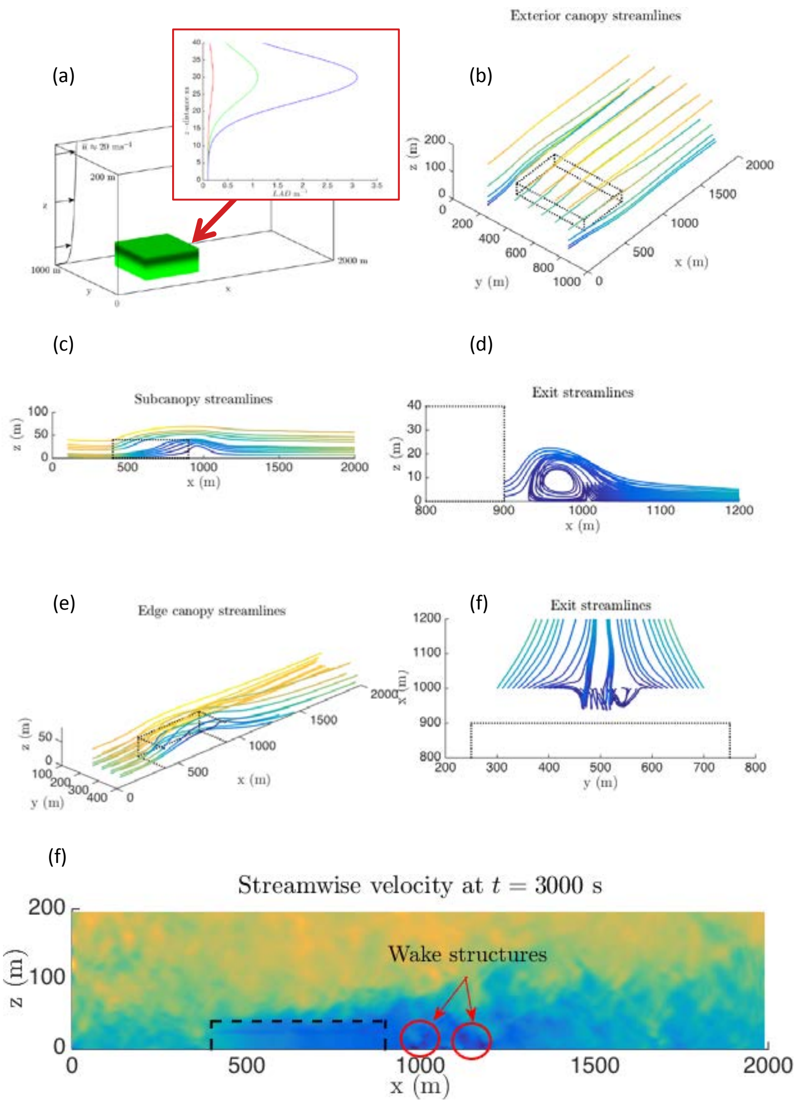


Figure 1. All streamline plots are for the 500 m, max(LAD)=3.1 m$^{-1}$ canopy. Streamlines are coloured by velocity magnitude (blue ~1 ms$^{-1}$, yellow ~15 ms$^{-1}$) (a) the domain outline and LAD (red: max(LAD)=0.2, green=1.1, blue=3.1, m$^{-1}$. (b) streamlines averaged over 1 hour in time, over the exterior of the canopy. (c) time-averaged streamlines along the canopy centre. Notice the lofting of the streamlines at the upstream edge of the canopy, called the impact region, and the lofting of the streamlines over the exit region. (d) time-average streamlines in the vicinity of the exit region highlighting a large recirculation vortex. (e) time-streamlines along the spanwise edge showing the three-dimensional structure of the flow. (f) Top view of the recirculation vortex. (g) Instantaneous plot of the centerline velocity highlighting the large wake structures shed from the canopy.

**Effect of canopy length and LAD Profile**

The LAD is varied from a very dense canopy representing spruce trees in a boreal forest [3], to a very sparse canopy representing eucalyptus trees in a regrowth forest [4]. The canopy length is independently varied between 100 m, 500 m, and 900 m for the most dense canopy. The centerline vertical profiles of mean velocity are plotted in figure 2 (a), (b).

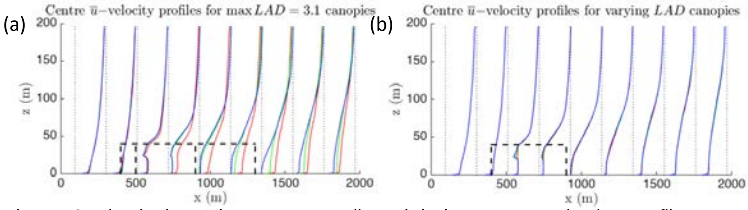


Figure 2. Black dotted: canopy outline. (a) the mean velocity profile over all canopy lengths. Red 100 m, green 500 m, blue 900 m. (b) the effect of three LAD profiles for the 500 m canopy. Red: max(LAD)=0.2 m$^{-1}$, green: 1.1 m$^{-1}$, blue: 3.1 m$^{-1}$

**Discussions and further work**

It is important to consider the effect of the flow regions on fire spread. In the impact region fire will suddenly slow as the driving wind velocity decays. Figure 2(b) suggests the flow velocity is only affected by the leafy tree crown in the impact region. Figure 2(a) shows the length of the canopy is critical for flow development and the redevelopment of the flow downstream.

It is important to extend this work to include a plume. Because a plume entrains fluid from every direction, the recirculation region is unlikely to persist as a fire propagates across the canopy edge. However, the complicated recirculation structure may effect the transport of firebrands. The wake structures, large regions of slow moving fluid, which are shed from the canopy may impact fire behaviour for a great distance downstream. Further simulations are required to understand the effect of the canopy on the rate-of-spread, and further work is required to extend the study to a realistic, irregularly shaped, inhomogeneous tree canopy.

**End user comment**

Predicting the effect of forest and shrub canopies on the wind at the height of bush fire flames is necessary for accurate fire spread prediction. Current approaches based on a constant 'wind reduction factor' over-simplify these effects. This project is contributing to better understanding of flow in canopies and future improved operational models.

*Dr Simon Heemstra, NSW Rural Fire Service*

**References:**

[1] E. Mueller et al. Canadian Journal of Forestry Research (2014) [2] K. McGrattan et al. FDS User Guide NIST special publication (2016)

[3] B. D. Amiro Boundary Layer Meteorology (1990) [4] K. Moon et al. Fire Safety Journal (2016)