Dynamic wind reduction factors have considerable effects on forest fires where variable canopy heights play important roles.

Mahmood Rashid1, James Hilton2, Duncan Sutherland3, Khalid Moinuddin1
1 Victoria University, Melbourne, Victoria, Australia
2 Data61, CSIRO
3 UNSW Canberra, ACT, Australia

The behaviour of fire is primarily governed by the wind flow and fuel types on the affected area. For the forest fire, tree canopies play an important role by reducing the wind velocity when it passes through the forest. The objective of this research is to apply a dynamic wind reduction factor (WRF) in an operational model to predict the fire rate of spread (RoS).

Introduction
Wind reduction factor is dynamic in nature, i.e., it changes with the wind velocity and fuel structures. For simplicity, fire behaviour analysts use a rule of thumb to estimate the WRF for a specific fuel type for operational fire prediction models e.g., in Spark [1], an operational fire simulation model developed by Data61 of CSIRO, the value of WRF is 3 for Eucalyptus forests. For a dynamic fire, passing through canopies, the relationship between the wind speed and RoS appears more complicated than can be described by a constant value as illustrated by Moon et al. [2]. Sutherland et al. [3]. Although research on complicated canopy interactions is ongoing, we have made a significant progress in enhancing RoS prediction in an operational model.

Methods
In our study, we are using Harman-Finnigan model [4] to calculate dynamic WRF. The Harman-Finnigan model for flow in and above a uniformly distributed canopy is a three layers model:
- Subcanopy - the Inoue Model [5] for subcanopy flow is used within the canopy
- Shear layer - across the top of the canopy and immediately above the canopy - the Rauvach Model [6] is used, and
- Displaced Log-Layer - above the canopy.

In our model WRF is calculated as:

$$ WRF = \frac{u_{\infty}}{u_{10}} $$

where, $u_{\infty}$ is open wind speed at 10 m above the ground and $u_{10}$ is the sub-canopy wind velocity at various heights.

Towards calculating WRF, we prepare raster maps of leaf area index (LAI) and vegetation height data respectively obtained from [7] and [8] to feed in Spark (e.g., Figure 1 (a) and (b) are the prepared raster maps of the area of 2009 Kilmore Fire, VIC).

Results
We tested our model with synthetic leaf area density (LAD) data to calculate WRF and apply that to Spark. The outcome of Spark’s two variant (i) base spark and (ii) spark with our model applying WRF are presented in Figure 2 (a) and (b).

Further, we run our model on eight actual bushfire cases (e.g., Lithgow 2013, Kilmore 2009, Forcett 2013, Wangary 2005 and others) to assess capability of our model. Figure 3 (a) and (b) present the outcomes of the 2009 Kilmore fire where 3(a) represents the fire without applying WRF and 3(b) represents fire after applying dynamic WRF. Black lines represent the final perimeter of the actual fire.

Discussion
In our results, the effects of dynamic WRF is evident, which is producing better predictions relative to the results with constant WRF. However, we observed some inconsistency in RoS in a few cases and our initial assumption is, this might happen because of very low resolution (1km x 1km) of the vegetation height data in comparison to Spark’s high resolution (30m x 30m). We aim to investigate further to find the root cause.

References
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