FIRE SPREAD PREDICTION ACROSS FUEL TYPES
BY PHYSICS-BASED MODELLING
Research Advisory Forum

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PROGRESS REPORT

1) Grassfires simulation
   a) Published online Int. J. Wildland Fire

2) Simulation of flow through vertically heterogeneous canopies
   a) Presented at AFAC 2018

3) Validation of a firebrand transport model
   a) Published in Fire Safety Journal 2017
   b) Further progress subject of breakout session

4) Initialise wind fields for physics-based simulations
   a) To be presented at AFMC 2018

5) Assess ability for surface-to-crown fire transition
   a) A paper submitted to Mathematics & Computers in Simulation

6) Investigate aspects of confined plumes
GRASSFIRE RATE OF SPREAD (ROS) – VALIDATION C064
CHENEY ET AL (1993)
GRASSFIRE ROS VS WIND SPEED – COMPARISON WITH EMPIRICAL MODEL
GRASSFIRE ROS–EFFECT OF GRASSHEIGHT

Dashed: Boundary layer mode; Solid: Plume mode

Plume dominated fire

\[ \gamma = 0.2946x^{0.801} \]

\[ R^2 = 0.9457 \]
GRASSFIRE- EFFECT OF SLOPE

RoS doubles for every ten degrees of slope is not supported

- More upslope cases will be simulated; Same number of downslope cases
- Currently modelling heat load on a house from an approaching fire (AS3959)
- Patchy grass – soon to start
EXTENSION OF GRASSFIRE

Cruz et al (2018) the effect of fuel load (weight) and moisture content
- for Fuel load, primarily bulk density variation, not grass height variation
- Different ignition protocol

\[
R = \begin{cases} 
(0.054 + 0.269 U_{10})\Phi(M)\Phi(C)\Phi(W), & U_{10} \leq 5 \text{ km h}^{-1} \\
(1.4 + 0.838(U_{10} - 5)^{0.844})\Phi(M)\Phi(C)\Phi(W), & U_{10} > 5 \text{ km h}^{-1}
\end{cases}
\]

Natural

\[
M_C = \frac{97.7 + 4.06H}{T + 6} - 0.00854H + \frac{3000}{C} - 30
\]

Our extension work:
- Fuel load
- Humidity (proxy for moisture)
- Ignition protocol
EXTENSION OF GRASSFIRE

\[ MC = \frac{97.7 + 4.06H}{T+6} - 0.00854H + \frac{3000}{C} - 30 \]

<table>
<thead>
<tr>
<th>( U_{10} ) (m/s)</th>
<th>Grass height (m)</th>
<th>Bulk density</th>
<th>Moisture(%) ( (H) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.14</td>
<td>3-4 for each grass height</td>
<td>3.55 (10)</td>
</tr>
<tr>
<td>6.5</td>
<td>0.175</td>
<td></td>
<td>4.5 (20)</td>
</tr>
<tr>
<td>7.5</td>
<td>0.21</td>
<td></td>
<td>6.3 (40)</td>
</tr>
<tr>
<td>8.5</td>
<td>0.315</td>
<td></td>
<td>7.5 (50)</td>
</tr>
<tr>
<td>10.5</td>
<td>0.475</td>
<td></td>
<td>10 (75)</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td></td>
<td>12.4 (100)</td>
</tr>
</tbody>
</table>

Use of non-dimensional parameter to determine number of simulations

Main aim to understand boundary layer / plume mode threshold, sub aim correlations
WIND REDUCTION FACTOR

Works done and in progress

- One shaped LAD (does not vary horizontally), variation of canopy length (first only wind flow, then with surface fire)
- LAD varies horizontally
- Various vertical shaped LAD

Utilization
- Recruiting Research Assistant for apps development for Fire Behaviour Analysts
Leaf area index (LAI) and Fraction of photosynthetically active radiation (fPAR) - MODIS, MOD15A2(c5) mosaic

LAI defines the number of equivalent layers of leaves relative to a unit of ground area, while fPAR measures the proportion of available radiation in the photosynthetically active wavelengths that is absorbed by a canopy.

**KEYWORDS:** MODIS, LPDAAC, vegetation

**DATA LICENCE & ACCESS RIGHTS:** CC-BY 3.0

**SPATIAL COVERAGE & RESOLUTION:** 1000 m resolution; Australia

**TEMPORAL COVERAGE & RESOLUTION:** 8 day composite; 2000 to ongoing

**PRODUCTION STATUS:** Updated as available from USGS

FIREBRAND DRAGON
BURNING PARTICLE LANDING SIMULATION
**FIREBRAND DISTRIBUTION MODELLING**

Non-burning particle

Burning particle

Cuboid particles - Reynolds No $\sim 10^5$
LARGE SCALE FIREBRAND SPOTTING

Diagram showing a large-scale firebrand spotting model with a three-dimensional box indicating dimensions X (m), Y (m), and Z (m). The box includes a section labeled 'Canopy.' A diagram of a forest fire with wind direction indicated and firebrands dispersed under the canopy.
SPOTTING FIREBRAND - DIFFERENT SHAPE

Disk shape: 32mm x 32mm x 2mm

Cylindrical shape: Dia=3mm, L=18mm
EXTENSION OF FIREBRAND MODELLING

1) Statistical model for operational models, such as SPARK
2) Inclusion of firebrand risk assessment in AS3959
FUTURE DIRECTIONS/ BENEFITS

• Better understanding of different mode of grassfire and better RoS correlations
  • dependence on fuel load, humidity, ignition protocol, slope, patchyness

• Assessment of heat and firebrand loading on structures & appraisal of AS3959

• Development of statistical models for firebrand landing for operational models, such as SPARK

• Better operational wind reduction factor and sub-canopy wind model – utilization

• Potential risk modelling
  • Estimation of fire breaks, prescribed burning planning etc
QUESTIONS?
WIND FLOW THROUGH VERTICALLY HETEROGENEOUS CANOPIES

Different values of $A$, $B$, $\mu$, and $\sigma^2$

$$\text{LAD} = A \exp \left( -\frac{(z - \mu)^2}{\sigma^2} \right) + B$$


sub-canopy $u$-velocity model of Inoue (1963) was improved by including a new parameter
WIND FLOW THROUGH VERTICALLY HETEROGENEOUS CANOPIES

Results

Mean u-velocity profiles

Mean u-velocity profiles normalised by the canopy top value. In (a) \( \sigma^2=0.325 \) is held constant and \( \mu=0.00 \) (red), 0.233 (green), 0.467 (blue), and 0.700 (black). In (b) \( \mu=0.70 \) is constant and \( \sigma^2=0.325 \) (black – the same curve as in (a)), 0.233 (blue), 0.142 (green), and 0.050 (red).
Improved sub canopy modelling

Modelled and simulated sub-canopy $u$ –velocity profiles. (a and b) contain the modelled profiles using the simulated $\beta$ (triangle symbols) and the observed $\beta$ (circle symbol) of Harman and Finnigan [2007] and a constant mixing length based on $LAI$. The modelled profiles in (c and d) use the simulated $\beta$ and $dLAI$. 