FIRE SPREAD ACROSS FUEL TYPES

Research Advisory Forum

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Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

PROGRESS REPORT

1) Physics-based simulation of grassfires
    a) Under review in Int. J. Wildland Fire
2) Simulation of flow through heterogeneous canopies
    a) Presented at AFAC 2017
3) Simulation of sub-canopy fires
    a) Subject of a workshop in the breakout
4) **Simulation of surface-to-crown transition**
5) **Modelling thermal degradation of herbaceous fuel**
6) **Confined plumes**
    a) **Presented at AFMC 2016**
7) Validation of a firebrand transport model
    a) Published in Fire Safety Journal 2017

FUTURE DIRECTIONS

1) **Fire developing downstream of a canopy**
2) Extension of heterogeneous canopy simulations
3) Extension of grassfire parametric study
4) Applying diagnostic models of wind fields to initialise physics-based simulations

PEOPLE INVOLVED

Khalid Moinuddin

Duncan Sutherland

Andrew Ooi

Jimmy Philip

2 VU PhD students + 1 advertised

1 UoM PhD student

1 VU Masters by research

2 VU Masters by course work

1visitng PhD student

PHYSICS-BASED FIRE MODELLING

1) Flame & smoke propagation and fire suppression simulation by computational fluids dynamics (CFD)-based modelling

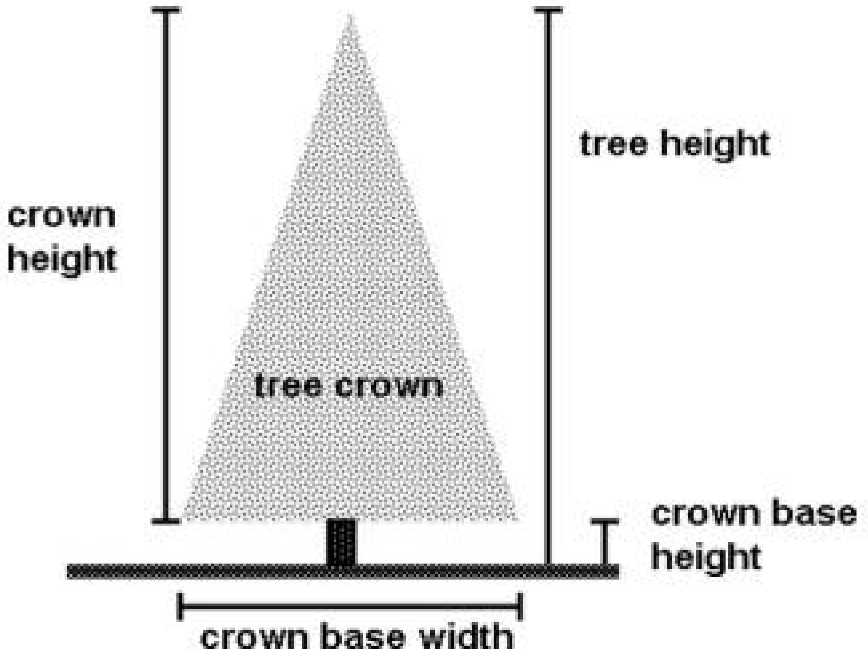
2) Start with fundamental <u>differential</u> equations for:
   a) Fluid momentum and mass transport (including turbulence)
   b) Thermal degradation & combustion of materials and transport of gasses and soot
   c) Heat transfer by radiation and conduction

3) This is time consuming but gives a more practical result than engineering equations *(simple equations from experiments)*
4) *We use Fire Dynamics Simulator (FDS) developed by NIST*

SURFACE FIRES TRANSITIONING TO CANOPY FIRES

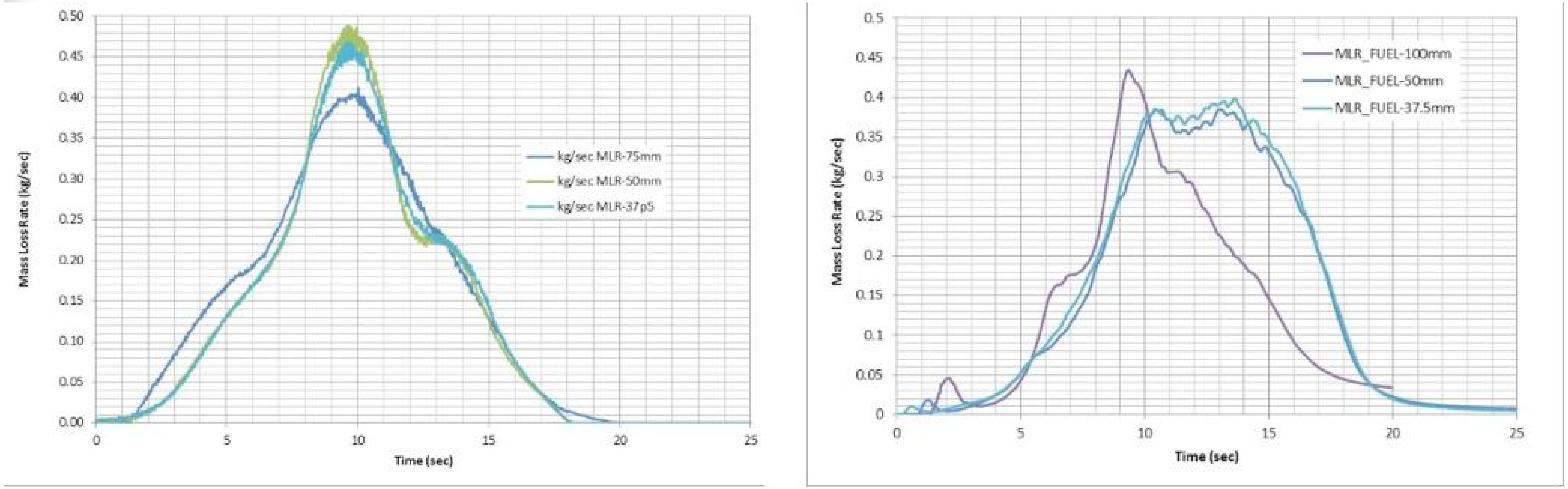
1. Simulations of single burning trees
   a. Achieve numerical convergence
   b. Benchmark results
2. Simulations of a surface fire igniting a crown fire
   a. Investigate the capability of FDS and WFDS
   b. Insight into the physical processes

SINGLE TREE SIMULATIONS



Setup, figures taken from Mell et al. Combustion and flame 2009

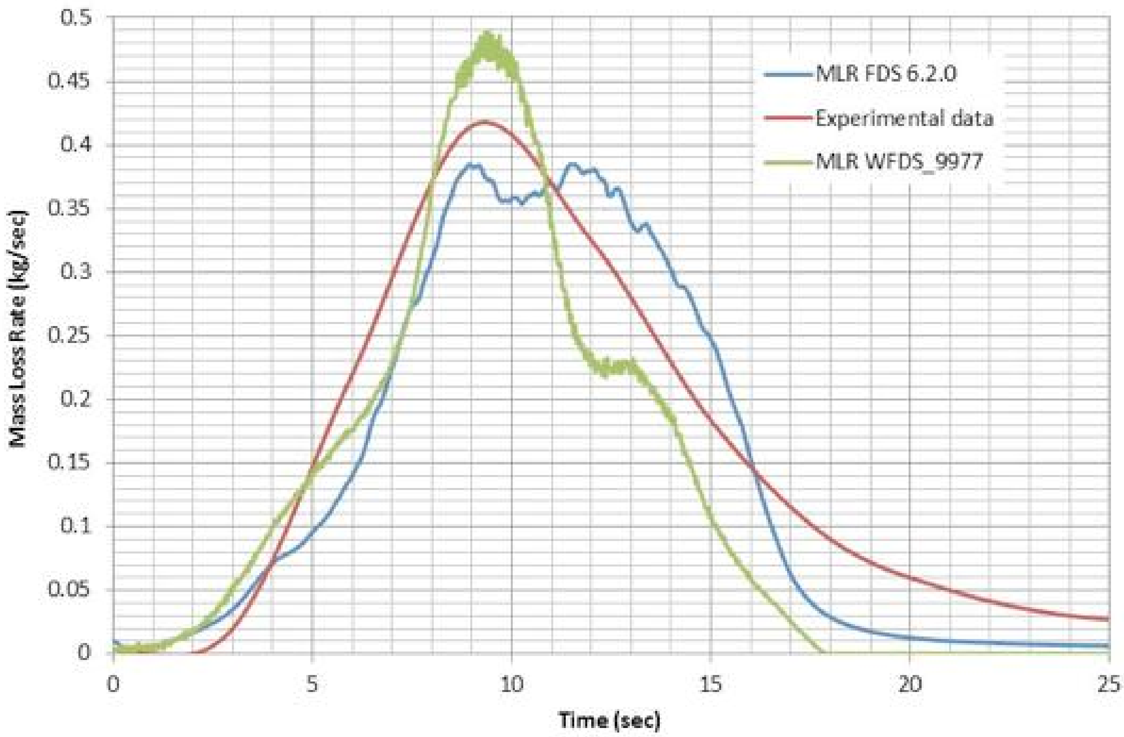
NUMERICAL CONVERGENCE



(a) WFDS_9977 (b) FDS 6.2.0

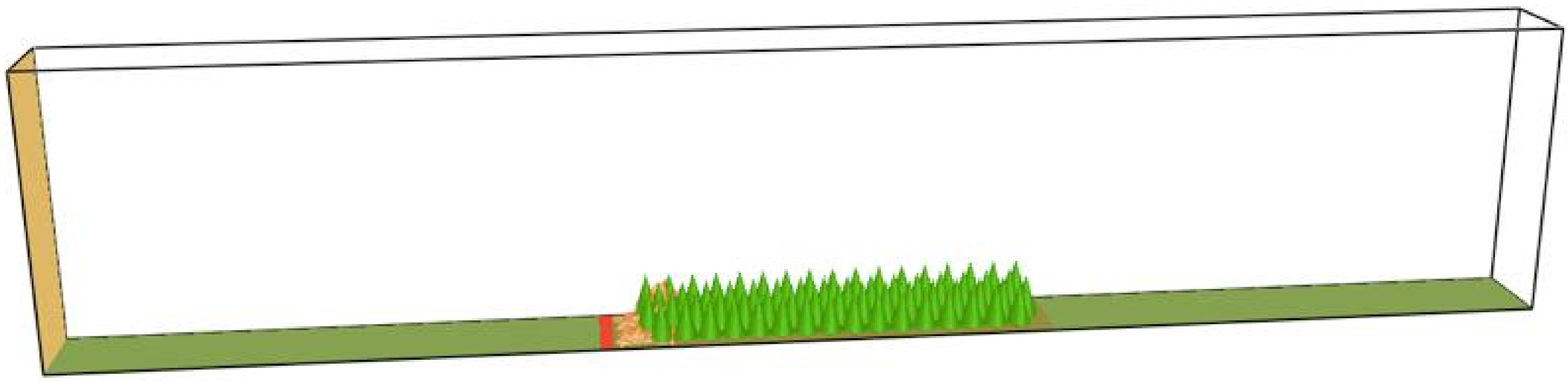
Comparison of Mass loss rate (MLR) results for 2.25 m Douglas fir tree simulations for grid sizes: 75 mm, 50 mm and 37.5mm

COMPARISON TO EXPERIMENTAL DATA



MLR results comparison with experimental data (Mell *et al*, 2009) – both numerical results are shifted by 1.5 sec.

SURFACE-TO-CROWN FIRES

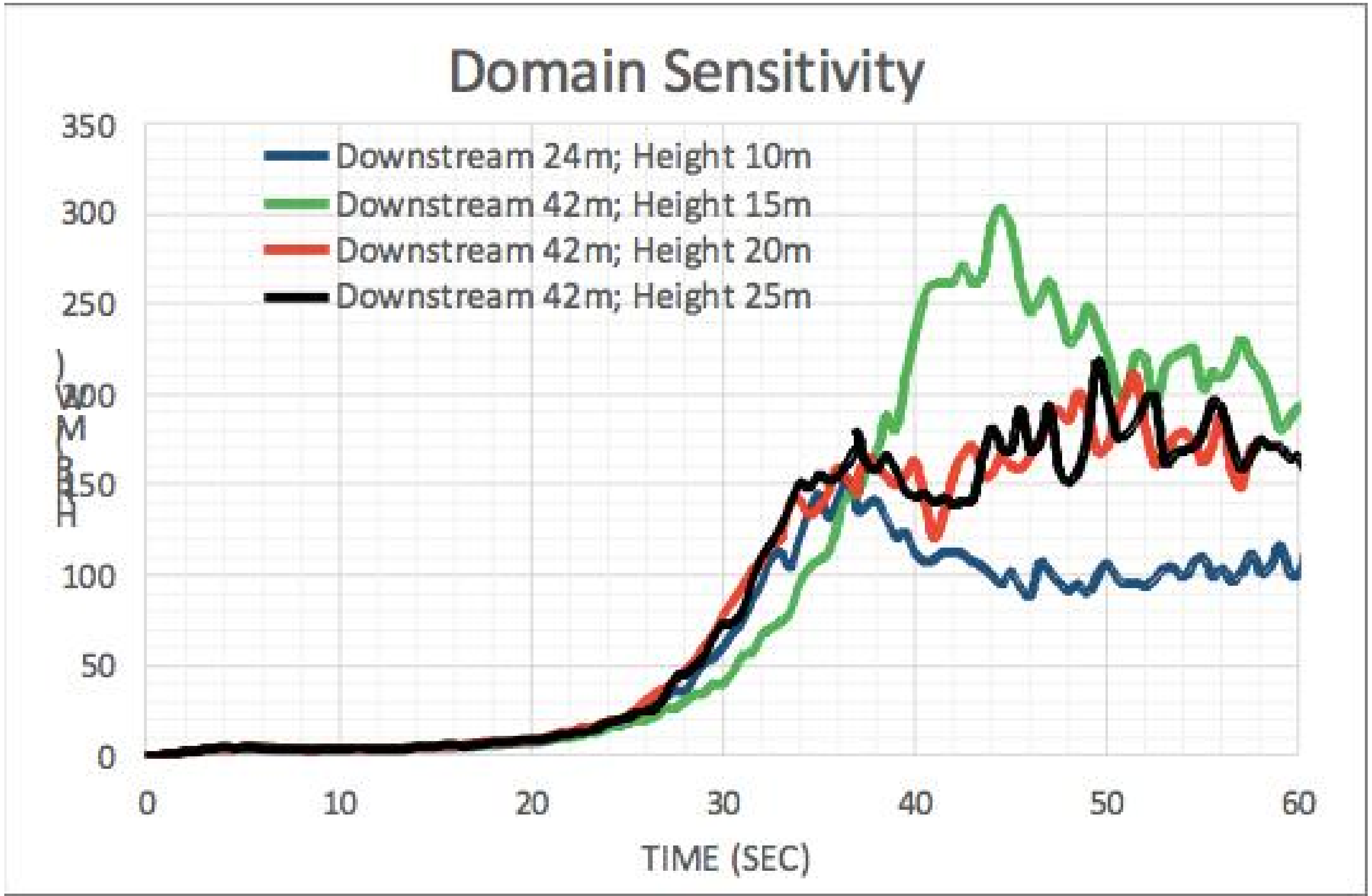


Graphical representation of surface fire-crown interaction simulation.

Domain is 124 m long, 8 m wide as shown in Power law (1/7) with wind speed ~ 13.5 km/h at 10 m
Surface fuel is modelled as grass

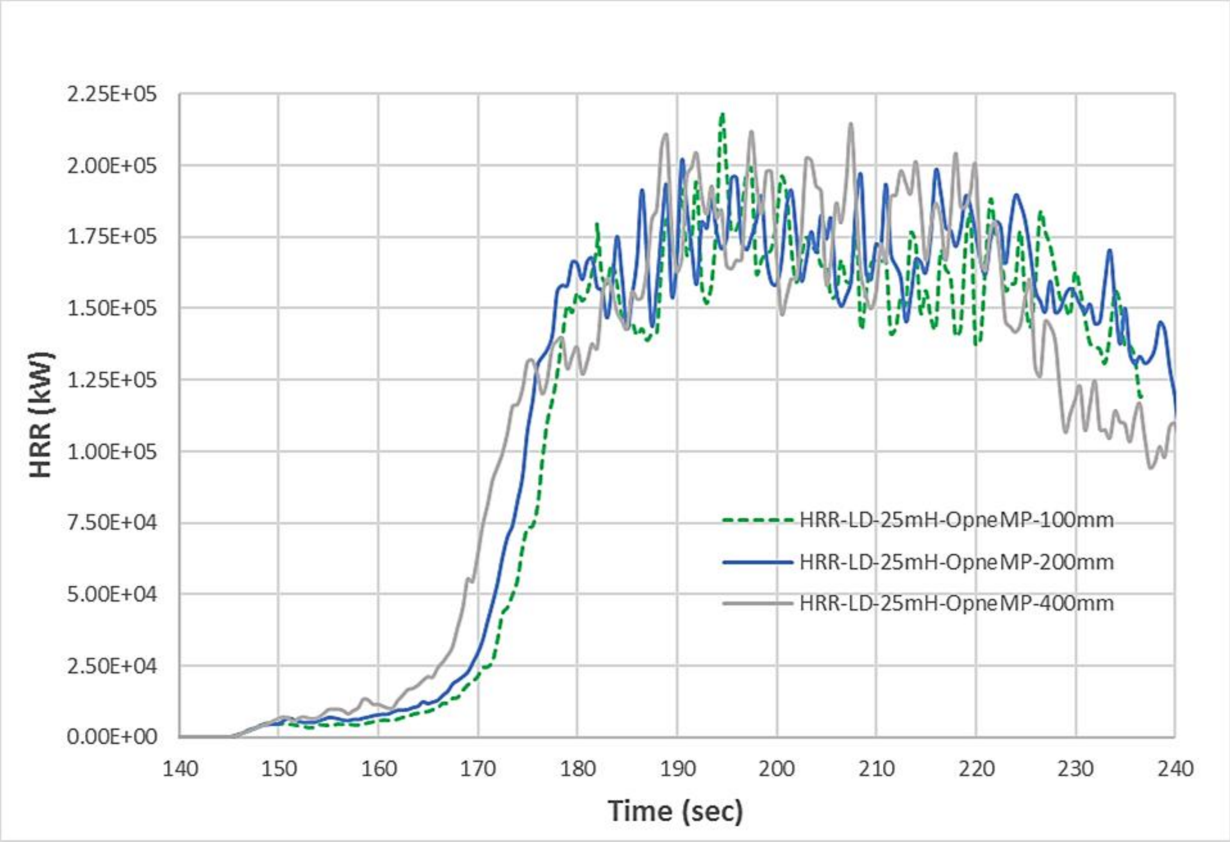
Four columns of Douglas Fir trees are modelled. Alternate columns had 16 and 17 trees in a staggered fashion. The columns are 2m apart and within the column, the trees are also 2m apart.

SIZE OF THE DOMAIN

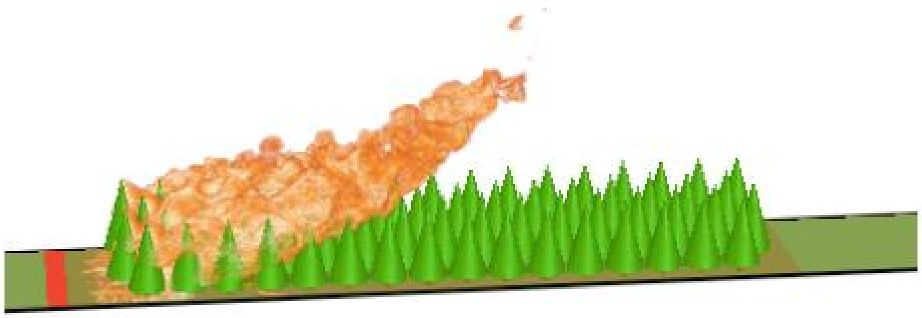


HRR vs time results from sensitivity analysis

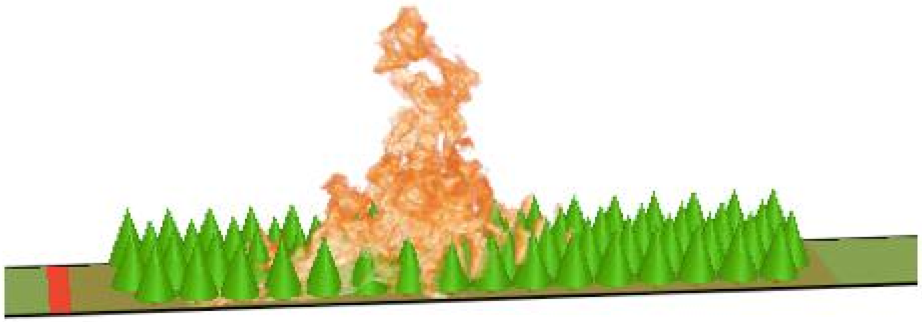
NUMERICAL CONVERGENCE



VISUALISATION OF FLAME

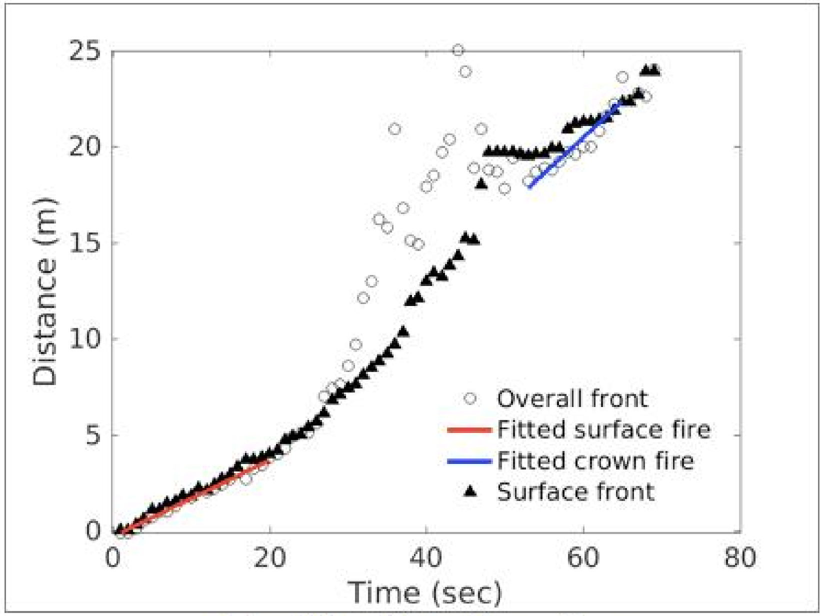


(a) Flame upon impacting the crown

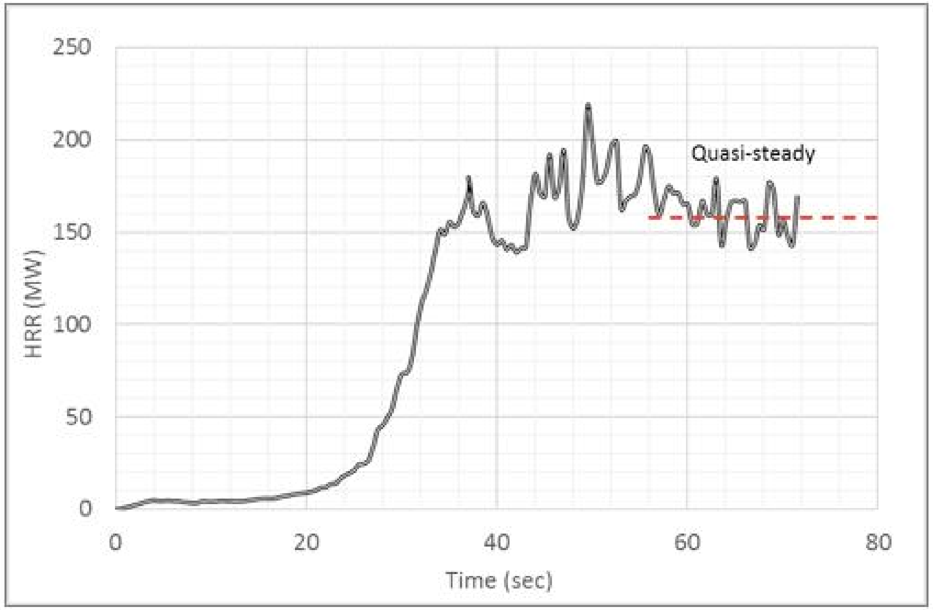


(b) Quasi-steady flame propagation

FRONT AND HRR



(a) Fire front location



(b) HRR

CONCLUSIONS

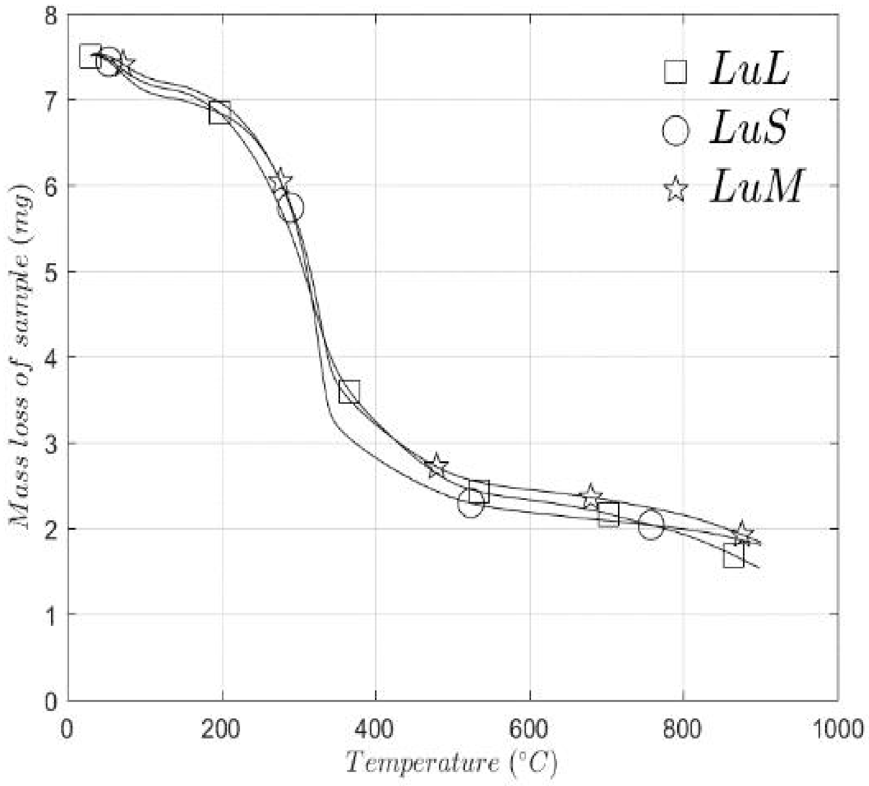
1) Can simulate single burning trees with numerically sound results which agree with experimental data
2) Simulation of surface-to-crown fire transition is feasible
3) The results suggest this is a supported crown fire: the surface fire inputs energy to sustain crown burning
4) Accepted for presentation at MODSIM, 2017, Hobart

THERMAL DEGRADATION OF HERBACEOUS FUELS

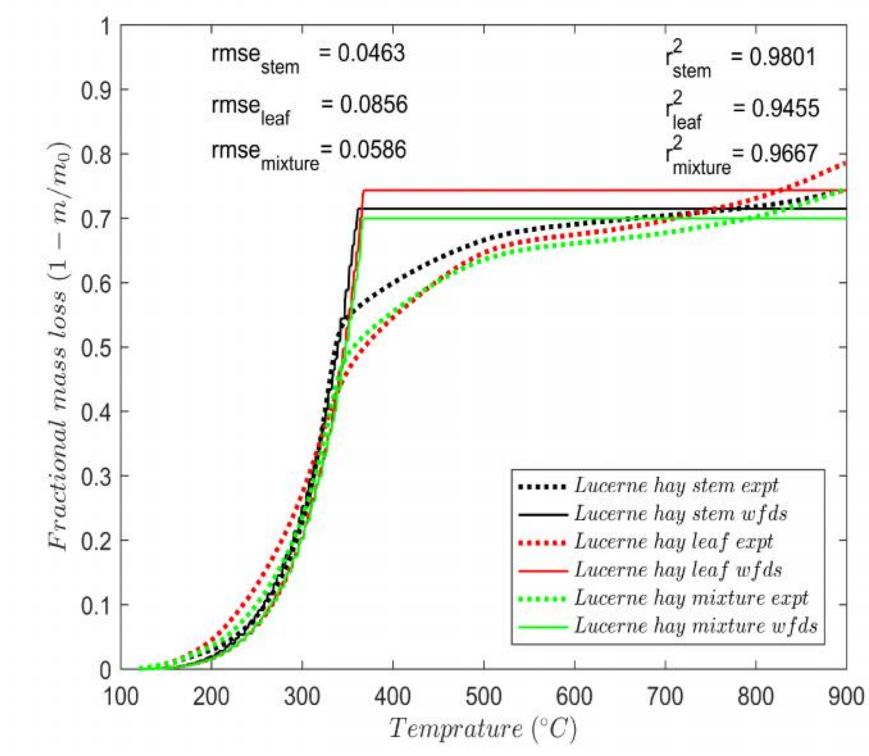
- VU PhD student: Rahul Wadhwani
- Pyrolysis is a thermal reaction where cellulosic material degrades into volatile gases, char and ash
- An integral part of physics-based model such as WFDS/FDS, FIRETEC, FIRESTAR
- Requires measurement of many thermo-physical and thermochemical parameters
- Deterministic approach and requires a vegetation data bank on thermo-physical and thermochemical properties
- This part of our work approach to reduce the number of parameters required and use simple models to run a simulation
- Two types of model- Linear and Arrhenius models

TESTING AT MICROSCALE

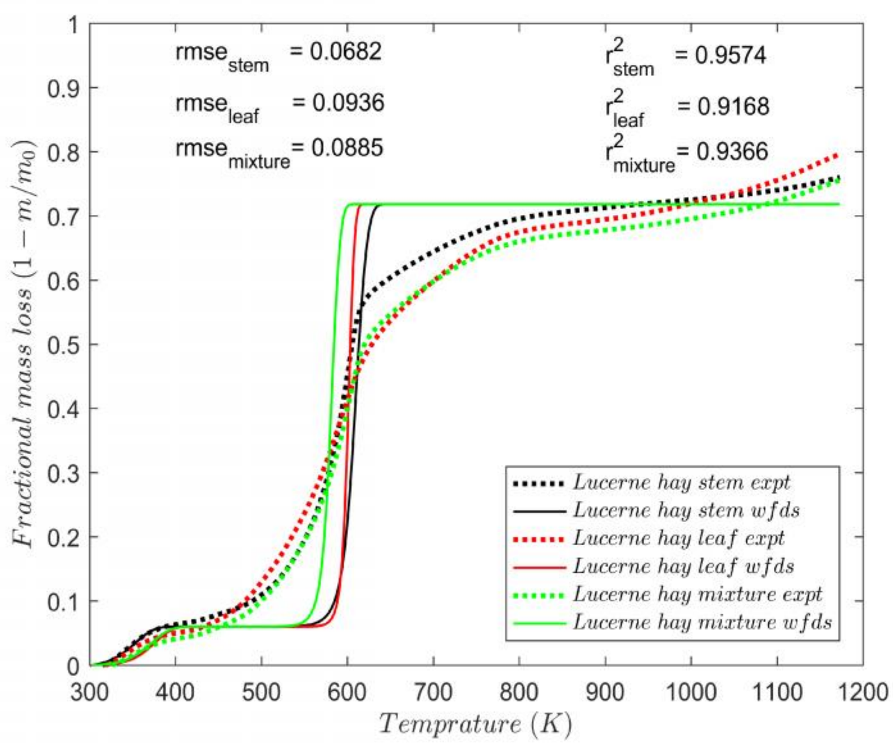
1) The test conducted on TGA samples of Lucerne hay
2) Heat of pyrolysis, thermal conductivity and heat capacity from DSC and hot disk analyser
3) Similar work is done on pine and eucalyptus forest litters



COMPARISION: LINEAR VS ARRHENIUS



Linear



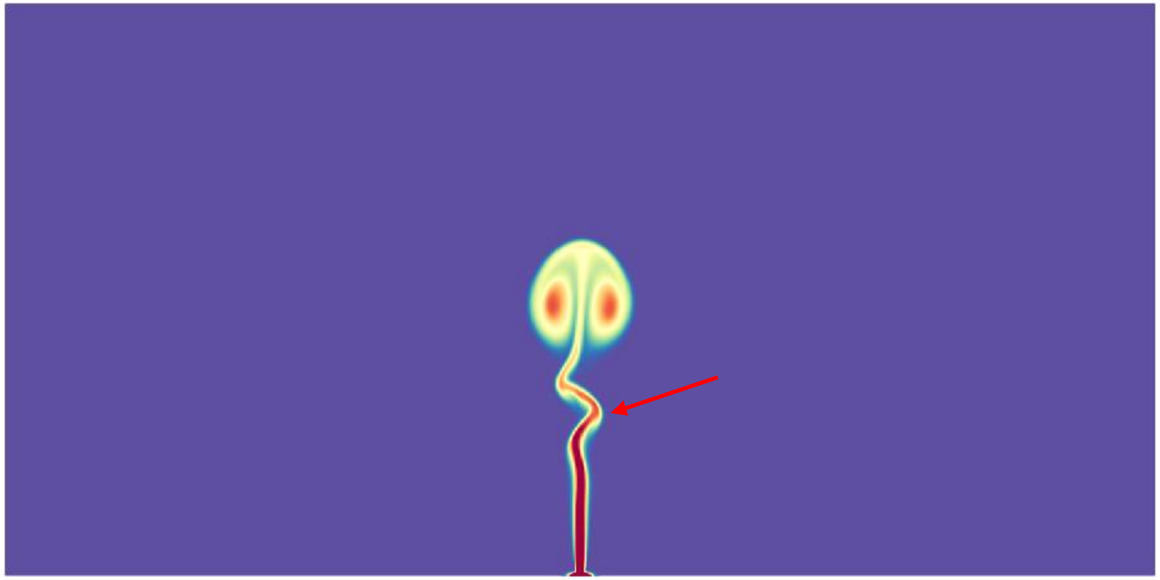
Arrhenius

Accepted for presentation at Asia-Pacific Conference on Combustion, 2017, Sydney

FIREBRAND DRAGON

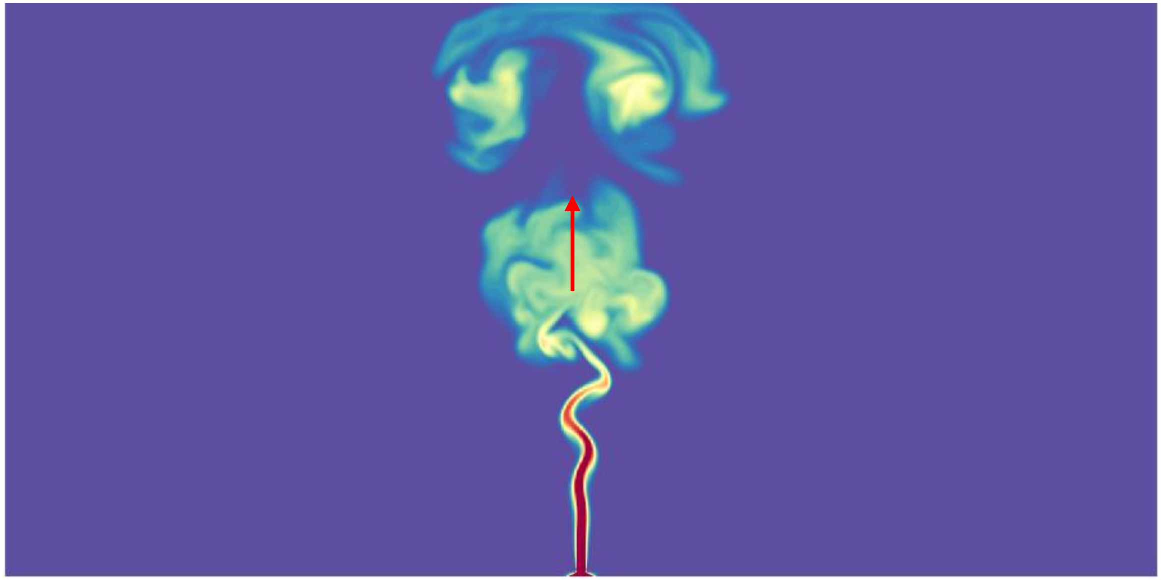
CONFINED PLUMES

University of Melbourne PhD student Nitheesh George



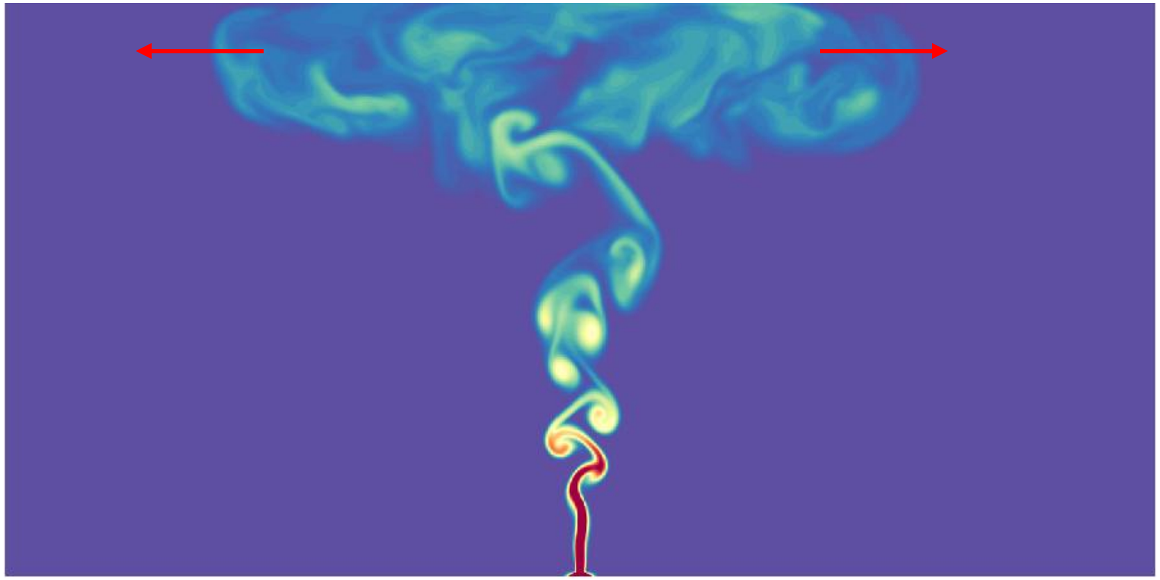
Transition from laminar to turbulent flow

CONFINED PLUMES



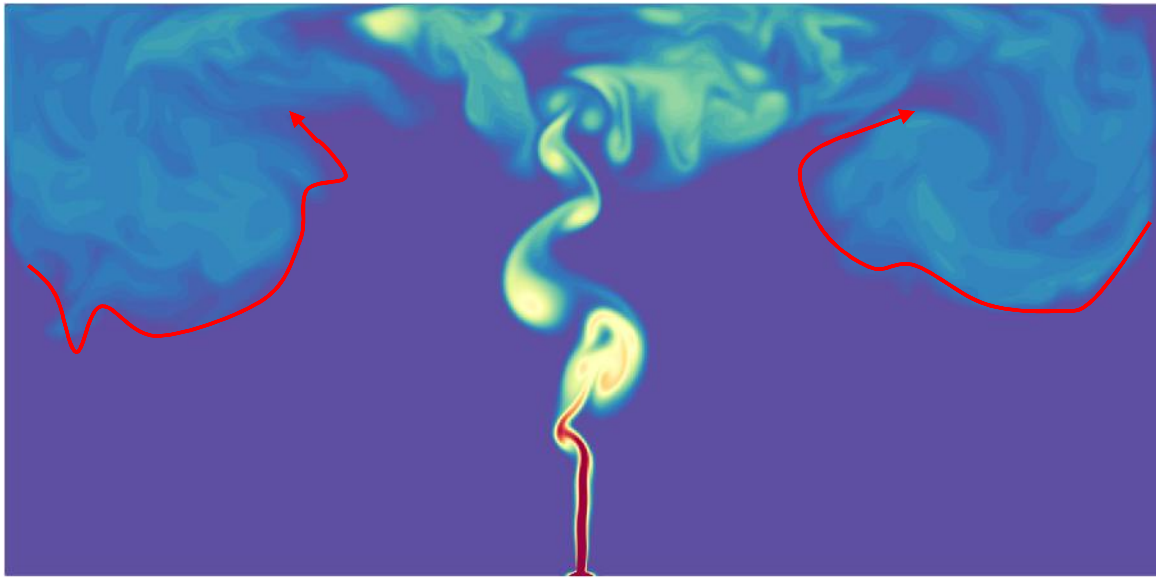
Hits the top wall

CONFINED PLUMES



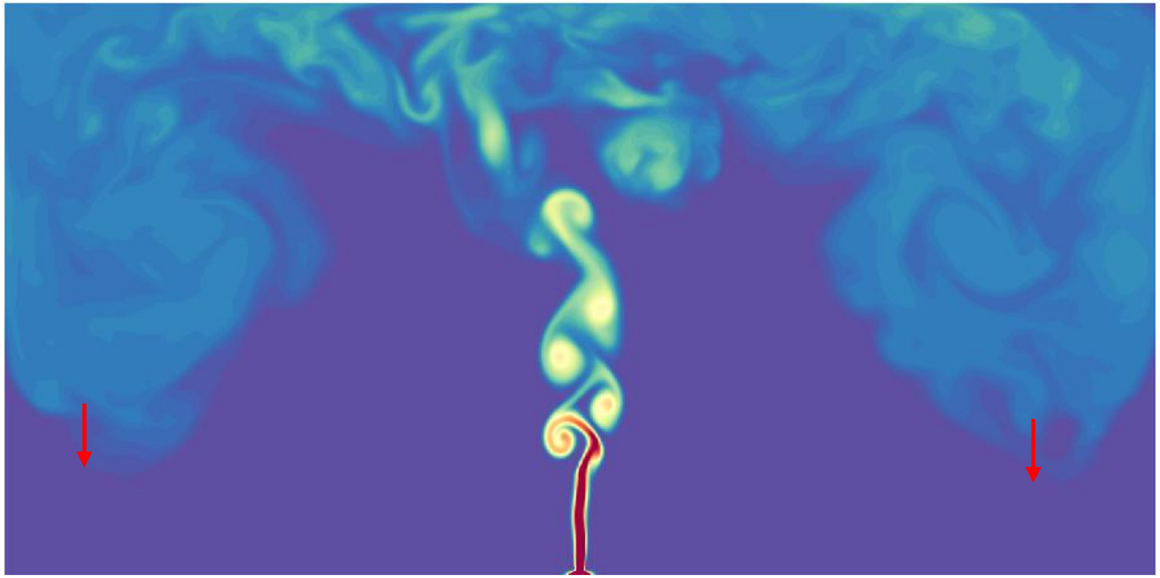
Lateral outflow

CONFINED PLUMES



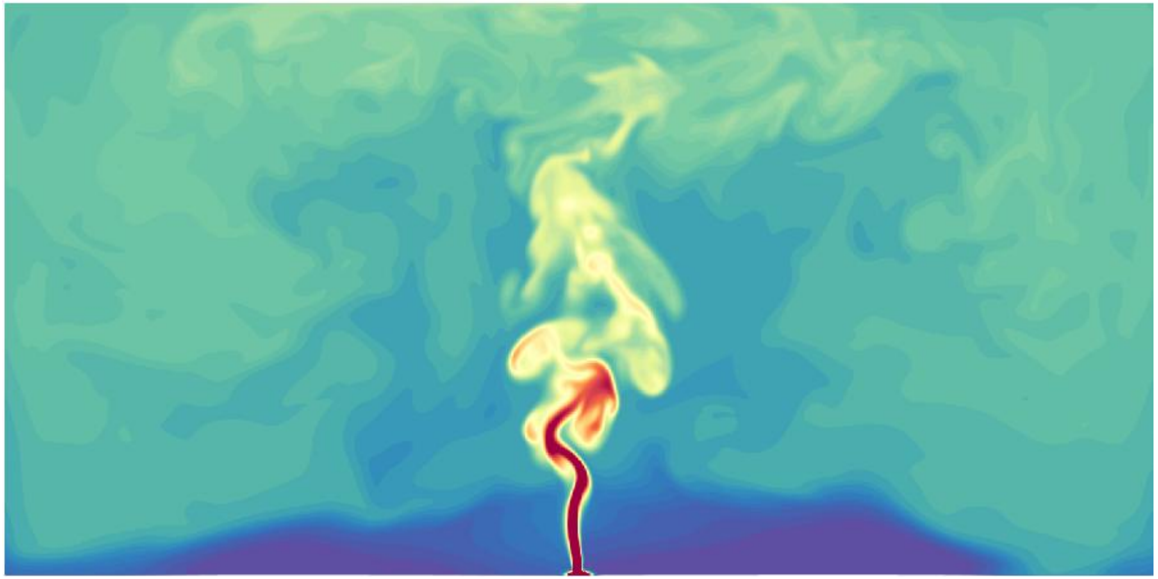
Overturning

CONFINED PLUMES



Descending front

CONFINED PLUMES



Asymptotic state

OTHER PROJECTS

1) Simulations of radiative heat load and fire contact with a house-like structure
2) Simulations of plumes interacting with tree canopies

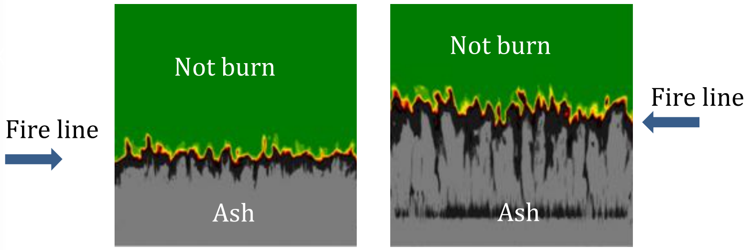
Assisting/collaborating with RMIT studying fire impact on bridges. Enhancing resilience of critical road infrastructure

FIRE DOWNSTREAM OF A CANOPY WITH FIRESTAR3D
3D FINITE VOLUME MODEL FOR THE PREDICTION OF WILDFIRE BEHAVIOR

Nicolas Frangieh: Visiting PhD student Nicolas Frangieh, Aix-Marseille University

Test Case : Grassland Fires with Periodic line fire

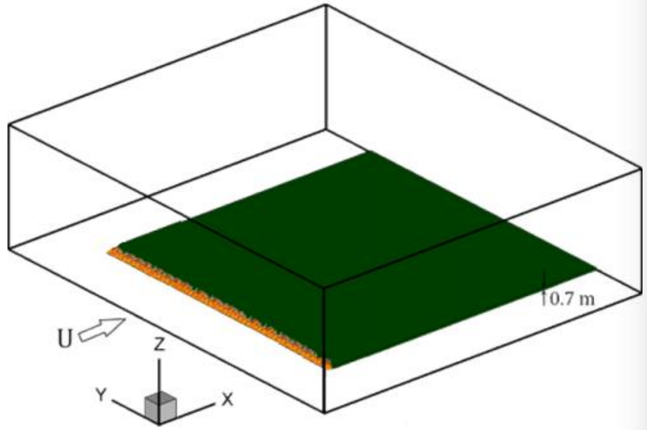
Top View At T=30s



U_{10} = 6 m/s U_{10} = 10 m/s

Wind speed = 2 -6 - 10 m/s
Packing ratio: α = 0.002
Fuel bed: ¢ = 0.7 m

Fuel density: °$_p$ = 500 kg/m^3
Surface/Volume ratio: ± = 4000 m^{-1}
Moisture content: M = 5 %



Objective of the collaboration with Victoria University : Studying the effect of large scale canopy-induced flow structures on downstream surface fires.

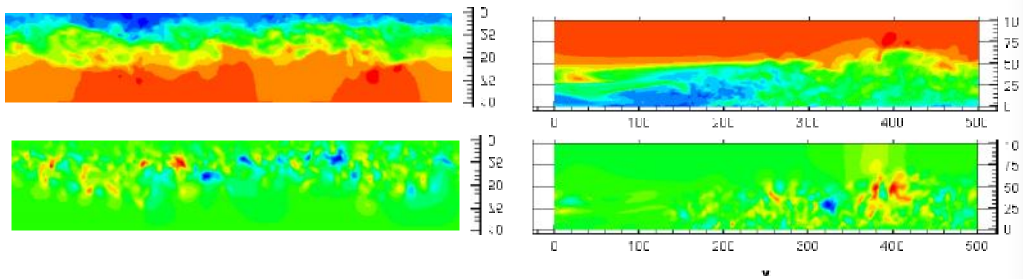
Work plan:

- ❑ Phase1 : establishing the flow regime in Canopy domain only (e.g. 2min of real time) and set this profile at the inlet boundary in phase2 (Dirichlet condition)
- ❑ Phase2 : And this phase is divided in two parts
  - Establishing the flow regime in the domain composed first from canopy, then grassland (e.g. 100m of canopy 300m of grass land) with a fixed inlet velocity profile obtained from above.
  - Ignition of fire in grass land.

Preliminary Results :

U velocity profile

W velocity profile



Top View

Ignition of fire in grassland

FUTURE DIRECTIONS

1) Extension of heterogeneous canopy simulations
   a) Include vertical variation of LAD (important for sub canopy flow prediction)
2) Extension of grassfire parametric study
   a) Simulate fires on slopes and on discontinuous fuel beds
3) Applying diagnostic models of wind fields to initialise physics-based simulations
   a) Idea is to use WindNinja to simplify the generation of initial and boundary conditions for FDS

QUESTIONS?