bushfire&natural HAZARDS CRC

BNHCRC PROJECT SUMMARY

THE SPREAD OF FIRES IN LANDSCAPES

Daniel Chung[2], Khalid Moinuddin[1], Andrew Ooi[2], Duncan Sutherland[1], Graham Thorpe[1], Rahul Wadhwani[1]

[1]Centrr for Environmental Safety and Risk Engineering, Victoria University, [2]Department of Mechanical Engineering, University of Melbourne, Victoria

An Australian Government Initiative

CRC AUSTRALIA

THE UNIVERSITY OF MELBOURNE

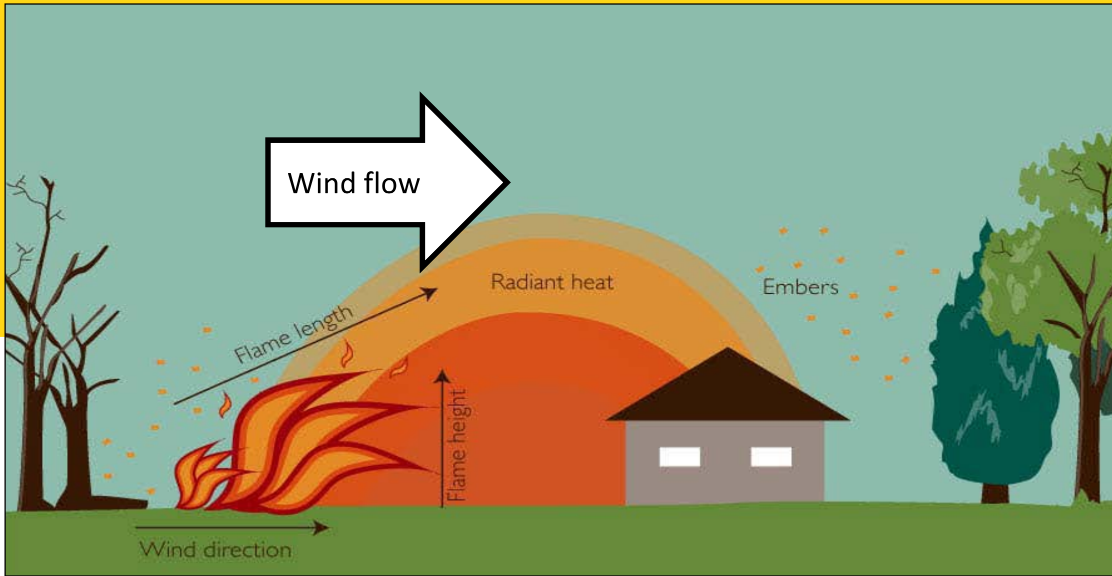
VICTORIA UNIVERSITY MELBOURNE AUSTRALIA

RESEARCHERS

- Victoria University
  - Khalid Moinuddin
  - Vasily Novozhilov
  - Duncan Sutherland
  - Graham Thorpe
  - Rahul Wadhwani
- University of Melbourne
  - Daniel Chung
  - Nitesh George
  - Michael MacDonald
  - Andrew Ooi

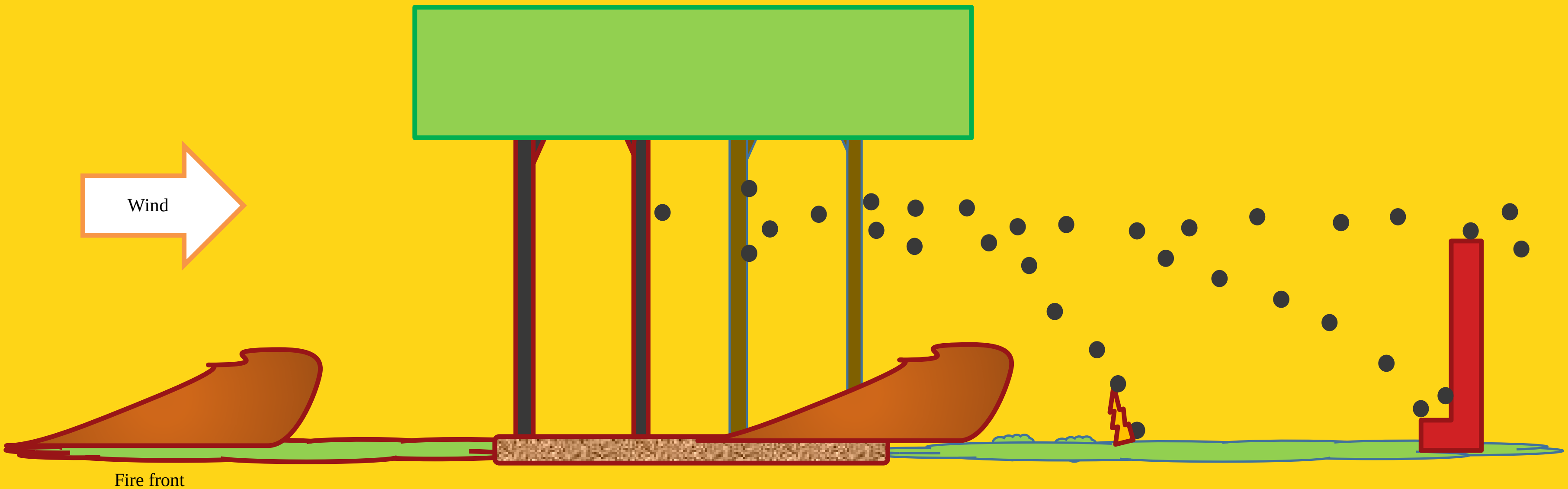
OVERALL PROJECT AIM

- Development of physics-based models of wildfire
  - Capture detailed mechanisms of building loss
    - Prediction of wind flow
    - Prediction of the fire front and fire intensity
    - Prediction of ember attack



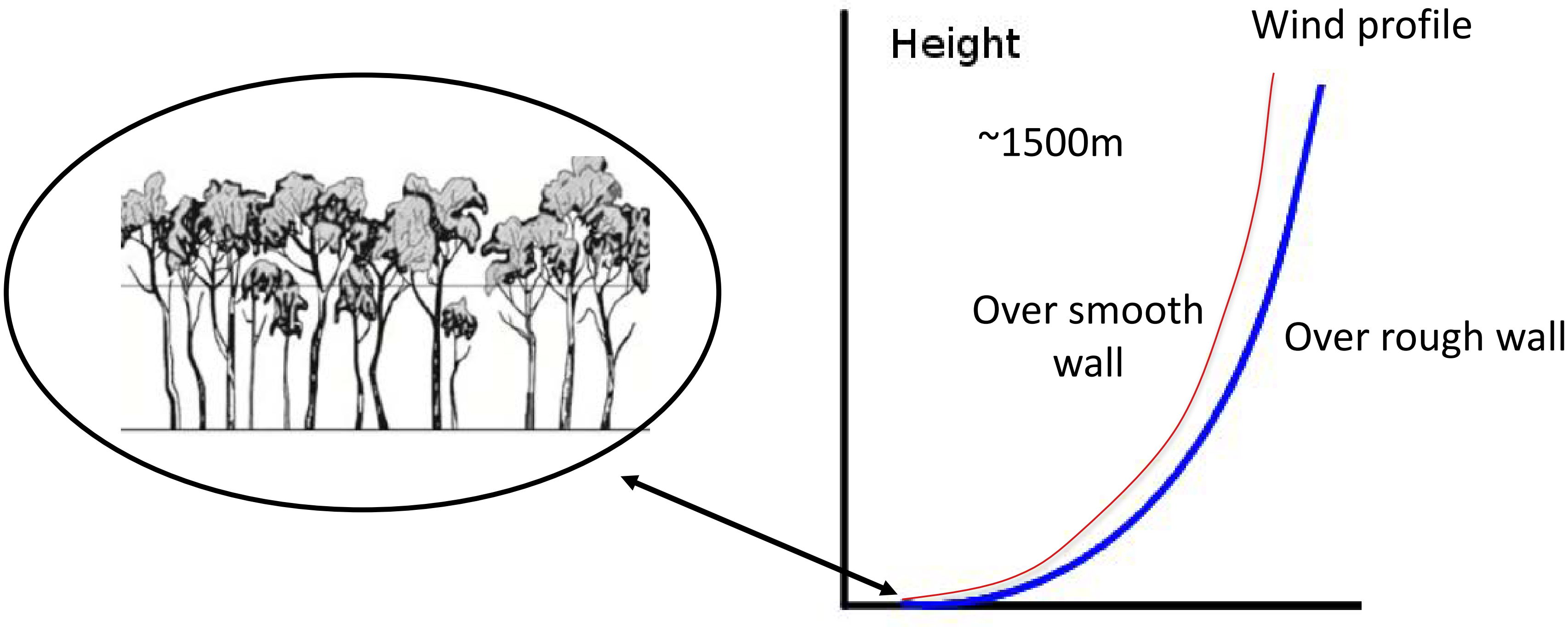
SCENARIO TO BE MODELLED

IDEALIZATION OF SCENARIO



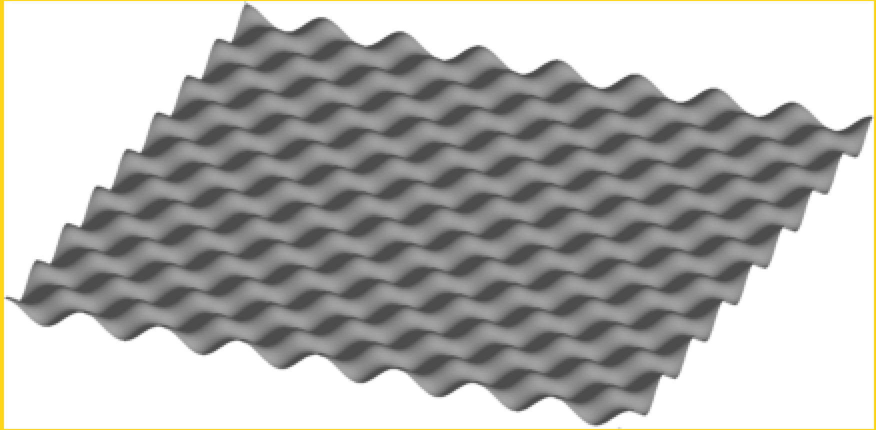
- Prediction of wind velocity within and above canopy
- Prediction of fire front movement
- Prediction of short range spotting

FLOW ABOVE CANOPIES (SURFACE ROUGHNESS)



- Atmospheric Boundary Layer (ABL) mapping is needed for initial and inlet conditions to the simulation
- To predict ABL, surface roughness needs to be accounted for
- Wall function for rough wall needs to be developed

SURFACE ROUGHNESS AS SINUSOIDAL

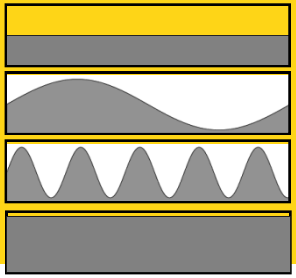


Smooth wall

$\Lambda = 0.11$ (sparse)

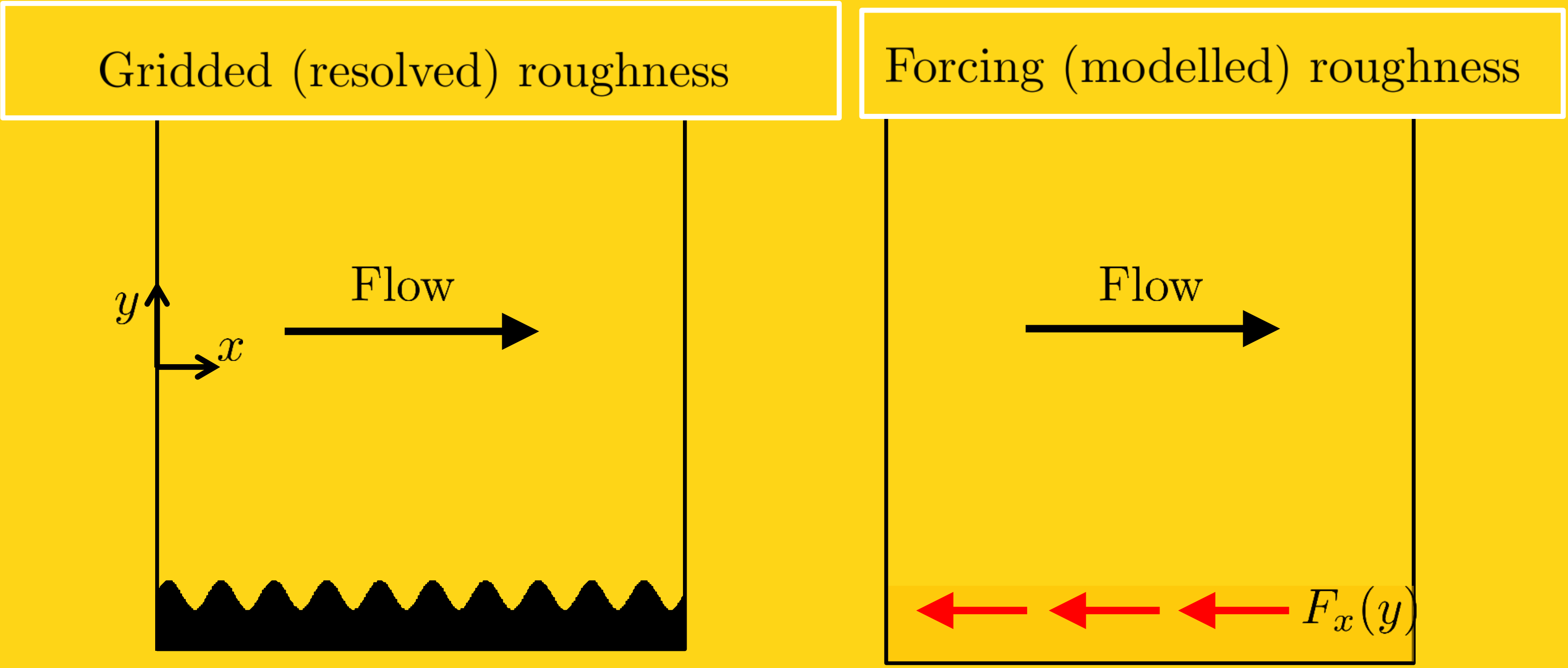
$\Lambda = 0.54$ (dense)

$\Lambda \to \infty$



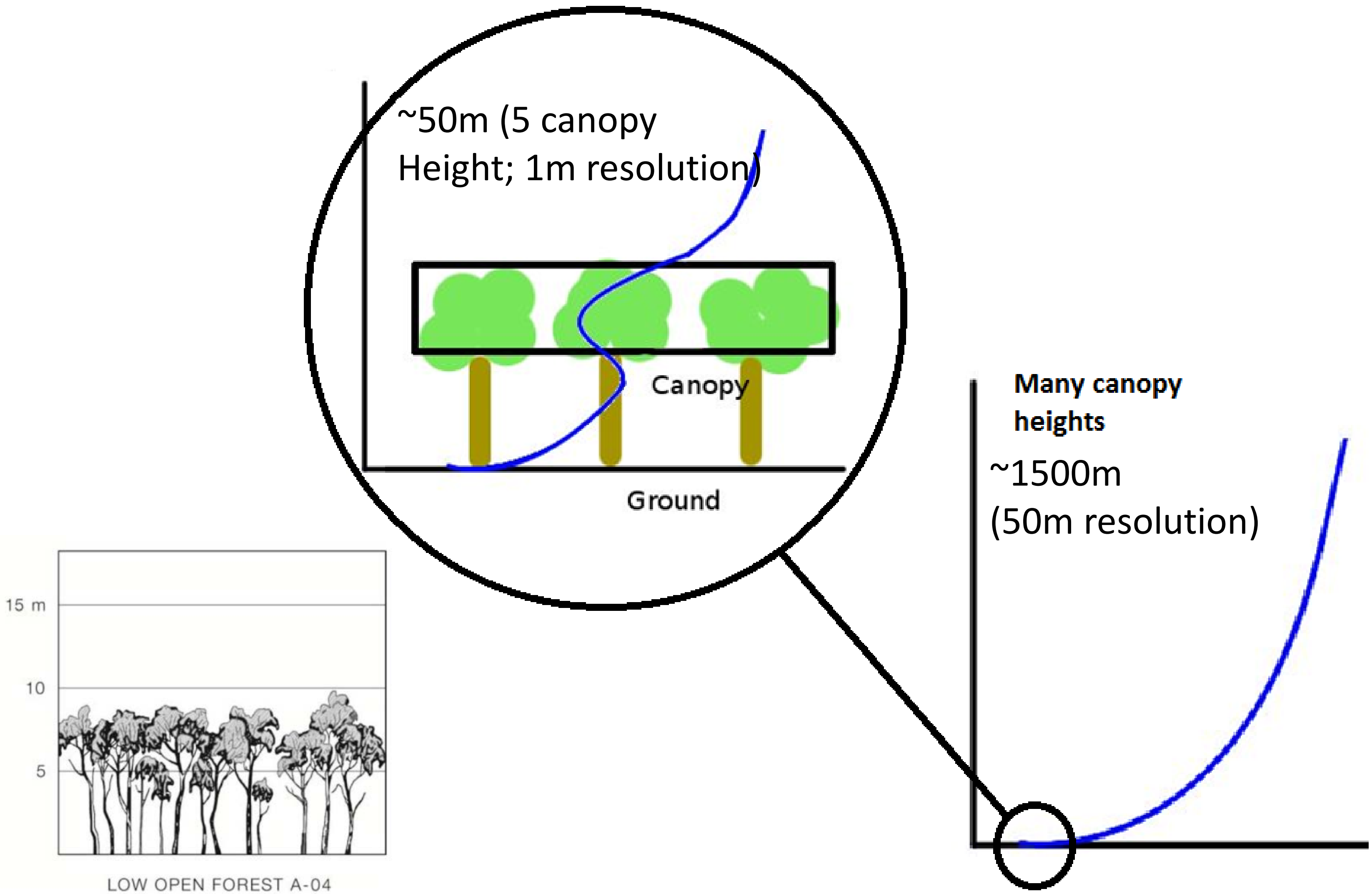
FINDING AND APPLICATION

- As the roughness becomes denser, the wall becomes smoother
- Modelling variable surface roughness using a drag-type function (Busse and Sandham (2012))



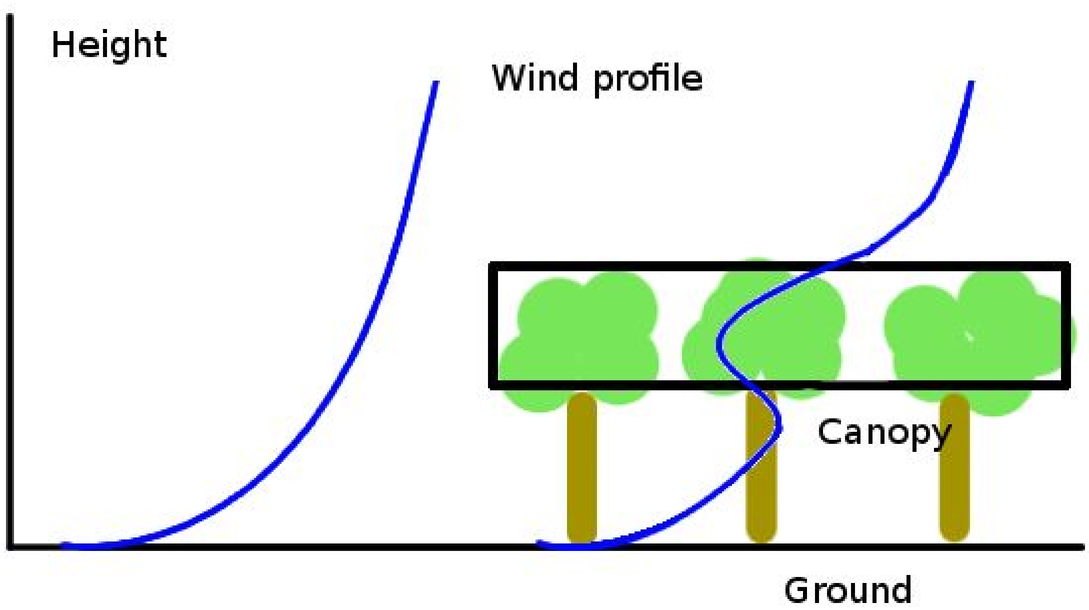
Turbulent flow over transitional roughness with varying roughness density
M. MacDonald, L. Chan, D. Chung, N. Hutchins and A. Ooi (Journal of Fluid Mechanics)

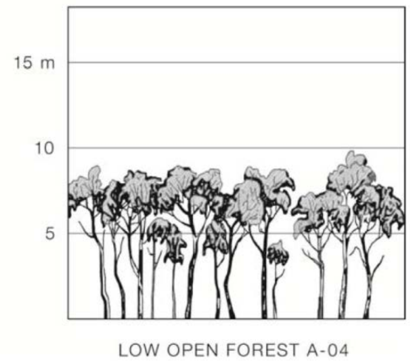
COUPLING ABL TO FLOW WITHIN CANOPY



WIND FLOW -PROJECT

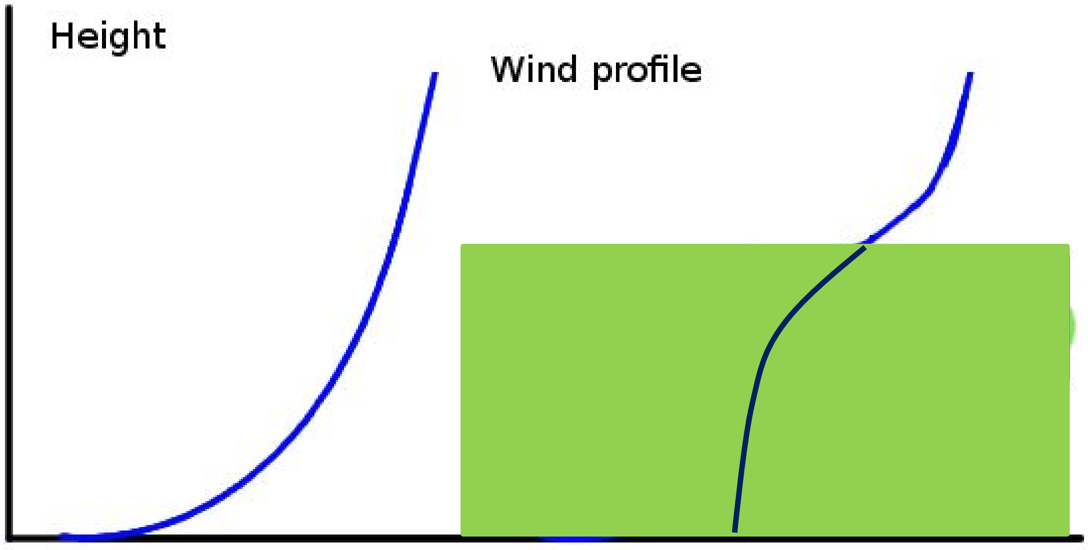
- The mean velocity profile

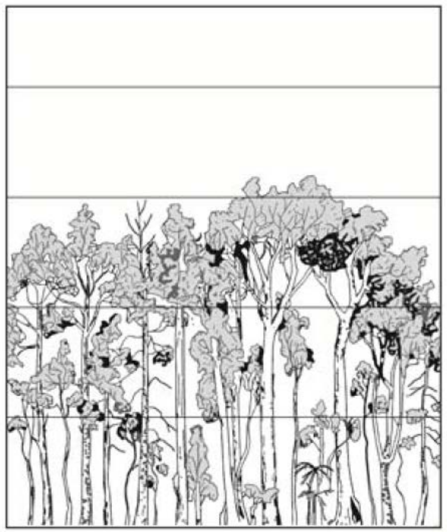




SIMPLER CANOPY FLOW

- Open forest



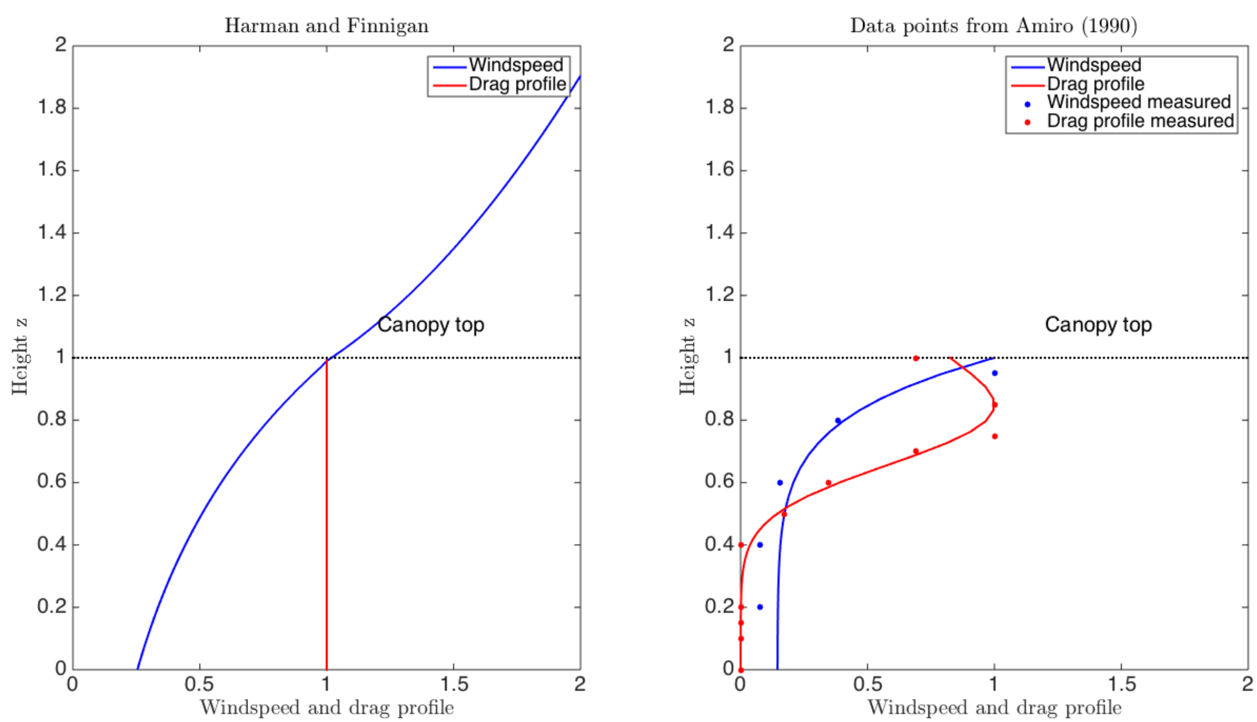


MODELS OF THE CANOPY

- An aerodynamic drag term to model the canopy region
  - $F_D = C_D(z)\,\rho\,A\,u|u|/2$
- Estimate C_D
  - From measured properties such as leaf-area index

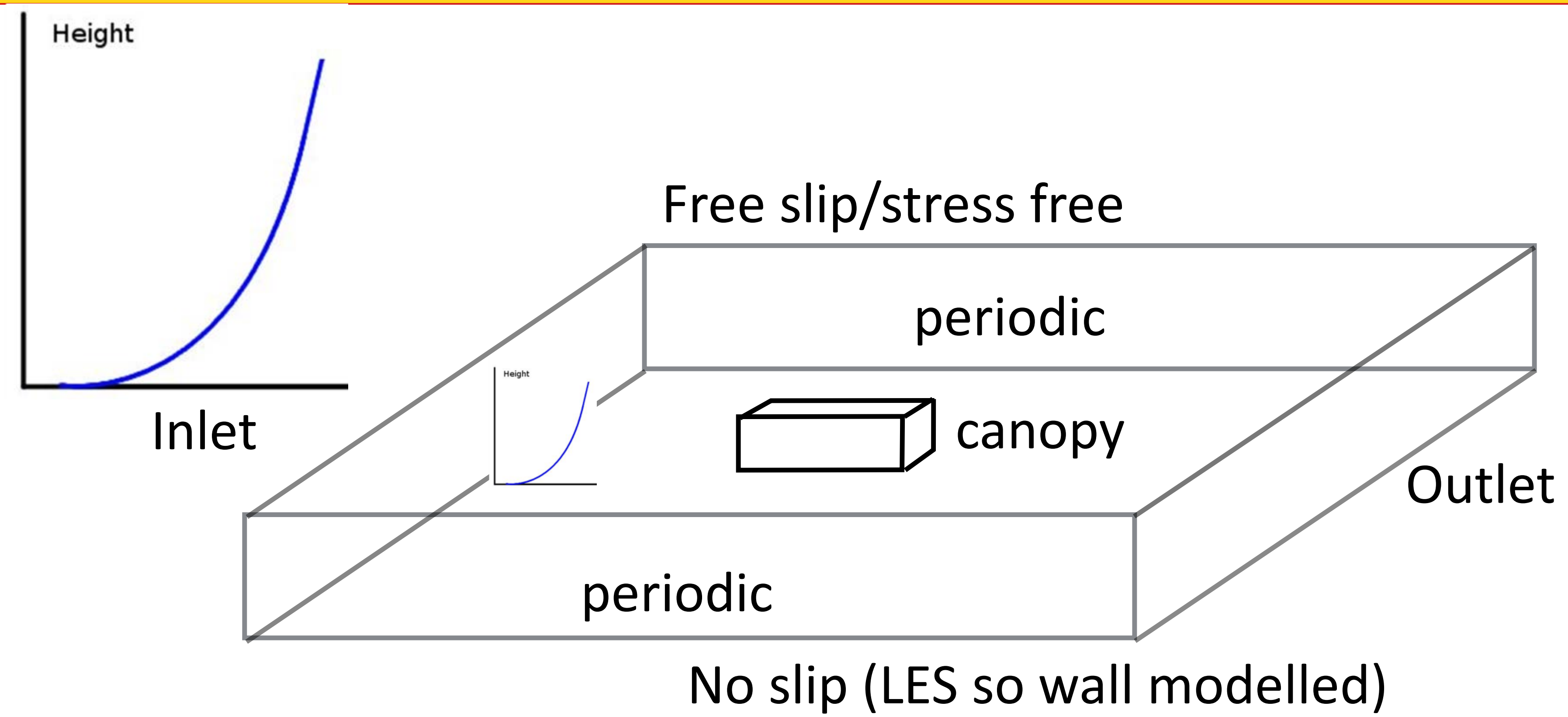
SOME RESULTS

- Harman and Finnigan equation; constant C_D and exact solution
- Allowing variable $C_D = f(z)$ needs numerical solution

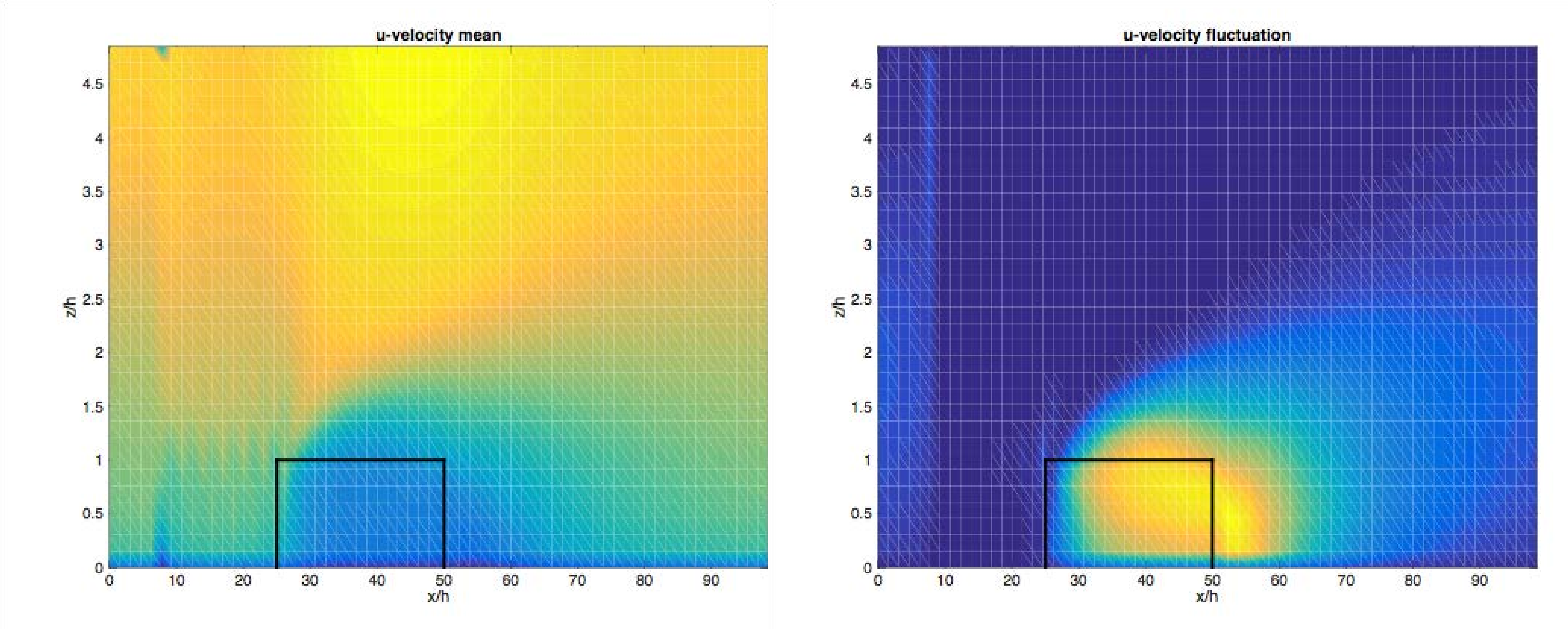


FDS OF ABL FLOW OVER A CANOPY

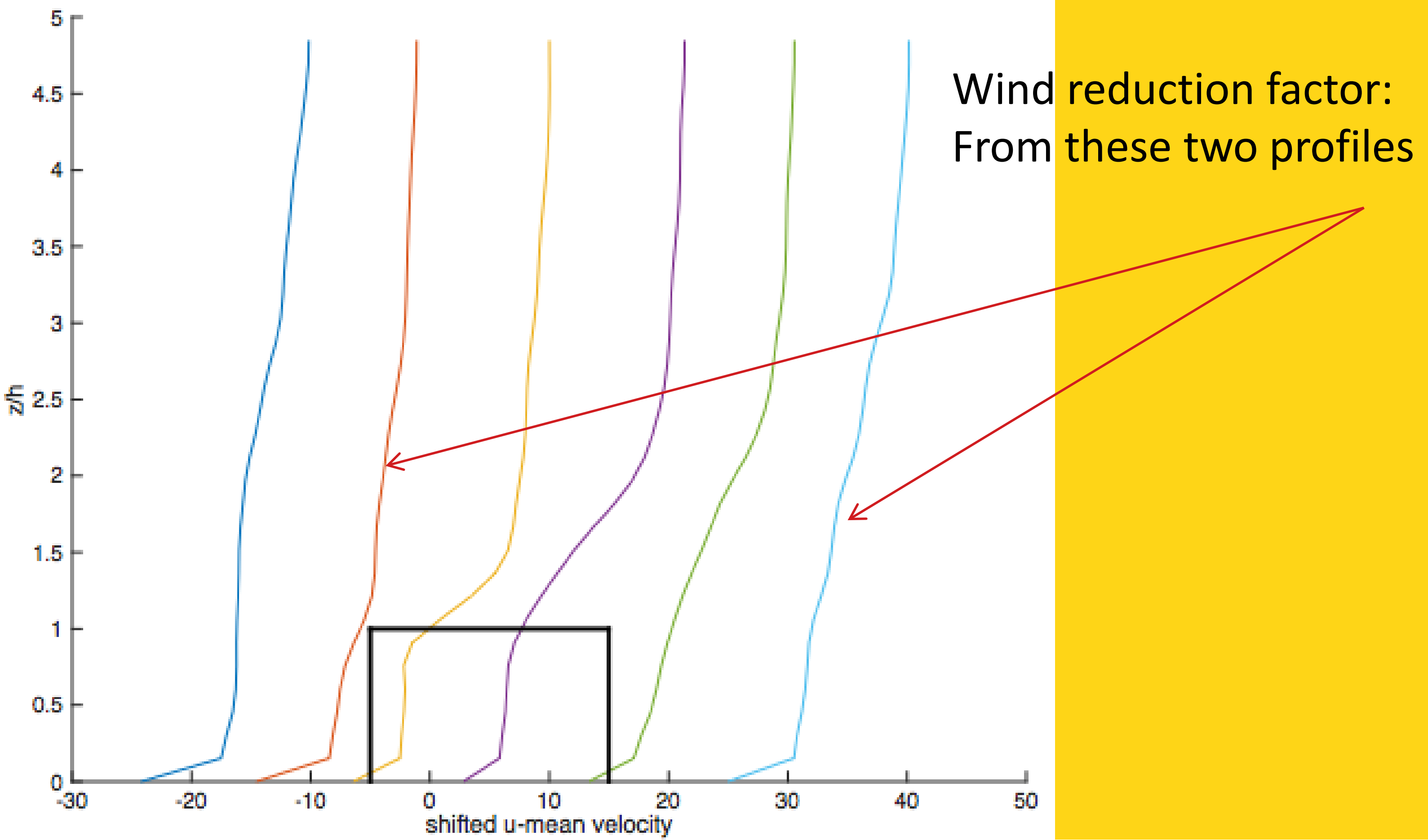
- ABL as inlet
- Turbulence also introduced



Preliminary simulations

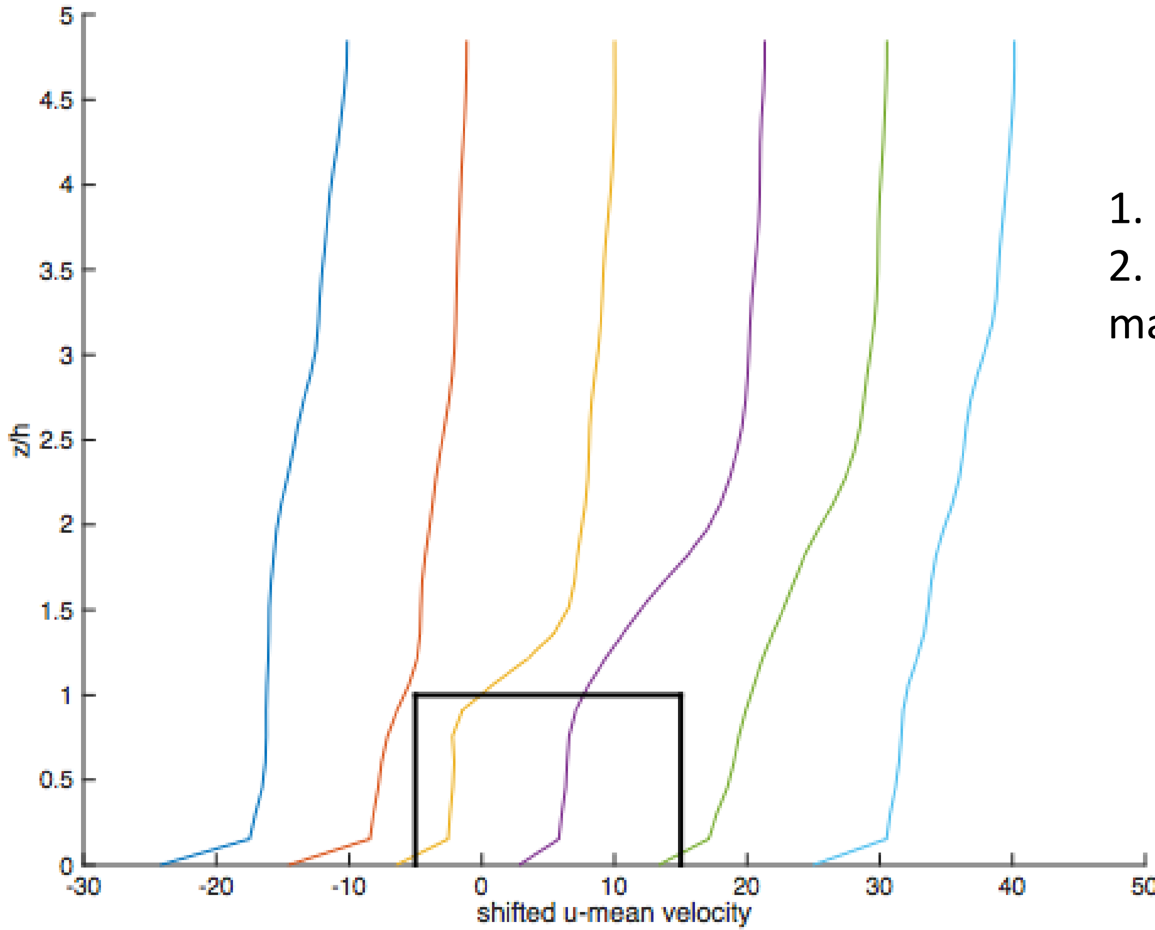


Preliminary simulations



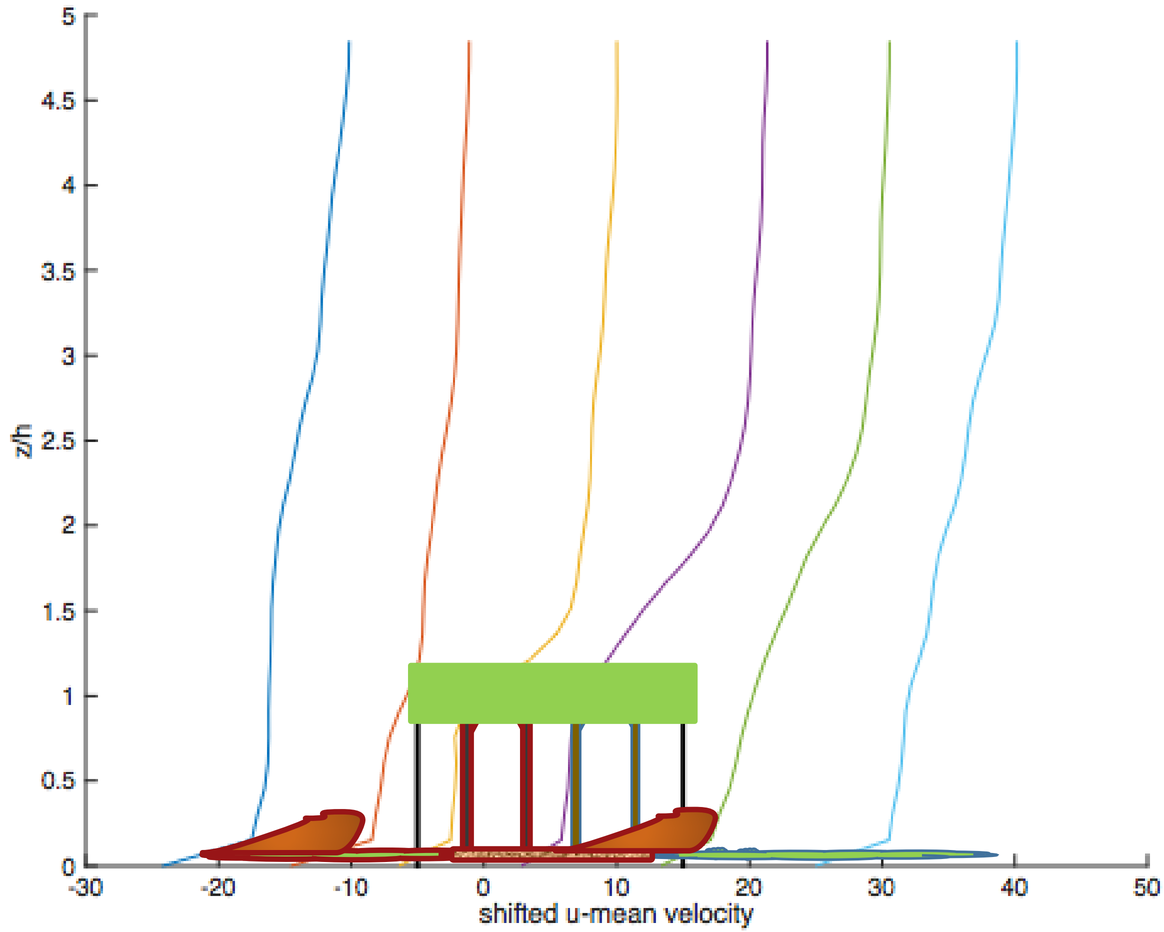
Need to extend to non-uniform canopies

SECOND APPLICATION OF CANOPY FLOW



1. Velocity mapping
2. Temperature mapping

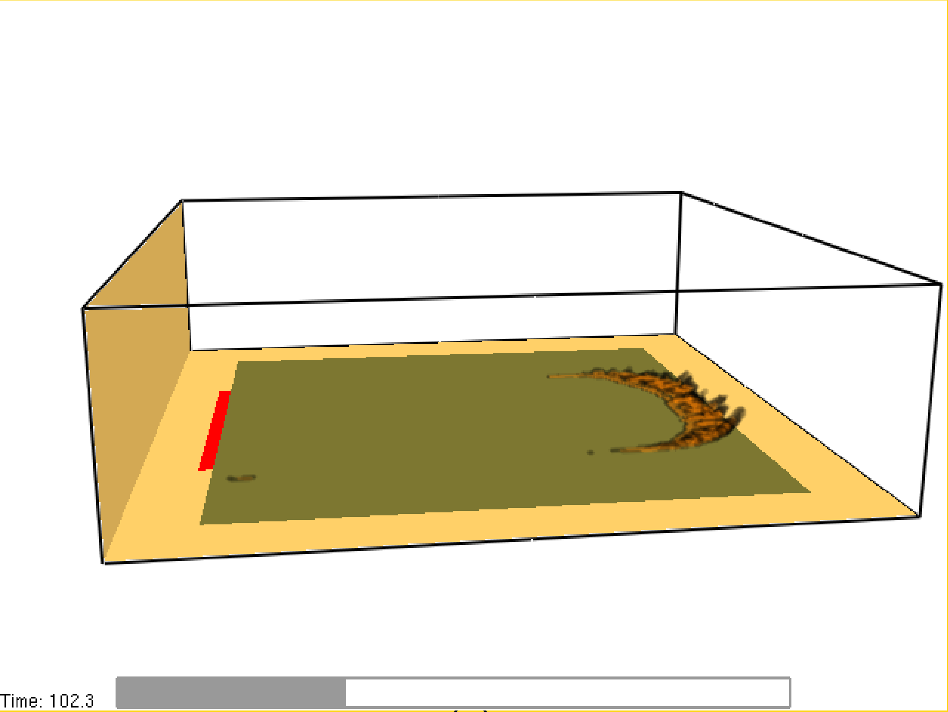
INSERTING FLAME AND FUEL



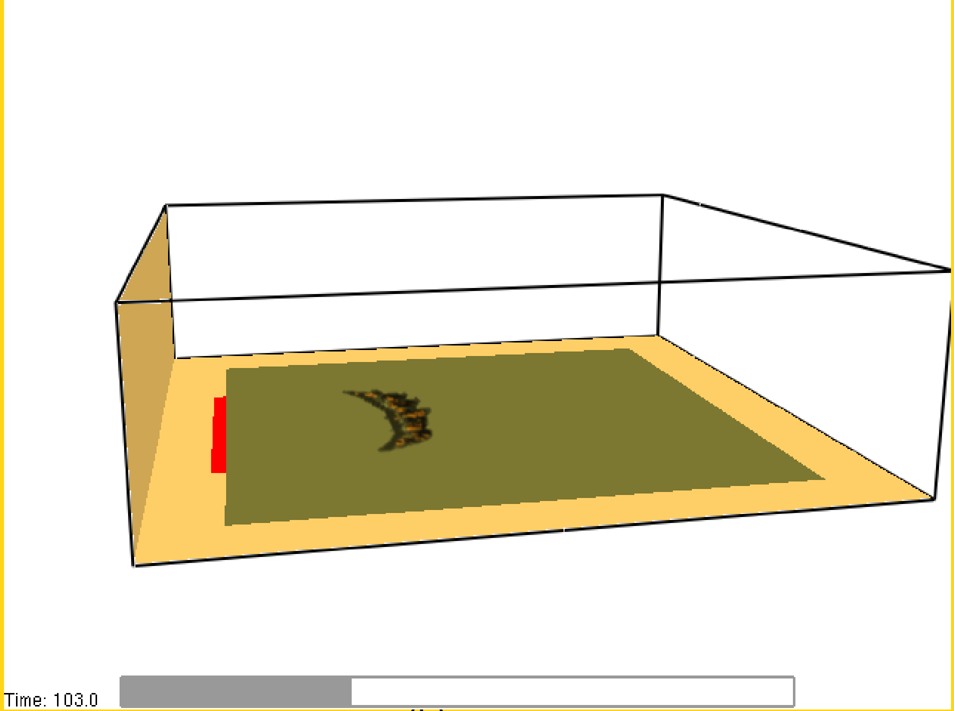
1m resolution

0.1 - 0.25m resolution

GRASS FIRE PRELIMINARY RESULT



(a)



(b)

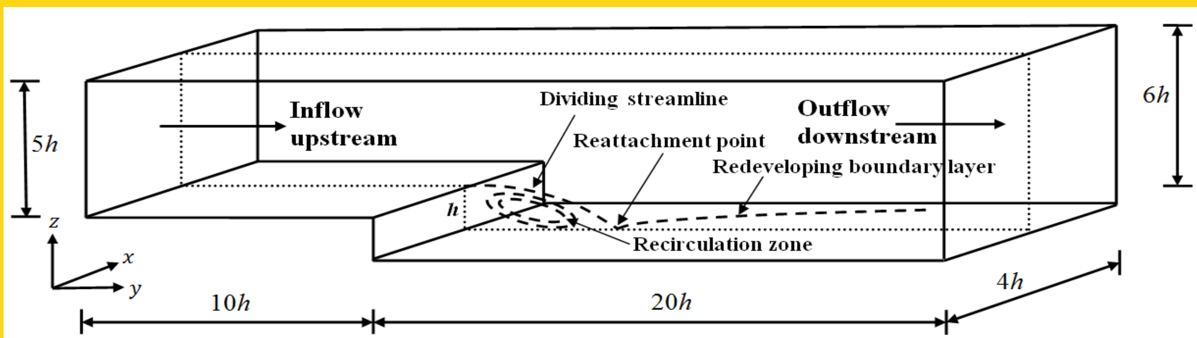
(a) Vegetation height 250 mm

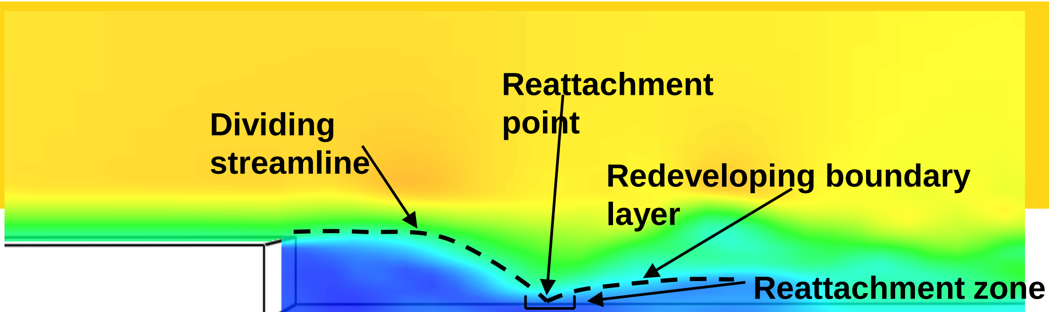
(b） Vegetation height 160 mm

- Spatial resolution of domain
- Boundary fuel element technique for pyrolysis
  - non-Arrhenius (simple)
  - Arrhenius (more advanced)

SPATIAL RESOLUTION OF DOMAIN

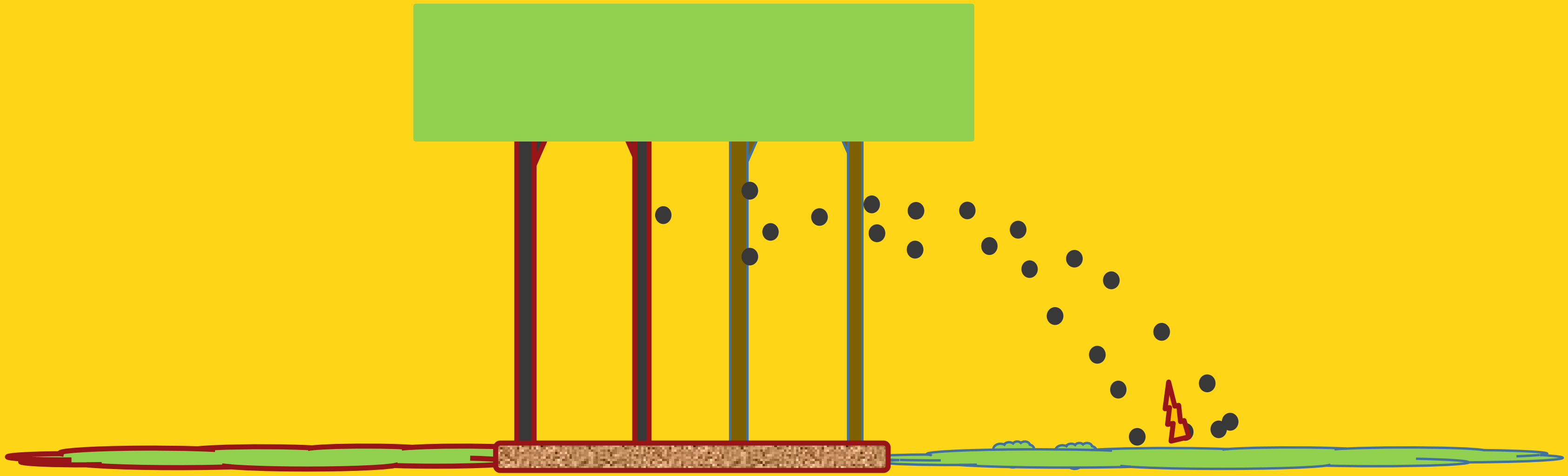
- Domain needs to be divided into cells in a way that the result is free from
  - averaging (numerical) error
  - turbulence modelling error
- New turbulence modelling technique is implemented



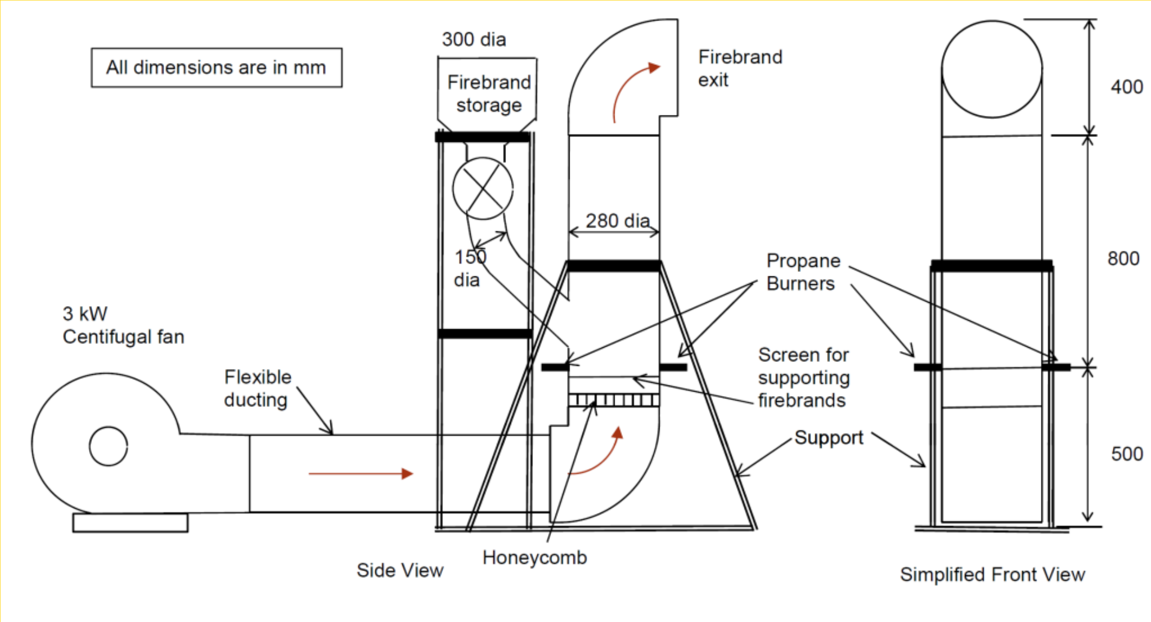


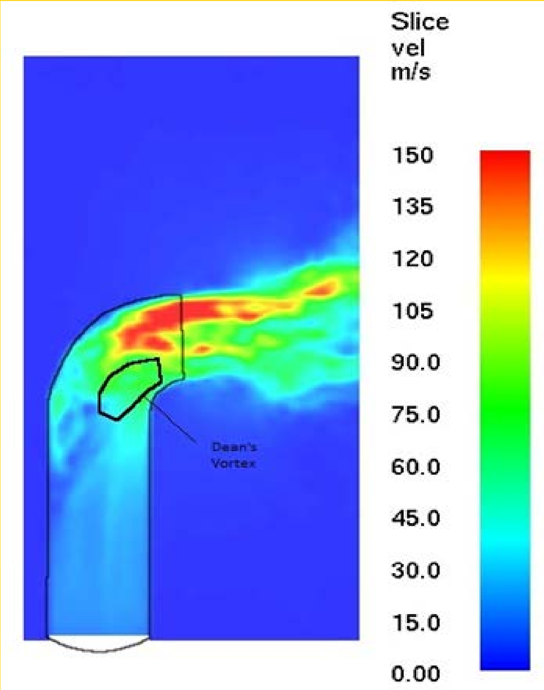
A systematic approach to explicitly filtered large eddy simulation (LES) to simulate turbulent flows
M. Sarwar, M. Cleary, K. Moinuddin and G. Thorpe (Journal of Fluid Mechanics)

SHORT RANGE SPOTTING STUDY



FIREBRAND DRAGON DESIGN

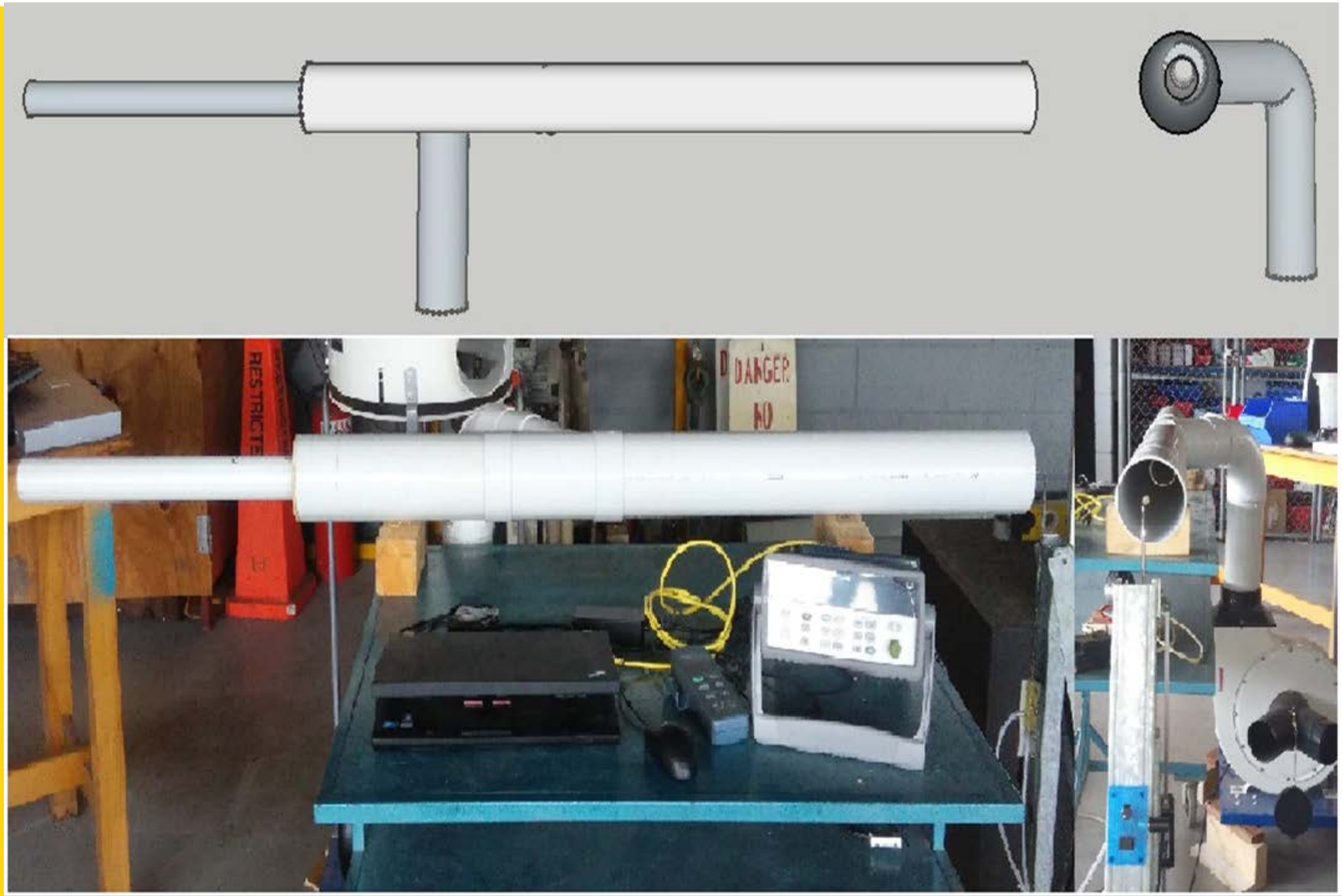




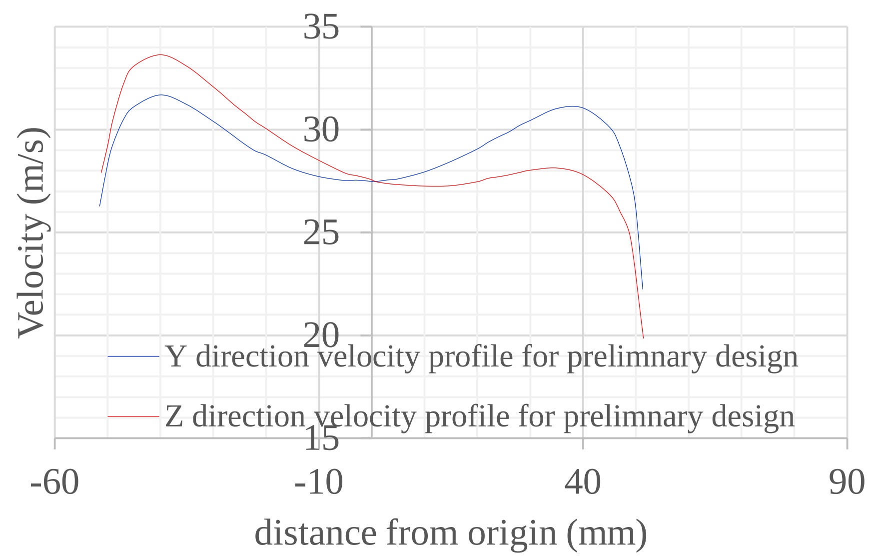
- Dean's vortex in NIST dragon

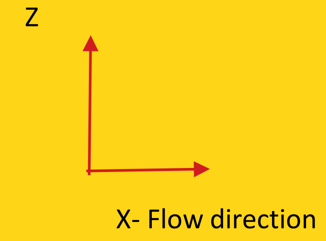
bushfire&natural HAZARDSCRC

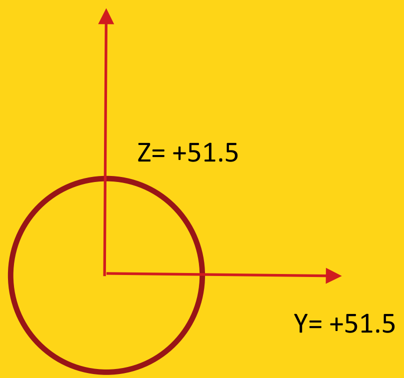
FIREBRAND DRAGON DESIGN



VELOCITY PROFILE OF AIR IN Z- & Y- DIRECTION

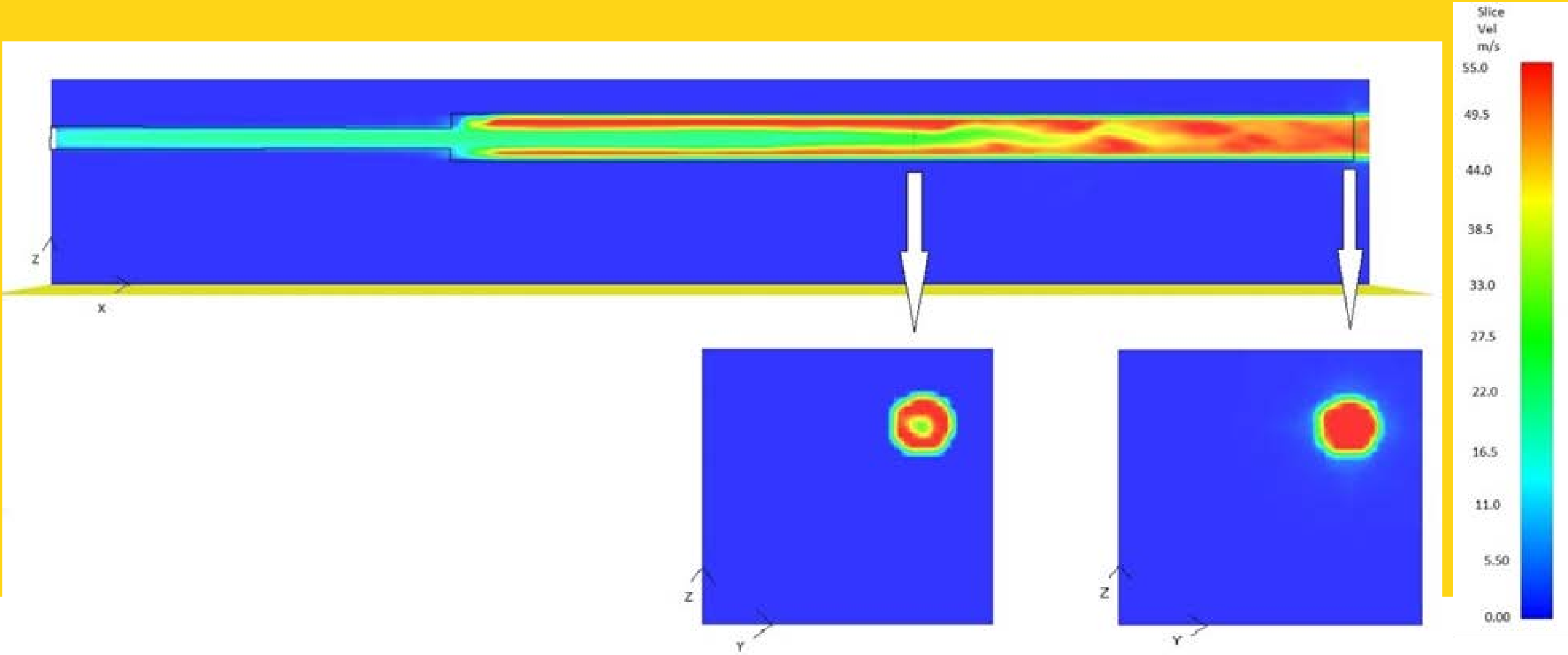




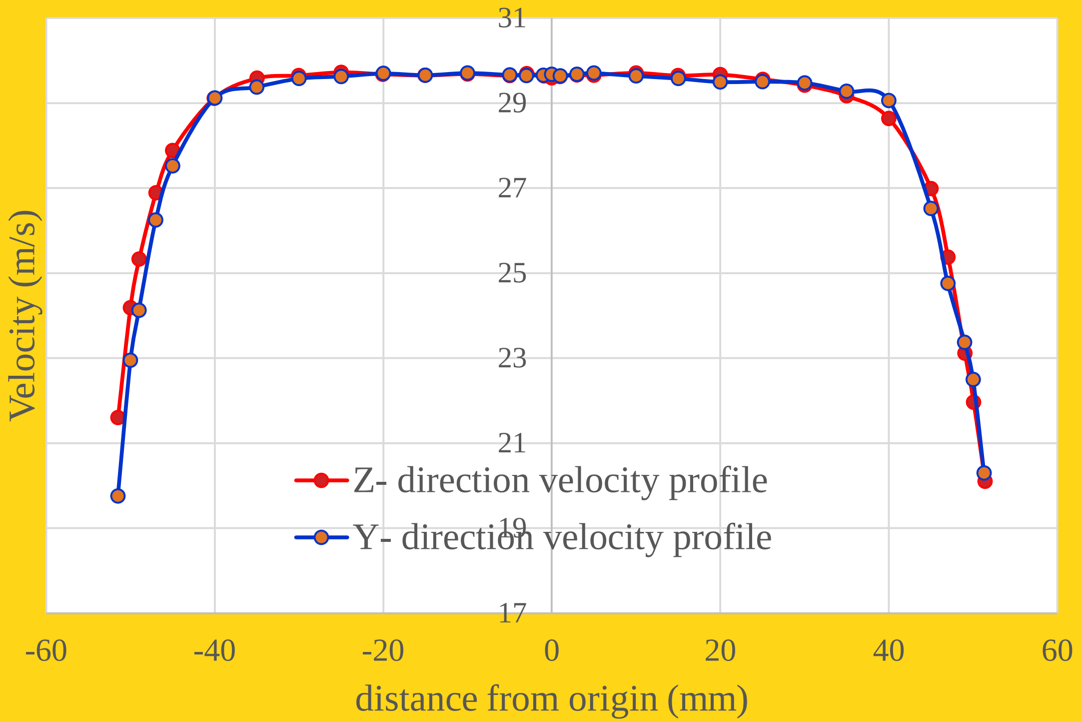


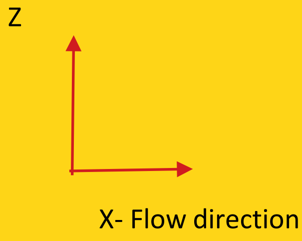
FIREBRAND DRAGON DESIGN

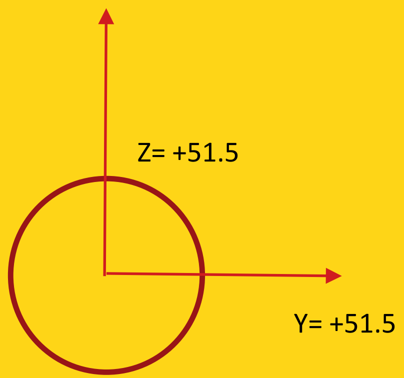
- Flow profile in firebrand generator with preliminary design length and modified length



VELOCITY PROFILE OF AIR IN Z- & Y- DIRECTION







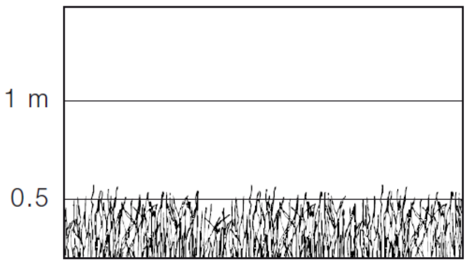
FIREBRAND DRAGON: RESULT

- Firebrand distribution (experimental)

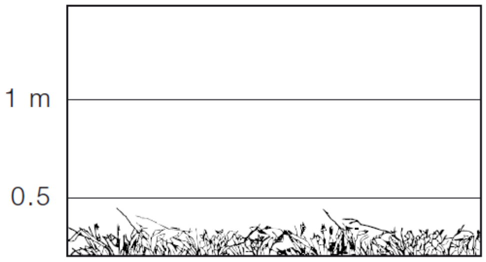
- Numerical simulation with FDS underway

IGNITION OF LITTER/GRASS

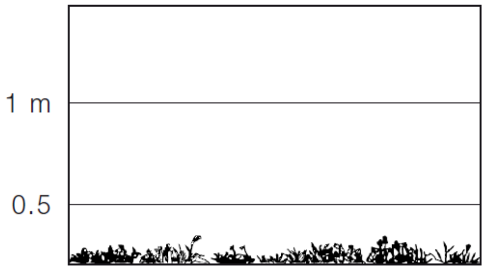
- Inspired by study of Ellis (2011) on ignition probability of dry Eucalyptus
- Need to evaluate FDS' pyrolysis model for ignition prediction
- Data collection and parameter estimation for grass (Cheney's experiment) and dry Eucalyptus (Ellis)



CLOSED TUSSOCK GRASSLAND G-21



DENSE SOWN PASTURE G-25



SOWN PASTURE G-26

APPLICATION OF OUR STUDY

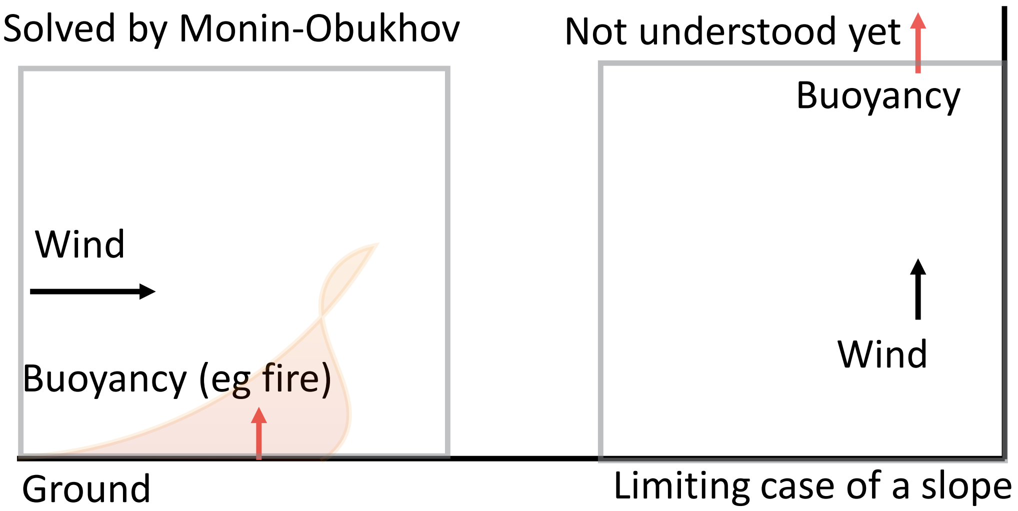
- Once we join all together we can quantify the risk to property from radiative heat from a fire
  - For example a grassfire (flat or curved planar-like)
- Australian Standard 3959 for bushfire attack level
  - Empirical models (e.g. McArthur) for the fire
  - Geometric approximation to radiative heat transfer
- Comparison of some AS3959 scenarios to full FDS simulation

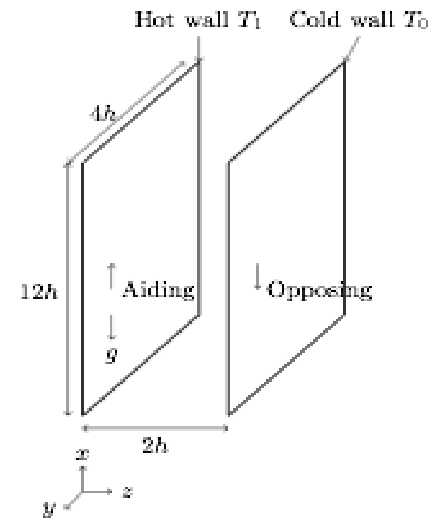
bushfire&natural HAZARDS CRC

ANY QUESTION?

FUNDAMENTAL VERTICAL FLOW STUDY

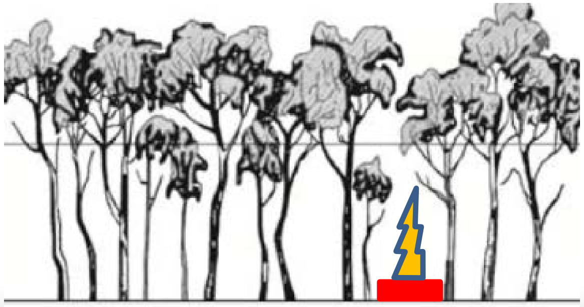
1) Pressure driven wall bounded vertical flow



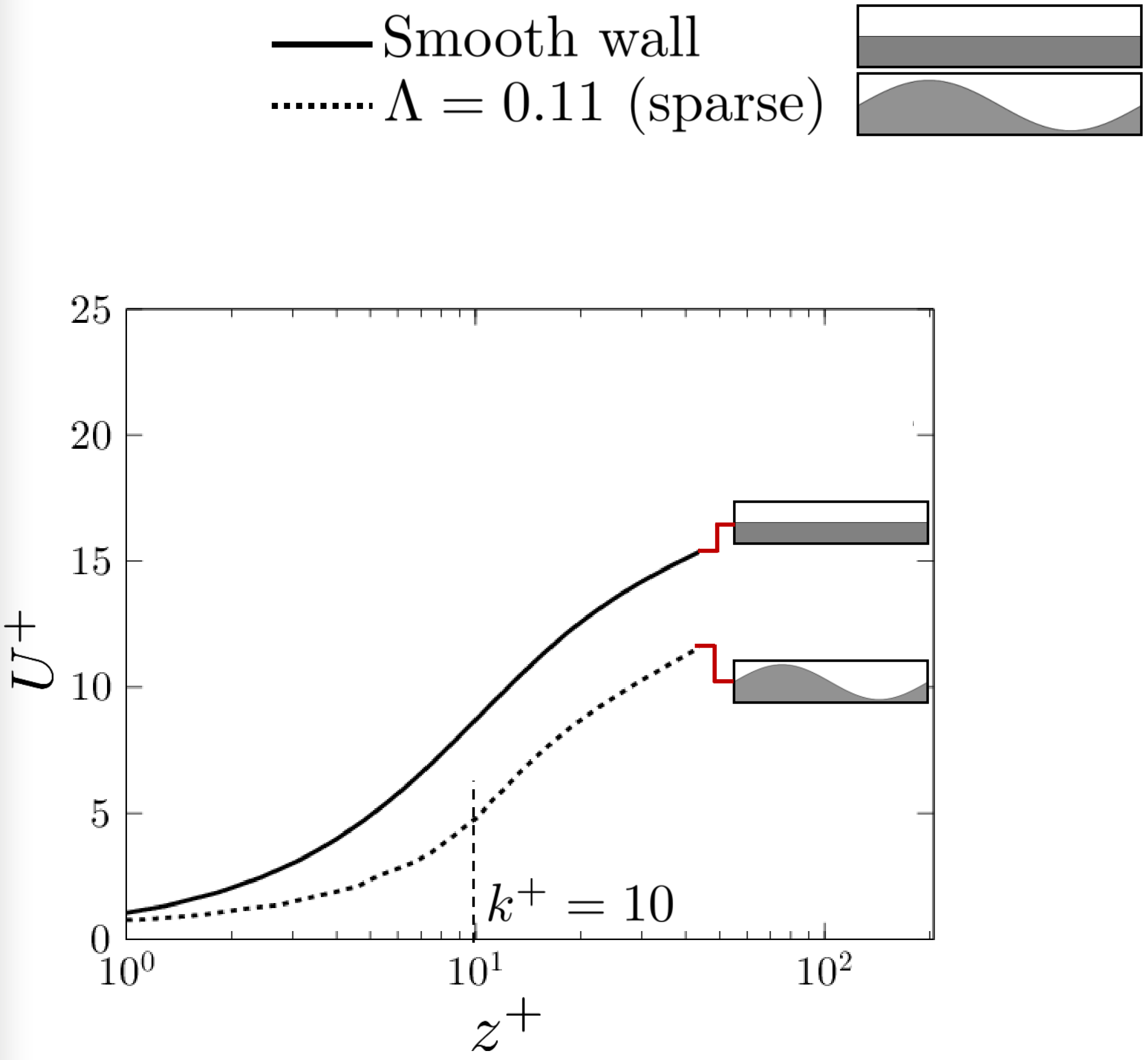


2) Plume from a line fire

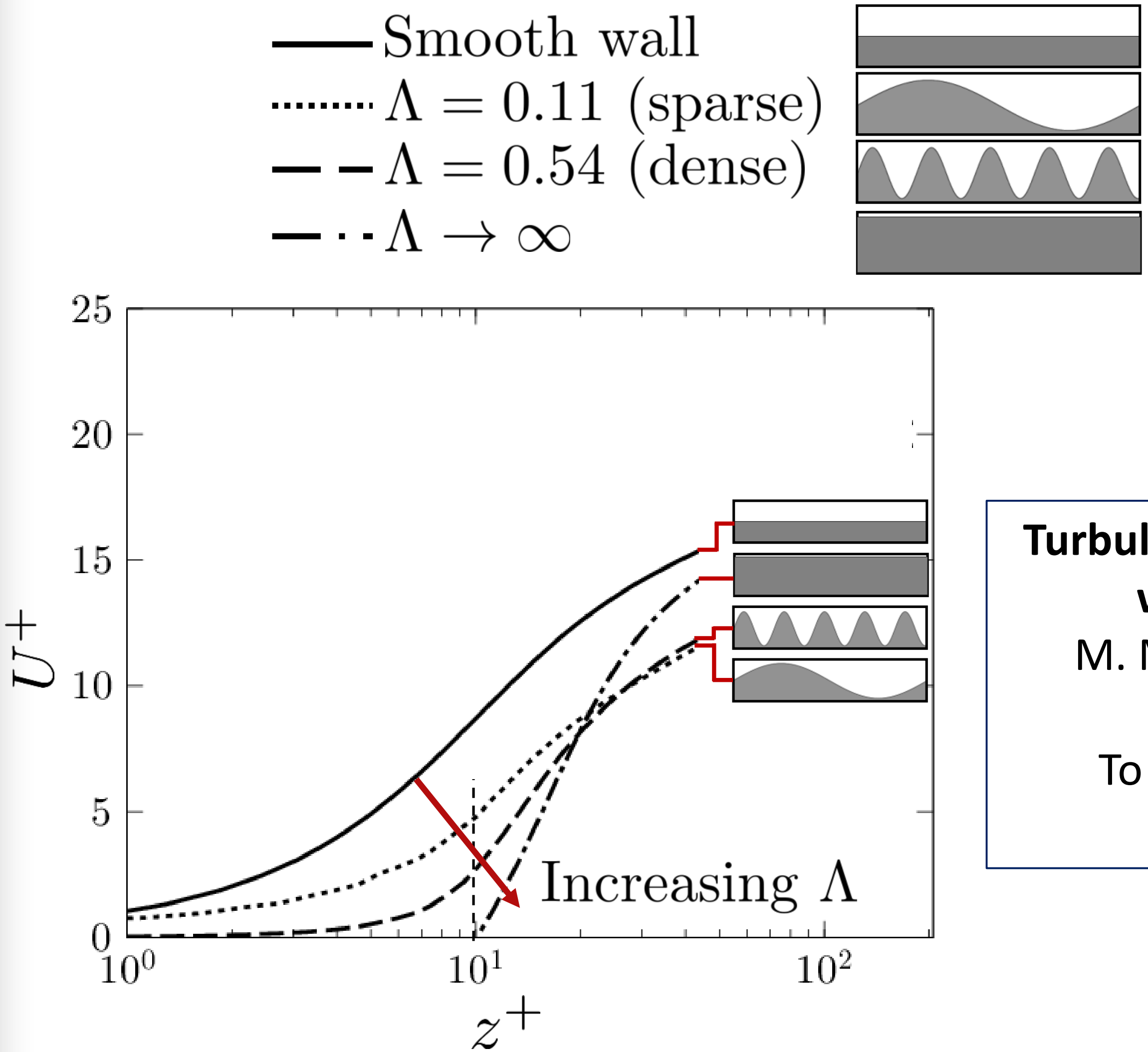
a) defoliage
b) how wind profile in canopy changes



Results



Results



Turbulent flow over transitional roughness with varying roughness density

M. MacDonald†, L. Chan, D. Chung, N. Hutchins and A. Ooi

To be submitted to Journal of Fluids Mechanics

FUTURE DIRECTIONS

1) Transforming physics-based models from laboratory scale use to community scale use (modelling some field measurements of Project Vesta), eventually to landscape scale (in hybrid form)
2) Coupling with a weather model
3) Use of topography and soil moisture as boundary conditions
4) Translating pure and fundamental research in the field of fire and computational science to the development of next generation fire prediction tool