bushfire&natural HAZARDSCRC

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

OUTLINE

PROGRESS REPORT

1) Physics based simulation of grassfires
2) Simulation of sub-canopy flows

FUTURE DIRECTIONS

1) Inhomogeneous canopies
2) Surface fires impacting on structures

PHYSICS-BASED FIRE MODELLING

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

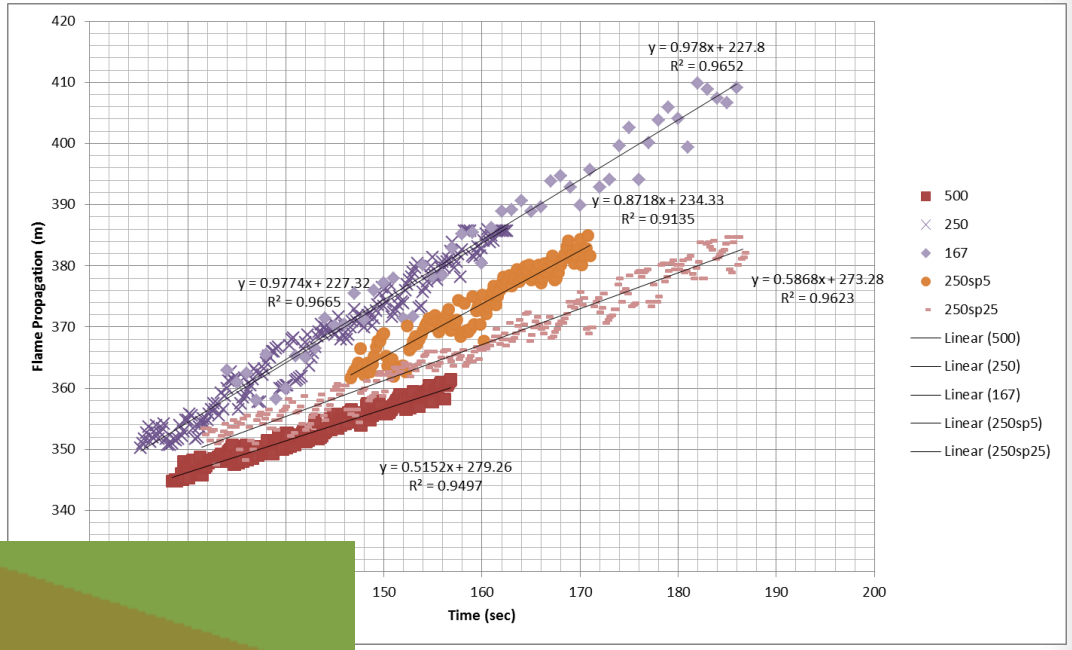
2) Start with fundamental differential equations for:
   a) Fluid momentum and mass transport (including turbulence)
   b) Thermal degradation & combustion of materials and transport of gasses and soot
   c) Heat transfer by radiation and conduction

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

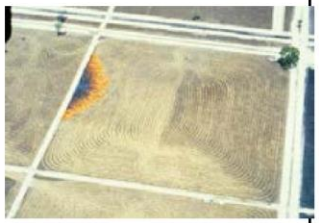
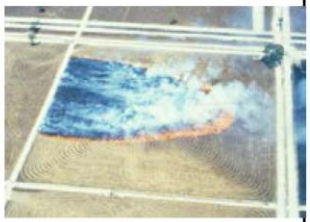
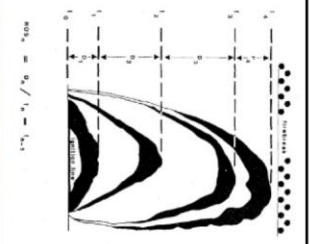
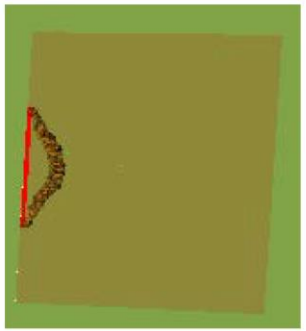
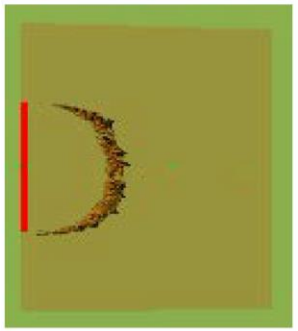
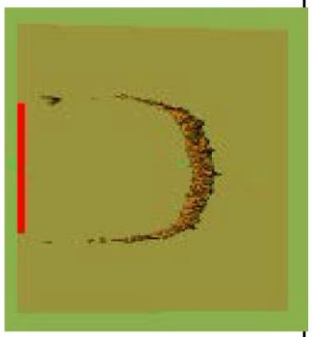
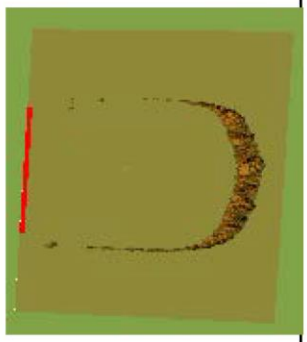
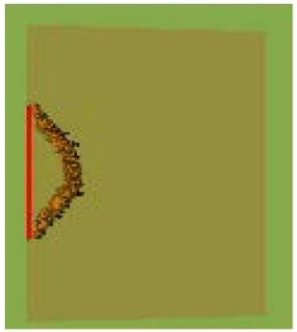
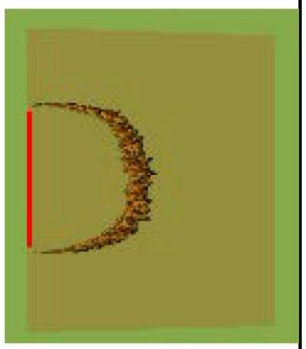
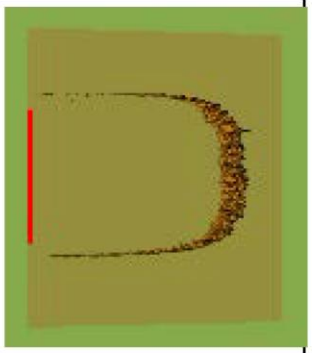
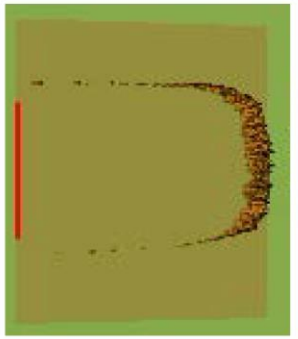
LARGE SCALE EXPERIMENTAL FIRES (GRASSLAND, CSIRO, AUSTRALIA)

Plot: 104 m x 104 m (+ development & downstream region)



Cheney et al Int. J. Wildland Fire 1998

MODEL VALIDATION: FIRE PROPAGATION

Experiment				
Simulation 6 m/s at 2m height at inlet				
Simulation 6.5 m/s at 2m height at inlet				
	27 sec after ignition	53 sec	85 sec	100 sec

RATE OF SPREAD – EMPIRICAL MODEL

Mark 5 version of McArthur model

Rate of fire spread (R) $\quad R = 0.13\,F$

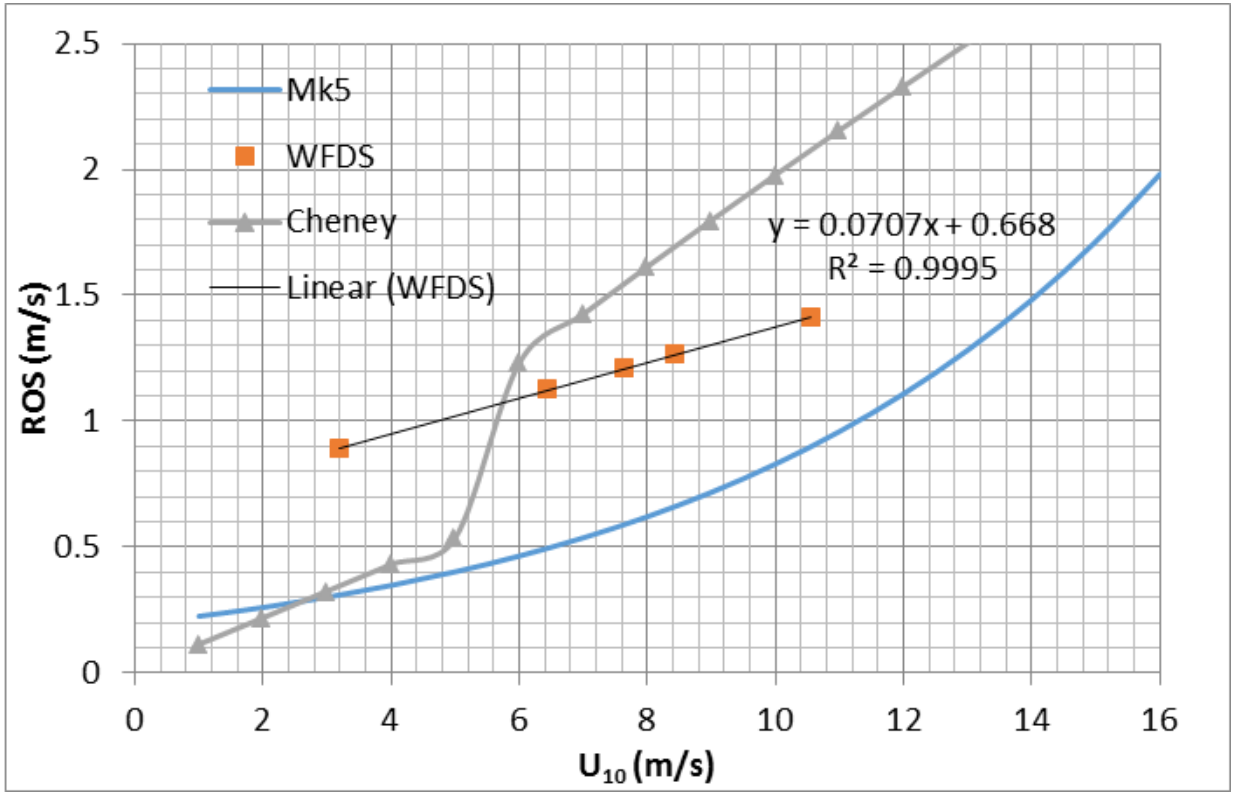
$$F = 3.35W \text{ x } Exp(-0.0897M + 0.0403V) \quad \text{when } M<18.8\%$$
$$F = 0.299W \text{ x } Exp(-1.686M + 0.0403V)\text{x}(30 - M) \quad \text{when } 18.8\%<M<30\%$$

CSIRO model (Project VESTA)

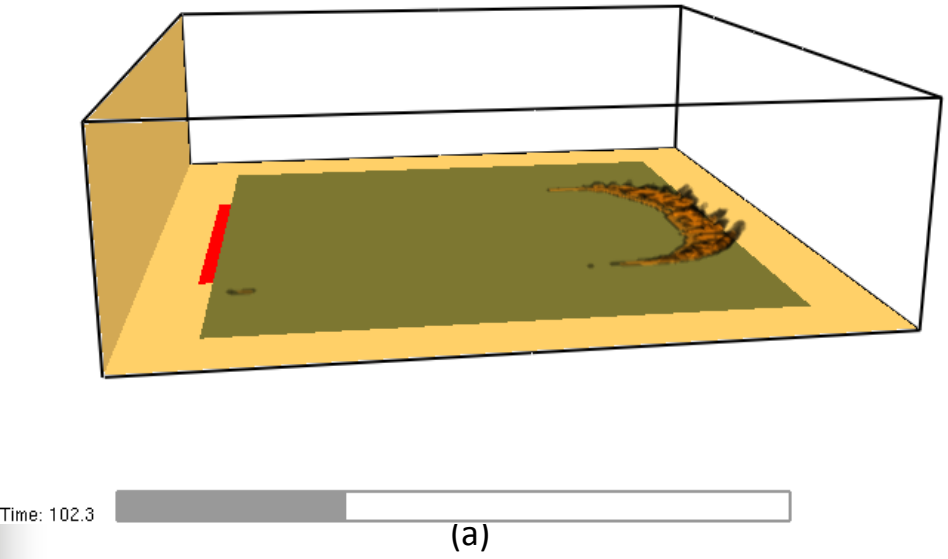
$$R_{cu} = \begin{cases} (0.054 + 0.209U_{10})\phi M\,\phi C & U_{10} \le 5\,\text{km h}^{-1} \\ \left(1.1 + 0.715(U_{10} - 5)^{0.844}\right)\phi M\,\phi C & U_{10} > 5\,\text{km h}^{-1} \end{cases},$$

$$\phi M = \begin{cases} \exp(-0.108\,\text{MC}), & \text{MC} < 12\% \\ 0.684 - 0.0342\,\text{MC} & \text{MC} \ge 12\%, U_{10} < 10\,\text{km h}^{-1} \\ 0.547 - 0.0228\,\text{MC} & \text{MC} \ge 12\%, U_{10} \ge 10\,\text{km h}^{-1} \end{cases}$$

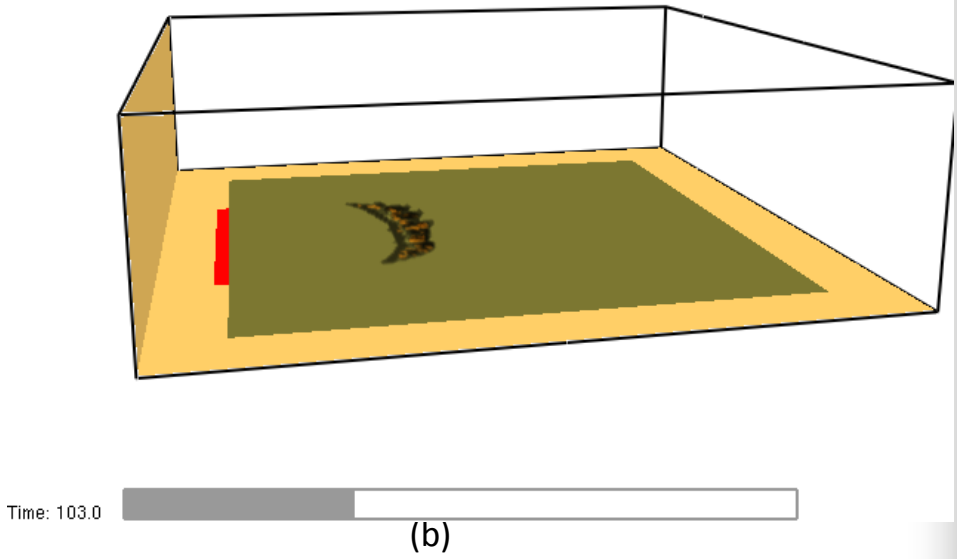
RATE OF SPREAD – FDS VS EMPIRICAL



GRASS FIRE RESULT-UNMOWED VS MOWED
CONSTANT AMOUNT OF FUEL



(a)



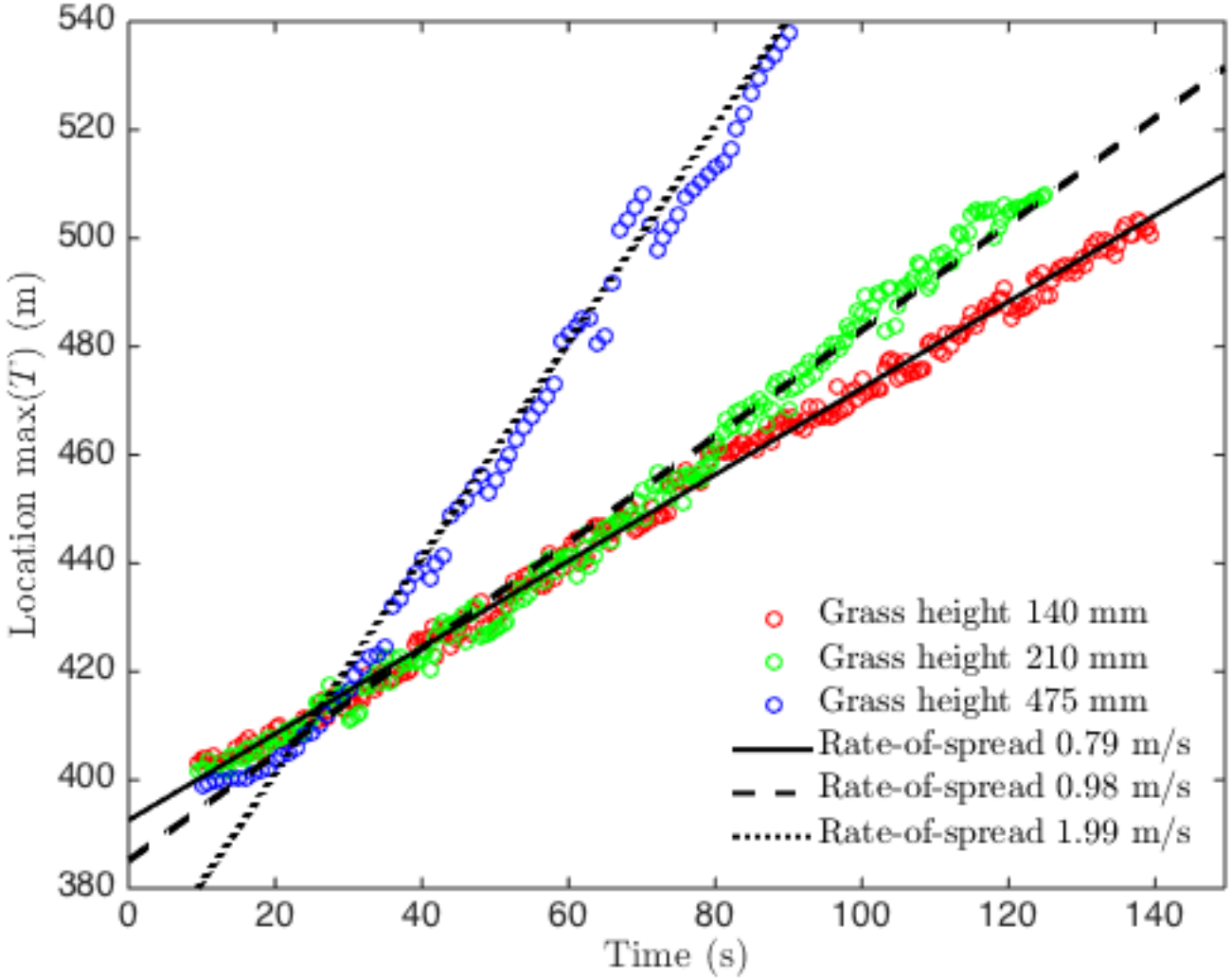
(b)

(a) Vegetation height 250 mm

(b) Vegetation height 160 mm

GRAPH OF RATE OF SPREAD

CONSTANT FUEL DENSITY



SIMULATED WINDS IN TREE CANOPIES

MCARTHUR MODEL (NOBLE 1980)

$$F = 2.0 * \exp(-0.450 + 0.987 * \ln(D) - 0.0345 * H + 0.0338 * T + 0.0234 * V)$$

$$R = 0.0012 * F * W$$

SIMULATED WINDS IN TREE CANOPIES

McArthur Model:

$$R = a_0 W \exp(-a_1 + a_2 \log(D) - a_3 H + a_4 T + a_5 u/\alpha)\,,$$

where W, D, H, and T are fuel and weather conditions
u is the open wind speed
a_i are positive empirical constants
α is the wind reduction factor

SIMULATED WINDS IN TREE CANOPIES

McArthur Model:

$$R = a_0 W \exp(-a_1 + a_2 \log(D) - a_3 H + a_4 T + a_5 u/\alpha) ,$$

where W, D, H, and T are fuel and weather conditions
u is the open wind speed
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SIMULATED WINDS IN TREE CANOPIES

McArthur Model:

$$R = a_0 W \exp(-a_1 + a_2 \log(D) - a_3 H + a_4 T + a_5 u/\alpha)\,,$$

where W, D, H, and T are fuel and weather conditions
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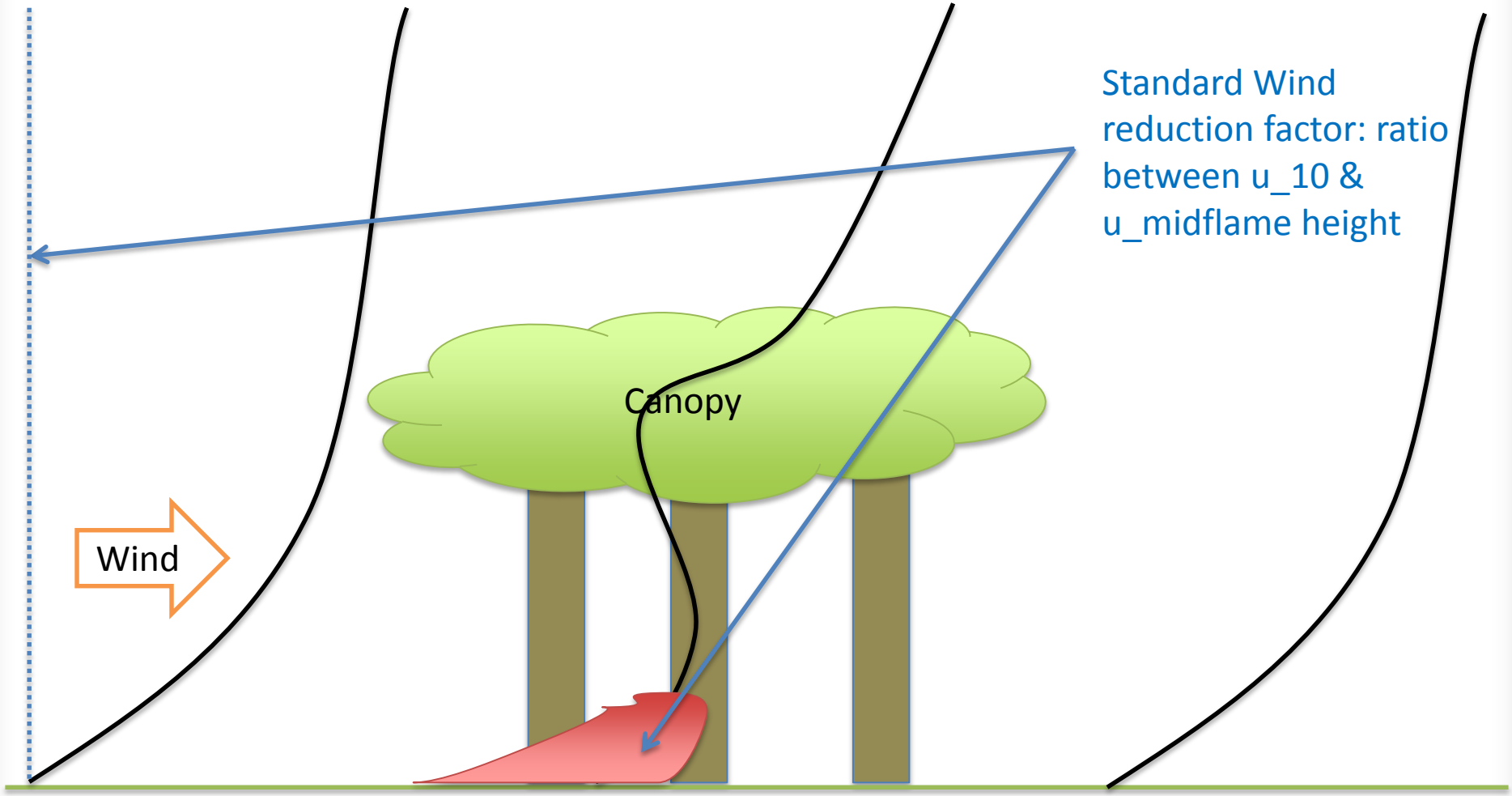
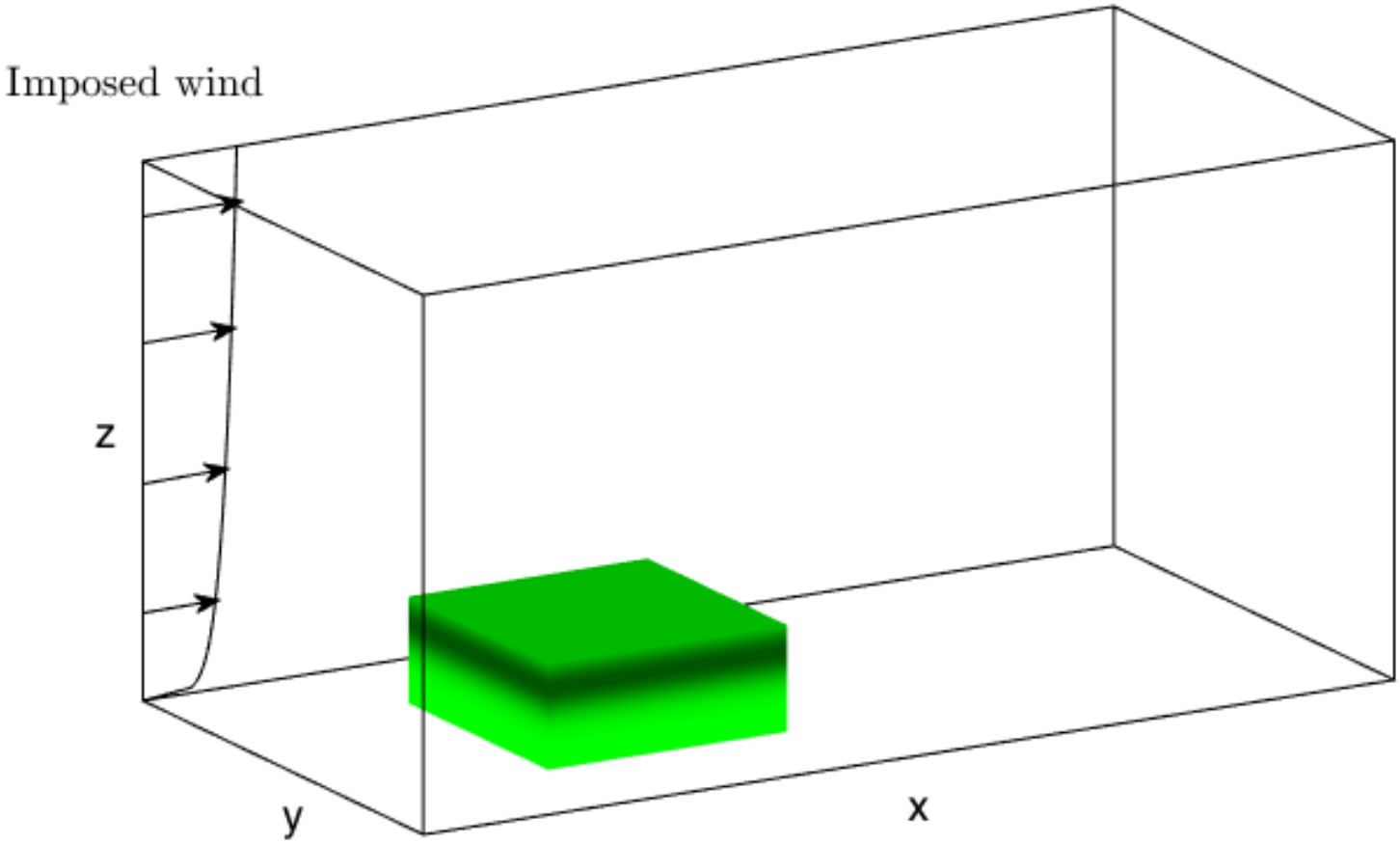
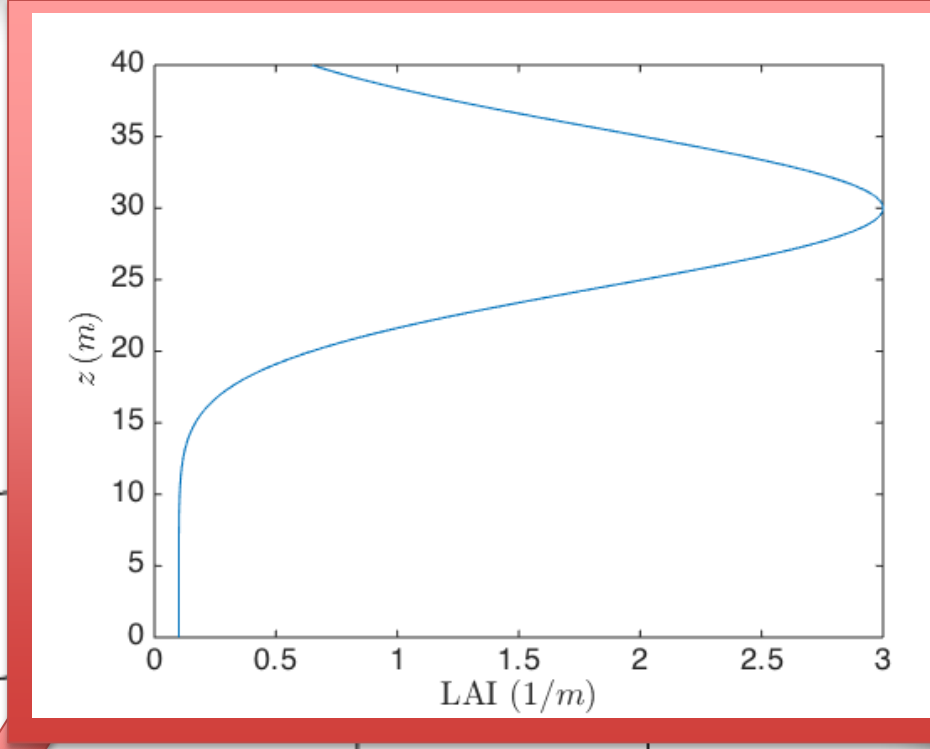
$\frac{u}{\alpha}$ models the flame-height wind speed in the canopy


Standard Wind reduction factor: ratio between u_10 & u_midflame height
Canopy
Wind

SIMULATION DOMAIN





Imposed wind

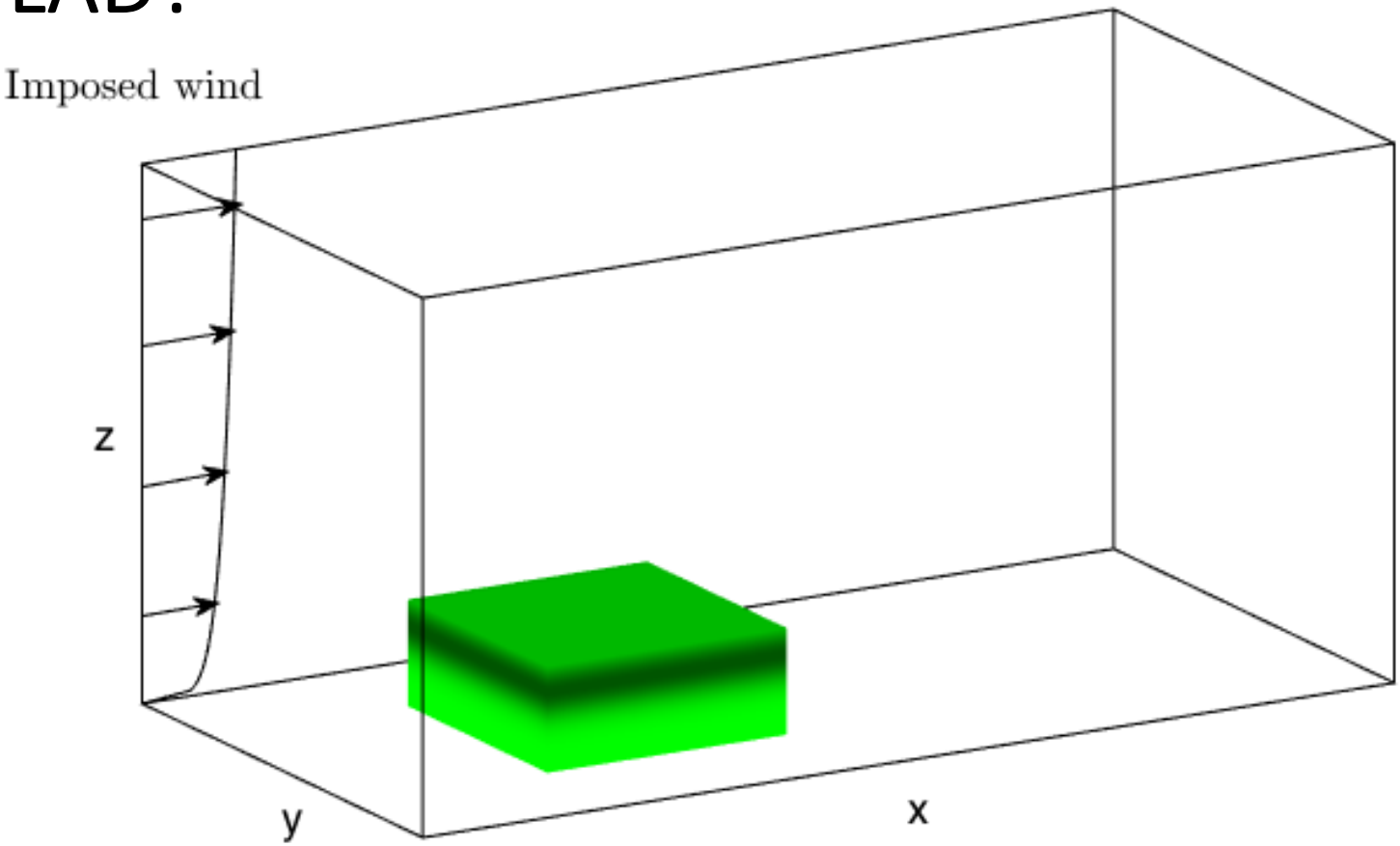
$u \approx 20$ m/s

z

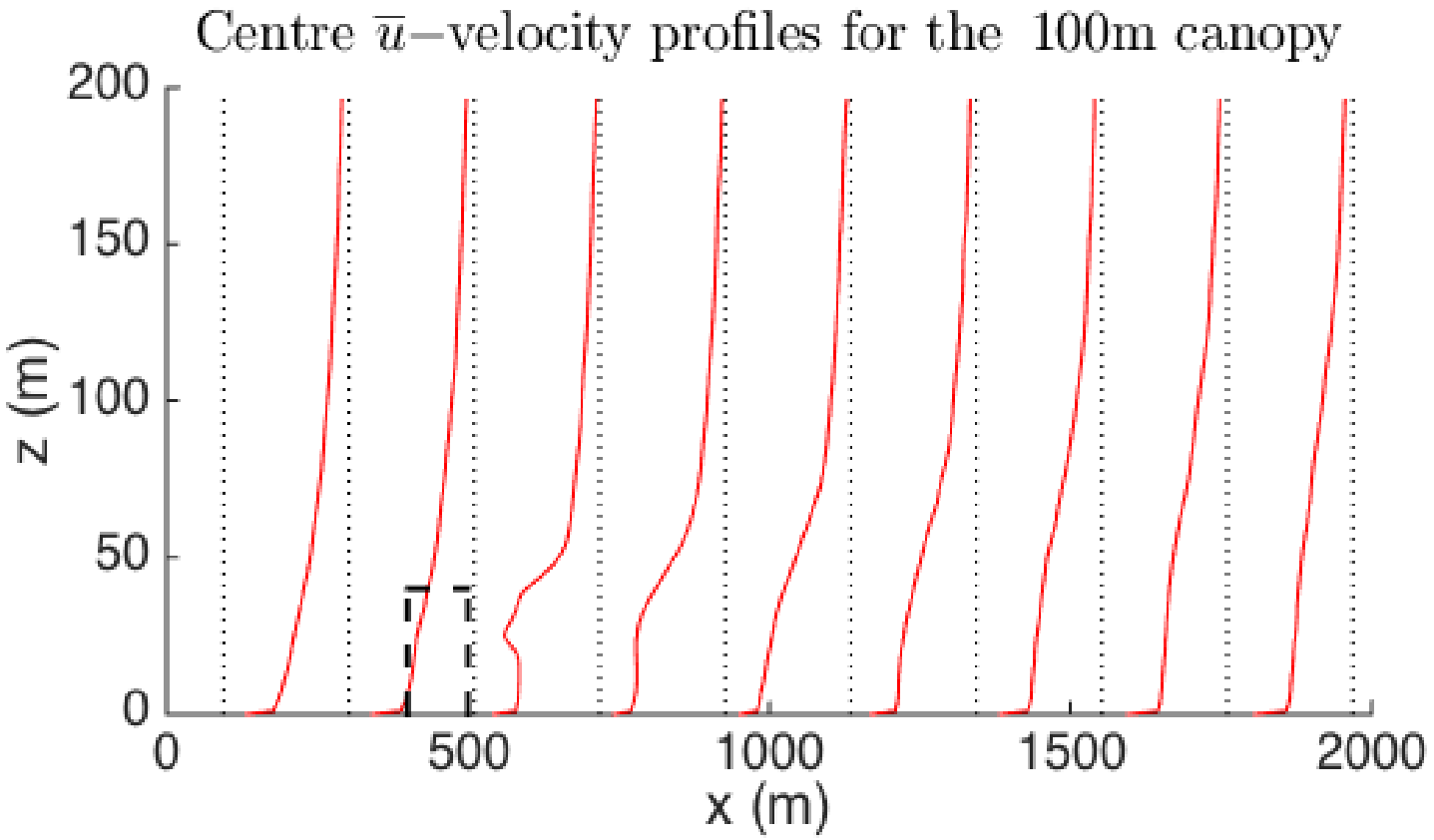
y

x

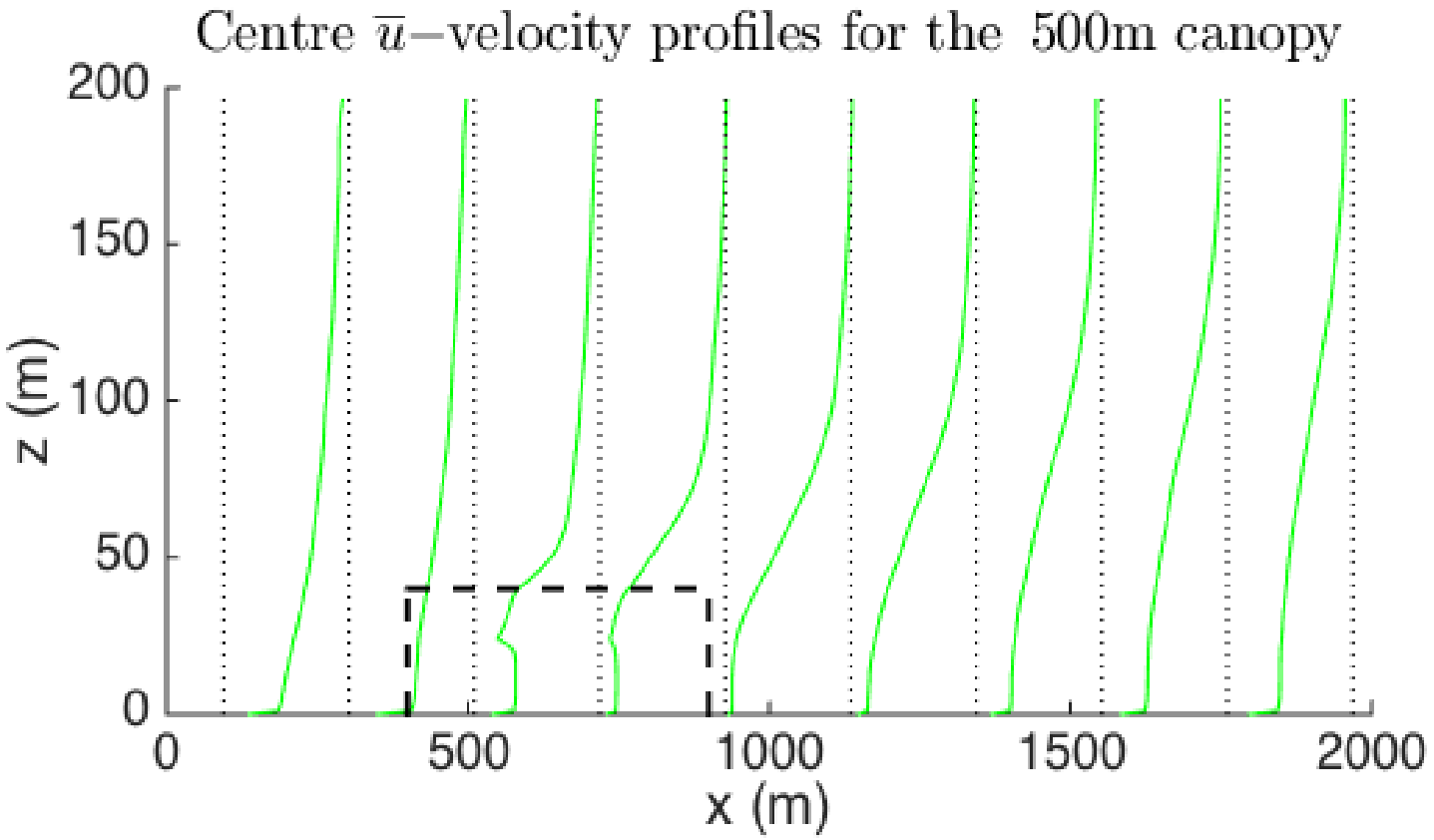
How does the wind profile change over different canopy lengths and LAD?



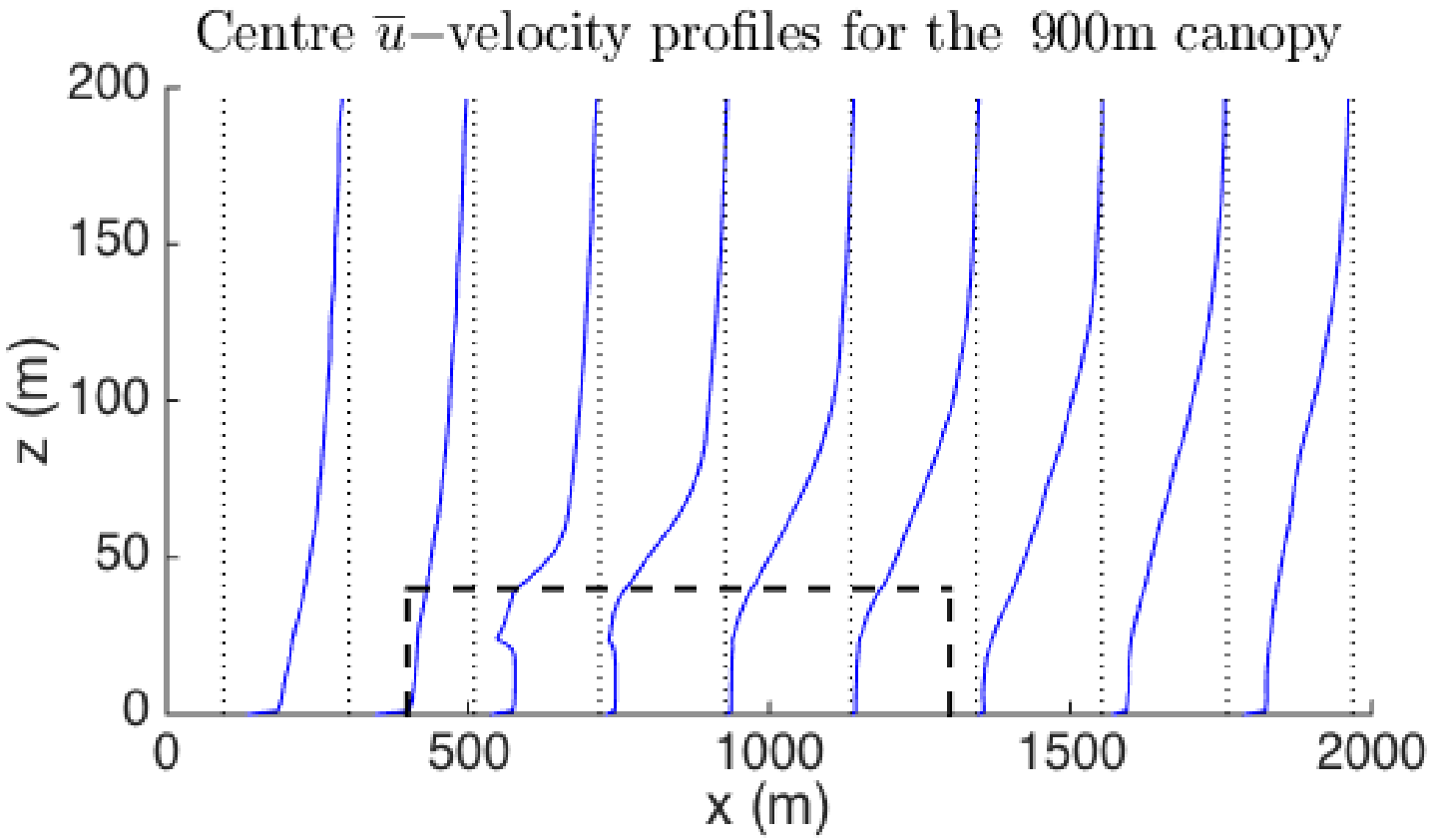
WIND PROFILES ALONG CANOPIES



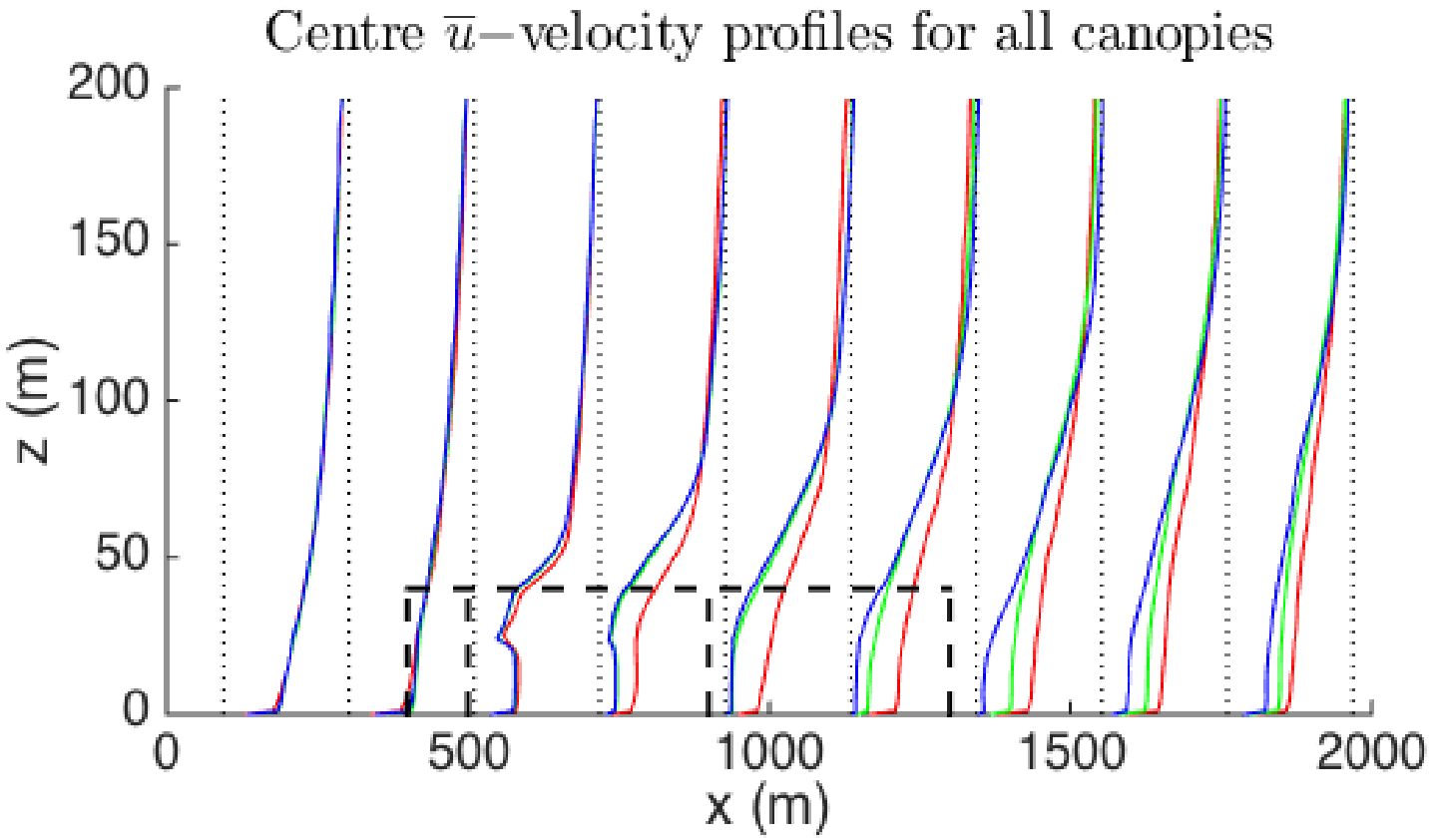
WIND PROFILES ALONG CANOPIES



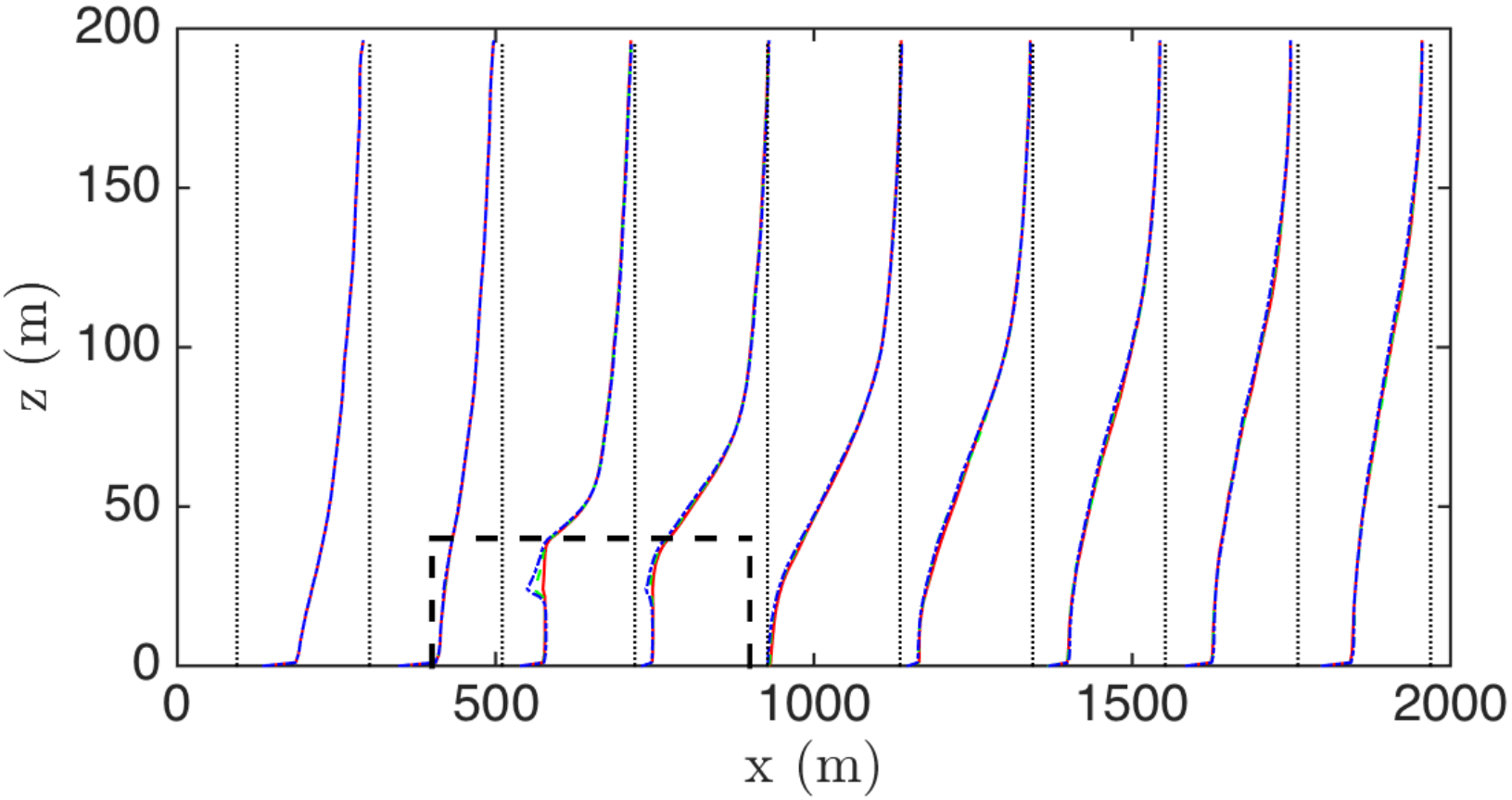
WIND PROFILES ALONG CANOPIES



WIND PROFILES ALONG CANOPIES

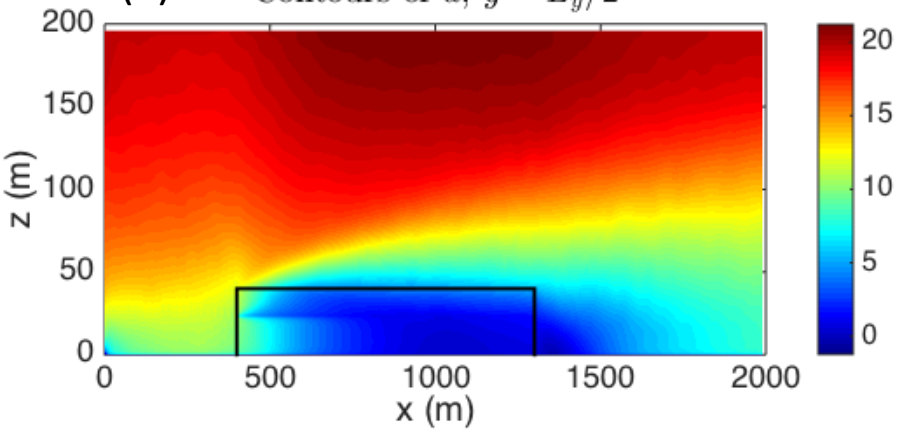


EFFECT OF LEAF AREA DENSITY

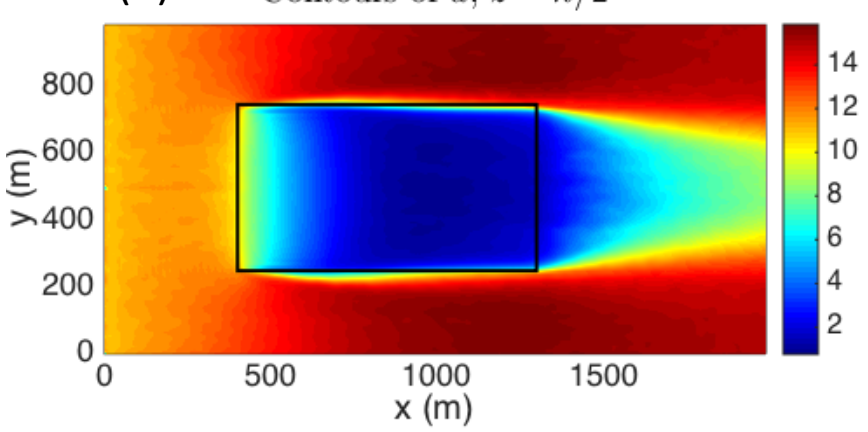


Variation across the canopy

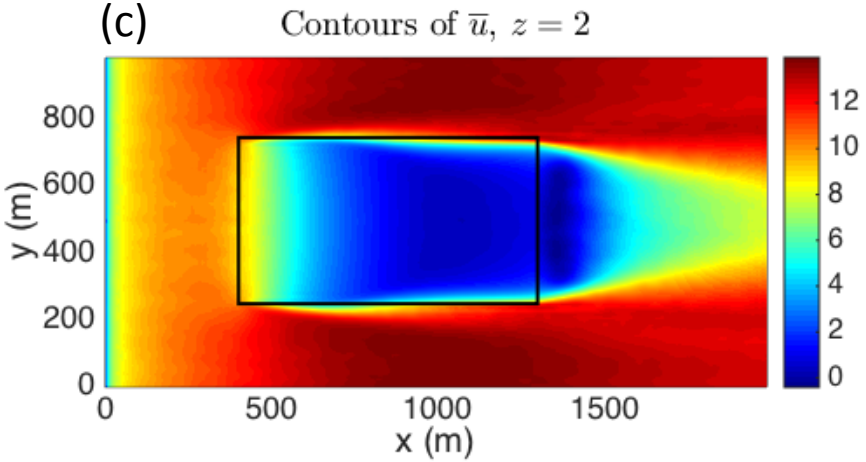
(a)



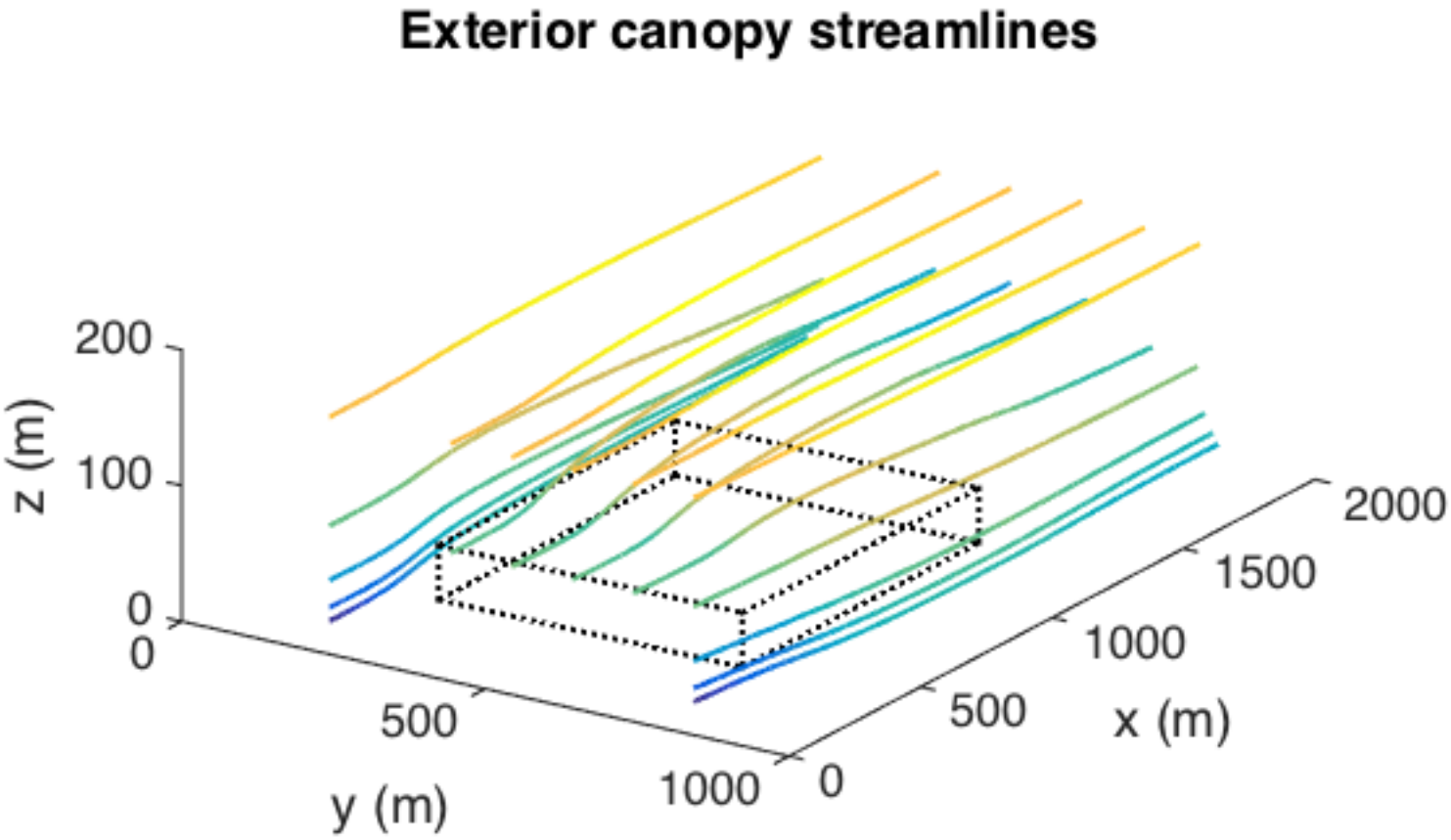
(b)



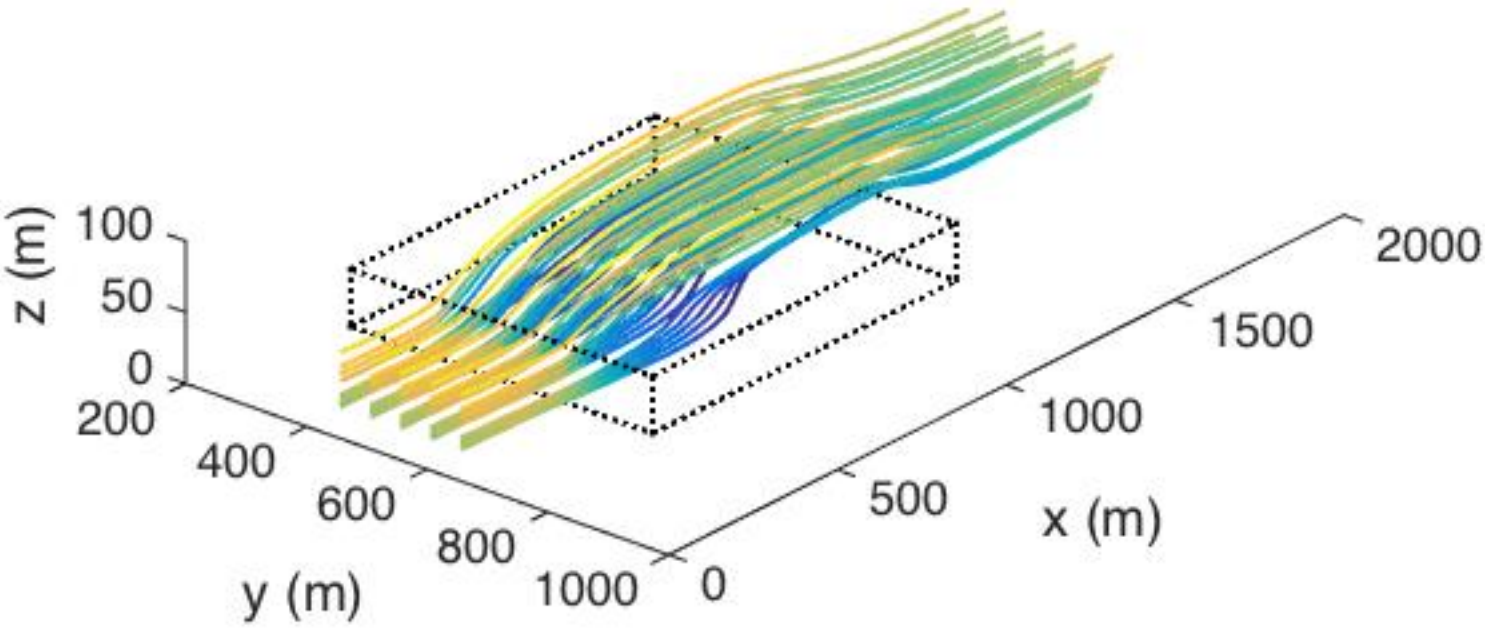
(c)

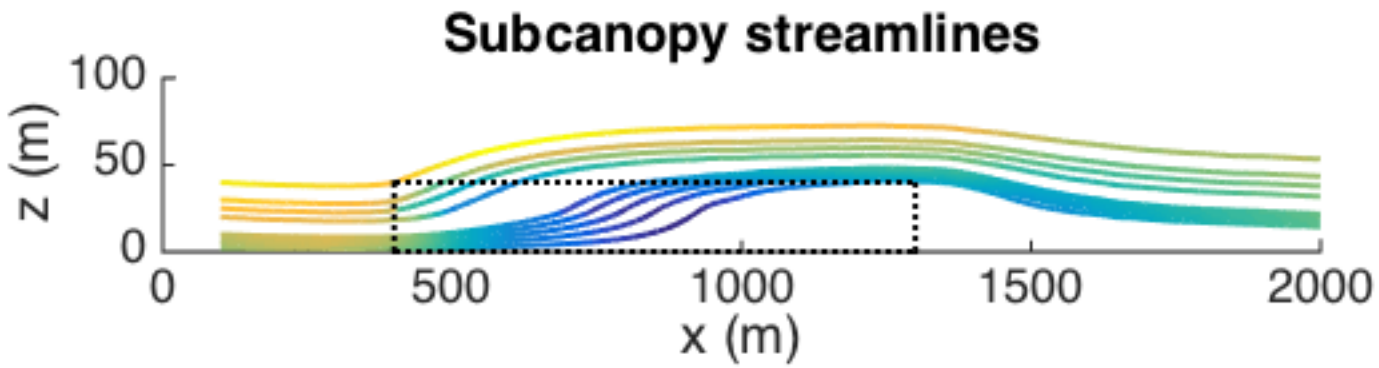


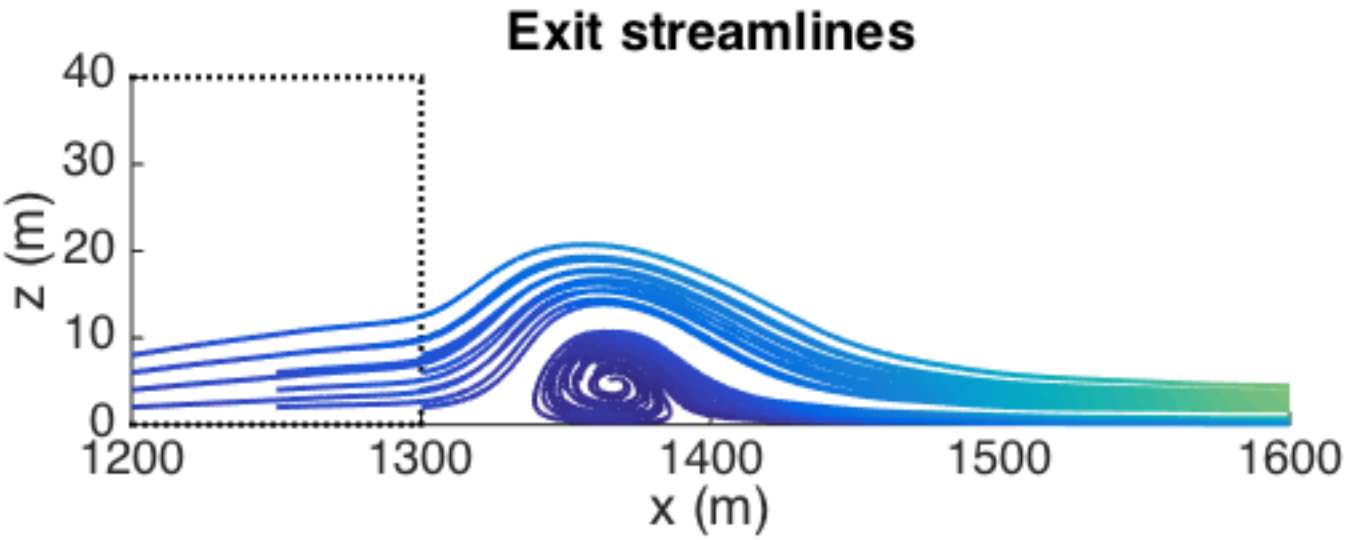
FLOW STRUCTURES



Subcanopy streamlines



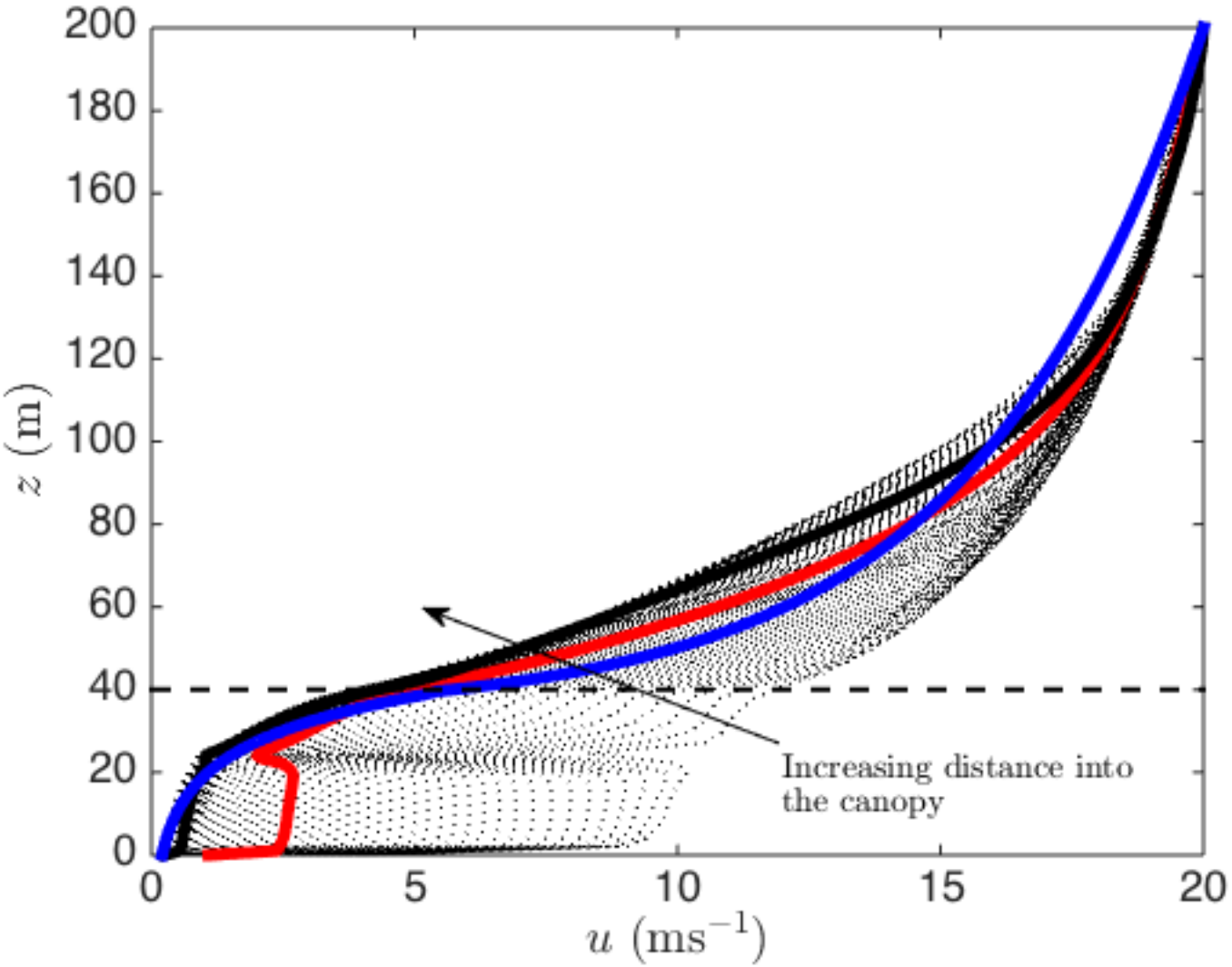

Subcanopy streamlines
z (m)
100
50
0
0
500
1000
1500
2000
x (m)


Exit streamlines
40
30
20
10
0
z (m)
1200
1300
1400
1500
1600
x (m)

STRESS-BALANCE MODEL (HARMAN AND FINNIGAN) REVISE

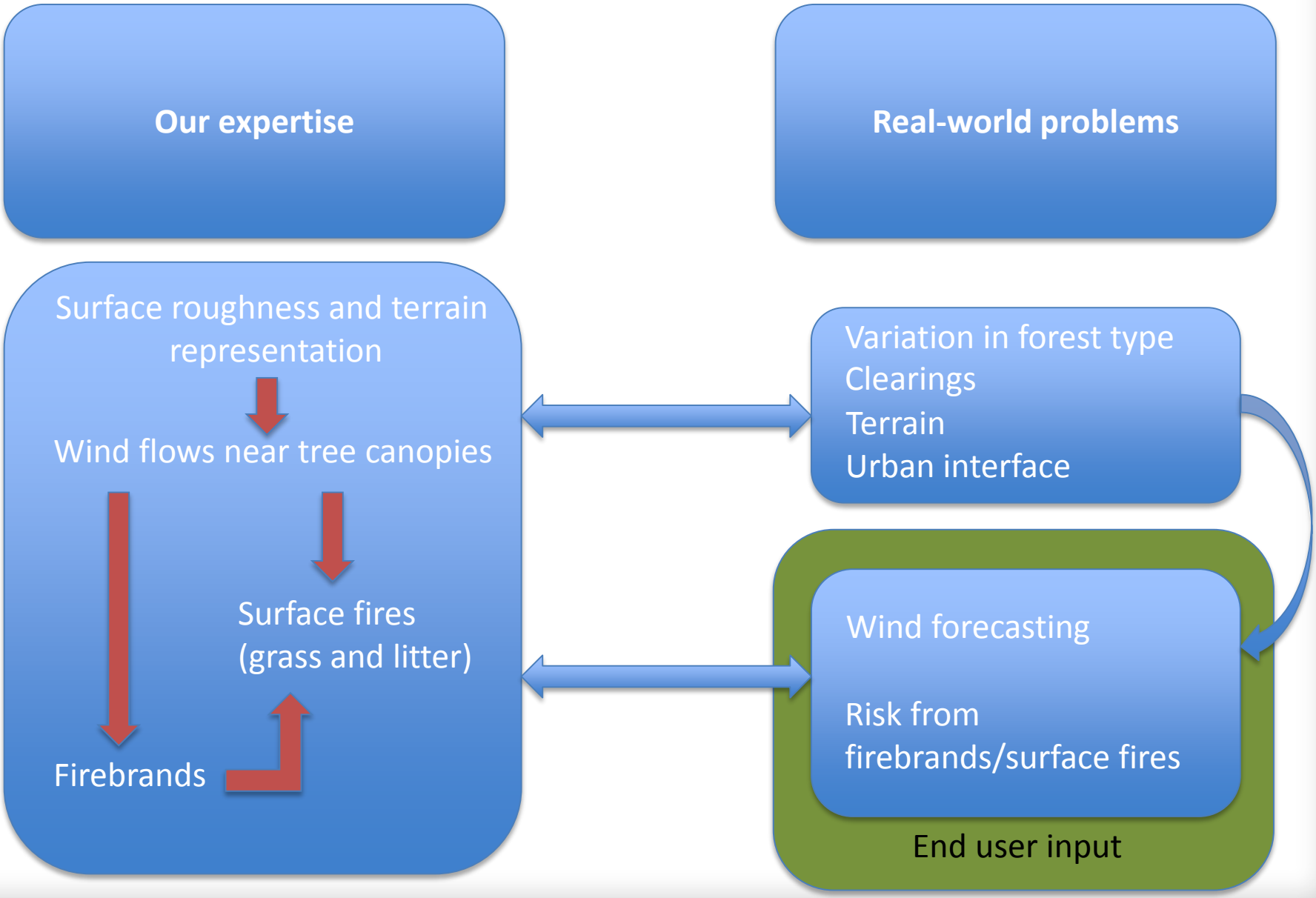
- An idealised canopy flow
- Two sources of momentum
  - Drag of the trees
  - Turbulent eddies
- Balance to give velocity profile:

$$\bar{u}_c(z) = \bar{u}_a(h)\exp\left(\frac{(z-h)c_D\bar{a}}{2\beta^2}\right).$$

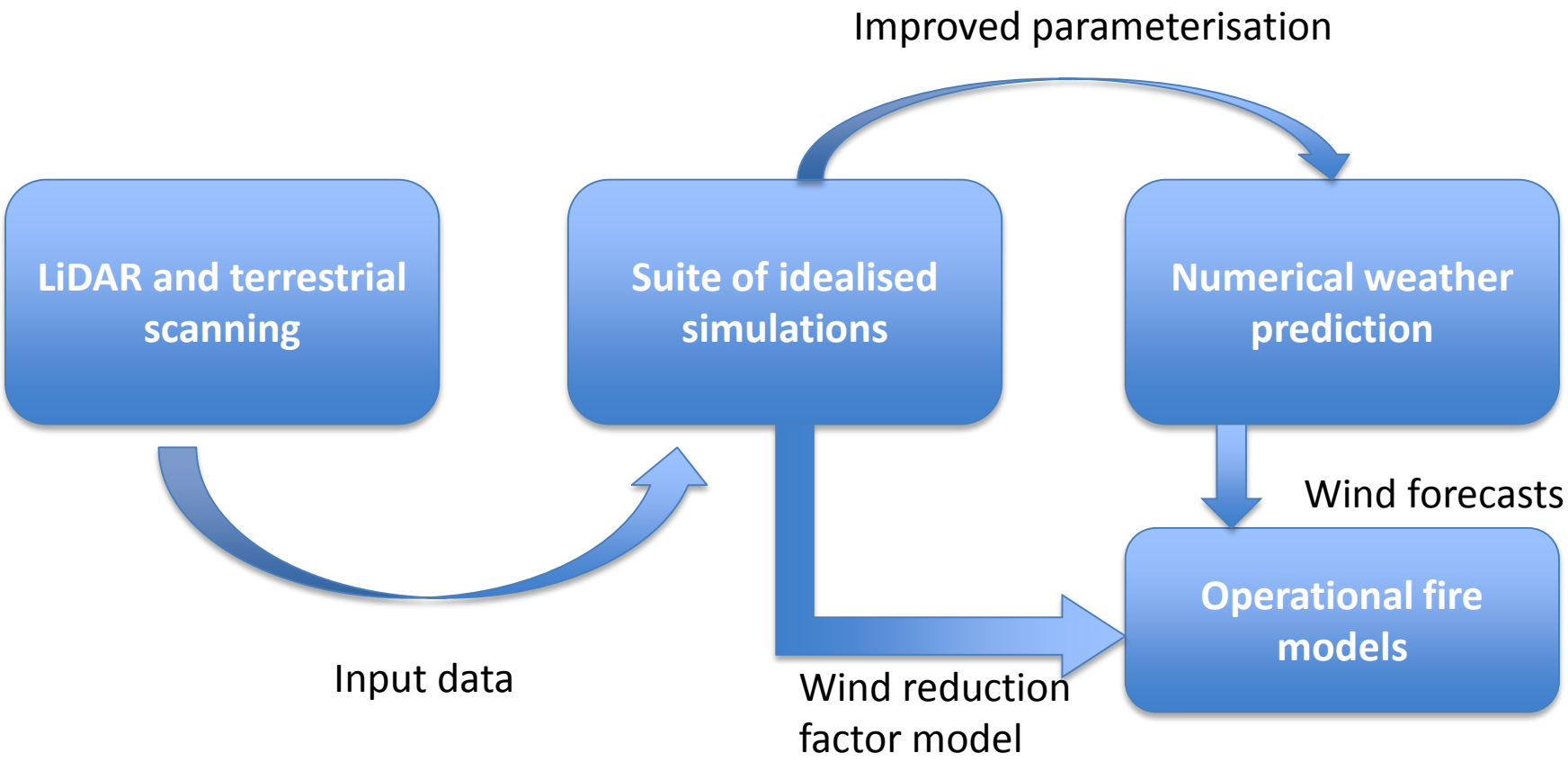


Blue: Harman & Finnigan Model, red: canopy average, black: developed canopy average
Dots: profile at a range of streamwise locations in the canopy Dashed: canopy top

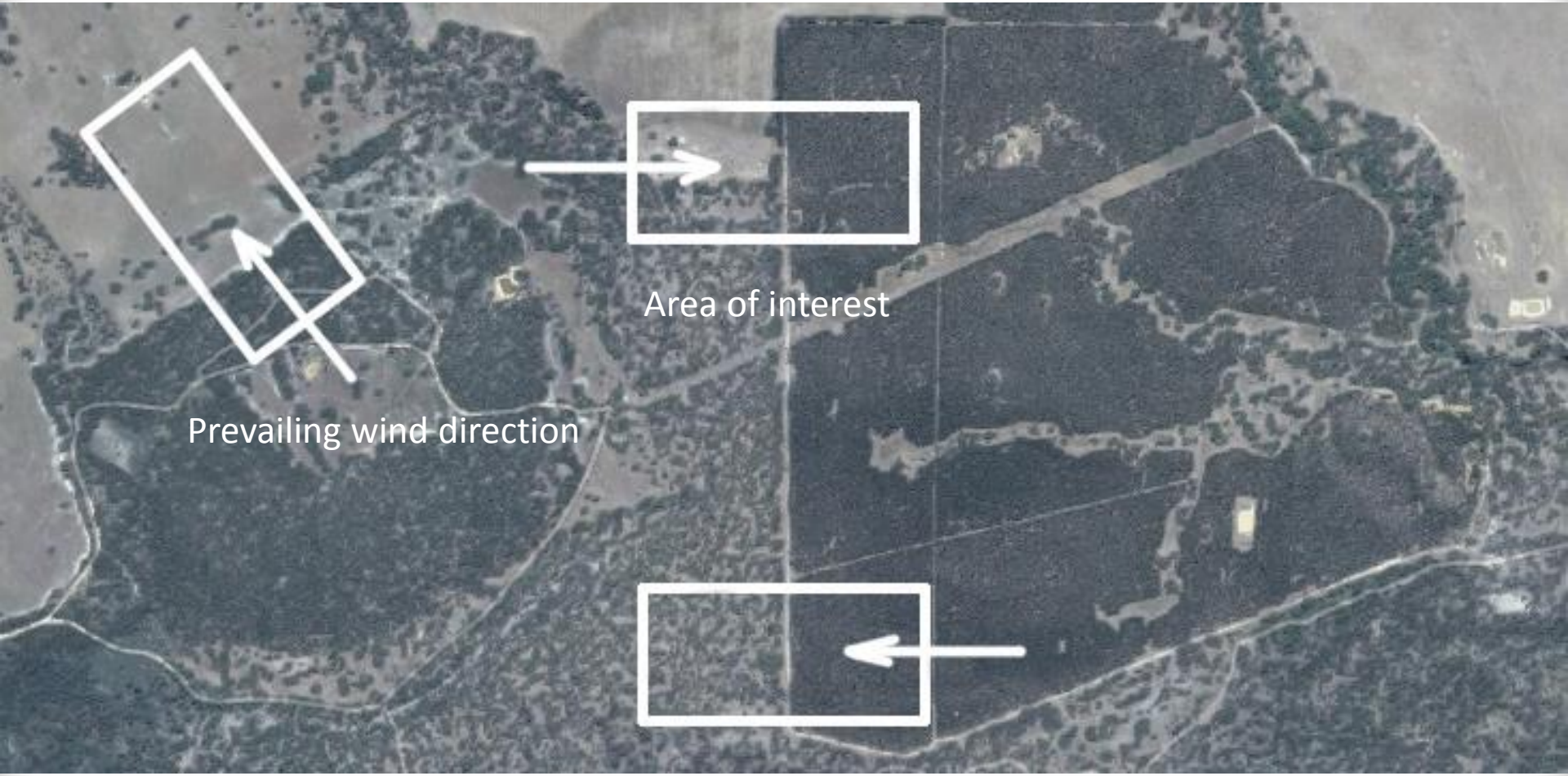
WHERE TO FROM HERE?



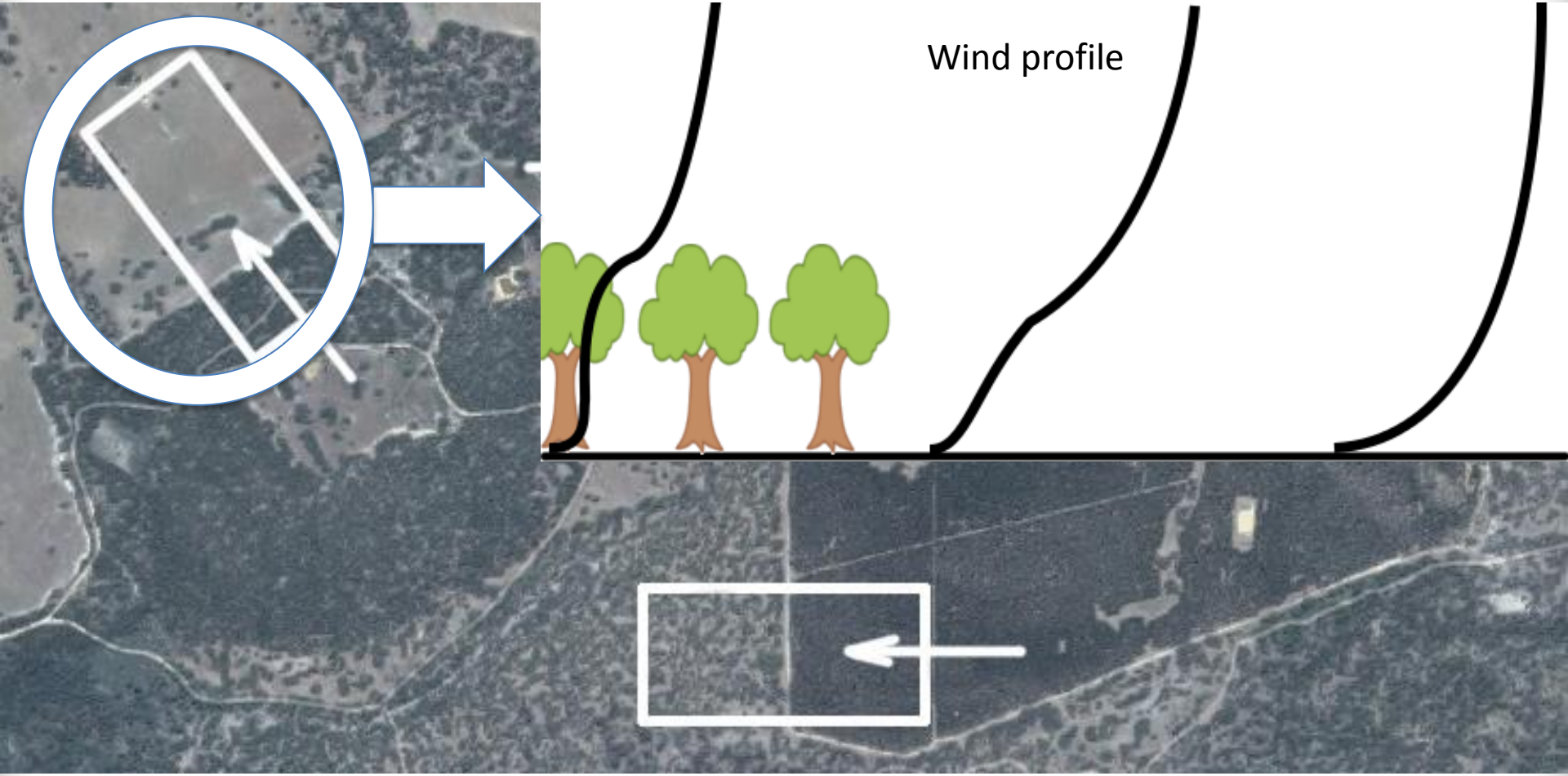
CANOPY WIND FLOW



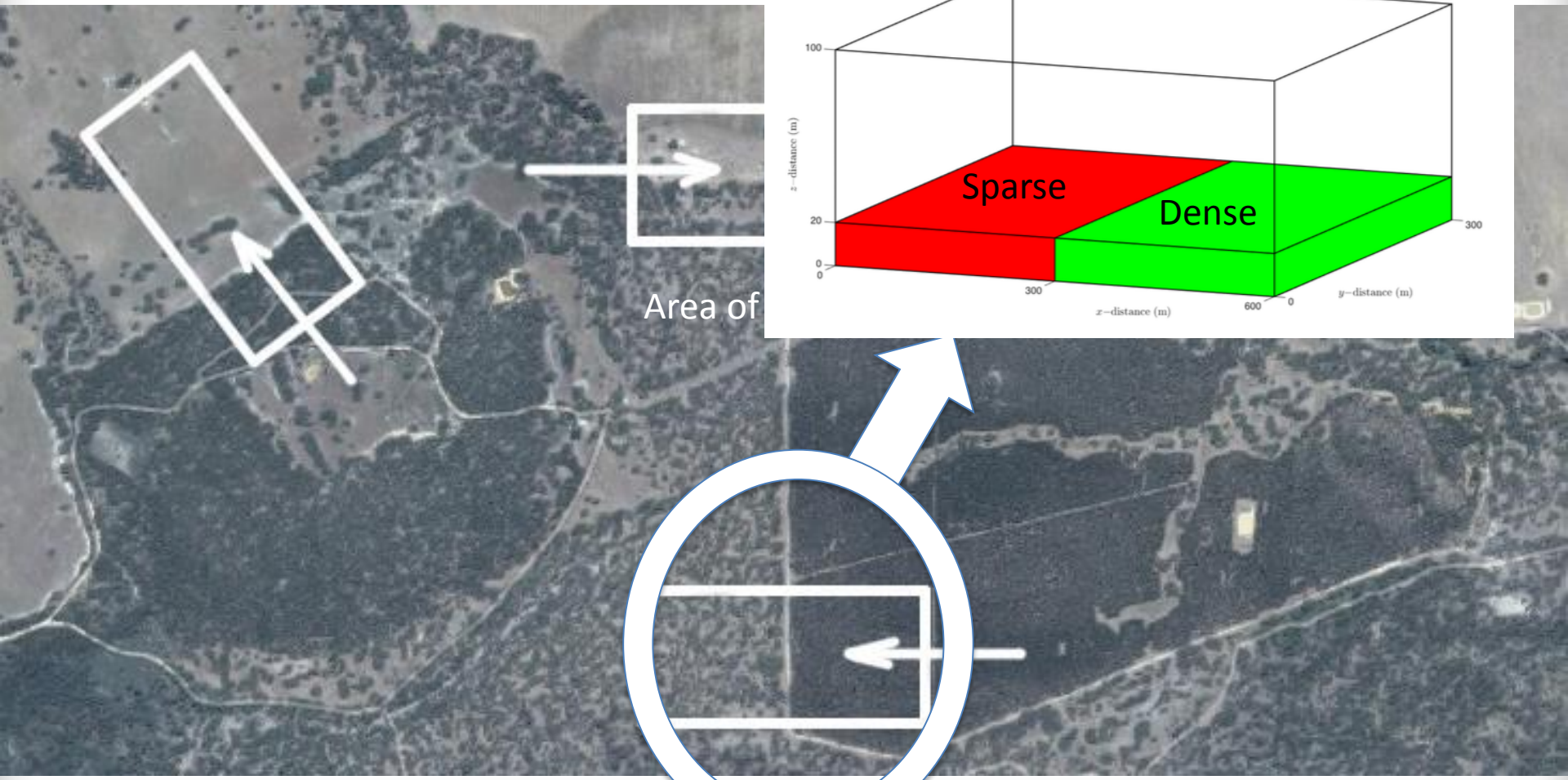
CANOPY WIND FLOW



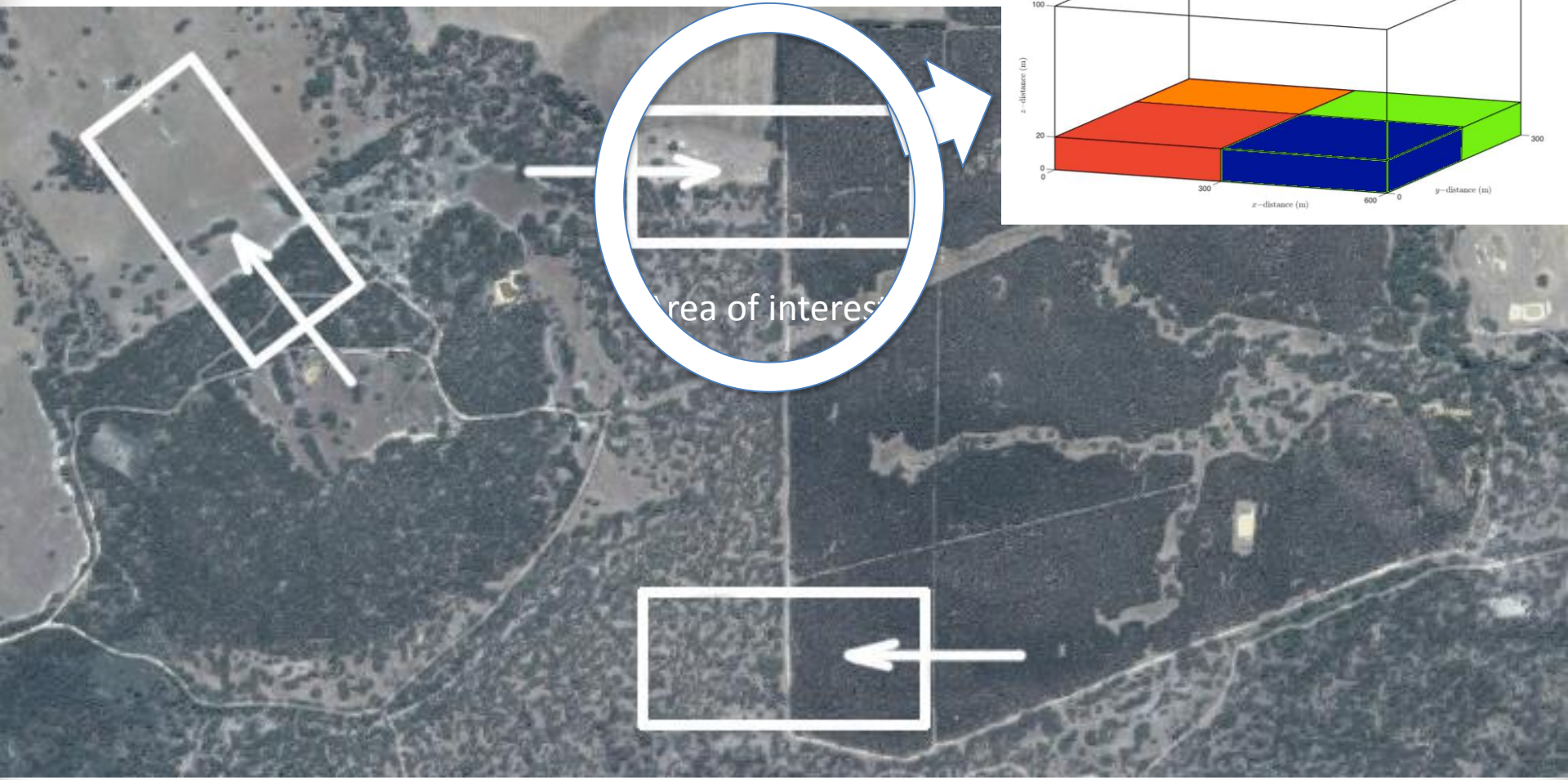
CANOPY WIND FLOW



CANOPY WIND FLOW



CANOPY WIND FLOW



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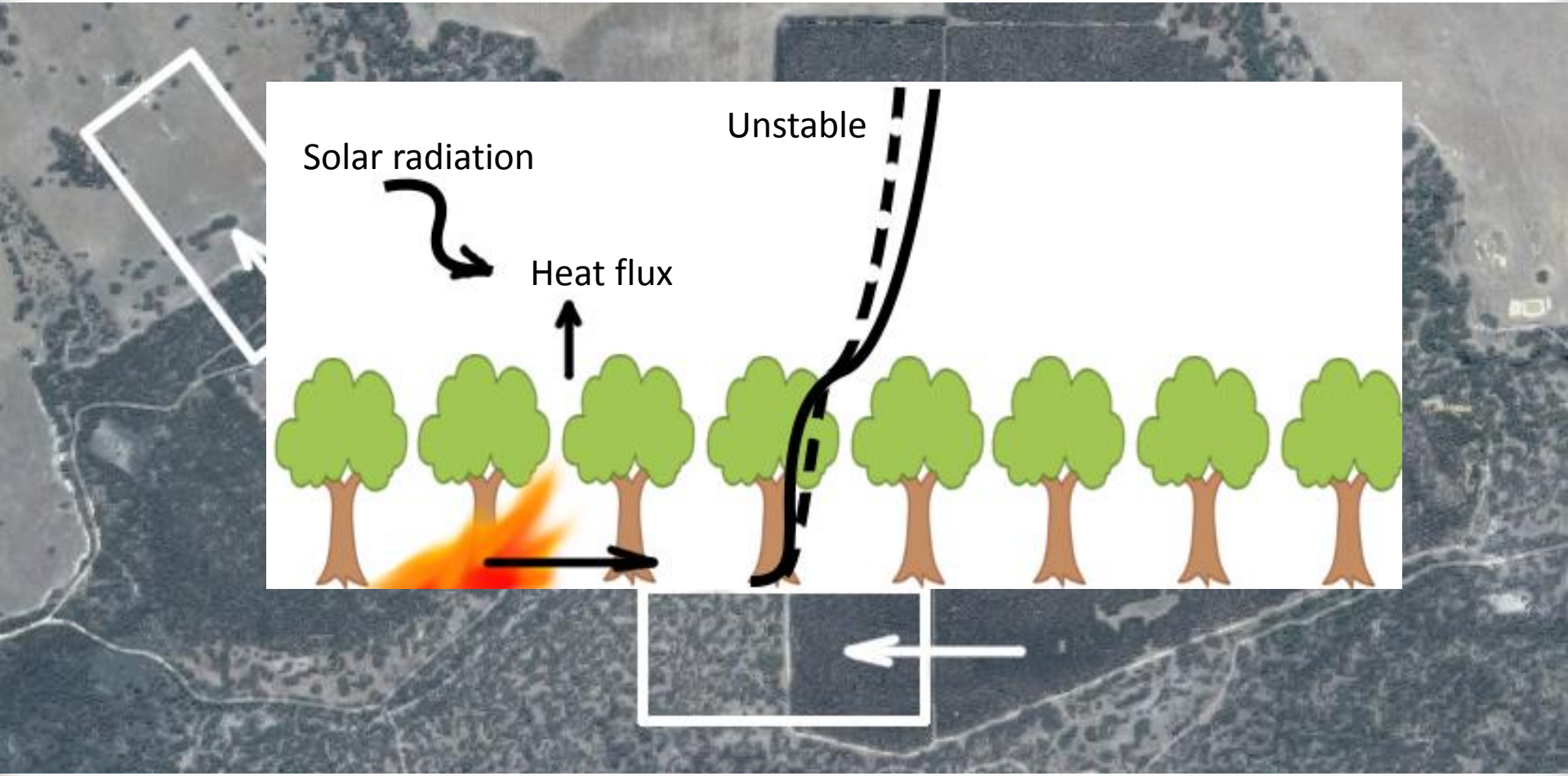
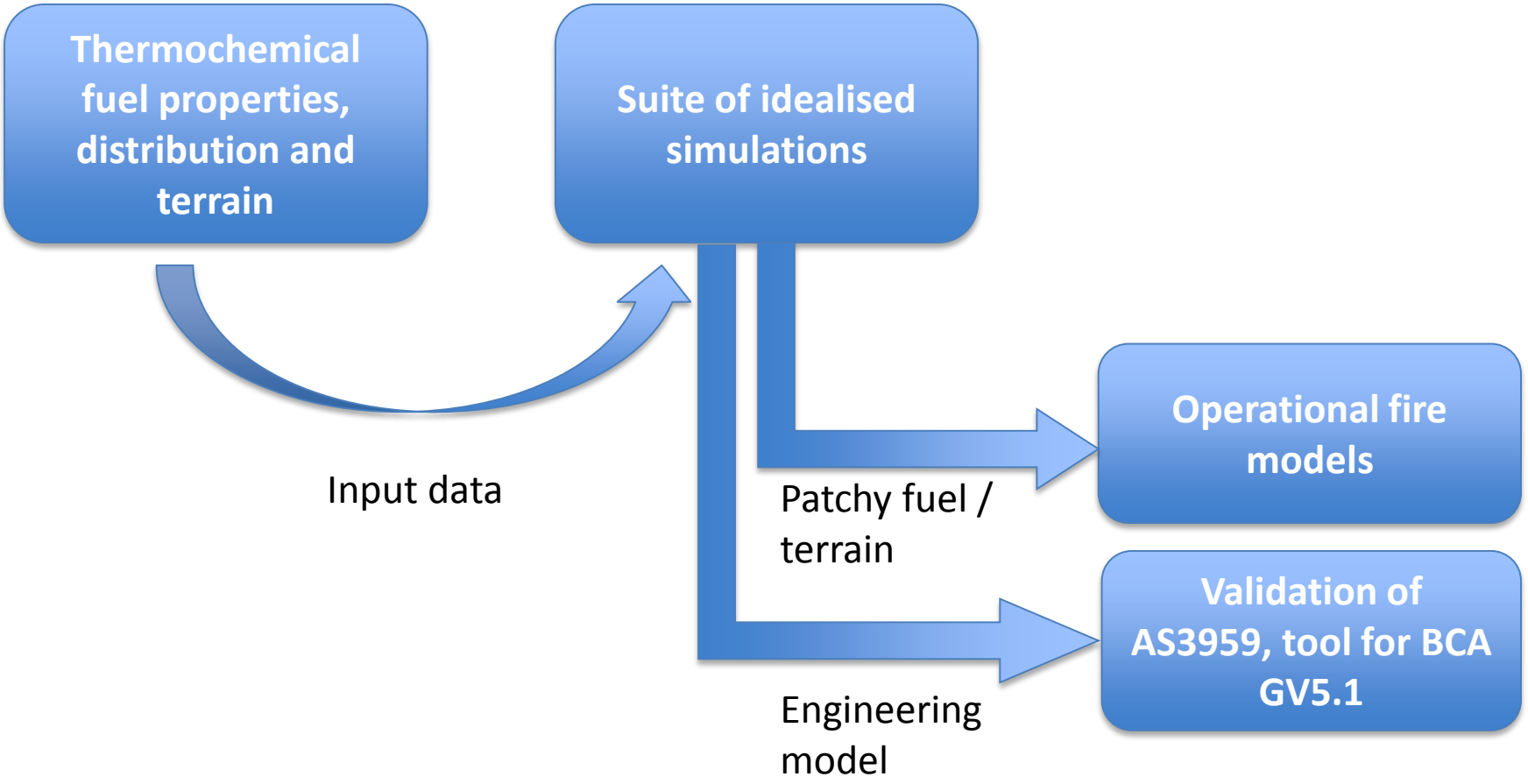


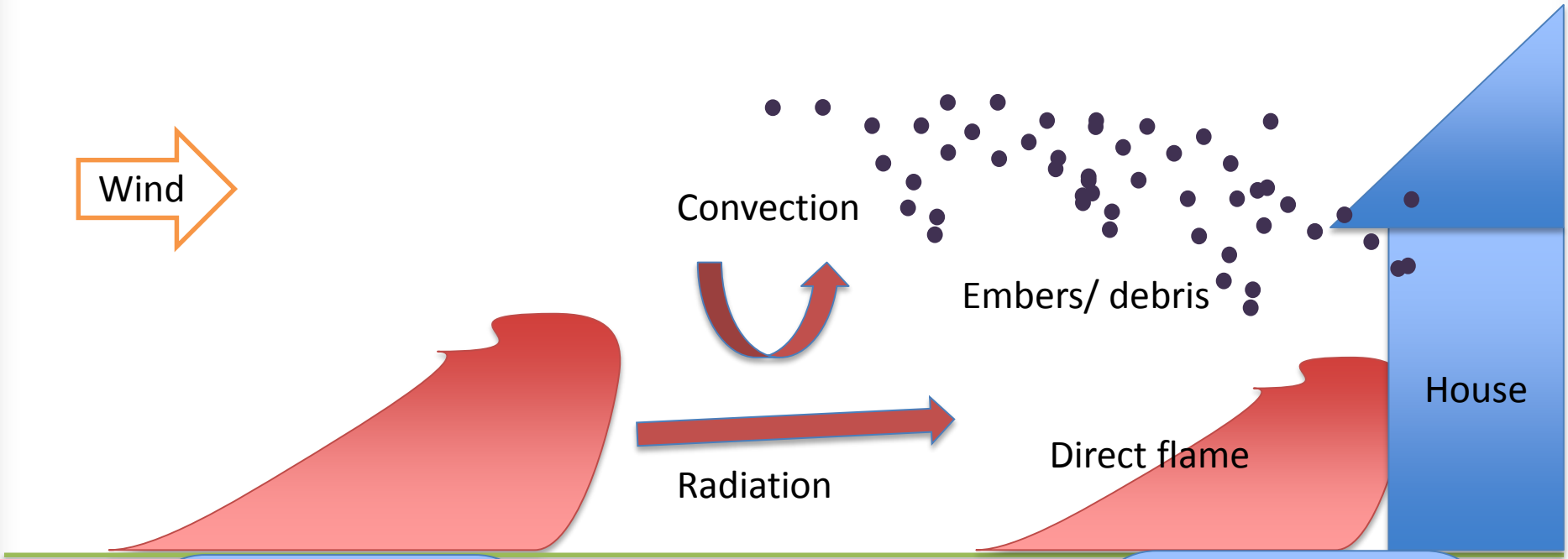
BENEFITS

- An easily implemented model for wind profile downstream of the canopy
- Sub-canopy wind model for inhomogeneous canopies
- Understanding the significant factors effecting sub-canopy winds

SURFACE FIRES



APPRAISAL OF AS3959/BCA GV5.1



Fire propagation function of
(a) Wind
(b) Slope (and terrain)
(c) Solar radiation (?)
(d) Fuel distribution

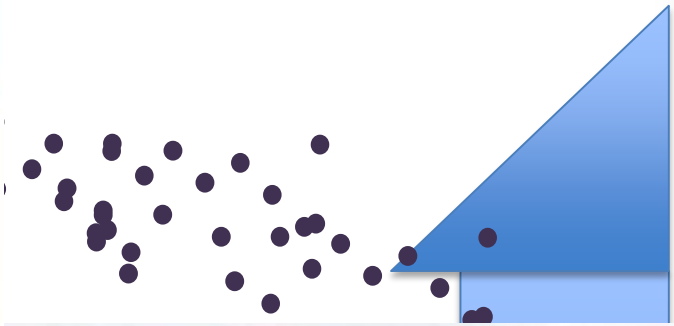
Ember attack function of
(a) Wind
(b) Shape
(c) Mass (?)
(d) Particle density (?)

Wind

Fire propa e
function
(a) Win
(b) Slope (and terrain)
(c) Solar radiation (?)
(d) Fuel distribution

APPRAISAL OF AS3959/BCA GV5.1

Wind



Fire p gation
func of
(a) d
(b) pe (a ain)
(c) Solar radia ion (?)
(d) Fuel distribution

(d) Particle density (?)

BENEFITS

- Assessment of heat and ember loading on structures
- Appraisal of standards
- Development of engineering models for heat and ember load
- Potential risk modelling
  - Estimation of fire breaks, etc

QUESTIONS?

Edge canopy streamlines