NEXT GENERATION MODELS FOR PREDICTING THE BEHAVIOUR OF BUSHFIRES

Challenges and Prospects

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An Australian Government Initiative

OPERATIONAL MODELS

Emergency services use mathematical models to predict the rate and direction of spread of bushfires.

The models must run much faster than real time so that a range of management scenarios can be investigated.

OPERATIONAL MODELS

The models are based on experiments – laboratory, controlled field experiments and wildfires.

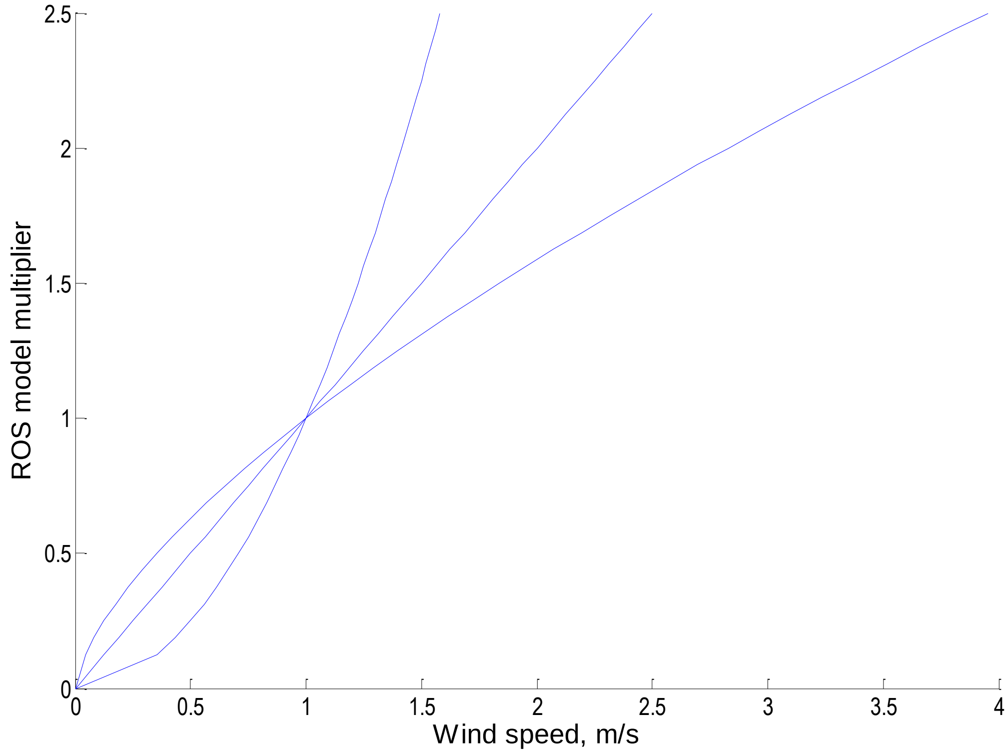
The rate of spread, ROS, may be expressed in terms of wind speed, W, in an equation that looks like

$$ROS = W^x$$

where x is a number that we estimate by fitting the equation to data.

EMPIRICAL MODELS AND RATE OF FIRE SPREAD

Can a wildfire outpace the wind on level ground?



Based on ideas from Sullivan, A. L. Wildland surface fire spread modelling, 1990–2007 (2) *Int. J.Wildland Fire*

EMPIRICAL MODELS AND RATE OF FIRE SPREAD

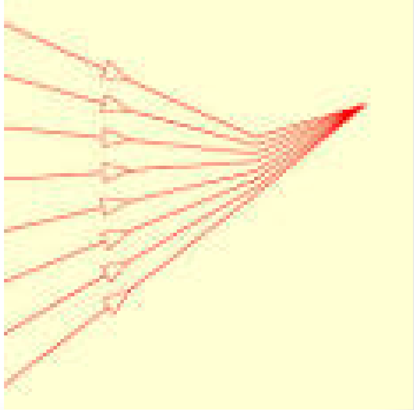
The effects of the moisture content of vegetation on *ROS* prove just as elusive to pin down.

EMPIRICAL MODELS AND RATE OF FIRE SPREAD

These inconsistencies point to the need for consilience – a requirement that conclusions drawn from data and analyses from a range of diverse sources concur.

It is argued that physics-based mathematical models that rely on the 'regularities of nature' have a greater chance of achieving consilience.

And they provide greater insights.



MEASUREMENTS MUST BE PACKED WITH INFORMATION

Sullivan raises questions concerning the input data required by empirical models.

If we take measurements of moisture content or wind speed, say, what useful information do they convey?

How should the measurements be made to ensure that they contain useful information?

THE MELDING OF KNOWLEDGE TO TAKE MEANINGFUL MEASUREMENTS

An answer is to draw on the principle of ‘omni-science’ – the general idea is to syncretise expertise drawn from a wide range of disciplines.

One of its principal motivations is to ensure we take measurements within an intellectual framework.

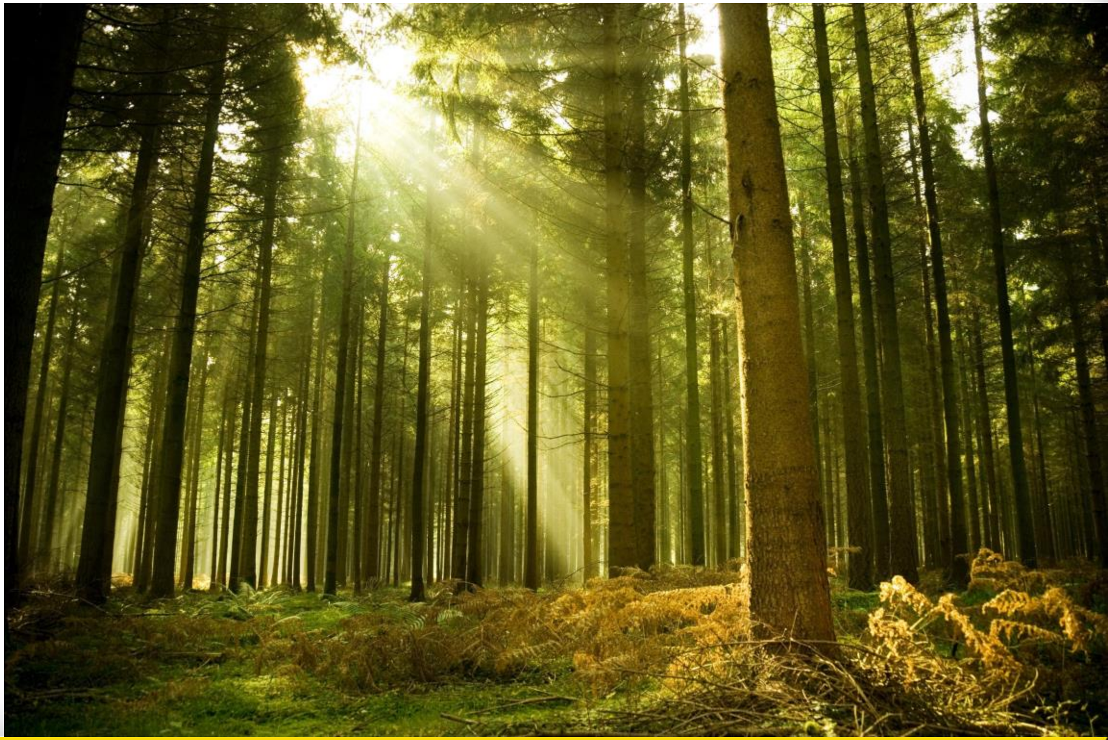
Thorpe, G. R. (2010) Omni-science: Transformative approaches to postharvest technology. 10th International Working Conference on Stored Products Protection. Estoril, Portugal, 27th June – 1st July 2010.

Applied Technologies, Inc.

LOCAL VARIATIONS IN AIR VELOCITY

Finnigan suggests that buoyancy forces may result in local variations in velocity – air rises above warm sunlit patches of ground, and descends due to cooling by transpiration.

If we could quantify this phenomenon it would make our interpretation of data more accurate.



FORESTHDWALL.COM.

BUSHFIRE MODELS MUST ACCOUNT FOR A WIDE RANGE OF LENGTH AND TIME SCALES.

The phenomena that govern the behaviour of bushfires encompass a large range of length and time scales.

We could consider that pyrolysis of vegetative material occurs on a molecular level – one billionth of a millimetre. Bushfires may affect the environment over distances of kilometres.

BUSHFIRE MODELS MUST ACCOUNT FOR A WIDE RANGE OF LENGTH AND TIME SCALES.

Another complication is that computing resources are still very limited to solve these kinds of problems.

Depending on the size of the bushfire we wished to model, we might be limited to considering phenomena that can be resolved on a scale of one tenth the height of the plant canopy.

BUSHFIRE MODELS MUST ACCOUNT FOR A WIDE RANGE OF LENGTH AND TIME SCALES.

We need to know the temperature, velocity, gas composition in the small volume that can be resolved by the computer.

BUSHFIRE MODELS MUST ACCOUNT FOR A WIDE RANGE OF LENGTH AND TIME SCALES.

Leaves, twigs, shoots and ground cover have much smaller dimensions that the computational region.

Here is the crunch: How do we account for these small features?

BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

We can find how the average temperature, the average air velocity vary within the canopy.

Here is the rub: When we average quantities we lose detail.

BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

Think about being told the average height of children in a class.
Do we know the height of any one child?

BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

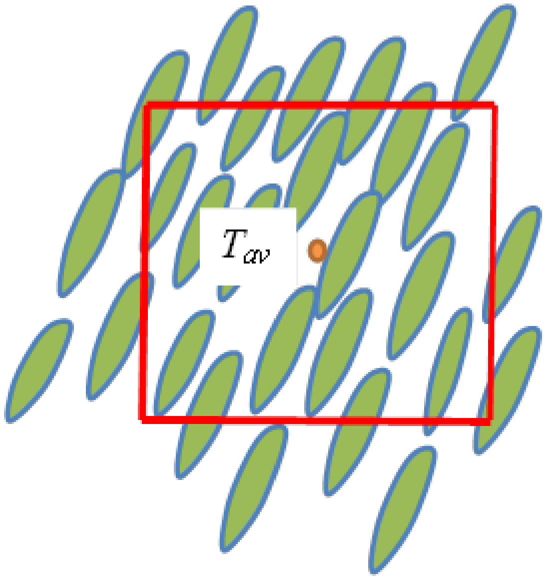
All is not lost – the volume averaging theorem will help.

Temperature gradient = *f*(number of leaves/m^3,thermal conductivity of leaves, shape of leaves, ……)

The problem is that when we average this relationship over a region of the plant canopy we end up with the average of a gradient.

BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

We need to be able to track the average temperature in a canopy.



BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

We can resort to the volume averaging theorem that tells us the following:

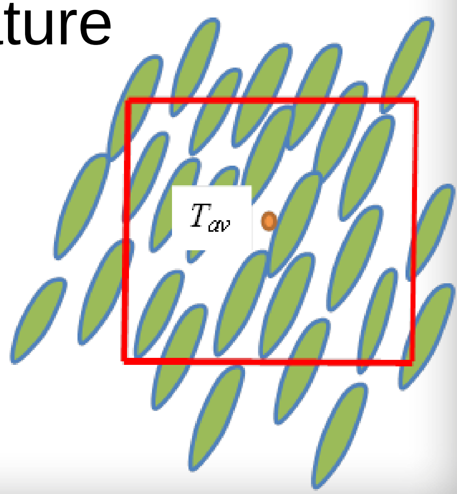
The average of the spatial variation in temperature (*say*)

=

The variation in space of the average temperature (*important*)

+

Some geometrical details of the canopy



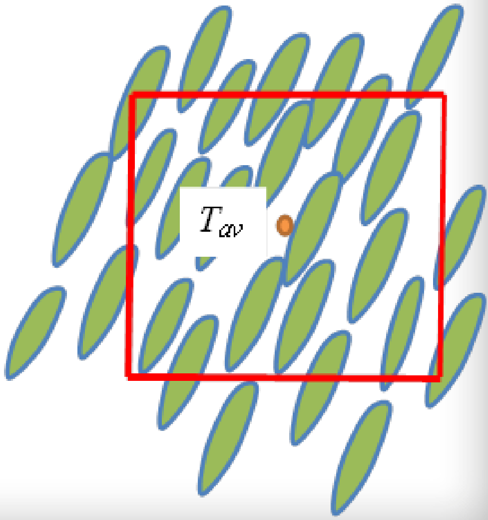
BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

Similar approaches to averaging the flow of air through canopies leads to new insights and data on:

The resistance to air flow due to the shape of the leaves in the canopy.

The variation of the resistance to air flow with height from the ground.

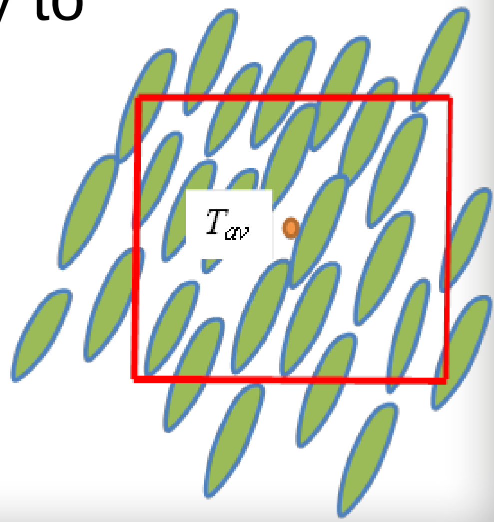
The rate of transfer of heat between the various layers of the forest.



BUSHFIRE MODELS MUST INEVITABLY AVERAGE QUANTITIES OF INTEREST.

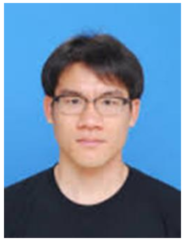
A beautiful aspect of this approach is that it can lead to being able to calculate the behaviour of these two phase systems (leaves and air) by knowing the properties of each phase.

These are often known because they are easy to measure.



THE NEXT GENERATION MODELLING TEAM

Daniel Chung – University of Melbourne



Andrew Ooi – University of Melbourne

Khalid Moinuddin – Victoria University

Graham Thorpe – Victoria University

THE NEXT GENERATION MODELLING TEAM

Newcomers:

Duncan Sutherland – a mathematician and postdoctoral fellow who commenced work with us on 1st September. Work on fluid mechanics.

Rahul Wadhwani – a PhD student from IIT Roorkee, and he will start within a week or so.

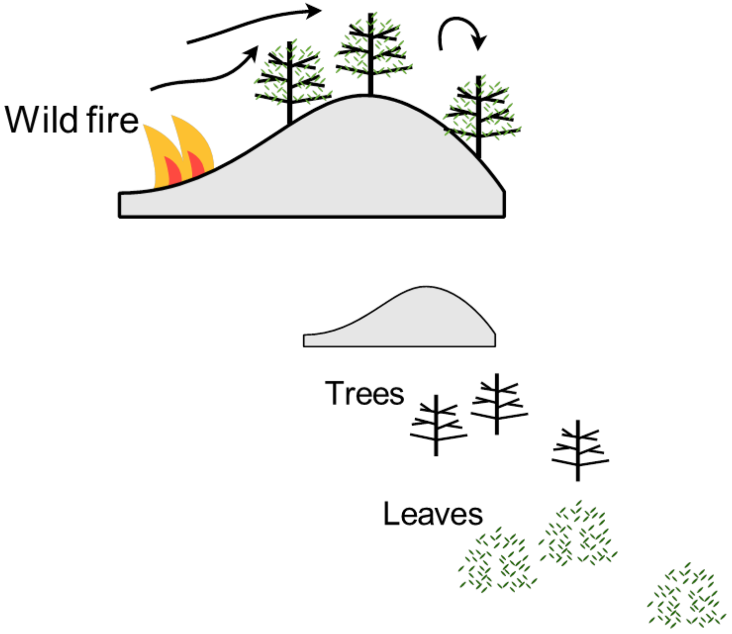
THE NEXT GENERATION MODELLING TEAM

Daniel Chung and Andrew Ooi bring very special skills to the project.

They study fluid flow in great detail, and they can provide benchmark data for our, more approximate solutions.

THE NEXT GENERATION MODELLING TEAM

Detailed studies of flow over regions of 3-D roughness.



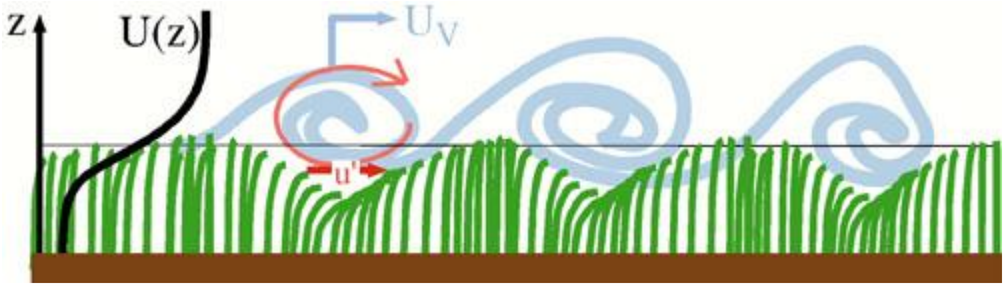
THE NEXT GENERATION MODELLING TEAM

We will not work in isolation – we are part of a well established national and international community of bushfire experts.

Our aim is be able to bring the latest developments in mathematical and computational techniques to the modelling of bushfires.

THE NEXT GENERATION MODELLING TEAM

An objective is to develop models of air flows that account for the important phenomena that govern air flows and fire spread through plant canopies.



From Heidi M. Nepf's webpage – an analogy only

MEASURE THE RATE OF HEAT RELEASE FROM AUSTRALIAN VEGETATION

The Centre for Environmental Safety and Risk Engineering at Victoria University has a 15MW calorimeter that is able to measure the heat release rate of burning vegetation.

WE HAVE FACILITIES TO STUDY THE INTERACTION OF BUSH FIRES WITH BUILDINGS

A USEFUL STEP ON THE WAY – SYNTHESISE THE EXPERTISE OF MEMBERS OF THE BNHCRC TO MODEL A FIRE IN A REPRESENTATIVE REGION OF BUSH