bushfire CRC

MODELLING FIRE SPREAD IN RUGGED TERRAIN

WHICH WAY THE WIND?

THE HIGHFIRE RISK PROJECT

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Introduction

Fire behaviour and spread modelling underpin almost all bushfire risk management practices. They can be used to:

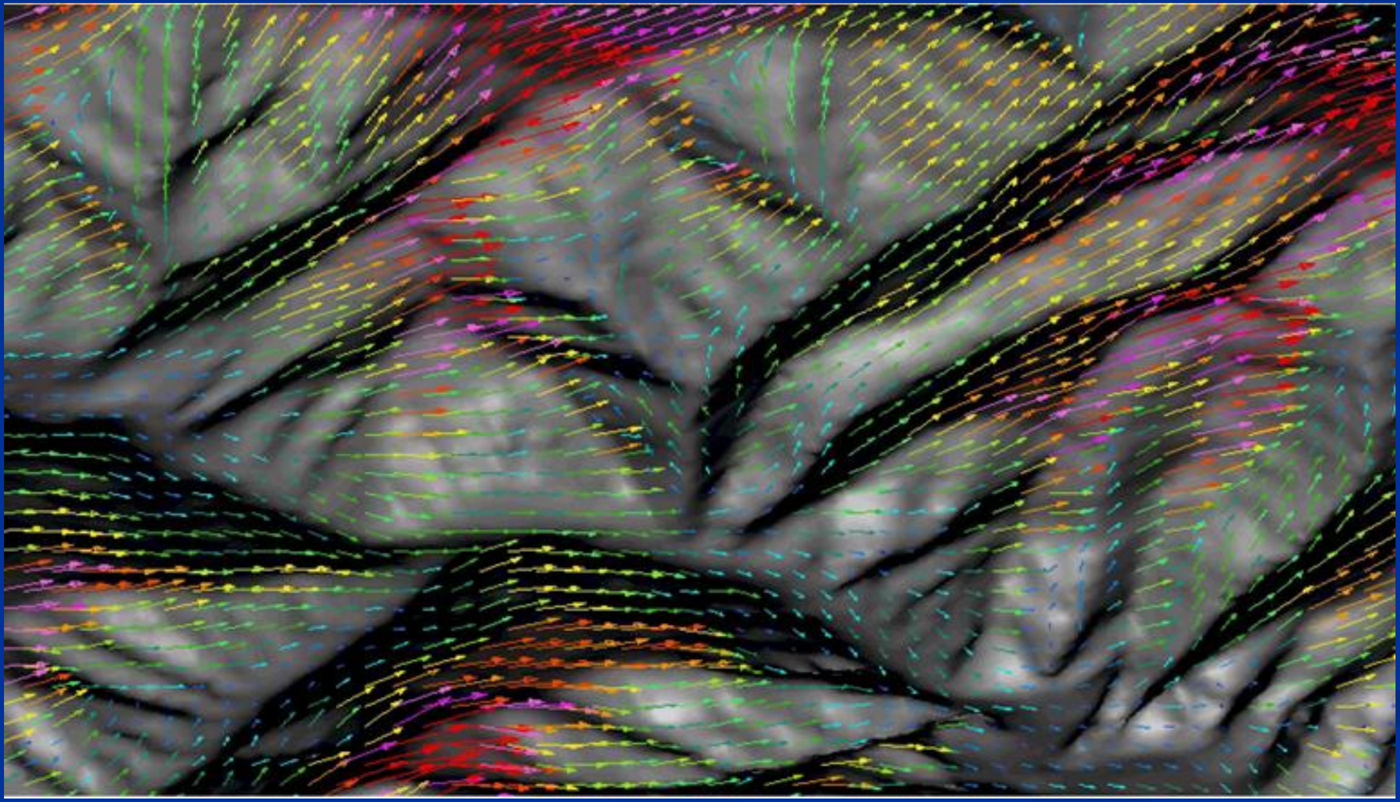
- Derive expected fire behaviour and spread in real time so that resources can be allocated accordingly during fire incidents
- Inform evacuation orders and other public warnings
- Inform longer term fuel reduction planning and allocation of asset protection zones

In rugged terrain, fire modelling faces a number of challenges. Two particular issues are:

- Wind-terrain interaction
- Effects of wind-terrain interaction on fire propagation

Wind-terrain Interaction

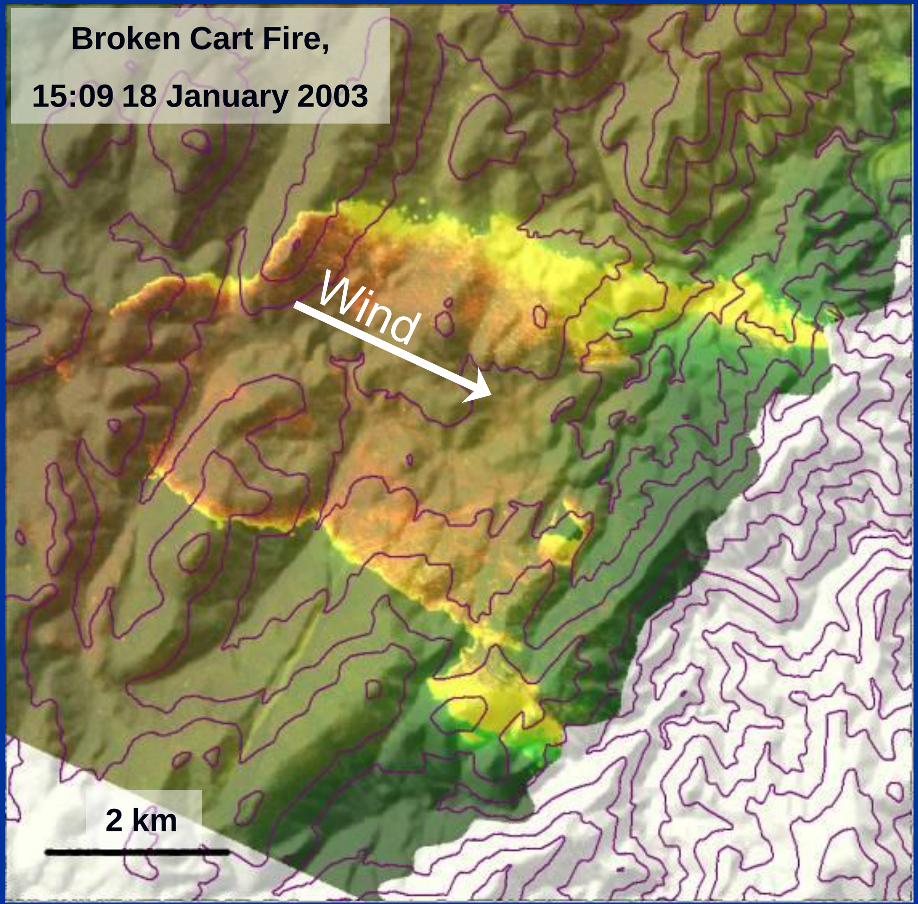
The interaction of ambient winds with complex terrain produces dynamic variability in both the speed and direction of surface wind fields.



Source: Wind Ninja (www.firemodels.org)

Effects on fire propagation

A bushfire can be driven by or can interact with terrain-forced winds, resulting in atypical and dangerous patterns of fire propagation.



Lateral spread as indicated by sharp kinks in the fire perimeter and lateral development of spot fires.

Extensive regions of active flame 2 – 5 km downwind.

Linked to pyrocumulonimbus formation

We refer to this phenomenon as "fire channelling"

Fire channelling events: McIntyre’s Hut and Brindabella Rd

Pyro-Cb over McIntyre’s Hut fire 24 minutes after line-scan imagery displays atypical lateral spread

1. Wind-terrain Interaction

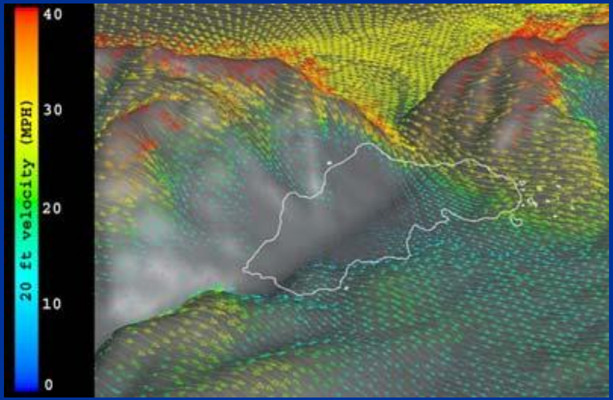
- Given an ambient wind speed and direction can we determine the wind speed and direction at some point in the landscape??
- What are the important driving factors in these wind-terrain systems??
- What is the effect of wind strength on the interaction??

2. Effects on fire propagation

- Are there consistent effects that can be identified??
- What drives these effects??
- Can we predict when and where such effects will occur??

Research

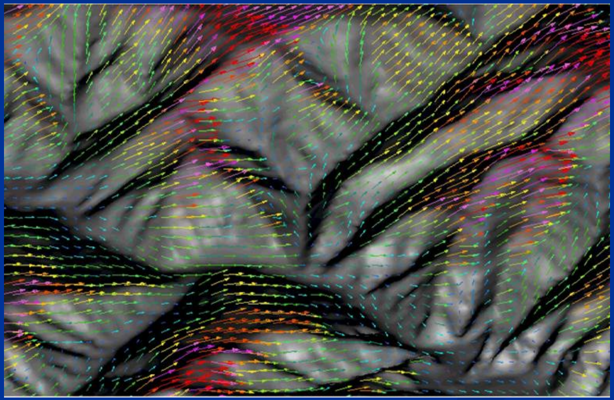
Wind terrain interactions are modelled using a number of different methods



<u>Computational Fluid Dynamics (CFD) methods</u>

Can be accurate but computational intensive and time consuming

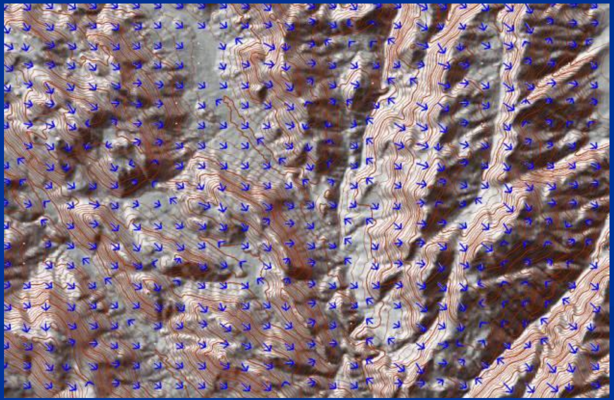
Not currently suitable for operations



<u>Kinematic or mass consistency methods</u>

Easier to implement than full CFD, but poorly reproduces nonlinear and turbulent effects

Currently used in Phoenix Rapid Fire



<u>Look-up table or other simple methods</u>

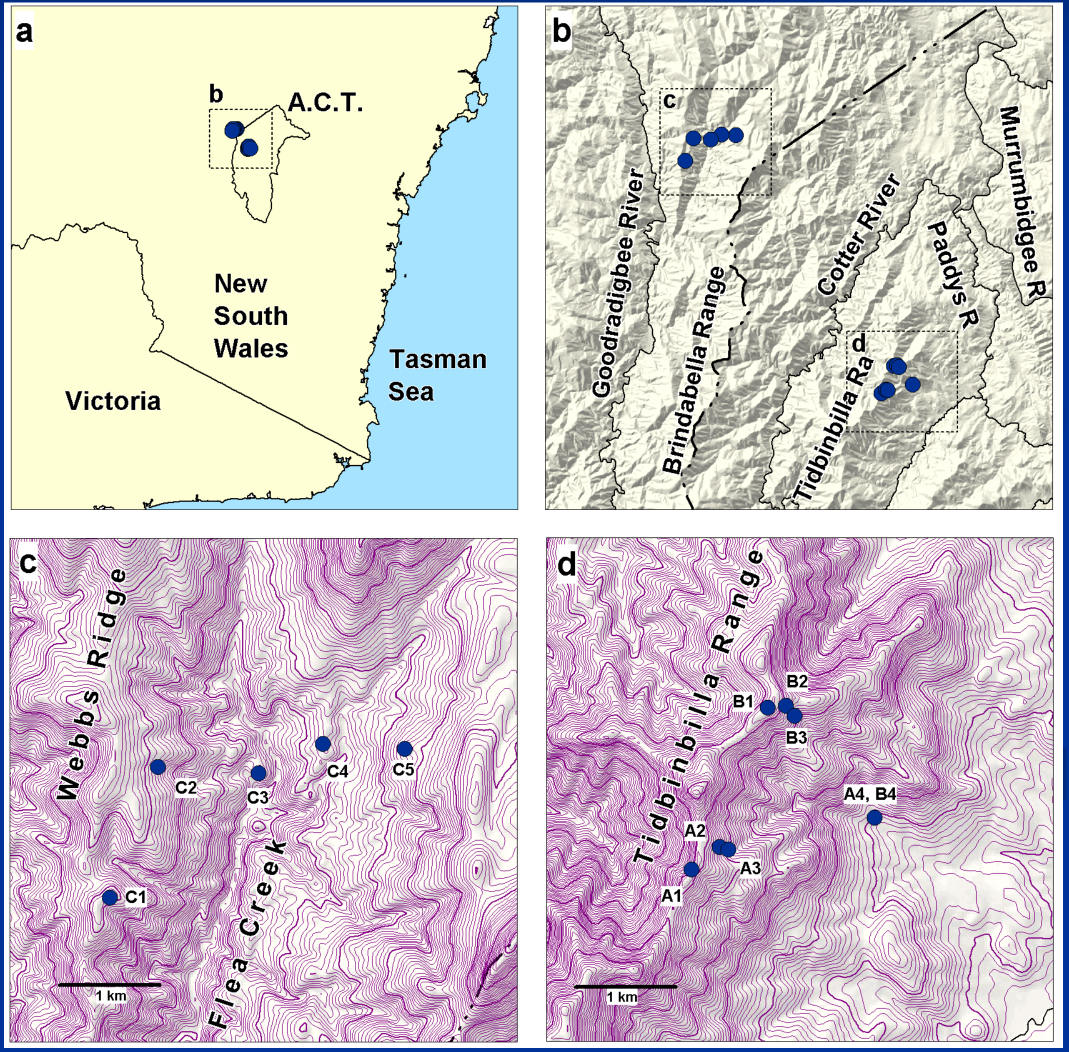
Very easy to implement but can miss nonlinear and turbulent effects

Easily used operationally

However…

A sure way to find out which way the wind is blowing at a point in the landscape is to go out and measure it!

We modified Davis Vantage Pro 2 weather stations so that they could be easily deployed in rugged terrain. We deployed 11 of them in three transects



The transects covered and an incised valley of approx. 300-500m relief (c) and two steep slopes of approx. 400-600m relief (d).

Sampling covered Dec 06-Oct 07.



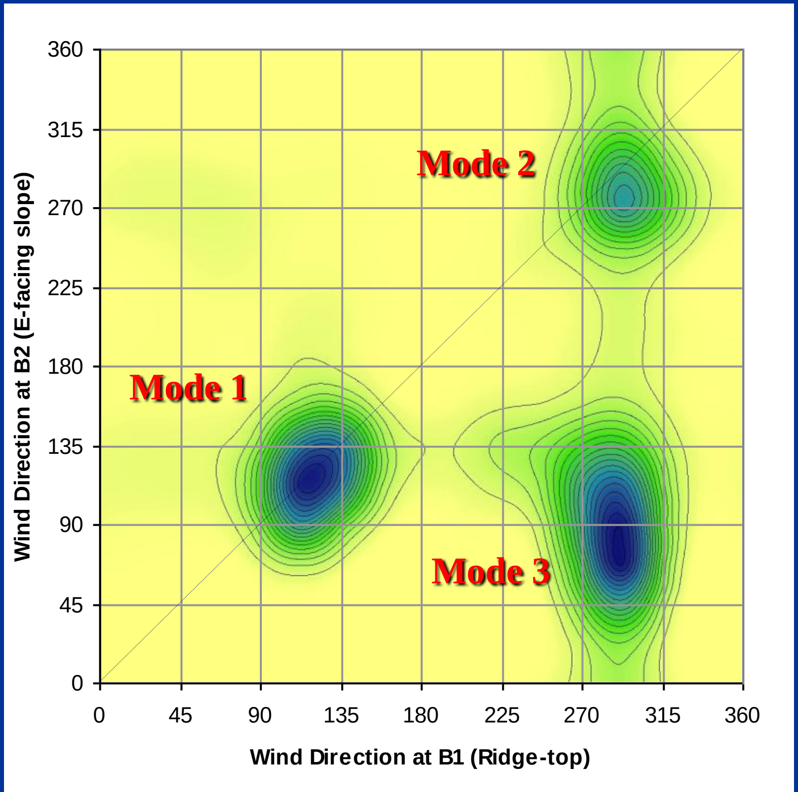
Wind direction data recorded at ridge-tops were paired with wind direction data recorded at points in the landscape according to date and time, and classified into 6 groups defined by the recorded ridge-top wind speed.

The data were used to derive joint wind direction distributions which became the main focus of analysis

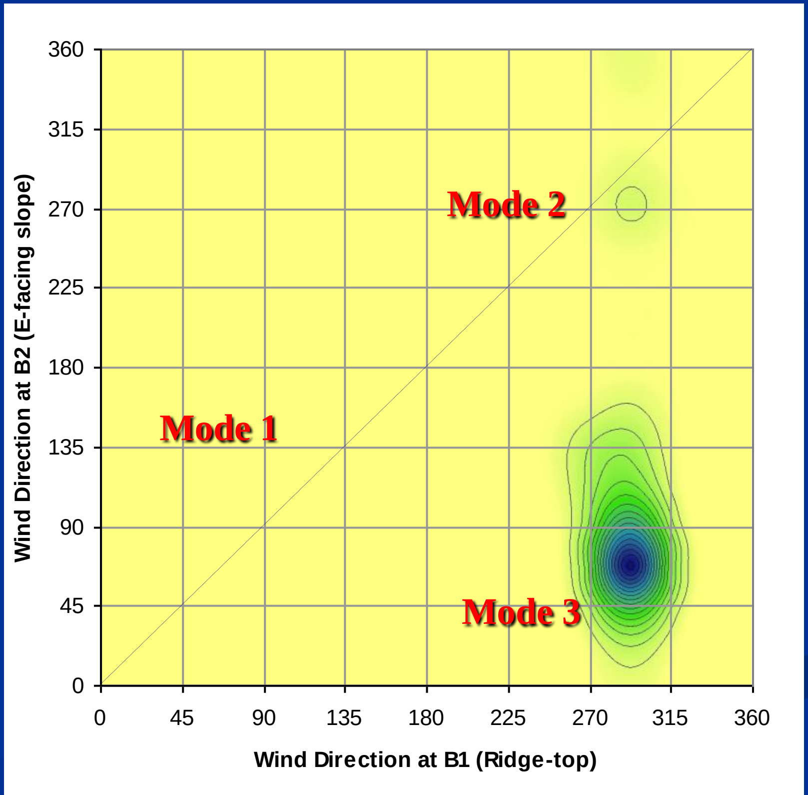


Joint wind direction distributions for the B1-B2 pairing

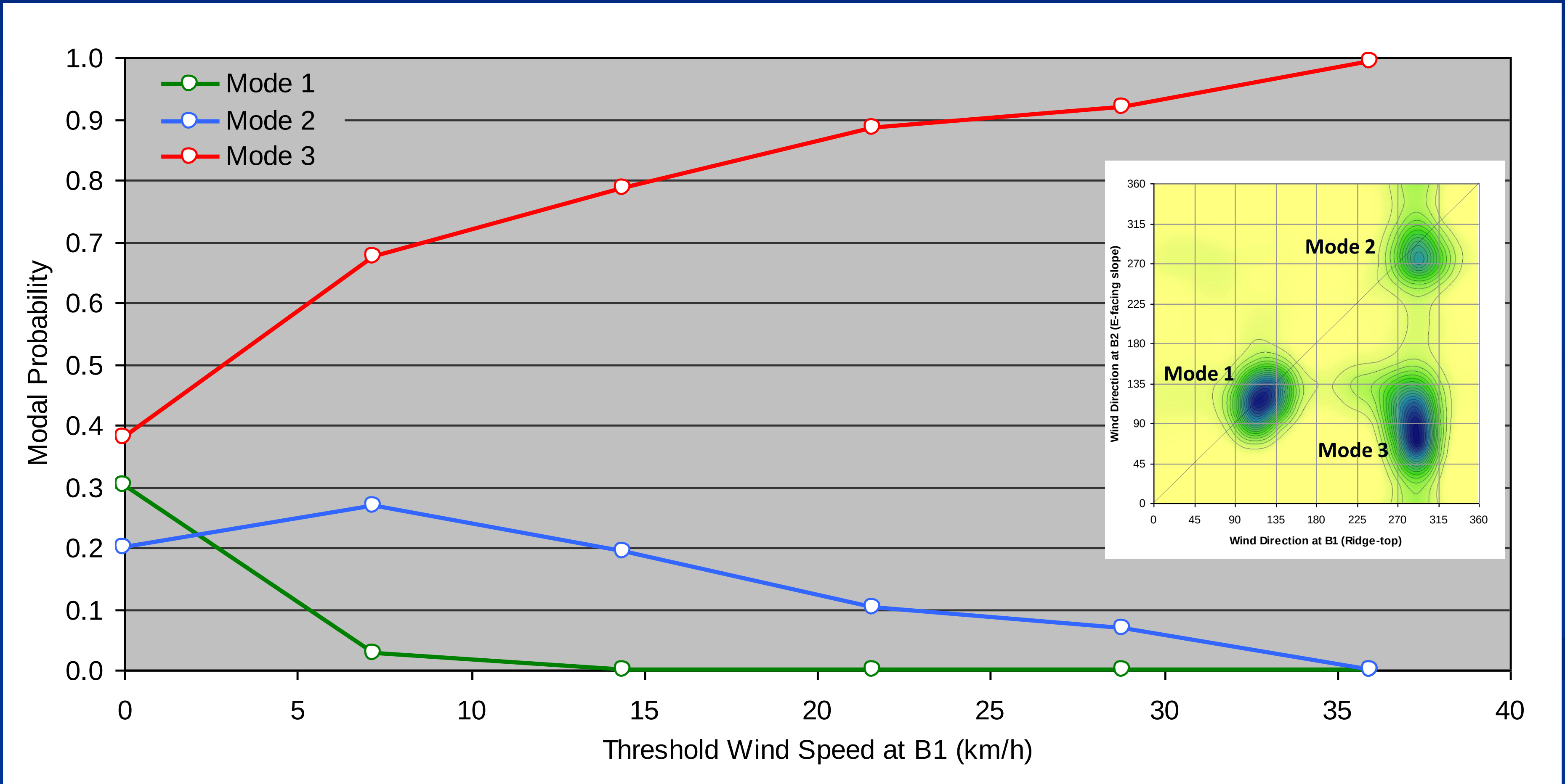
Wind speed at B1 > 0 km/h



Wind speed at B1 > 25 km/h

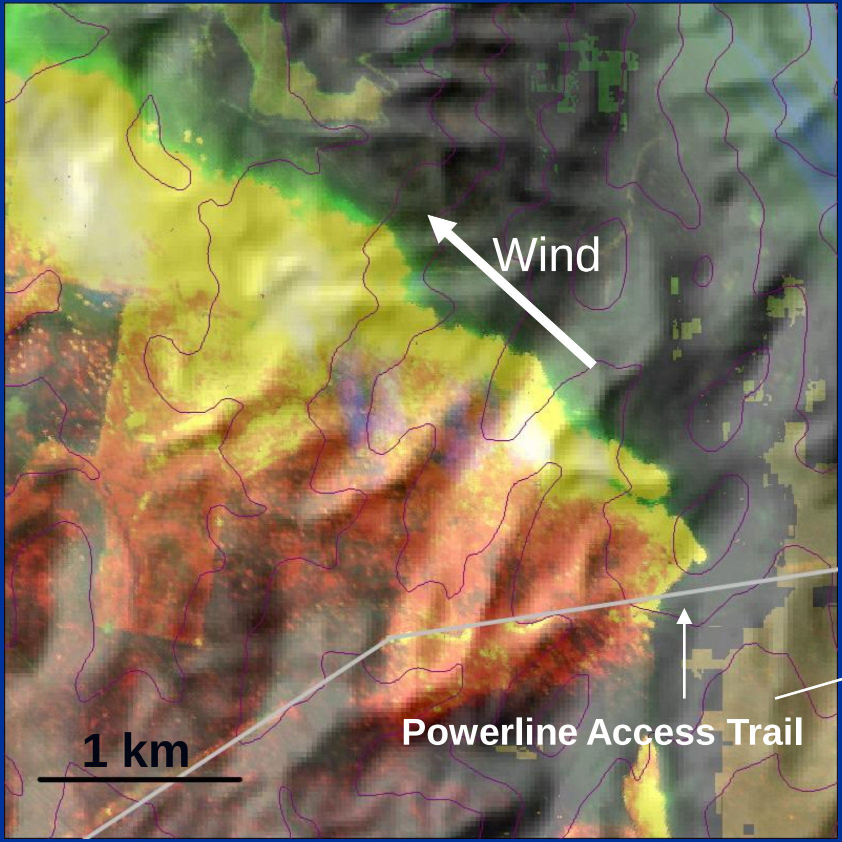


The effect of ambient wind speed on the probability of various wind responses



Research

The effect of wind-terrain interaction on fire propagation was investigated using wind, terrain and fire data (including photographs and multispectral line-scans)



The Blue Range Fire Channelling event: 18 Jan 03

Identifying regions prone to fire channelling

The ‘terrain-filter’ model

$$\chi(\sigma,\delta)=\begin{cases}1 & \text{if } \gamma_s \geq \sigma \text{ and } |\theta_w-\gamma_a|\leq\delta,\\ 0 & \text{otherwise.}\end{cases}$$

θ_w is the direction the wind is blowing to

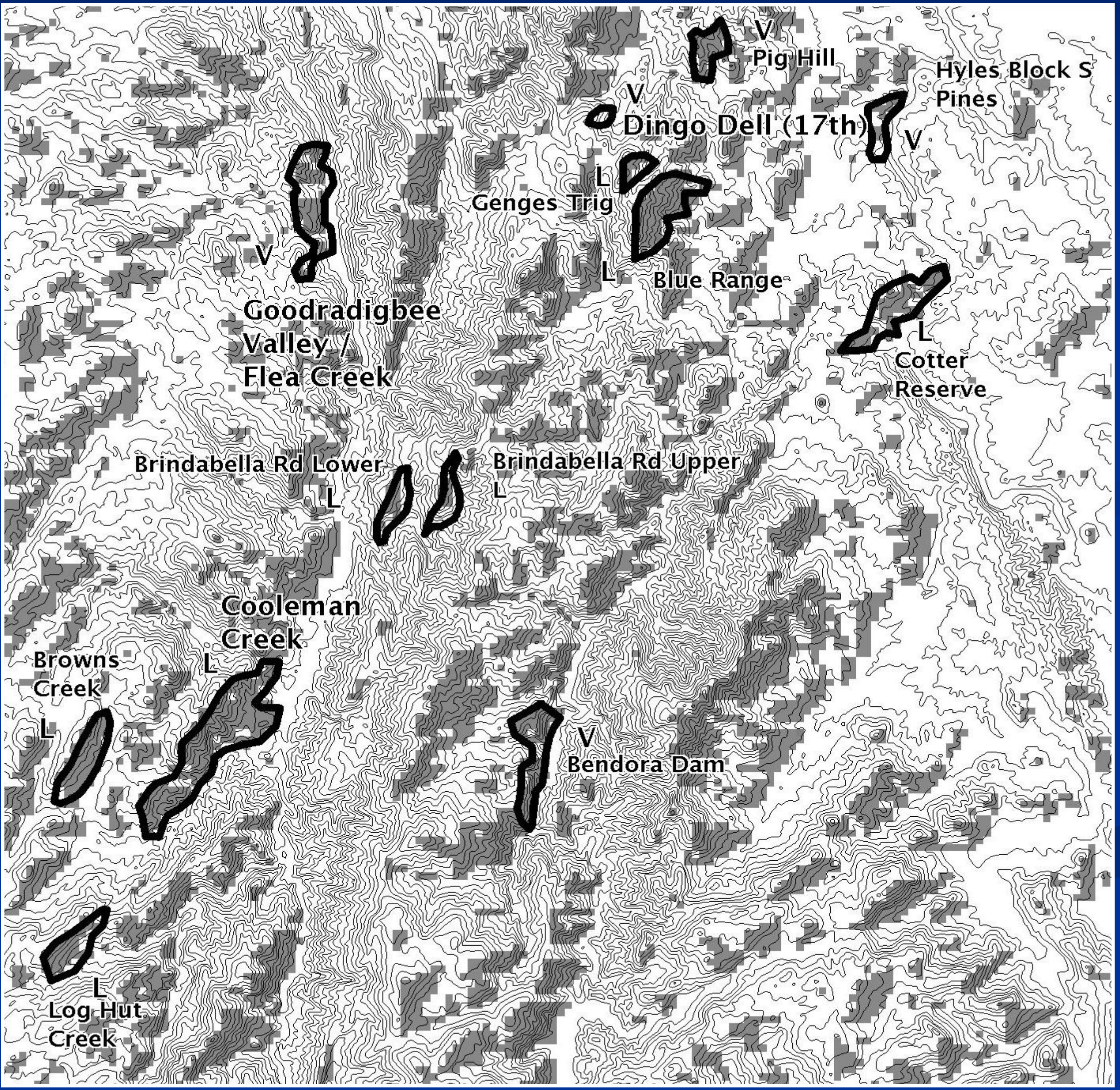
γ_s is the topographic slope angle

γ_a is the topographic aspect

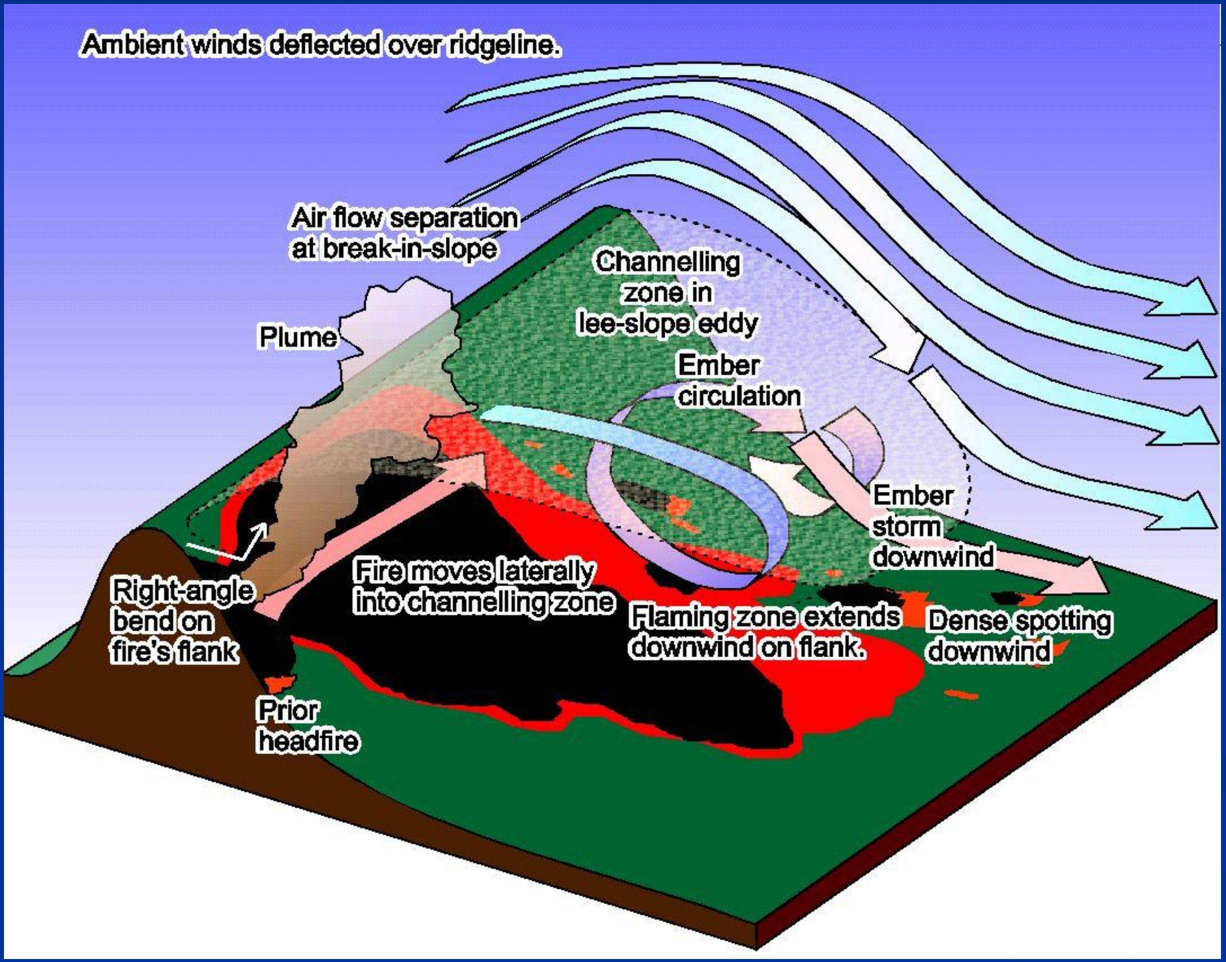
σ and δ are the model parameters

- σ is the threshold topographic slope
- δ is the threshold aspect discrepancy

In simple terms, the model identifies steep slopes that are approx. lee-facing

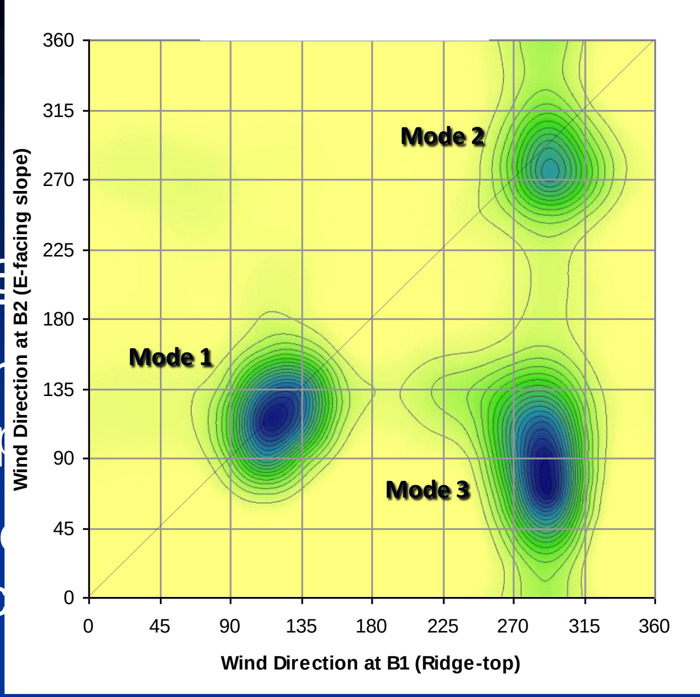


Using the available data we ruled out a number of possible mechanisms that could result in the atypical spread. This left us with a likely mechanism for the fire channelling phenomenon



Hypothetical mechanism for fire channelling along a slope

1. Wind-terrain inte



- When winds are str ... te. This means that winds will be upslop ... landscape
- Our findings provid ... ” fire severity patterns observed after Blac ... ant fires, where the most severe fire behavio ... pes
- The wind direction at a point in the landscape is not uniquely determined by ambient wind speed and direction. This raises some doubts about the use of deterministic models
- The probabilistic approach used in the research is naturally suited to Monte Carlo modelling of fire spread patterns (i.e. randomly sampling model inputs to give a range of model output with associated probabilities)
- Others… see our Fire Note “Characteristics of wind over complex terrain”

Implications

2. Effects on fire propagation

- Lee slopes can be very dangerous, esp. under extreme fire danger conditions
- The fire channelling process can very efficiently and rapidly spread a fire across a landscape and can result in the transition of a fire to a pyro-Cb.
- Areas downwind of fire channelling events will not generally experience a “fire front”, rather they may experience a “swarm of embers”, which can quickly surround structures with fire – this has implications for household bushfire protection plans and building codes in these areas
- Our findings provide a mechanism for the “anti-intuitive” fire severity patterns observed after Black Saturday and other significant fires, where the most severe fire behaviour was associated with lee slopes
- Others… see our Fire Note “Wind-terrain interaction and bushfire propagation over rugged terrain”

Some relevant peer-reviewed HighFire Risk Publications

Sharples, J.J., McRae, R., Weber, R., Wilkes, S. (under review) Wind-terrain effects on rugged landscape fire propagation: fire channelling. *International Journal of Wildland Fire.*

Sharples, J.J., McRae, R.H.D., Weber, R.O. (2010) Wind characteristics over complex terrain with implications for bushfire risk management. *Environmental Modelling and Software,* in press, doi:10.1016/j.envsoft.2010.03.016.

Sharples, J.J., Mills, G., McRae, R., Weber, R. (2009) An empirical probabilistic study of wind directions in complex terrain. *18th IMACS and MODSIM09 Proceedings, July 13-17, Cairns.*

Sharples, J.J., McRae, R.H.D., Weber, R.O., Gill, A.M. (2009) A simple index for assessing fuel moisture content. *Environmental Modelling and Software*, 24, 637-646.

Sharples, J.J., McRae, R.H.D., Weber, R.O., Gill, A.M. (2009) A simple index for assessing fire danger rating. *Environmental Modelling and Software*, 24, 764-774.

Sharples, J.J. (2009) An overview of mountain meteorological effects relevant to fire behaviour and bushfire risk. *International Journal of Wildland Fire*, 18, 737-754.

Sharples, J.J. (2008) Review of formal methodologies for wind-slope correction of wildfire rate of spread. *International Journal of Wildland Fire* 17, 179-193.

THANKS!