

Earth, Wind and Fire

Bushfire 2004
Fusing the Elements
Presenters Application Kit

YOUR DETAILS:

First Name: Peter

Surname: Ellis

Organisation: CSIRO Forestry and Forest Products

Position: Experimental Scientist

Address: PO Box E4008 Kingston ACT 2604

Telephone: 02 6281 8386

Facsimile: 02 6281 8348

Email: peter.ellis@csiro.au

PRESENTATION DETAILS:

Title of Presentation: "Spotting the problem: researching for the solutions"

Key Issues: Firebrands and spotting are the main cause of loss of control of fires and of house losses at the bush-urban interface. Prediction of spotfire and firebrand distribution is complex and requires understanding of firebrand behaviour of different materials, including their potential to ignite fuel beds, the behaviour of fires in different forest types and fuel ages, fire convection plumes and wind fields above and below vegetation. We discuss the extent and potential of research in providing predictive models.

Length of Presentation: 25 - 30 mins

Style of Presentation: Paper

Summary (no more than 10 key words):

How present research into spotting and firebrand distributions should be extended and applied, in order to assist decision-making and management, for bushfires, prescribed burns and at the bush-urban interface.

Abstract:

Arguably, the most useful models concerning firebrands and spotfires would predict their distribution for given vegetation types and weather conditions. Such models would assist in managing bushfires and prescribed burning, assessing the risk to properties at the bush-urban interface and determining fuel management strategies to mitigate firebrand production. These models require knowledge of aerodynamic, combustion and ignition characteristics of firebrands, accurate models of wind profiles and convection, and measurement of firebrand and spotfire distribution for a wide range of vegetation types and fuel loads.

To date, I have measured and modelled firebrand behaviour for a limited number of bark types and measured firebrand distributions for one forest type. I have produced a preliminary model, which uses a simple non-rotating 2-dimensional model of a

bushfire convection plume and predicts maximum spotting distance for a range of conditions.

In this paper I discuss the application of the model for maximum spotting distance, the limitations of this model and its underlying assumptions, and the likelihood that narrow, rotating convection processes are a frequent transport mechanism of firebrands. I indicate how measurements of firebrand distributions from experimental fires may potentially be used to assess relative firebrand risk to properties at the bush-urban interface.

Introduction

The most useful models concerning firebrands and spotfires would predict their distribution for a range of vegetation types and fuel ages and for a range of weather conditions. The potential application of models of firebrand and spotfire distributions includes tools for the management of both wildfires and prescribed fires, fuel management of strategic areas, and the prediction of “ember attack” at the bush-urban interface.

Prediction of spotfire and firebrand distribution is complex and requires understanding of the firebrand behaviour of different materials, including their potential to ignite different fuel beds, the behaviour of fires in different forest types and fuel ages, fire convection plumes and wind fields above and below vegetation.

Spotting models may be wholly empirical or based on models of physical processes such as aerodynamic and combustion behaviour of firebrands. The latter calculate trajectories of firebrands lofted within either ‘2-dimensional’ or rotating ‘3-dimensional’ models of convection processes. Most models predict the maximum spotting distance likely for given fuel and wind conditions.

Existing spotting models

McArthur (1967) produced an empirical model which predicts mean spotting distance for stringybark forest, based on mean fuel quantity and fire danger index. Models by Tarifa *et al.* (1965; 1967), Young (1973), Albini (1979; 1981; 1983a; 1983b) predict trajectories of single firebrands lofted in 2-D models of convection processes. They use models of firebrand behaviour obtained from measurements of wood samples tethered in horizontal or vertical wind tunnels. Ellis (2000) derived models of stringybark firebrand behaviour using untethered bark samples in a vertical wind tunnel and calculated trajectories within a 2-D model of a convection plume within a wind field. His model predicted maximum spotting distance for given values of fire intensity, wind velocity, the initial height of the firebrand above ground and its initial position relative to the downwind boundary (termed x_{p0}). The vertical velocity of the convection column was estimated using a model for the plume from a line-fire (Raupach 1990). One problem with the Ellis model is that it is extremely sensitive to parameter x_{p0} . This value is difficult to estimate and may represent the time a firebrand sample remains in the convection column rather than indicate the width of the convection column (Ellis 2000).

Lee and Hellman (1969; 1970) measured and modelled the trajectories of particles of different shapes within a turbulent, swirling convection plume (i.e. 3-D plume) produced by a gas flame. Muraszew *et al.* (1975, 1976) and Muraszew and Fedele (1976) measured the characteristics of rotating ascending convection columns generated in a laboratory and then modelled the trajectories of wooden cylinders and wood and bark plates within models of full-scale firewhirls.

In order to validate spotting models it is necessary to quantify spotting and firebrand activity, and relate them to practical parameters of fire behaviour, wind fields, fuel conditions and the firebrand characteristics of these fuels. This is not possible to do using only observations from wildfires because little data is available and it is not always accurate.

There have been few attempts to measure the distribution of viable firebrands (embers) ahead of bushfires. Christian (1969) measured ember production from burning houses in order to model fire spread in the event of nuclear attack. Tolhurst¹ (*pers. comm.* 1999) measured the density of firebrand material generated by prescribed fires in long-unburnt stringybark forest, of which an unknown proportion burnt out prior to reaching the fuel-bed.

The Spotfire Project

Measurements made during the 2001 spotfire project (Ellis 2003), which was part of the Project Vesta experiments in dry sclerophyll forest (Cheney *et al.* 1998, Gould *et al.* 2001), were used to refine a spotting model by Ellis (2000) and to test models by McArthur (1967) and Albin (1983a). The experiments, performed in 2, 5 and 22 year-old fuel and for a Forest Fire Danger Index (FFDI) of 10 to 12, also quantified short distance spotting behaviour and investigated the relationship between spotfire and firebrand distributions, fire behaviour and fuel age. The fuels surrounding the fire plots were 2 years old.

Firebrand distributions

The distribution of firebrands is important information because it quantifies potential spotfire material. The potential for igniting spotfires would be greater under conditions of higher FFDI and in finer and older fuels. The dominant overstorey species was jarrah (*E. marginata*) and most of the firebrand material collected by observers or on the firebrand sample sheets downwind of the fire-plots appeared to be jarrah bark. I assumed that most of the firebrands resulted after the fires reached the break. Firebrand density decreased as an exponential function of distance downwind of the firebreak and at right angles to wind direction was approximated using a normal distribution. When results for the two sets of experiments were pooled, the maximum firebrand density measured 50 m downwind of the fire-break was positively correlated with fuel age. The bark consumption for these fires is similarly correlated with fuel age (*pers comm.* L. McCaw² 2003).

Spotfire distributions

Spotfires were tagged where possible, using metal markers. Numbers were estimated where they were too numerous to tag, as could occur in front of a moving fire or immediately downwind of a fire-break. Short-distance spotting to 50 m from moving fires often appeared to be associated with strong downdraft phases. Short distance spotting immediately after a fire reached a break appeared to occur as a shower of almost simultaneous spots, which was followed by protracted less intense spotting from burning trees immediately upwind of the break. The distance and intensity of

¹ Dr Kevin Tolhurst. Fire Ecology and Management, School of Forestry, University of Melbourne, Victoria.

² Dr Lachire McCaw, bushfire scientist, Department of Conservation and Land Management, Wetsern Australia.

short distance spotting, with the exception of the fire in 22 year-old fuel on the second set of experiments, was positively correlated with fuel age. For this experiment we defined longer-distance spotfires as those which occurred from 50 m to several hundred metres. Generally, the number of the longer-distance spotfires increased with increasing fuel age. The most distant spotfires for each fire appeared to result from periods of heightened fire intensity which were characterised by short bursts of greater-than-average flame heights.

Firebrand characteristics

We measured the firebrand behaviour of samples of jarrah bark in the CSIRO vertical wind tunnel and found that they approximated the behaviour of small samples of messmate stringybark (*E. obliqua*). This finding validated the use of models which describe the firebrand behaviour of samples of messmate bark to calculate the trajectories of samples of jarrah bark. The shed flakes of jarrah bark tended to be thinner than those of messmate bark and for this reason it is possible that jarrah bark may not be an effective firebrand material at distances greater than 2 kilometres.

Validating Ellis spotting model

Using values for mean fire intensity, the Ellis (2000) model significantly under-predicted maximum spotting distances for the Project Vesta 2001 fires. During the spotfire project I associated the longer-distance spotting events with relatively short bursts of fire activity which were indicated by relatively tall flames. Hence, we used estimates of fire intensity during these bursts in order to refine Ellis' model. We used recorded estimates of the flame height during these bursts to derive fire intensity using Byram's (1959) equation. We used the recorded estimate of flame depth as the value for x_{p0} . Using these inputs, the Ellis (2000) model performed reasonably well for five of the 2001 fires and for two 1998 fires where long-distance spotting was observed. We subsequently constructed a preliminary model for predicting maximum spotting distance from stringybark forests. The model uses inputs of estimated flame height sustained during bursts of fire intensity and wind speed above canopy. The distances are calculated assuming that variable x_{p0} is double the observed flame height. The estimates of flame depth observed during the spotfire project experiments were usually greater than observed flame height by a factor of between 1 and 2. This means that the refined spotting model may over-predict maximum spotting distances.

However, the refined model by Ellis has limited application and weaknesses in its assumptions of firebrand transport. The model uses a simple 2-D model of a convection plume which has constant updraft velocity and a constant horizontal component of velocity which is a function of updraft velocity and windspeed above canopy. The plume model (Raupach 1990) predicts updraft velocities of about 8.5 and 11 m s⁻¹ for fire intensities of 5,000 and 10,000 kW m⁻¹ respectively. It will only predict maximum spotting distance rather than spotfire and firebrand distribution. An assumption of the model is that a firebrand is lofted from a position upwind of the downwind boundary of the convection plume and is transported upwards and across the plume until it exits the downwind boundary and commences its descent. In addition, there is an assumption that there will be a firebrand of optimum size for the conditions and which will attain the maximum spotting distance. The model will not predict spotting at particular combinations of updraft velocity and wind speed because under these conditions firebrands are shown to burn out within the convection

column. Spotting is a stochastic process, which is not reflected in the model.

Aerial infra-red video imagery of fires appears to show the frequent occurrence of short-lived, narrow firewhirls within what appears, in visual imagery, to be a single large convection column. These firewhirls appear to have updraft velocities of tens of metres per second, to persist for only a few seconds and to result in spotting activity.

Implications and applications

In jarrah forest (*E. marginata*), significant reduction in spotting distance and intensity will result if fuels are maintained at an age of less than 5 years. Because jarrah bark appears to be the main firebrand material it will be necessary to reduce bark loads on stems and not only reduce surface fuel loads. The “ember attack” from this forest type, burning under conditions of High Forest Fire Danger, decreases rapidly with increasing distance downwind of the break in fuel. These findings have implications for the management of fuels both for fire suppression and at the urban interface, as well as for separation distances between houses and dry sclerophyll forest.

The preliminary spotting model by Ellis may find application, although it will still have shortcomings in its assumptions concerning firebrand transport and in its capabilities. It appears necessary to develop 3-D models of convection plumes, including fire whirls, over topography. Existing models derived from measurements of firebrand behaviour could then be meshed with the convection model to predict distributions of firebrands and spotfires, rather than predict a single value for maximum spotting distance.

Measurements of firebrand and spotfire distributions for a wide range of conditions, could be used to predict the probability or relative intensity of spotfires or firebrands at given distances downwind of firebreaks. This type of information could be applied in fire management and in risk assessment at boundaries, including the urban interface, although its application to events involving extreme fire behaviour, may be problematic.

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