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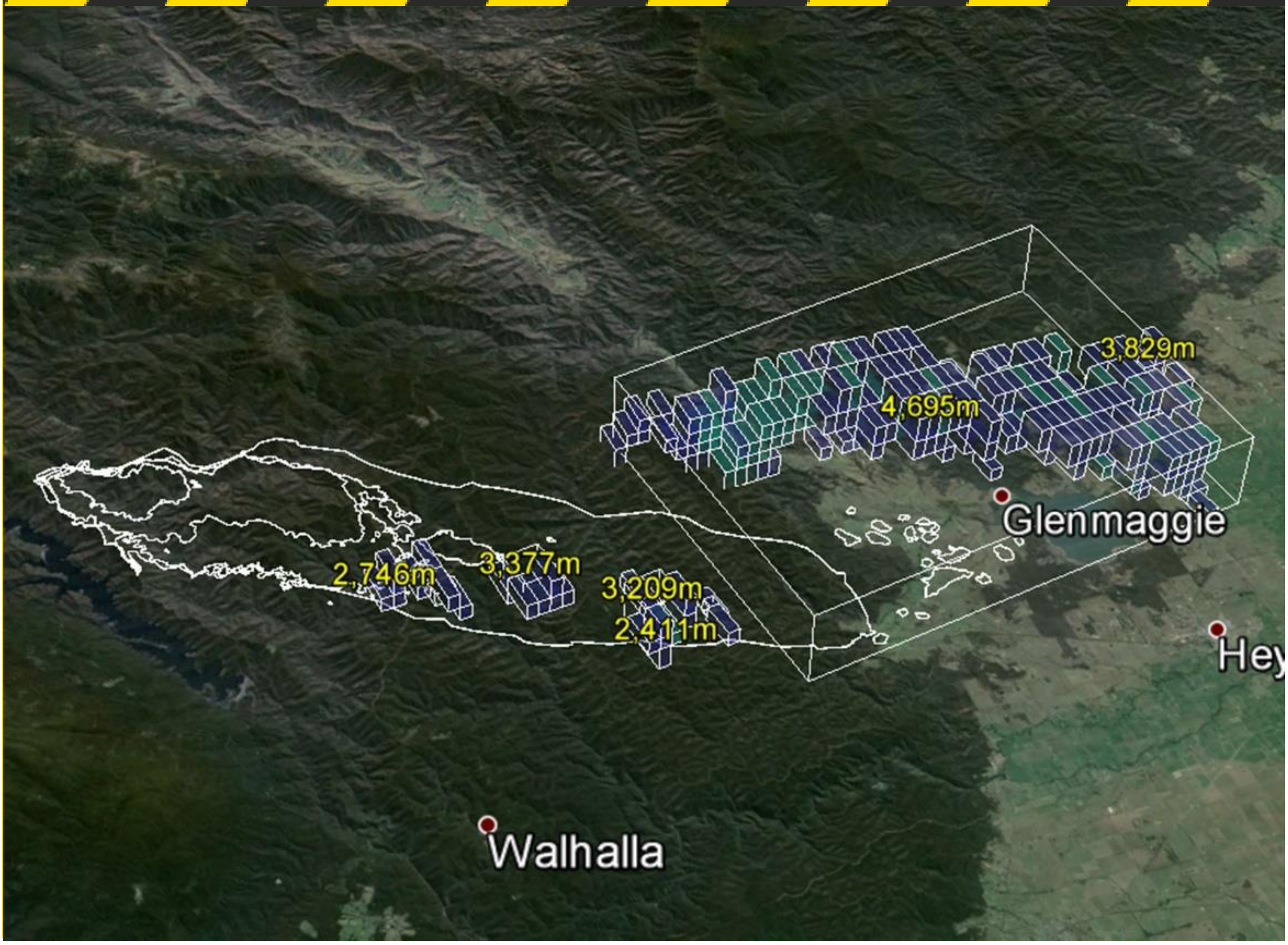
DETERMINING THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR

Annual project report 2015-2016

Tom Duff, Trent Penman, Alex Filkov
University of Melbourne
Bushfire and Natural Hazards CRC



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EXECUTIVE SUMMARY

As extreme fires cause a disproportionate amount of impact to the environment and the community, there are significant incentives to being able to predict their occurrence and behaviour. Most existing fire behaviour models have been developed based on data and observations of fires that were small to moderate in size. Consequently, they are not able to emulate the dynamic bushfire behaviour that can occur under extreme conditions.

Indeed, current operational fire spread models assume that fires will burn at an approximately constant (quasi-steady) rate of spread under a specific set of environmental conditions (e.g. VESTA, McArthur Mk5, CSIRO models). While a number of advances have been made in understanding bushfire development under extreme conditions, these have not been quantified in a manner that is suitable for inclusion in a fire behaviour modelling framework.

The main aims of this project are to investigate the conditions and processes under which bushfire behaviour undergoes major transitions, including fire convection and plume dynamics, evaluating the consequences of eruptive fire behaviour (spotting events, convection driven wind damage, rapid fire spread) and determining the combination of conditions for such behaviours to occur (e.g. unstable atmosphere, fuel properties and weather conditions). To do this the collation and analysis of existing data on extreme fire behaviour will be done.

END USER STATEMENT

Dr. Simon Heemstra, *Operational Services, Rural Fire Service, NSW*

I am pleased with the work that has been done to get the project off to a good start, particularly engagement of end-users in development of methods and selection of case studies. I look forward to all the fire agencies involved working with the project team to develop a data set of extreme fire events. This will form a valuable resource for future analysis both in this project and into the future.

INTRODUCTION

Bushfire is one of the most frequent natural hazards affecting Australia (Bradstock et al. 2012). It has shaped the Australian landscape and ecology and is an intrinsic part of the natural system of this continent. Yet, in extreme cases, bushfires are devastating events that cause injuries and fatalities and destroy property and communities. Although hundreds of fires burn every year in Australia, very few of these cause significant damage. Since 1939, six events in Australia account for more than 60 percent of all house loss from fire, and house loss is almost always associated with extreme fire weather (Blanchi et al. 2010). For example, vast tracts of land were consumed in extreme bushfires during the 2002/03 and 2006/07 fire seasons, resulting in multiple fatalities and the loss of numerous dwellings and important infrastructure. The fires also devastated ecological, cultural and hydrological assets, with ongoing consequences. The 'Black Saturday' fires in Victoria during February 2009 resulted in 173 fatalities and direct economic costs conservatively estimated at $4.4 billion (2009 Victorian Bushfires Royal Commission (VBRC), 2010a). The Ash Wednesday fires in Victoria and South Australia in 1983 caused 75 fatalities and over 2800 buildings were destroyed (VBRC 2010b, 2010c).

The growing incidence of large wildfires over the last decade has revealed the need for more appropriate and effective measures for assessing bushfire risk. The mix of extended drought periods and the increasing number of homes built in canyons and on slopes surrounded by bush and shrubland has only exacerbated the already difficult problem of managing wildfire risk in these areas.

According to McRae and Sharples (2011) extreme fire events develop energy transfer processes of the convective plume with the atmosphere, well above the surface which explains their rapid spread and aggressive burning making the surface meteorology and fuel characteristics less influential. These fires behave in a manner that goes beyond the suppression means and fire-fighters are unable to control the fire spread even in the most prepared and equipped regions (Hyde and Williams, 2007 and Williams and Hamilton, 2005). Only when the fire burns into different vegetation and/or the weather moderates is it possible to control these fires. The difficulty or impossibility to control explains that these fires can burn larger areas.

There is increasing evidence that fire propagation can be significantly affected by dynamic feedback processes that result in the continual escalation of fire spread rates and intensities even when environmental conditions are consistent (e.g. eruptive fire behaviour, vorticity-driven lateral spread, fire tornadoes, fire storms). These dynamic feedbacks appear to be able to arise via a number of different pathways including wind terrain interaction, fire-atmosphere coupling and high densities of ember driven ignitions.

To comprehensively account for the effects of dynamic fire spread, it is first necessary to describe the phenomena and the conditions under which they occur, including fuel conditions, surface weather and atmospheric profiles. It is expected that associations between particular fire behaviour features and their environmental drivers will be identified and these will then allow the development of quantitative and probabilistic relationships.

PROJECT BACKGROUND

OBJECTIVES

Most existing fire behaviour models have been developed based on data and observations of fires that were small to moderate in size. Consequently, they are not able to emulate the dynamic bushfire behaviour that occurs under extreme conditions. As extreme fires cause a disproportionate amount of impact to the environment and the community, there are significant incentives to being able to predict their occurrence and behaviour. Indeed, current operational fire spread models assume that fires will burn at an approximately constant (quasi-steady) rate of spread under a specific set of environmental conditions (e.g. VESTA, McArthur Mk5, CSIRO models). Currently there are no operational fire spread models that can take into account dynamic effects.

In order to adequately assess the potential benefits of alternative fire management and risk mitigation actions, including prescribed burning, public warnings and building regulations, bushfire behaviour must be reliably predicted in a spatially and temporally explicit way, capturing the extreme and dynamic nature of fires across different size classes. The inadequacy of current fire prediction models to predict extreme and dynamic fire behaviour means that the risks, as they are perceived through consideration of fire spread model output, are likely to be underestimated. At the very least, the exact nature of the risk may be poorly appreciated and accounted for if the exact physical mechanisms that constitute the source of risk are not well understood. For example, houses that are designed to sustain radiant heat to a certain level may be significantly underprepared when the dominant mechanism of fire propagation transitions to an ember storm or if extreme pyrogenic winds form.

While a number of advances have been made in understanding bushfire development under extreme conditions, these have not been quantified in a manner that is suitable for inclusion in fire behaviour modelling framework. One of the main aims of this project is to develop statistical models that allow for the inclusion of dynamic effects when they are important (i.e. when fires grow sufficiently large and complex). To do this we will seek to identify the thresholds beyond which dynamic fire behaviour becomes a dominant factor, the effects that these dynamic effects have on the overall power output of a fire, and the effects that such dynamic effects have on fire impacts (e.g. fire severity).

PROPOSED STRATEGY

The research objectives outlined above will be realized through a series of three overlapping research activities:

1. Collation of fire behaviour observations.

We are working directly with agencies to obtain reconstructions of fire events. This will include structuring a database, standardising data formats and processing historic reconstructions. This will involve collating both fire data (isochrones, linescans etc.) and accessory data (weather observations, forecasts etc.). We will also develop and make recommendations on standards for future reconstructions.

2. Analysis of extreme fire weather and fire behaviour.

This activity is intended to determine the existence of thresholds in fire and environmental conditions (weather, fuel, topography) that lead to fires exhibiting extreme phenomena such as fire tornados and ember storms.

This will be achieved by using data pertaining to past fires to identify processes that lead to extreme pheomena. This will include analyzing smoke plume observations obtained from Bureau of Meteorology (BOM) Weather Radar, 3D numerical weather predictions and impact maps. These sources will be used to determine a number of fire related parameters including the strength of convective winds, spotting patterns and profiles of fire energy release through time. This information is expected to allow an understanding of the processes and thresholds behind the occurrence of extreme phenomena.

3. Determination of factors associated with extreme fire behaviour and development of predictive functions.

The aim of this activity is to develop simple statistical relationships to represent dynamic fire phenomena that can be integrated into existing fire behaviour models.

An analytical approach will be used to determine relationships between specific characteristics of extreme fire behaviour and the conditions under which they occur. This will include analysing the conditions on the ground (fuel, surface wind observations, temperature and relative humidity), fire properties (observed fire flame heights, rates of spread, spotting characteristics, smoke plume properties and suppression activity) and atmospheric conditions. Statistical methods will be used to determine if thresholds exist for which extreme fire activity occurs and to describe the nature of activity when it does occur. The approach will recognize the differences in fire size classes and incorporate effects that are relevant to the scale of the fires. These statistical relationships are intended to act as a substitute for complex physics based models to enable faster than real-time prediction of extreme fire behaviours.

WHAT THE PROJECT HAS BEEN UP TO

The project started shortly before June 30, 2015. The first 6 months of the project were taken up with project design and the recruitment of a research fellow to undertake the research. Towards this, a candidate Alexander Filkov was selected. Alexander was an international candidate based at the Tomsk State University in Siberia.

As Alexander is an international researcher, there were some minor delays to the project as it was necessary that he achieve appropriate visas and immigrate to Australia with his family. Alexander commenced working full time at the university in February, 2016. Work has since progressed rapidly, and the project is on schedule.

Initial work includes a review of extreme fire behaviors to consider in Australian conditions and the development of criteria on which to focus data collection.

A workshop was held on the 20th of May at the AFAC offices in Melbourne. At the workshop, there were representatives from fire agencies from WA, NSW, ACT, SA, Victoria and Queensland, as well as representatives from BOM and the University of New South Wales. The stakeholders:

- Provided feedback on the proposed research methodology for examining extreme fire behaviour.
- Contributed to the identification of a study set of fires.
- Assisted in the identification of available datasets for the study.
- Agreed to provide large spatial data sets for modelling and analyses.

The outcomes of this workshop will be extended in the coming year through face to face meetings in each of the relevant states. In addition to agency collaboration, Melbourne University has been actively working to develop links to the BOM fire research projects and other BNHCRC researchers such as Jason Sharples.

In addition to local work, Thomas Duff is currently undertaking an external travel fellowship (funded by the Churchill Trust) to foster international collaboration on research on extreme fire behaviour and rare fire events. This is expected to get additional data and act as a source of leverage for this project. This includes visiting the University of Athens, undertaking experimental work at the University of Coimbra in Portugal, and working on research methods with the University of Edinburgh and the Missoula Fire lab in the US. Trent Penman met with US Forest Service research staff in Portland Oregon May 2016 to develop future collaborations in fire behaviour and impact research.

Given the early stage of the project, we do not have useable research products, but a number of potential follow up projects have been identified and we are currently working with stakeholders to identify means to complete these projects.

Additional outputs include the research group presenting at the 5th International Fire Behaviour and Fuels Conference (Melbourne, April 2016), the International Society for Ecological Modelling Global Conference (Baltimore USA, May 2016) and the International Forest Fire Risk Workshop (Aix en Provence, France, May 2016).

CURRENT TEAM MEMBERS

Researchers:
Dr Thomas Duff, University of Melbourne
Dr Trent Penman, University of Melbourne
Dr Alexander Filkov, University of Melbourne

Project End users:
Dr. Simon Heemstra - A/ Group Manager Community Resilience | Operational Services, Rural Fire Service, NSW
Dr. Neil Burrows - A/Director Forests and Ecosystem Management, Parks and Wildlife WA

End users:
Tim Well, VIC CFA
Musa Kilinc, VIC CFA
Matthews Stuart, NSW RFS
Mike Wouters, SA DEWNR
Andrew Sturgess, Qld
Lachie McCaw, WA
Adam Leavesey, ACT
Gran Alan, NT
Mark Chladil, TFS
Andrew Stark, ACT RFS
Laurence McCoy, NSW RFS
Ralph Smith, WA DFES
Jason J. Sharples, UNSW
Jeff Kepert, BOM

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