HAZARD NOTE

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CAPTURING THE VARIABILITY OF WIND FOR MODELLING THE VARIABILITY OF BUSHFIRES

ABOUT THIS PROJECT

This research was part of a PhD study, *Statistical characterisation of wind fields over complex terrain with application in bushfire modelling*, which was part of the Bushfire and Natural Hazards CRC project *Fire spread prediction across fuel types*.

AUTHOR

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SUMMARY

Understanding uncertainty in fire modelling, and characterising predictions in terms of likelihood or risk, allows fire managers and emergency services to make more informed decisions. With the emergence of probabilistic fire modelling frameworks, where predictions capture multiple possible scenarios, it has become clear that to characterise the full extent of the uncertainty within bushfire prediction, the variability of input parameters must be accurately captured. In particular, the variability of wind has been shown to account for much of the variability in fire spread. By adopting a statistical approach, this study analysed the variability of wind direction and strength, working towards a statistical characterisation of wind over complex terrain. Better modelling of the uncertainty of wind can feed directly into fire spread models, allowing fire behaviour analysts and managers to make more informed decisions.

Above: THE BENDORA FIRE, CANBERRA 2003, SHOWING THE WIND'S INTERACTION WITH THE COMPLEX TERRAIN CREDIT: LANNON HARLEY. SUPPLIED BY ACT EMERGENCY SERVICES AGENCY

CONTEXT

After 30 years of discussion, probabilistic approaches to fire modelling are emerging to tackle the issue of uncertainty. These approaches allow for random fluctuations in inputs and consider a range of fire prediction outputs in terms of likelihood, probability or risk. However, these approaches still rely on deterministic models or simplified assumptions; they are trying to capture the uncertainty of fire spread without capturing the variability of its drivers.

BACKGROUND

The spread of bushfires is highly sensitive to wind speed and direction, with sudden changes often resulting in drastic changes in the rate and direction of fire spread. Accurate estimation of wind across the landscape and over time is therefore a critical component of fire spread modelling. However, estimation of wind across rugged terrain is far from trivial. The complex interactions between prevailing winds and varying landscape features are often over-simplified within operational bushfire models due to computational constraints.

BUSHFIRE AND NATURAL HAZARDS CRC RESEARCH

This PhD research aimed to improve the understanding of wind through a statistical characterisation capable of complementing current modelling approaches; providing a more informed wind modelling framework for bushfire prediction.

A key issue in addressing this aim was the lack of wind data available. Data were collected across Flea Creek Valley, west of Canberra. This region was significantly impacted by the 2003 bushfires and wind data had been collected in 2007, leading to questions of how vegetation regrowth might impact wind flow.

In 2015, data were also collected at the National Arboretum Canberra, allowing for a more controlled vegetation environment. Analysis from this study enabled a comparison of wind speed and direction over contrasting vegetation but similar topography, and varying topography but uniform vegetation.

RESEARCH FINDINGS

To analyse this data, new statistical techniques were needed to account for the circular nature of wind direction. Firstly, wind was considered in terms of directional wind response distributions. These distributions exhibit circular properties, but it was shown that simple data strategies could be adopted to account for this in analysis. These not only performed better than existing techniques, but are easily available for fire and land managers, not just mathematicians.

Statistical comparison of directional wind response showed that vegetation and topography had an interactive impact on wind. For example, post fire vegetation regrowth had a significant impact on wind direction across Flea Creek Valley, except on the valley floor where broader mechanisms dominated the wind flow. Equally, clear thresholds in vegetation and aspect were found for the generation of wind reversal regions at the National Arboretum Canberra.

The probabilistic representation of wind fields as directional wind response was used to evaluate an operational deterministic wind model in the context of ensemble-based fire modelling. It was shown that the application of this model can be adapted to capture the variability of wind direction observed across the landscape.

HOW COULD IT BE USED?

This research consisted of four key contributions to the scientific community. Firstly, two new wind datasets were collected across topography and spatial and temporal resolutions most relevant to significant surface fire behaviours. These datasets are now available for continuing research into wind dynamics in mountainous landscapes and varying vegetation.

Secondly, wind was recast in probabilistic terms to better suit emerging probabilistic fire modelling frameworks. Capturing wind behaviours in terms of likelihood enables the quantitative characterisation of risk throughout the fire modelling process.

Thirdly, new statistical comparison techniques were developed and used to formally identify areas of the landscape where topography and vegetation had significant impacts on windspeed and direction. This has significant implications for bushfire prediction where identified wind patterns have been consistently linked to extreme fire behaviour.

Finally, the evaluation of current wind models highlighted the potential for complementary use of physics-based deterministic approaches and statistical analysis to model uncertainty in wind. Better modelling of this uncertainty will feed directly into ensemble-based and stochastic fire models aiming to capture the uncertainty of the entire fire modelling framework, and provide managers and decision makers with as much accurate information as possible.

FUTURE DIRECTIONS

As with many PhD projects, this research asks many more questions than it answers. The data collected is available for further interrogation and analysis to aid the answering of numerous further questions. The new mathematical and statistical techniques introduced require further validation and analysis to ensure they are robust and ready for generalisation. Finally, the statistical analysis of wind and the wind models developed through this research provides the building blocks for statistical modelling of wind over complex terrain capable of complementing the currently operational wind models used for bushfire prediction.

DIRECTIONAL WIND RESPONSE

The directional wind response of the prevailing wind to changes in the landscape beneath it can be represented as the distribution of the observed prevailing wind direction and that measured at the same time on the surface within the landscape.

END-USER STATEMENT

"Firefighting in the ACT, like much of south east Australia, involves working in rugged terrain. We have long had a good understanding of how wind and slope can change the spread of a fire. However, we all have on occasions been caught out by a fire doing unexpected things. To avoid this we need a solid understanding of how the prevailing wind flow is altered by its interaction with terrain.

"It is only through the hard work of measuring winds in places that are difficult to get to that we have begun to know what to expect. Rachael's work provides tools to help us suppress bushfires safely and more effectively, and to light up hazard reduction burns with the least chance of problems occurring."

- Rick McRae, Risk Analyst and Fire Behaviour Analyst, ACT Emergency Services Agency

FURTHER READING

Quill R (2017), Statistical characterisation of wind fields over complex terrain with applications in bushfire modelling, PhD Thesis. School of Physical, Environmental and Mathematical Sciences, University of NSW Canberra

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